IRPA13 Glasgow

13th International Congress of the International Radiation Protection Association

13 - 18 May 2012

Living with Radiation – Engaging with Society

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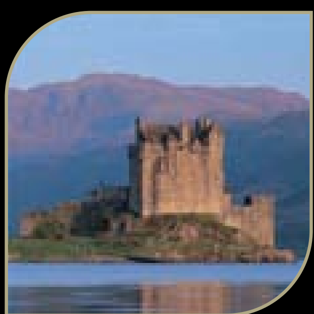
IRPA 13



IRPA13 Abstracts

13 - 18 May 2012 ■ SECC ■ Glasgow ■ Scotland

Hosted by:

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Introduction from the Congress President

Dear IRPA13 Congress Delegate,

Welcome to the IRPA13 Book of Abstracts,which displays all the abstracts submitted to the Congress. Abstracts for the invited presentations in the Plenary Sessions, Symposia and Fora are also included where available.

Abstracts within the principal Technical Sessions and associated Poster Sessions are arranged in accordance with our defined scientific areas as follows:

1. Biological and Health Effects of Ionising Radiation
2. Measurements and Dosimetry
3. Radiation Protection System Development and Implementation
4. Stakeholder Engagement and Involvement
5. Non-Ionising Radiation
6. Planned Exposure Situations: Industry and Research
7. Planned Exposure Situations: Medicine
8. Planned Exposure Situations: Radioactive Waste Management
9. Emergency Exposure Situations
10. Existing Exposure Situations
11. Protection of the Environment
12. Fukushima

These areas are colour-coded to assist you in navigating through the programme.

IRPA13 is placing emphasis on developing our next generation of radiation protection professionals. To this end we have established a Young Professionals Prize competition for the best presentation by a young person at the Congress. There are 17 entrants nominated by Associate Societies, and these presentations are indicated by an asterisk (*) in this book.

Given that the theme chosen for the Congress is Living with Radiation – Engaging with Society we also attach a copy of IRPA's Guiding Principles on Stakeholder Engagement, which we commend to your attention.

I am sure that you will have an enjoyable and stimulating Congress, and I look forward to meeting as many of you as possible.

Roger Coates

Roger Coates
IRPA13 Congress President

This document contains the abstracts for IRPA13. For best results, we recommend viewing it in full screen mode. You can switch to full screen mode by pressing Ctrl+L (Command+L on a Mac). You can exit full screen mode at any time by pressing Escape.

The abstracts are arranged in the following categories. Clicking on a category will take you to the relevant list of abstracts in the table of contents. From there you can click on the title of an abstract to go directly to that abstract. There is a home button at the top of each page which will bring you back to this page.

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P03.82. Radiation Protection Research at the U S Nuclear Regulatory Commission

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P03.96. Some Inconsistencies in the IAEA Publication Entitled: "Optimization of Radiation Protection in the Control of Occupational Exposure"

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P03.98. Argentine Regulatory Experience Related to the Application of Specific Standards in the use of Radioactive Material in Industries.

P03.99. Can, And Should, The Management of Radiological Materials And Hazardous Chemicals Be Harmonised?

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P07.134. Dosimetric Monitoring of Workers Exposed to Ionizing Radiation in Radiology Services in Burkina Faso, 2009-2011

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P07.137. Negatives Results In Radiological Examinations In Hospitals Of Peru -2010

P07.138. Medical Exposure Increase versus General Health Care Improvement – Contribution to the Discussion

P07.139. “Pregnancy”: A New Justified Model for Better Radiation Protection in Diagnostic Radiology

P07.140. Stakeholder Involvement in Medical Radiation Protection: A Report of the HERCA WG “Medical Applications” Concerning the Involvement of CT Manufacturers

P07.141. French pluralistic Working Group « Patients Information for Diagnostic X-Rays Examinations »

P07.142. Towards Safer and More Effective Use of Radiation in Healthcare – Results from European IRPA 2010

P07.143. Evaluation of Patient Dose During Endoscopic Retragrade Challangiopancreatography

P07.144. Example of Patient Dose Optimization in Interventional Radiology

P07.145. Evaluation Of The Dose To Skin Of Patients In Interventional Radiology With The Use Of Radiochromic Film

P07.146. The Identification, Communication & Use of Dose Constraints in the Optimisation of Interventional Radiology & Interventional Cardiology Procedures, & in the Training of the Interventional Staff.

P07.147. Collaboration between IAEA and Latin-American Society of Interventional Cardiology regarding Radiation Protection

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P07.153. Pediatric Exposition in Hemodynamics Services in the State of Bahia, Brazil

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P09.63. Average Annual Effective Doses at Inhabitants Living on Contaminated Territories at Long Time After the Chernobyl Accident

P09.64. Plutonium Levels in Air and Vegetables from a Contaminated Area: A Review of Results and Estimation of the Related Inhalation and Ingestion Doses

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P10.40. Investigation of Radon Isotopes Content In Dwellings and Public Buildings of Russian Federation

P10.79. An Aid to the Study of the Behavior of Radon and Air Pollutants in the Atmospheric Boundary Layer

P10.80. Evaluation of Indoor Radon Level Due to High - Exposure Building Material Used in Iran

P10.81. Presence of a Radioactive Gas in Archeological Excavations, Determination and Mitigation

P10.82. Environmental Risk Assessment of Radon from Ceramic Tiles

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P10.84. The mesurment of radon in the environment: publication of a new ISO standard

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P11.03. The Common Reed Seeds' Viability From Water-Bodies With Different Levels of Radioactive Contamination

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P11.09. Study on the Bioaccumulation of 210Po in the Biota of Pondicherry, South East Coast of India

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P11.18. Determination of Uranium in Soil by KPA using Diphonix® resin

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P11.21. Characterization of Artificial Radionuclides and Sedimentation in Sediment Core of Crater Lake, Baengnokdam of Mt. Halla, Korea

P11.22. Concentrations of Radionuclides in Soil and Assessment of the Environmental Gamma Dose

P11.24. Radionuclide Concentration Factors in the Mullet (Mugilidae) Species Mugil cephalus - from Seawater, Sediment and Mud with Detritus

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P11.29. Iodine-129 And Iodine-127 In Seawater Of The North Sea And In Precipitation From Northern Germany

P11.30. Radionuclides Contamination Within 60 Km from The Fukushima Daiichi Nuclear Power Complex after the Accident On March 11, 2011

P11.31. Participation of the IFIN-HH Dosimetry Laboratory for Personnel and Environment (LDPM) at the Proficiency Test AQUACHECK-2011.

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P11.33. Dose Rate Measurements of the Phosphogypsum Deposition Site and the Surrounding Environment

P11.35. Improved System for Collecting Stack Samples for Tritium and Carbon-14 Analysis

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P11.37. "Data Mining" Of Environmental Radioactivity Surveillance Data

P11.38. Dose Assessment to Marine Biota: Evaluation of Key Environmental Parameters

P11.39. Radiation and Ecological Conditions of the Offshore Waters nearby the Site for SNF and RW Temporary Storage at Andreeva Bay

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P11.41. Assessment of Environmental Radioactivity in Natural Food Products from Northern Norway

P11.42. 137Cs Distribution in the Northern Adriatic Sea(2006-2011)

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PL1.1
The Sievert Lecture: The Story of Tritium

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Since its discovery in 1934, tritium has been of continuing scientific interest as a tracer for atmospheric and hydrological processes. Since the 1940s, it has also been of scientific, engineering and radiological protection interest because of its production in nuclear reactors, particularly heavy water reactors; its use in nuclear weapons; and in many industrial applications. A story of tritium serves to illustrate the wonderful variety of scientific and engineering disciplines involved in radiological protection and the exciting challenges presented to new graduates coming into the field. The story is complimentary to the conference theme—living with radiation; engaging with society—since concerns and controversies about tritium in the public environment continue to arise. In my talk I draw largely from my own involvement in tritium-related topics—biokinetics, dosimetry, measurement and monitoring, environmental dispersion, biological effects, epidemiology and effluent management—as a way of illustrating some of the early developments, of highlighting current research needs and of drawing attention to continuing issues, some of which have implications for radiological protection in general. A running theme is that, as with all science, there is a need for scientific scepticism; measure, don't just model. The overall conclusion is that although the radiological characteristics of tritium are now sufficiently understood for most practical radiological protection purposes, there are still areas where studies related to tritium could be helpful. Examples are experimental studies on mammalian radiocarcinogenesis, the dosimetry of tritium-labelled compounds and epidemiological studies on nuclear workers. There are also areas where new technologies will present new radiological problems; for example, tritiated particles in fusion power facilities. The continuing public concern about health effects from tritium reflects broader concerns with effects of low levels of radiation exposures in general and how we model them. Such concerns prompt a need to examine how we can construct a protection model that preserves the useful features of the current model but, at the same time, better reflects current understanding of the impact of radiation at low doses.

PL2.1
Overview of Low Dose/Dose-Rate Cancer Epidemiology

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The study of Japanese atomic bomb survivors has moderate statistical power to examine low-dose cancer risks, since it includes about 30,000 survivors who received 5-100 mGy for whom cancer risk has been documented for up to 60 years after exposure. The atomic bomb dose-response curve for total solid cancer does not suggest that risk per unit dose is less at low doses than at high doses, although there is some upward curvature for leukemia. Nevertheless, the atomic bomb study cannot address the major question of cancer risk after protracted or highly fractionated radiation exposure. Some of the most sensitive epidemiologic indications of risk at low doses are for thyroid cancer after childhood exposure and for leukemia after childhood or prenatal exposure. In addition, major studies of occupational, environmental and medical radiation exposure provide evidence, albeit mixed, for radiation effects after exposure at low doses and dose-rates. A summary of findings from the largest such studies will be presented. One hypothesis that there may be risk at low doses and low dose-rates because of heterogeneity in susceptibility, i.e., the presence of a highly radiosensitive subset within the population. Though there is reasonably good evidence that those exposed at an early age are at higher radiation risk of cancer than those exposed in adulthood, we have yet to identify replicable genetic susceptibility factors that have a substantial impact on low-dose radiation cancer risk in the general population.

PL2.2
Non-Cancer Effects, Especially Circulatory Diseases

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There is a well established association between high doses of ionizing radiation exposure and damage to the heart and coronary arteries, although only recently have studies with high quality individual dosimetry been conducted that would enable quantification of this risk adjusting for concomitant chemotherapy. The association between lower dose exposures and late occurring circulatory disease has only recently begun to emerge in the Japanese atomic bomb survivors and in various occupationally-exposed cohorts, and is still controversial. Excess relative risks per unit dose in moderate and low dose epidemiological studies are somewhat variable, possibly a result of confounding and effect modification by well known (but unobserved) risk factors; at least for endpoints other than heart disease there is statistically significant ($p<0.001$) heterogeneity between the risks.

For some time it has been known that high radiation doses of 1 Gy or more could induce posterior subcapsular cataract. Accumulating evidence from the Japanese atomic bomb survivors, Chernobyl liquidators, US astronauts and various other exposed groups suggest that cortical cataracts can also be induced by ionising radiation, although there is little evidence that nuclear cataracts are radiogenic. The accumulating evidence implies a linear dose response, although modest thresholds (of no more than about 0.6 Gy) cannot be ruled out.

A variety of other non-malignant effects have been observed after moderate/low dose exposure in various groups, in particular respiratory and digestive disease and CNS (and in particular neuro-cognitive) damage. However, because these are generally only observed in isolated groups, or because the evidence is excessively heterogeneous, these associations must be treated with caution.

PL2.3
Update on radiobiological mechanisms at low does/ dose-rates

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For decades the two paradigms of the cellular radiation response have been that radiation damages DNA leading to gene mutation, and that this response is linear. Whilst this may well hold true for some situations there is a wealth of evidence that forces us to at least reconsider these two paradigms. The challenges to conventional wisdom centre mostly on how radiation exposure is processed. They includes the coordination of radiation responses that occur at the tissue rather than the cellular level; the lack of a DNA- or clonal expansion-based etiology for non-cancerous late health effects; the ascendance of epigenetic regulation as the primary response to environmental stress; and not least the influence of susceptibility modifying factors that effect events other than DNA damage responses.

In parallel to these fundamental shifts in understanding how processing occurrs, there is also a change in perception on the consequences of dose and dose rate effects. It is convenient to assume that there is a unifying biological response throughout the dose range. However, the growing body of evidence indicating non-linearity of responses at low doses and dose rates cannot be discounted.

In this presentation we will consider the evidence supporting a new paradigm of radiation action, where multicellular, non-linear dose responses evoke biological changes other than DNA damage.

PL2.4
Health Effects of EMF – Scientific Update

Vecchia, P*

ICNIRP, Oberschleissheim, Germany

Knowledge about health effects of electromagnetic fields has greatly improved in recent years, allowing ICNIRP to revise its exposure guidelines on the basis of a more solid rationale. Overall, the conclusions of a comprehensive review of the literature have not been modified the previous evaluations: ICNIRP still maintains that only acute effects have been scientifically established and therefore can form the basis for exposure restrictions. Looking more in detail into the different frequency ranges, no adverse health effects of static magnetic fields have been identified up to 8 T, although some evidence exists of disturbances (phosphenes and vertigo) above 2 T. For low-frequency (LF) electric and magnetic fields, the stimulation of excitable tissues has been confirmed as the main interaction mechanism; the corresponding thresholds for adverse health effects have been refined with respect to the previous guidelines. The stimulation of magnetophosphenes has been documented in the lower part of the LF range; although phosphenes do not represent a health risk per se, they may be seen as a first response of the nervous system to the external field, and require some consideration in the definition of exposure limits. For radiofrequency (RF) electromagnetic fields, the recent studies have reinforced the previous conclusion that the absorption of electromagnetic energy is the only established interaction mechanism and that the associated thermal effects are the only adverse responses to the exposure. Uncertainties still remain about the possibility of long term effects of chronic exposure below the recommended limits. Some epidemiological studies suggest a link between exposure to power-frequency magnetic fields and childhood leukaemia, but a causal interpretation of these findings is not supported by biological studies. For radiofrequency fields, the studies – mainly focused on mobile phones - have not provided consistent evidence of brain tumours or other long-term effects. The epidemiological evidence is weaker compared to LF fields, and is not supported by findings of in-vivo and in-vitro biological studies. While IARC has classified both LF and RF electromagnetic fields as possibly carcinogenic for humans, ICNIRP considers that the present evidence cannot form the basis for the definition of exposure limits. However, IARC's classification means that more research is needed to provide more definite answers to the question of long-term effects.

PL3.2
Rebuilding Trust in the Science of Radiation Protection

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Decisions regarding the presence of radioactive contamination in the environment and remediation actions have to be based on sound science and to be successful require not just stakeholder input, but stakeholder acceptance. However, the science of radiation protection that underlies these decisions is not readily understood by most people and for the most part is associated with significant distrust. The presentation will discuss why it is essential to build trust with stakeholders in these situations and will identify essential elements for building this trust. Methods to achieve stakeholder trust will be discussed and examples provided.

PL3.4 Experiences in Stakeholder Engagement for Risk Management Decisions

Renn, O*

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The notion "risk governance" refers to an integrated concept on how to deal with environmental problems, and so-called complex, ambiguous and uncertain impacts in particular. These ideas have been informed by interdisciplinary research drawing from sociological and psychological research on ecological behaviour, Science & Technology Studies (STS) and research by policy scientists and legal scholars about regulatory styles, institutional regimes and structural impediments to more inclusiveness. The notion of governance pertains to the many ways in which all relevant actors, individuals and institutions, public and private, deal with interventions that impact the environment and its service to human societies. It includes formal institutions and regimes and informal arrangements.

The term *inclusive* governance refers to a policy style by which different actors, in particular, governmental actors, experts, private companies and representatives of civil society are invited and welcomed to consult decision makers or even co-determine key policies and decisions for risk reduction and mitigation. For this purpose new procedures for stakeholder involvement have been developed and partly tested. Beyond this horizontal level of inclusion environmental policies have to be aligned to the vertical levels, starting from the local, over the regional, national to the EU or even international level. Both directions, representing the vertical and horizontal governance dimensions, face many challenges and problems.

The lecture will introduce the major experiences with the application of the inclusive governance model for dealing with risk management decisions such as siting technical facilities, infrastructure planning and energy consumption. It will summarize the attempts to secure support for collective action, feeding in plural preferences and designing cooperative measures. It will conclude with some general lessons for future research and practical applications.

PL4.2
The System of Protection: Future Developments – ICRP Perspective

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There are many challenges facing the different organisations involved in radiological protection over the coming years. ICRP has contributed to the System of Radiological Protection since 1928 by helping to develop standards and providing guidance and recommendations. ICRP consists of the Main Commission, 5 Standing Committees and the Scientific Secretariat, with Task Groups established to research and write specific reports. A Strategic Plan for 2011-2017 has been developed by ICRP to define both its structure and operation and also to identify important challenges, objectives and initiatives that will guide the future programme of work. An overview of the Strategic Plan and a focus on certain aspects of the work of ICRP will be presented.

PL4.4
System of Radiation Protection: EC Perspective

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European Commission, Luxembourg, Luxembourg

The European Commission has adopted a proposal for a consolidated and revised Basic Safety Standards Directive under the Euratom Treaty. This Directive is very similar to the International Basic Safety Standards as a result of close cooperation as well as of the fact that both standards are inspired by ICRP Publication 103. There are different interpretations however of the new situation-based philosophy of ICRP. The concept of "planned exposure situations" is read differently in the context of the principle of justification ("introduction of new sources") and in the context of regulatory responsibilities. The possible application of dose limits is also closely related to the concept of justification, and a more transcendental point of view leads in the Euratom BSS to the conclusion that the exposure of aircrew is a planned exposure situation, and that dose limits apply to any occupational exposure to radon in workplaces.

ICRP Publication 103 has been an important step forward in ensuring a consistent approach to radiation protection in all exposure situations. The system of protection nevertheless remains very complex and difficult to understand by the general population. This deficiency has been highlighted by the Fukushima emergency situation. An additional lesson from Fukushima is that, while the proper application of the radiation protection systems requires a lot of good judgement by national authorities, the resources and time for informed decisions is often not available. Hence there is a need for clear and simple guidelines, in particular for international trade in potentially contaminated goods. Current international standards, for instance for transport of radioactive material, and criteria, for instance exemption levels, reflect good practice in normal situations rather than in the aftermath of an emergency.

PL4.11 New ICRP Recommendations and Regulatory Development – Findings of The 2010 European IRPA Congress

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The Helsinki 2010 3rd European IRPA Congress highlighted the 2007 ICRP Recommendations (ICRP 103) at an International Organisations' Forum and devoted an entire Session to 'Recommendations, standards and regulations'. In addition, new regulatory developments were also discussed at several other Sessions.

At the time of the Congress, ICRP 103 had not yet been integrated into any international regulatory instruments, let alone implemented in any national legislation. Therefore, much of the time devoted to ICRP 103 was spent on describing what it actually says and what possibilities and concerns people envisaged. It was clear that ICRP 103 was broadly accepted as a basis for new regulatory standards, but some concerns were voiced regarding 'practice/intervention problems' which were perceived as not yet fully resolved.

Several existing regulatory standards were also presented at the 'Recommendations...' Session, along with case studies of their application and analyses of desirable properties of future standards. In addition to 'overall' standards and systems, the scope included specific topics such as measurements/monitoring, commissioning/ authorisation, clearance, discharges, decommissioning, and remediation. Risk, it was concluded, remains a useful yardstick to set regulatory requirements, and (Quality) Management Systems were shown to be useful tools.

Participants questioned whether satisfactory conditions at a site can be specified objectively. Areas that were identified as definitely requiring further attention included the justification of diagnostic examinations (where stakeholder involvement was recommended), multimodal medical imaging, and TENORM discharges. Different perceptions between countries and different 'radiation protection cultures' were identified as challenges.

One of the regulatory issues that were raised at other Sessions was that final high-level waste disposal is now close to licensing in some countries. The roles of different 'experts' need to be specified, and training needs must be addressed. ALARA programmes and peer comparisons (also between sectors) have regulatory implications even if not prescribed in regulations. Much attention was devoted to the importance of stakeholder involvement, certainly also relevant in the context of new regulatory developments; this however will be covered in another report on the conclusions of the Helsinki Congress.

PL5.4
Fukushima Lessons and Challenges in Japan

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The 2011 Off the Pacific Coast of Tohoku Earthquake and the resulting tsunamis struck the Fukushima Dai-ichi Nuclear Power Stations (Fukushima NPS) of Tokyo Electric Power Co. (TEPCO) at 14:46 on March 11, 2011 (JST), followed by a nuclear accident unprecedented in both scale and timeframe.

The Fukushima NPS accident has the following aspects: it was triggered by a natural disaster; it led to a severe accident with damage to nuclear fuel, Reactor Pressure Vessels and Primary Containment Vessels; and accidents involving multiple reactors arose at the same time. Moreover, a mid- to long-term initiative is needed to settle the situation imposing a large burden on society, such as a long-term evacuation of many residents in the vicinity, as well as having a major impact on industrial activities, including the farming and livestock industries in the related area. There are thus many aspects different from the accidents in the past at the Three Mile Island and the Chernobyl Nuclear Power Plants. The accident is also characterized by the following aspects. Emergency response activities had to be performed in a situation where the earthquake and tsunami destroyed the social infrastructure such as electricity supply, communication and transportation systems across a wide area in the vicinity. The occurrence of aftershocks frequently impeded various accident response activities.

This accident led to a severe accident, shook the trust of the public, and warned those engaged in nuclear energy of their overconfidence in nuclear safety. It is therefore important to learn lessons thoroughly from this accident. The lessons could be classified into several categories, bearing in mind that the most important basic principle in securing nuclear safety is having defenses in depth.

PL5.7
Citizen Monitoring Following the Fukushima Disaster

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ACRO, Hérouville Saint Clair, France

In the case of a nuclear accident, access to the measurement of radioactivity becomes vital. Authorities have laboratories and experts to answer their questions in order to help them with the decision making process. Citizens also need detectors, laboratories and experts to answer their own questions and help them make decisions. Fukushima disaster has shown that a top-down decision process is ineffective in a post-accidental context. For an effective protection, authorities and population should share the same vision of the risks. But confidence and respect is very difficult after a nuclear disaster that challenges the expertise of the authorities that failed to ensure safety. Authorities should encourage the diversity of measurements.

Authorities have distributed individual dosimeters to all children and pregnant women of the Fukushima Prefecture. This helped to find hotspots and protect the population.

Concerned members of the population rushed to buy simple dose rate detectors and found many hotspots, sometimes older than the Fukushima accident. Their first findings were not well accepted by the authorities who ignored this ‘amateur’ work. But alarmed by discoveries of radioactive hot spots far from the Fukushima Daiichi nuclear plant, Japan finally issued guidelines to help citizens and local officials to detect contaminated areas and to clean them safely. The residents, with the help of university experts to teach them how to use radiation-measuring devices, created the most accurate map of the contamination of Haramachi Ward in the city of Minamisoma.

The next step in the necessary empowerment of the population is to provide them direct access to laboratories that can analyse the contamination of various kinds of samples. Many citizen initiatives to run independent laboratories have emerged in Japan since 11 March 2011. Some are NGO others private companies. Most of these measurement stations are equipped with simple NaI scintillators that are not always sufficient. These initiatives need an official recognition and accreditation system.

The French NGO ACRO which runs a laboratory accredited by French authorities has analysed more than 300 samples from Japan and has help several initiatives to open independent laboratories in Japan. As the analyses were done to answer to the questions of the population, a large variety of samples were tested with contrasted results. All the results are on line in three languages (Japanese, English and French). In particular, ACRO has analysed many urine samples from Japanese children and house dust collected by vacuum cleaners.

ACRO also has initiated the creation of a more powerful laboratory in Japan equipped a germanium semi-conductor spectrometer in order to help the many structures equipped with simpler detectors. We also initiated a network with a Japanese university to ensure that the results provided by the network members are reliable and trusted by the population and authorities.

S3.1.3
IRPA Radiation Safety Culture; The Criteria Of Success:

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IRPA has stressed the importance of enhancing radiation safety protection culture throughout the world. Creation of a positive radiation safety culture encompasses the entire organization, from the top down and needs to be integrated throughout an organization.

Successful sustained positive radiation safety culture takes a comprehensive effort. These efforts will vary from discovering any problems with your radiation safety program, maintenance of rules and a regulation, testing to make sure education is retained and promoting positive reinforcement. Audits must be designed to fit the particular industry you are in.

Comprehensive steps to work toward a successful safety culture are presented and discussed. Methods must be fitted to a particular industry and may need to be changed to fit the personnel and situations encountered as well as the significance of not meeting safety culture way points.

S3.1.4
Assessment tools for the IRPA Guiding Principles for Establishing a Radiation Protection Culture

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Within the first draft of the IRPA Guiding Principles for Establishing a Radiation Protection Culture a significant part is focused on the identification of the best and optimal tools required and needed to assess the level and quality of the RP culture.

The key points identified in this document for the criteria of success are the elements to be assessed with proper tools in order to identify issues and problems opposing the improvement of the RP Culture or just to measure the level obtained by the RP Culture in a given situation.

The criteria to raise and to establish certain levels of culture, in the different fields of human activities, are generally depicted by: the continuous educational processes, the access to multimedia, and the effective communication among workers, directors with workers, and workers with patients and public. In this document specific aspects to be implemented for RPC in the different areas of ionizing radiation applications from medical, industrial and research, are presented.

The assessment tools should be structured in such a way, not only to obtain a picture of RP Culture at a given time, but also to help in finding trends and progresses or regressions in RPC.

By crossing the areas of use of RP with the ways of impacting RP Culture, a list of different tools are suggested at national level for professionals and directly involved people, at national level for the public awareness, at local level, for instance in a medical RP application and at the level of a third party "industrial" involved in RP equipments supply.

Some of the presented and listed assessment tools can be considered of a general use and extended to other conditions and situations where the degree of success in establishing and growing the RP culture needs to be assessed, but other more specific and peculiar tools will be needed for particular conditions.

S3.1.5
Engage Stakeholders and the Role of RP Professionals and IRPA Associate Societies

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At the IRPA12 Congress in Buenos Aires in October 2008, the Executive Council decided to actively support an initiative for enhancing Radiation Protection (RP) culture among the RP professionals worldwide. The draft document has been divided into four parts, the last of them is presented here.

The issue developed goes about stakeholder involvement and the engagement of the Associate Societies (AS) of IRPA. The first topic is based on the already elaborated "IRPA Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement".

As the first step of stakeholder engagement it is proposed to address the RP professionals and the media. The RP professionals are the "fighters in the first line". They have to know, what RP culture means and where the development should go to. The second stakeholder group was chosen because of their enormous influence on the one hand and the remarkable lack of knowledge and misinformation on the other hand which was obvious in the aftermath of the Fukushima Accident.

The implementation plan corresponds basically with the road map for the IRPA Guiding Principles, but it has to be elaborated in more detail by the IRPA AS with respect to each society. The culture is always regional or national and this has to be reflected through the IRPA AS. The ways of bringing RP culture to the RP professionals may be manifold and will therefore differ between the societies. Each society will find their own, best suited way, which will also depend of the resources available.

The implementation process will take some time. It can not be expected that the current situation will change in a short term. Therefore sustainability is needed.

The IRPA 13 Congress will be an opportunity to discuss the draft paper. Any suggestion of the congress participants is welcomed.

S4.1.3
The Chernobyl Accident: Understanding Its Wider Impact on the People of Belarus

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Belarus was the country most severely affected by the 1986 Chernobyl accident. However, despite promises made at the time, it has become a 'forgotten emergency'. This has been facilitated by the official international consensus that the accident did not produce serious radiation-induced health consequences, apart from the thyroid cancer in children, and that the biggest impact was on the mental health of the affected populations.

This paper argues that the way in which the accident and its health consequences for Belarus were framed has had significant implications for those affected, and not only in terms of the lack of assistance. It will show that for many, including Chernobyl 'liquidators', the lack of attention and appreciation of their suffering and/or sacrifice is often more devastating. Equally devastating for the people still living in the contaminated territories is being portrayed as having the 'Chernobyl dependency syndrome', and being largely left to deal with the consequences of the accident on their own.

The paper concludes with a call to the international radiation protection community not to forget those affected, to be attentive to their perspectives and needs, including the need to protect themselves and their families, and to receive necessary assistance to that end.

S4.1.5
Past Experiences and Lessons Learned Under the Rongelap Resettlement Program

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During the period between 1946 and 1958, the United States conducted 66 atmospheric nuclear weapons tests on and around coral atolls located in the northern Marshall Islands. Partitioning fission yields leading to injection of radioactive debris into the stratosphere show that nuclear tests conducted in the Marshall Islands made a significant contribution (about 20%) to world-wide fallout deposition. The Bravo test conducted at Bikini Atoll on 1 March 1954 was the most significant surface contaminating event conducted over the entire U.S. atmospheric nuclear test campaign (1945-1962). Bravo was a high-energy, experimental device with a reported fission yield of 9 Mt (UNSCEAR, 2000). Local inhabitants of Rongelap and Utrok Atolls to the east of Bikini were accidentally exposed to fresh fallout deposition, and had to be evacuated to Kwajalein Atoll for medical care. The Rongelap community initially returned home in 1957 only to enter into self-imposed exile during May of 1985 after it was revealed in scientific reports that Rongelap Atoll remained contaminated with long-lived fallout radionuclides.

The Bravo event left behind a chronicle of mis-information, an innate distrust of U.S. agencies, and social disruption as well as a deep-rooted sense of societal fear about radiation exposure. This paper gives a historical perspective on the many challenges that stakeholders have faced in establishing a path forward towards sustainable resettlement of Rongelap Atoll. The Rongelap Resettlement Program is considered a precedent setting activity whereby a local atoll government has actively engaged U.S. agencies in a partnership to develop a roadmap for resettlement based on shared levels of responsibility. A number of successful measures have been implemented under the DOE Rongelap Support Plan (RSP). The scientific basis for much of this work stems from vastly improved understanding of exposure pathways and long-term behaviors of key fallout radionuclides in coral atoll ecosystems, opportunity to implement practical and effective remedial measures, greater involvement of stakeholders, more timely and open disclosure of data and information, and introduction of a self-help regiment whereby Marshallese technicians trained in whole body counting will be able to monitor the returning population.

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S4.2.1
Recipe For Successful Science Teacher Workshops

Tarantino, CA*

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This paper discusses the strategies for paving a success path in conducting Science Teacher Workshops. Mixing the ingredients of teamwork, diversity, innovation, and humor, with an added spoonful of laughter, teachers of the 21st century become enthusiastically engaged in learning about radiation science. Through partnerships with private industry, government, academia, and professional societies the Virginia Chapter, HPS, has hosted numerous productive and enjoyable workshops designed to meet the challenges facing teachers of the 21st century. The approaches used to maximize and leverage resources economically will be shared. While presented with multidiscipline learning opportunities, teachers are equipped with a wide and varied spectrum of networking options which they can elect to pursue following the workshop. The recipe prescribed in this paper allows teachers to learn the facts about radiation science in a fun way while they receive the latest developments and state-of-the-art technologies of the nuclear field.

S4.2.2
Teaching Radiation Protection in Schools

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Today's challenge in the field of radiation protection (RP) involves measures to make the work in radiation protection more attractive for young people and to provide attractive career opportunities, and to support of young students and professionals in their need to gain and maintain high level knowledge in radiation protection.

Within European Network for Education and Training in Radiation Protection II (ENETRAPII) project a special attention is given to attract a new generation of professionals in RP.

The primaries activities for building a strategy for attracting of young people to the application fields of ionizing radiation and radiation protection were based on several case studies:

• surveying national and international initiatives for attracting young people to develop an interest in radiation protection;
• analyzing human resources (HR) shortage in RP and defining suitable measures for addressing the HR shortage in RP;
• designing The Radiation Protection Action Plan for providing continuous professional development for science teachers and early-stage radiation protection researchers;

The case study on the Analysis of human resources (HR) shortage in RP was done in order to find the causes of HR shortage in RP and to define suitable measures to recruit and educate young people as experts, technicians and skilled staff in the radiation protection field.

The main findings on the human resources (HR) shortage in RP and on the measures to address HR shortage in RP, emphasis the trend of young people turning away from science.

In order to reverse the trend of young people turning away from science it is necessary to attract more young people by awaking their interest in radiation applications and radiation protection already during their schooldays and later on during their out-of-school education (university or vocational education and training) by rethinking the RP teaching in schools.

S4.2.3
Radiation Protection Culture at School: Feedback Experience and Perspective

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The radiation protection culture corresponds to the set of knowledge and know-how allowing people to be informed and to behave and decide accordingly with regard to exposure situations involving ionizing radiation. In this perspective, the aim of the development of this culture is to provide people the means to understand the risk associated with exposure to ionizing radiation, as well as the origin and the localisation of the radioactivity in the different places. It also aims at providing the means for appraising the efficiency of the different protective measures already implemented or to be implemented. The development of this corpus of knowledge and know-how at school is based on the practical experience instead of a purely theoretical approach, and has to favour the cooperation between teachers and radiation protection experts in relation with the local contexts concerning exposure to ionizing radiation.

Experiences with schools have been developed first in the context of the post-accidental situation in Belarus and more recently in France to deal with exposures associated with radon or discharges of nuclear installations, as well as exposures in the medical sector. The success of the first experiences clearly relies on the willingness of the teachers and the students to experiment the development of the radiation protection culture, mainly out of the traditional school programme. It also relies on the flexibility and the dynamics of the work performed with the young students. It allows them at the same time to address scientific topics related to their own context in cooperation with experts and to challenge the relationship between science and society in addressing social, economic or philosophical dimensions according the teachers involved.

Furthermore, the relationship developed with professionals for scientific mediation (Pavillon des Sciences) was crucial to favour the development of knowledge and know-how instead of theoretical approaches of radiation protection. The place of radiation protection experts is also essential: this is a real challenge for us to present to a young public what is at stake in radiation protection in terms of: public health, research, protection and surveillance of the environment. There is a need to find the good wording, the meaningful experiences and the limited set of useful knowledge to deal with the radiation protection issues with young people.

In the perspective of enlarging the experiences already developed, it could be useful to: - Develop pedagogical documents describing the approaches implemented together by teachers and radiation protection experts;

- Favour local initiatives in establishing relationship between school teachers, scientific mediation professionals and radiation protection experts;

- Organise the sharing of these experiments at the national and international levels, notably through Radiation Protection Societies and IRPA.

S4.2.4
A Swiss-German Approach to Introducing Pupils, Students, and Young Professionals to Radiation Protection

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Due to a variety of reasons, not least in consequence of the lasting public debate on nuclear power and the risks of radiation, the readiness of pupils (and teachers) for being engaged in radiation affairs is rather poor. With or without nuclear power use, however, we shall certainly need young professionals in the well established radiation protection domains now and in the future, too. Thus, the Swiss-German Association (Fachverband für Strahlenschutz, FS) looks upon the encouragement of young people and young professionals as one of its prominent jobs.

In order to introducing pupils, students, and young professionals to radiation protection topics, the FS has established three different lines of funding :

• The first line aims at pupils (age between 16 and 18) and teachers in schools. Radiation protection projects are to be performed in groups of 1 to 5 pupils with one teacher. Support is given by FS-members who have appropriate laboratories or other facilities available. Each project is funded by € 500. The results are presented annually at a particular little symposium with prizes and awards. In total, 25 projects with about 80 pupils involved have been performed since 2007.

• The second line is for students in radiation related study courses. The FS supports studies abroad by funding one semester outside of Switzerland or Germany with € 1,000 per student. Up to 2011 9 students have been funded.

• The third line is a young scientists award, called "Rupprecht-Maushart-Preis", initiated in 2008. The prize is awarded every two years to an outstanding thesis related to radiation protection performed at a Swiss or German university or comparable academic institution. In essence, the conditions of the "Rupprecht-Maushart-Preis" are in line with the Young Professionals Award of the IRPA.

The experiences, difficulties, shortcomings, and expectations of the approach are to be discussed.

Society:

Swiss-German Association for Radiation Protection Fachverband für Strahlenschutz (FS)

Organisation:

THM, University of Applied Sciences

Institute of Medical Physics and Radiation Protection

Giessen, Germany

S4.2.5
The Project of the Spanish Nuclear Industry Forum to Elaborate a Didactic Interactive Material on Radiological Protection.

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The Training Department of the Spanish Nuclear Industry Forum, has a wide experience in preparing educational material on issues related to energy, including nuclear energy. At the beginning of 2011, this Department launched a new project in order to develop an interactive educational material on Radiological Protection. This material will initially be in Spanish and will be available for free use in the Forum webpage "Rincón educativo" (www.rinconeducativo.org)

The aim of the Project is to develop an attractive, comprehensive and interactive material, to facilitate students and teachers to become familiar with the radiological protection and in general with ionising radiations. The material is intended for primary, secondary and high schools. The novelty of this project is that is being developed based on the European framework of "key competences for learning". The Competences, as defined by the European Commission, are *"a set of knowledge, skills and attitudes that all individuals need for personal fulfilment and development, inclusion and employment"*. To facilitate the acquisition of competences, it is essential to define and select appropriate tasks, which must make sense inside and outside the classroom, be useful and interesting, contextually pertinent, varied and proper for the objectives to be achieved. Ultimately, the goal is to create an integrated structure of tasks, activities and exercises that facilitate the achievement of as many key competences as possible.

The didactic material being elaborated by Forum, follows this integrated structure of tasks, activities and exercises. Besides, the material developed also includes reference texts, links to pertinent websites and video tutorials on basic aspects related to ionising radiation.

Students, through the development of a specific task, and the related activities and exercises, will learn the differences between ionizing and non ionising radiation, the origin and characteristics of the different types of ionising radiation, the methods available to detect and measure radiation, the detrimental effects that can produce in human health, the existing protection actions to minimize these risks and the main fields of application of ionising radiation on man's behalf.

S4.2.6
Teaching of Radiation Protection in Primary and Secondary Schools

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The medical use of radiation has greatly expanded in the last three decades. A range of actions is used to improve quality care, radiation safety and more appropriate use of radiation. These actions could be grouped under five strategies: conduct research, promote awareness, provide education and training, strengthen infrastructure and implement policies.

The stakeholders are informed and empowered by awareness campaigns and web-based informative resources. Providing education and training at undergraduate and postgraduate levels is an effective means to improve awareness and promote an appropriate use of radiation and radiation safety. The innovative teaching of radiation topics in schools supports this strategy.

To celebrate the 100-year discovery of x-ray and WC Rontgen's 150th birthday, the Royal Australian and New Zealand College of Radiologists (RANZCR) launched a Roentgen Anniversary Celebration Efforts (RACE) program in 1995. Forming part of this program were two publications "X-rays: the Inside Story for Primary Schools" and "X-rays: the Inside Story for Secondary Schools". The end-users were schoolteachers, primary and secondary school students. One of the objectives was to address the low awareness in and scarce educational resources on the medical use of radiation, radiation safety and radiation protection in this group.

The RANZCR collaborated with other stakeholders, including the Australian Science Teachers Association (ASTA). The teaching tools include a Teacher's Manuel, a set of activity cards, an Image Library, a poster, and a video. The sponsor was Toshiba Australia. The teachers observed various activities in a radiology department and discussed their queries with staff members before drafting the material.

Each RANZCR member was given a copy of the publication and asked to donate this to a school of their choice in Australia or New Zealand. The ASTA informed their members of this project and how the material could be used in classes.

With an increasing public awareness and interest in the medical use of radiation, it is timely to consider an update of these publications and a possible wider dissemination to school students and their families at an international level. Under a globalized environment, collaboration between professional organizations, agencies and authorities will provide strength and synergy, minimize duplication and spearhead actions to improve patient care, radiation safety, radiation protection and appropriate use of radiation in medicine.

S7.1.2
Management of Patient Dose in Radiology: Which Models can achieve Optimisation?

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There continues to be a steady expansion in the use of X-ray imaging throughout the world. In some industrialized countries, doses from medical exposures now make up the largest component of the dose to the population. Effective management of this use of radiation requires robust arrangements for the justification of exposures and for optimisation of protection to ensure that doses are the minimum necessary to fulfil the clinical purpose. Countries throughout the world are now undertaking surveys of patient dose, but these do not necessarily achieve optimisation of patient protection. A limited survey of organisational arrangements relating to the management of patient dose in different countries has been undertaken. This has been based on completion of survey forms by medical physics contacts, coupled with knowledge of the authors of practices in the countries. Performance testing may be undertaken by hospitals, health authorities, private consultants or government organisations. Patient dose surveys may also be carried out by these parties, but are often carried out as part of university research projects. In order for dose surveys to have an impact, action must be taken upon the findings, but there may not be an effective link between the surveyors and the hospital staff to ensure that this is done. This paper will consider the possible advantages and disadvantages of various models and give an indication of the prevalence of the different approaches in countries around the world. The authors will draw conclusions about the approaches that are most likely to be effective in achieving optimisation of patient protection in radiological procedures and propose recommendations for the development of effective programmes for management of patient dose.

S7.1.3
Current Epidemiology Studies of Risks Associated With CT Scans

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Epidemiology studies are invaluable for radiation protection purposes . While risk models are very useful and often relatively quick to calculate, they are better when complemented by the results of studies that directly observe health effects of radiation exposures in the populations radiation protection is aimed at. Of all medical radiation exposures, the one of growing interest from both a radiation research and public health perspective relates to the use of CT scans which are available worldwide at over 300,000 centres, with the number of machines continuing to increase. Whilst benefits to patients in most settings of having a CT scan can be substantial, concerns have been raised over the relatively high radiation doses associated with CT (for example, the dose to the stomach is around 50 times higher from an abdominal CT compared with that from an abdominal X-ray), particularly in terms of potentially increased future risks of cancer. The patient group of most concern are children, who are more susceptible to the effects of radiation, in part due to their longer post-irradiation life expectancy, and because following the same radiation dose they experience greater radiation-induced tissue damage than adults. Children are also known to receive higher radiation doses than necessary when scanned using CT settings designed for use with adult patients. Risk projections in relation to CT scanning to date have been based on extrapolations, primarily from atomic bomb data. As CT usage continues to grow and to become more widespread and technologies change, the understanding of any risks involved to patients is crucial. In this talk, an overview of ongoing studies in this area will presented.

S9.1.1
Current Thinking on the Early Effects from Uniform and Non-Uniform Radiation.

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As with many other injuries, the sooner that a seriously irradiated person can receive appropriate medications, the greater the chance of survival. But in order to develop countermeasures that will provide such treatments, we must have a clear understanding of the biology of both the injury and the physical response. However, despite decades of modeling and preclinical research, augmented with experience dealing with casualties from radiation events, our understanding of the complexity of the radiation injury continues to evolve. Our current understanding of the immediate and early events following high-dose irradiation will be discussed, including differences that may be seen due to heterogeneous exposure. This will include our more recent appreciation for syndromes beyond that classically considered part of the acute radiation syndrome (ARS). In addition, potential targets for protection and mitigation will be explored.

S9.1.2
Early Effects from Internal Radiation: State-of-knowledge and Need for an Improved Assessment

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A high radionuclide level exposure of members of the public may induce a serious internal contamination. Consequently potential early health effects may occur, these latter have to be known and understood in order to prevent adverse effects by administration of adequate medical countermeasures.

This presentation will review the health endpoints previously described in epidemiological or animal studies. It will highlight the relative importance of the conditions of exposure (nature of radionuclide, speciation, route of contamination…) towards their potential toxicological effects. Some rare human knowledge for several radionuclides is well established; but most data have been reported from animal experiments preventing their easy extrapolation for accidental situations involving human contamination. Otherwise, toxicological data are available just for some 'major' radionuclides. For 'minor' radionuclides, chemical analogies have been done considering these compounds could behave such as surrogates of 'major' radionuclides and induce the same adverse health effects. But in some cases no sufficient data are available for predicting potential adverse effects at early time, their reversibility or their time-evolution.

Therefore there is a need of research for identifying early biomarkers for diagnosing biological effects before they become health effects. The identification of biomarkers would be very useful not only for adapting the right countermeasures to the contaminated members of the public but also for prioritizing of affected population in case of a large-scale radiation emergency.

S9.1.4
Stem Cell Therapy As Medical Countermeasures For External Radiation Burns

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The medical management of severe radiation burns after accidental overexposure to ionizing radiations was a major therapeutic challenge unresolved since these 7 last years with the classical therapeutic approach derived from the management of thermal or electrical burns. The evolution of radiation-induced lesions often becomes uncontrolled and the final option is a last surgical act leading to a high morbidity and disability. Based on pre-clinical results, adult stem cell therapy was postulated to favour the radiation burn healing process. The benefit of Mesenchymal Stem Cell local administration for ulcerated skin and muscle restoration after high dose radiation exposure has been successfully demonstrated by IRSN group. The clinical benefit of MSC combined or not to surgery in promoting the healing of cutaneaous radiation syndrome (CRS) has been then successfully demonstrated by Military Percy hospital team in 9 patients overexposed accidentally to radiation since 2006.

Finally, several strategies need to be developed in order to enhance the beneficial effect of stem cell therapy for counteracting the deleterious effect of irradiated environmental tissues.

S9.1.5
Medical Countermeasures for Treating Internal Deposits of Radionuclides

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Internal contamination with radionuclides presents the problem that radiation dose is delivered chronically to the host based on the physical and biological half time of the radionuclide. Thus, there is the opportunity to reduce health risk if the retention time of the radionuclide in the body can be decreased and excretion accelerated. This is the goal of decorporation therapy. This presentation will summarize the methods available for decorporating a wide variety of radionuclides. Physical removal methods such as surgical excision, GI tract stimulants and bronchoalveolar lavage can be used to decorporate radionuclides from their initial deposition sites (wound, GI tract, lung). Conversely, if the deposited radionuclide is physiologically soluble, then chemical methods using complexing, chelating and blocking agents have been shown to be efficacious in varying degrees. More recent additions to the traditional decorporating methods and agents will also be summarized – some successful, some not. Finally future research needs and directions will be described.

S10.1.1
Residential Radon, Smoking and Lung Cancer

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Recent epidemiological data enable the extent to which radon causes lung cancer in ordinary homes to be estimated. They also provide insight into the way in which cigarette smoking modifies the risk of radon-related lung cancer. These new data have substantial implications for optimum strategies for the control of radon-related lung cancer.

Keywords: Radon, smoking, lung cancer

S10.1.2
ICRP Radon recommendations

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The Commission is updating its recommendations on protection against radon exposure according to its new general recommendations (Pub 103 and Pub 101 on optimisation). The future publication will remain in line with the previous Pub 65 dedicated to radon. It will also take into account the recent Pub 115 on the lung cancer risk from radon and progeny. Radon exposure arises in dwellings, workplaces and mixed-use buildings. Because the most part of the risk is due to exposure at home, it should be addressed mainly in a public health perspective. The approach developed is integrated (focussed as far as possible on the management of the building whatever its occupants), graded (according to responsibilities, especially in workplaces) and ambitious (aiming at reduce both the highest exposures and the overall risk). The recommended strategy, implemented through a national action plan, is mainly based on the optimisation of the protection below a reference level, combining prevention and mitigation. In workplaces, the exposure is regarded as an occupational exposure according to either a quantitative criterion (reference level) or a qualitative criterion (positive list of radon prone work activities). The approach is expected be applicable in all existing exposure situations.

Keywords: Radon exposure, Prevention, Mitigation, Dwellings, Buildings, Workplaces

S10.1.3
The Impact of UK Government Targets for Smoking Cessation on the Effectiveness of the Radon Remediation Programme.

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Smoking and radon gas are both known causes of increased lung cancers, with smoking being the most significant risk, In the UK there are separate initiatives to reduce the risk from each. Programmes to find houses with raised radon levels, and then encourage householders to take remedial action have been running in radon affected areas for some years. However, to date only around 40 % of householders have tested their homes, and, of those who find radon levels over the Action Level, only around 15% have taken action to reduce radon levels.

Smoking Cessation Campaigns operated by local National Health Service (NHS) bodies have achieved some success and reduced the percentage of smokers from 45% in 1974, to 28% in 1998, and now to around 20 % in 2010. The Government has recently published the target of reducing this to 10 % in England in 2020.

It has been shown that the two risks together are sub-multiplicative, and that most radon-induced lung cancers occur in smokers. Therefore the two initiatives to reduce risk are not independent, and a reduction in the number of smokers will reduce the effectiveness of the radon remediation programme.

Our group has studied the characteristics of those who remediate their homes to reduce radon risk, and has shown that they are older, have fewer children, and include fewer smokers than the general population, and so radon remediation programmes are not reaching those most at risk.

This paper considers the impact of the Government's targets for Smoking Cessation on the effectiveness of the radon remediation programme, and makes recommendations for future public health initiatives in light of the interaction between the two risks.

S10.1.4
The National Radon Program – a Success Story Continuing in Canada

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Recent scientific studies have conclusively linked an increased risk of developing lung cancer to levels of radon found in homes. These studies prompted the Canadian federal government to collaborate with provincial and territorial governments to review the Canadian radon guideline. Based on the latest scientific information and following a broad public consultation, the guideline was lowered from 800 to 200 Bqm^{-3} in June 2007. The revised guideline provides advice that is more broadly applicable and more protective than the previous guideline. In addition to residential homes, the guideline also applies to public buildings with a high occupancy rate by members of the public. Efforts are being made to harmonize workplace exposure limits with this guideline as well. A recommendation for techniques to be employed in new construction to minimize radon entry and facilitate post-construction radon reduction, should this subsequently prove necessary, has also been made an integral component of Canada's revised guideline.

To support the implementation of the revised guideline, a National Radon Program was developed in collaboration with the Federal Provincial Territorial Radiation Protection Committee, an intergovernmental Committee established to advance the development and harmonization of practices and standards for radiation protection within federal, provincial and territorial jurisdictions of Canada. The National Radon Program consists of 5 components: 1) establishment of a national radon laboratory as a centre of excellence on radon testing, 2) radon testing projects to increase the understanding of radon levels across Canada, 3) development and maintenance of a radon database and mapping of radon potential areas of Canada, 4) radon research and 5) the development and implementation of a radon education and public awareness strategy to help inform and protect Canadians from the risks of long-term exposure to elevated levels of radon. Significant progress has been made in all 5 areas of the National Radon Program since its inception in 2007. Details of the successes and major achievements accomplished over the past five years, ongoing activities and new challenges are highlighted and discussed for Canada's National Radon Program.

S10.1.5
A Nationwide Radon Survey in Finland - Prevention in new Construction

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The status of radon prevention in new construction was surveyd in in Finlnd in 2009. In this study, the indoor radon concentration was measured in 1 500 new low-rise residential houses. The houses were randomly selected and represented 7% of the houses that received building permission in 2006. The average radon concentration of all the houses measured, which were completed in 2006 to 2008, was 95 Bq/m^3, the median being 58 Bq/m^3. The average was 33% lower than in houses completed in 2000 to 2005. The decrease was 47% in provinces with the highest indoor radon concentration and 26% elsewhere in the country. In houses with a slab-on-ground foundation that had both passive radon piping and sealing measures carried out using a strip of bitumen felt in the joint between the foundation wall and floor slab, the radon concentration was on average reduced by 57% compared to houses with no preventive measures. Preventive measures were taken nationwide in 54% of detached houses and in provinces with the highest radon concentration in 92% of houses.

S11.1.1
Effects of Chronic Radiation Exposure on Plant Populations

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One of the major difficulties in the implementation of an ecological risk assessment is a lack of knowledge about the effects from chronic low-level exposures to radioactive contaminants. To understand effects of real-world contaminant exposure properly we must pay attention to what is actually going on in the field. However, for many wildlife groups and endpoints, there are no, or very few, studies that link accumulation, chronic exposure and biological effects in natural settings. The results of long-term field observations in the 30-km Chernobyl NPP zone, in the vicinity of the radioactive wastes storage facility (Leningrad Region), at radium production industry storage cell territory (the Komi Republic), in the Bryansk Region affected by the Chernobyl accident, and in Semipalatinsk Test Site, Kazakhstan that have been carried out on different species of wild and agricultural plants are discussed. Although radionuclides cause primary damage at the molecular level, there are emergent effects at the level of populations, non-predictable solely from the knowledge of elementary mechanisms of the pollutants' influence. Plant populations growing in areas with relatively low levels of pollution are characterized by the increased level of both cytogenetic alterations and genetic diversity. Accumulation of cellular alterations may afterward influence biological parameters important for populations such as health and reproduction. Presented data provide evidence that in plant populations inhabiting heavily contaminated territories cytogenetic damage were accompanied by decrease in reproductive ability. However, in less contaminated sites, because of the scarcity of data available, it is impossible to establish exactly the relationship between cytogenetic effects and reproductive ability. Radioactive contamination of the plants environment activates genetic mechanisms, changing a population's resistance to exposure. However, there are ecological situations in which enhanced resistance has not evolved or has not persisted. Consequently, there are good theoretical and practical reasons for more attention being paid to the mechanisms by which populations becomes more radioresistant and to those situations where radio-adaptation appears not to be taking place. Since radio-adaptation plays an important role in response of populations on radiation exposure in natural setting, this process need to be incorporated into management programmes designed to minimize biodiversity loss under conditions of chronic exposure to radionuclides.

S11.1.3
RBE and Radiation Weighting Factors as Applied in the Context of Protection of the Environment from Ionising Radiation

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It has long been recognized that the degree of biological impact on an organism resulting from a given absorbed dose of ionising radiation can vary depending upon the type of radiation involved. This difference has been experimentally quantified and reported as the "relative biological effectiveness" (RBE) of specific radiation types. RBE values have been measured for a variety of end points in in vitro experiments that include human and animal cell lines, as well as in vivo experiments with animals. Such studies have shown that the magnitude of a biological effect depends not only on dose and the type and energy of the radiation delivering the dose, but also on the rate at which the dose is delivered and, most importantly, the endpoint under study. The need to apply this knowledge to radiation protection of humans has led to an aggregation and analysis of RBE data to develop such constructs as "radiation weighting factors". In recent years, radiation protection has taken on a broader meaning, and is now evolving to include protection of the environment from ionising radiation. However, the application of radiation weighting factors in the context of assessing biologically significant doses to animals and plants is not without some controversy. Protection of biota from the effects of ionising radiation has largely focused on endpoints which are relevant at the population level, such as reduced reproductive fitness. This means that use radiation weighting factors derived from evaluations of stochastic effects, as in the system of protection for humans, appears inappropriate. This presentation discusses efforts to develop a logical, transparent, and defensible approach to establishing radiation weighting factors for use in assessing impacts to non-human biota. It also considers the challenges in differentiating stochastic from deterministic impacts.

S12.1.1
Fukushima Panel Discussion

Kosako, T*

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We express our deepest sympathy to all those affected by the Great East Japan Earthquake, tsunami, and Fukushima Daiichi nuclear disaster, all of which have had a serious impact on Japan. Soon after the Fukushima Daiichi nuclear disaster, Japan Health Physics Society (JHPS) established a Q&A section on our website and has answered questions from the public in our capacity as a group of radiation protection professionals. In addition, we held symposia on Measures for Dealing with the Nuclear Disaster and Their Criteria on 16 June 2011 and on Exposure to Radiation among the General Public on 12 August 2011. We also held a session on the Fukushima Daiichi nuclear disaster at the 44th JHPS Annual Meeting on 18 October 2011 to deepen understanding and promote discussion about various topics related to the disaster. On 17 December 2011, we also held a comprehensive symposium on Measures for Dealing with the Fukushima Nuclear Disaster from the viewpoints of radiation exposure assessment and nuclear waste management, focusing on internal exposure, and we identified the important issues involved in radiation protection to be examined in the future.

To comprehensively discuss our society's activities carried out over the year following the earthquake, we summarized a report on the issues involved in radiation protection on the basis of the findings and lessons learned through the responses to the Fukushima Daiichi nuclear disaster, and the responses of and the recommendations from JHPS.

We will endeavour to further the study of health physics and radiation protection through future discussion and provide useful references for local residents and administrative organizations. In the near future, we will carefully analyze the actual state of the Fukushima area to propose recommendations in cooperation with overseas associated societies such as the Asian and Oceanic Association for Radiation Protection (AOARP), the International Radiation Protection Association (IRPA), and the Health Physics Society in the US.

F2.1.1 Current and Recent ICRU Activities in Radiation Protection Dosimetry and Measurements

Menzel, H*

International Commission on Radiation Units and Measurements (ICRU), Switzerland

The ICRU has maintained since its inception in 1925 a continuous involvement in the development of concepts, quantities, units and measurement procedures related to radiation protection, both on its own and in collaboration with the International Commission on Radiological Protection (ICRP).

In 1977 the ICRP introduced a system of dose limitation that included the use of the quantity effective dose equivalent as the weighted sum of the dose equivalent in different organs. Because effective dose equivalent (and its successor effective dose) is not a measurable quantity, ICRU introduced in 1985 operational quantities for individual and ambient monitoring of external radiations which can be determined experimentally and are aimed at providing an adequate estimate for effective dose equivalent. ICRU published reports on practical guidance for the determination of operational quantities and, jointly with ICRP, published dose conversion coefficients for protection and operational quantities. The system of operational quantities is currently being reviewed by an ICRU Committee (see presentation by Dietze et al.).

The ICRU has also provided practical guidance for radiation protection measurements in a variety of areas including *Gamma ray spectrometry in the environment* (ICRU 53), *Dosimetry of External Beta Rays for Radiation Protection* (ICRU 56), *Retrospective Assessment of Exposure to Ionizing Radiation* (ICRU 68), *Direct Determination of Body Content of Radionuclides* (ICRU 69) and *Sampling for Radionuclides in the Environment* (ICRU 75). Currently a report on *Measurement and Reporting of Radon Exposures* . is being prepared.

ICRU continues to address also fundamental issues of radiation dosimetry. For example, recently a report on *Quantification and Reporting of Low- Dose and Other Heterogeneous Exposures* has been published (ICRU 86). (see presentation by Michael and Braby). A report on *Physical Key Data for Measurement Standards in the Dosimetry of Ionizing Radiation* is close to being completed.

ICRU and ICRP are collaborating in preparing and publishing data and recommendations in several joint reports. Examples are report on *Adult Reference Computational Phantoms* (ICRP 110). Based on the ICRP recommendations in ICRP 103, these phantoms have been used to provide updated the earlier joint report on *Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures* which was published very recently (ICRP 116).

F2.1.2
Operational Quantities for External Radiation Exposure - Actual Shortcomings and Alternative Options

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The routine assessment of radiation exposure is in terms of the protection quantities equivalent dose in an organ or tissue and effective dose which are defined as mean doses in the organs and tissues of the human body. Primary exposure limits are always given in terms of these quantities. These quantities are, however, not measurable. For practical applications in radiological protection operational quantities have, therefore, been defined which are used for the assessment of values of protection quantities. For situations of external radiation exposure a system of operational dose quantities (quantities for area and individual monitoring) have been defined by ICRU and ICRP which have been in use for more than 20 years. While principally these quantities are said to be measurable, the calibration of dosemeters is usually performed in radiation fields with well specified energy distribution of fluence rates (or kerma rate in case of photons) and the application of reference fluence-to-dose equivalent conversion coefficients (recommended by ICRU, ICRP and ISO) for the specification of reference values at the point of interest.

During recent years attention has been paid to the deficiencies in the definitions of these operational dose quantities, and an ICRU Task Group is now discussing these problems. The deficiencies became more relevant for high-energy radiation which has increased in importance, e.g. radiation in aviation altitudes and in space, radiation at high-energy accelerators for research, and for medical applications.
Specific deficiencies with dose quantities for area monitoring are:

• Fundamental problem that ICRU 4-element tissue cannot be fabricated.
• Dose equivalent is defined as absorbed dose in tissue times *Q(L)*, where *L* is the LET in water.
• Conversion coefficients for photons and neutrons are calculated using the kerma approximation *in vacuo.*
• Secondary radiation produced in air by the primary radiation is not included in the definition.
• For high-energy radiation the dose built-up in the ICRU sphere is not attained at a depth of 10 mm.
Most deficiencies are more relevant for quantities for area monitoring, e.g. *H**(10), than for individual monitoring, e.g. *Hp(d)*.

A revision of operational dose quantities for external exposure is a difficult task because of its great impact on radiation monitoring in practice, and on the design and calibration procedures of dosemeters for use in many fields of radiological protection. The advantages and disadvantages of changes need to be carefully discussed before a recommendation canbe given.

For area monitoring various options are proposed:

• Calculate conversion coefficients using the kerma approximation in the ICRU sphere as before.
• Calculate conversion coefficients for the ICRU sphere surrounded by air instead of vacuum.
• Define conversion coefficients by approximating the conversion coefficients (AP or ISO exposure or an envelope function) for effective dose or for organ and tissue equivalent doses without using the ICRU sphere.
• Use the existing conversion coefficients for photons, electrons and neutrons where they fit well but define new coefficients for other radiation types and energies based on the assessment of effective dose etc.

For individual monitoring the situation is slightly different because no specific phantom is defined for the definition of *Hp(d)*. For calibration of personal dosemeters, however, an ICRU tissue slab phantom has been defined and for high energy radiation the problems and options are similar to those for area monitoring.

F2.1.3
ICRU Report 86: A Consideration of Low-Dose Metrics

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Absorbed dose and several related quantities are appropriate metrics for quantifying most radiation exposures. These quantities represent, or are derived from, the mean energy deposited per mass at a point or within a region of interest. Certain situations, however, require more detailed information. An example is when evaluating the consequences of low-dose exposure of a biological system. Here, physical measurements should include the spectrum of energy-deposition events that occur at the level of individual cells, depending on whether they have, or have not, been traversed by one or more tracks. Cell-cell interactions and non-targeted effects have been shown to influence some low-dose responses. ICRU Report 86 examines the specification of exposures in low-dose and other situations where the heterogeneity of energy deposition is a significant factor. The report considers approaches that would make the nature of the energy deposition in discrete targets more apparent than it is when using the absorbed dose alone.

F3.1.2
The Precautionary Principle and the Ethical Foundation of the Radiation Protection System

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The precautionary principle is one of the core values structuring the radiation protection system. Finding its roots in the Western tradition in the virtue of prudence developed by Aristotle, the concept of precaution can also be found in the Buddhist philosophy, the teaching of Confucius and in the ancient traditions of the peoples of Eurasia, Oceania and America.

The precautionary principle was incorporated into the radiological protection system in the early fifties in order to take account of the uncertainties about the risk and the irreversibility of the stochastic effects. Thereafter, the system was structured with the three principles that remains valid today: justification, optimisation and limitation, optimization being without doubt the cornerstone. Two aspects should be underlines in the implementation of these principles. The first is without doubt the progressive recognition that approaches which aim to base the search for "reasonable" levels of protection in the form of equations as a way to implement the precautionary principle necessarily involve over simplification. This led to successively incorporate into the optimisation process components developed in the field of management techniques and approaches calling on the direct involvement of all parties involved in the implementation of protection. The second aspect is related to the change of logical mindset when one moves from the approach of preventing proven risks (deterministic effects) to the precautionary approach aimed at mitigating hypothetical risks (stochastic effects). This difficulty is manifest in the handling of threshold values and associated dose limits. One moves from prevention to precaution while keeping the same form, but changing some of the basics. Not all parties who have to adapt this frame of reference to their daily work grasp the change in operation and some continue to think on the lines of limiting "precautionary" values as being the same as limiting "preventative" values. It is for this reason that the precautionary principle needs a clear culture, like that which the ALARA culture currently seeks to promote.

The paper presents first the ethical values underlying the precautionary principle. The second part presents how the system of protection evolved to incorporate the uncertainty associated to the existence of stochastic effects associated to radiation exposure. The third part reviews the procedural aspects associated to the practical implementation of the precautionary principle through the optimisation of protection process that apply to all exposure situations. In conclusion the paper addresses the pitfalls associated to a wrong appreciation of the role of the precautionary principle in the system of radiological protection and the importance to develop a strong ALARA culture among professionals in order to overcome the associated difficulties.

F3.1.3
A Cross-Cultural Approach to Questions of Ethics in Radiation Protection

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In spite of the on-going globalization in many areas, questions of right conduct and good life are still discussed almost exclusively in terms of classical Western ethical concepts such as utilitarianism or deontology. A cross-cultural dialogue in this area is only beginning. It must address differences and similarities in the approaches taken to ethics by people from various cultural backgrounds, ethnic origins, and religious affiliations. This contribution will endeavour to do so with regard to the ethics of radiation protection.

I will argue that certain principles applicable in this area are accepted by people virtually everywhere in the world. They may not answer the more intricate questions of the ethics of radiation protection, but provide basic criteria. Without going into any depth, the following areas can be identified in which cross-cultural agreement does exist: peaceful discourse; fairness (the "Golden Rule"); human dignity; concern for the underprivileged; intergenerational equity; and the „Precautionary Principle".

A lot of work needs to be done, of course, to clarify what exactly these principles mean to people of different cultural backgrounds, how they apply in practice to the questions of radiation protection, and whether there are other principles, values and norms which could have implications in this context.

Forum abstracts

F7.1.1
The Role of MPE/QE/RPO – The View of the IOMP

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As defined in the IOMP Policy Document Medical Physicist (MP) are health professionals. The domain of MPs is the medical application of ionizing & non-ionizing radiation in diagnosis and treatment of diseases. Having completed education & specialist training and after professional certification the MP (CMP) is competent to practice independently. The IOMP has specified the education and training requirements. The CMP is comparable to the MPE as introduced in the EU-BSS and corresponds the Qualified Expert (QE) in medical physics as defined in the BSS. Medical Health Physics (Radiation Protection in Medicine) is one of the subfields of medical physics. MPs as key players in radiation medicine and by virtue of their education and training are competent to undertake all the responsibilities of the Radiation Protection Officer (RPO). With appropriate training, MPs are also competent to work as a Radiation Protection Expert (RPE) in the sense of the BSS.

F7.1.3
The IAEA Inter-Regional Project on Harmonization of Medical Physicist Roles and Responsibilities in Radiation Medicine

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The shortage of clinically qualified medical physicists, insufficient education and training, and lack of professional recognition in many countries have been identified as the main issues to be addressed internationally. In response to these findings, the IAEA has established the inter-regional Technical Cooperation Project INT/6/054 “Strengthening Medical Physics in Radiation Medicine”. The World Health Organization (WHO) and major medical physics professional societies worldwide, including the International Organization for Medical Physics (IOMP), the European Federation of Organizations for Medical Physics (EFOMP), the American Association of Physicists in Medicine (AAPM), the Latin American Association of Medical Physics (ALFIM), the Asia-Oceania Federation of Organization for Medical Physics (AFOMP), the European Society for Therapeutic Radiology and Oncology (ESTRO), the European Commission (EC), and the International Radiation Protection Association (IRPA), as well as regional counterparts from Europe, Africa, and Latin America, were invited to co-operate. The group developed a joint report “Requirements for the Education and Clinical Training of Clinically Qualified Medical Physicists” that defines appropriately and unequivocally the roles and responsibilities of a clinically qualified medical physicist in all specialties of medical physics related to the use of ionizing radiation. Important non-ionizing radiation imaging specialties are also considered for completeness. Roles and responsibilities in occupational and public radiation protection and safety are defined too. On the grounds of the medical physicist tasks, the document provides recommended minimum requirements for the academic education and clinical training of clinically qualified medical physicists, including recommendations for their certification and registration, along with continuous professional development. Overall, inter-regional criteria have been established that support the harmonization of education and clinical training worldwide, as well as promoting the recognition of medical physics as a profession.

F7.1.6
The Role of MPE/QE/RPO in Hospitals – The African Perspective

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Background: The International Atomic Energy Agency (IAEA) has greatly improved the training of Medical Physicists and radiation scientists in most of the African countries. As defined in the IAEA BSS, the sole aim is to ensure safety and security of all radiation sources, to safeguard the radiation workers, members of the public, the environment and the patient when it comes to medical practices against accidental exposures. With this background, in Africa it is mandatory for each IAEA member state to have a regulatory body to regulate the use of ionising radiation in the existing practices in the entire country. In hospitals, with the support of the Health managers, it is the work of the Medical physicist to ensure that safety and protection is paramount. However, the regulators should over see the safety and protection of medical practices in addition to others elsewhere in the country at a national level. In the hospitals there is a need for collaboration among the Medical Physicists, hospital managers and the regulators for effective utilization of the use of ionizing radiation in medicine. This research aimed at analysing the current scenario and collaboration among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practice in IAEA African member countries.

Objectives: To assess the current levels of participation and collaboration among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practices in IAEA member states in Africa.

Methods: The study was conducted by Federation of African Medical Physics Organisations (FAMPO) Executive members during two independent foras. Two questionnaires tailored among regulators, Medical Physicists and hospital managers in the safe use of ionizing radiation in medical Practices were designed. One was used to 24 participants from the regulatory bodies of different IAEA African member states that represented their countries during the Regional (AFRA) Training course for trainers in the use of ICT teaching materials in radiation protection held between 20-24 February, 2012 in Gaborone Botswana . The second one was addressed to 11 medical Physicists that participated during the AFROG conference held between 20-24 February, 2012 in Kampala Uganda.

Results: Several gaps exist among the regulators, medical physicists and hospital managers when handling issues of safe use and protection of radiation sources in medical practices in most African IAEA member states. Training of medical physicists and regulators has been done by the IAEA with little support from the Health managers. Few member states have medical physics and radiation protection associations.

Conclusion: To bridge the gaps, existing qualified Medical Physicists in different IAEA African member countries should sensitize the health managers and policy makers about the role of the Medical Physicists and the training involved. Then through these medical physicists, associations like FAMPO and regional radiation protection associations should bridge the gaps among radiation regulatory bodies, Medical Physicists and hospital managers using different foras like training courses, conferences and all activities should be posted on the different relevant and acceptable websites for dissemination. More training centres for medical Physicists and other radiation scientists should be established.

Key terminologies: FAMPO, Medical physics, regulators, Africa and Training

TS1a.1
Inflammatory Response in Radiation Induced Late Effects

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Late effects of radiation are generally irreversible and can have devastating effects on quality of life of people exposed either accidentally or during therapeutic radiation treatments . Although many etiologies have been suggested regarding these late toxicities, inflammatory parameters involved during the late phase are less known. The following study was conducted to examine the response of the immune system in the inflammatory reactions in patients with late skin injuries after radiotherapy or interventional fluoroscopy procedures. The expression of adhesion molecules ICAM1 and β1-integrin on granulocytes and lymphocytes , as well as changes in subpopulations of T lymphocytes and the level of C-reactive protein , a well- studied inflammatory marker were evaluated. The follow up of twenty five patients , out of 160 referred to Burn Hospital from 1997, that showed late cutaneous reactions graded according to the RTOG / EORTC system is reported here.

The analysis of adhesion molecules expression revealed a higher expression of β1 Integrin on lymphocytes of Grade IV patients compared to non exposed controls . It was also noted a decrease in its expression values in the follow up of patients with good response to therapeutic treatment . This was paralleled by a tendency to a decrease in the T(CD4+) / T(CD8+) ratio of G4 patients with bad evolution compared to G4 patients with good evolution .

The parameters analysed, which require confirmation in a larger study , in combination with other inflammatory indicators, could be used as potential follow-up markers of the chronic radio-induced inflammation process just as its response to therapeutic treatments.

TS1a.2
Signs of Late Radiation-induced Genomic Instability in Persons Chronically Exposed to Radiation

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The key role in the development of late chronic radiation exposure effects in man is played by probabilistic structural and functional changes in somatic cells. The objective of our studies is to find out if there still exist changes at the cellular and molecular level in exposed individuals decades after long-term chronic radiation exposure and after reduction in dose rates to the background levels.

The Techa riverside population chronically exposed beginning from 1949 was studied. The hemopoietic system is assigned to critical systems under the conditions of the population exposures on the Techa. Cumulative RBM doses reach 9.0 Gy.

A dose-dependent increase in the quantity (µmol/l) of NO_2- (25.0±1.5 vs 18.9±2.0) and a decrease in malonic dialdehyde concentration mmol/l: 41.8±0.9 (in the dose group >0.5 G) vs 46.2±1.6 in the controls was revealed. There was no difference in the concentration of superoxide dismutase between the exposed and unexposed persons. The number of DNA breaks was assessed based on the tail moment using the DNA-Comet assay. Significant differences between the number of double-strand breaks (4.75±0.43 in the exposed persons vs 1.64±0.30 in the controls) and single-strand DNA breaks (1.28±0.13 vs 0.54±0.20, respectively) were registered in the exposed as compared to the unexposed individuals. The assessment of double-strand DNA breaks is indicative of an increased number of exposed subjects with excess of the referent value (M±1.0σ) in comparison to the controls. At the same time individuals with the number of DNA breaks exceeding the referent level were exhibiting apoptosis activation measured using the TUNEL assay (%): 0.93±026 vs 0.44±0.15, as well as an increase in the proportion of cells at the cycle arrest (chk-2), %: 0.95±0.25 vs 0.53±0.2. A similar picture was also observed when single breaks were studied.

In spite of the activation of the apoptosis and cell cycle control, exposed individuals manifested a significant increase in the rate (%) of somatic mutations (CD3-CD4+ cells) 0.19±0.03 vs 0.10±0.01 in the control group. The rate of mutations in exons 5,6,7,8 of Tp53 gene was, too, significantly higher in the exposed persons (14.8%) as compared to the controls (3.4%).

Thus, decades after exposure dose rates were reduced to the background levels, exposed individuals were exhibiting changes in the process of peroxidation of lipids, increased numbers of DNA breaks which brought about activation of apoptosis and cell cycle control and, as a consequence, a high rate of mutations in somatic cells.

The data obtained correlate well with the high relative risk of leukemia mortality estimated for the Techa River cohort since it is assumed that genomic instability plays an important part in the origin of malignancy.

We interpret these results as an evidence of manifestations of radiation-induced genomic instability in chronically exposed individuals.

KEYWORDS: chronic radiation exposure, genomic instability, hemopoiesis

TS1a.3
Oral Administration of Multiple Antioxidants Reduced Damage in Lethally Gamma-Irradiated Animals

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This study evaluated the efficacy of an antioxidant mixture administered orally before and/or after gamma-irradiation with doses that produced bone marrow syndrome (mice), gastrointestinal (GI) syndrome (sheep) and GI-central nervous system (CNS) syndrome (rabbits) on survival rate (mice), survival time (sheep) and lung damage (rabbits). Antioxidant mixture was administered orally before (1 day) in mice or before (daily for 7 days) and after (daily for 7 days) irradiation in sheep and rabbits. Animals received whole-body gamma-irradiation delivered in a single dose 7.5 to 9.5 Gy to mice, 4.41Gy to sheep and 9.011 Gy to rabbits. An antioxidant mixture increased the 30-day survival rate from 0 to 40 % in irradiated mice, the survival time from7 to 38 days in irradiated sheep without any supportive care. All rabbits died irrespective of treatment. About 25% of rabbits receiving 9.011 Gy died of CNS syndrome in 4 hours with or without antioxidant treatment. Necropsy of these animals showed that the lungs of irradiated control rabbits were dark, necrotic and without a lobular architecture. However, the lungs of antioxidant treated animals exhibited minimal pulmonary hemorrhage while maintaining the lobular architecture. These levels of radiation protection after an oral administration of antioxidants have never been demonstrated.

TS1a.4
Global Gene Expression Responses to Low- or High-dose-rate Radiation in the Thymus of ICR and AKR/J mice

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Our goal was to identify common expressed genes and pathways in the thymus of ICR and AKR/J mice on 100 days after irradiation. Thus, we performed microarray analysis for thymus of ICR and AKR/J mice, respectively. We categorized differential expressed genes by the analysis of DAVID Bioinformatics Resources v6.7 and validated gene expression patterns by QPCR analysis.

At the non-irradiated groups, 1406 expressed genes and 10 pathways were found in the ICR mice, whereas 843 expressed genes and 4 pathways were found in the AKR/J mice. At the low-dose-rate (^{137}Cs, 0.7 mGy/hr)-irradiated groups, 1123 expressed genes and 6 pathways were found in the ICR mice, whereas 1078 expressed genes and 11 pathways were found in the AKR/J mice. At the high-dose-rate (^{137}Cs, 0.8 Gy/min)-irradiated groups, 2125 expressed genes and 8 pathways were found in the ICR mice, whereas 1722 expressed genes and 10 pathways were found in the AKR/J mice.

By comparing differential expressed genes from irradiated ICR and AKR/J mice, we found common 103 radiation-sensitive expressed genes. The 27 of 103 genes were differential expressed in both ICR and AKR/J mice. Tac2 was significantly upregulated in the low-dose-rate irradiated mice. Interestingly, the genes involved in adipokine-, insulin-, and PPAR-signaling pathway were expressed in the low-dose-rate irradiated mice. The downregulation of glucose uptake (Glut4)- and glycolysis (LPK)-related gene expression was detected in the low-dose-rate irradiated mice. We suppose that low-dose-rate radiation may influence on glucose metabolism and contributed to suppress the incidence of thymic lymphoma in AKR/J mice. We also expect that these tools are an important advance in the application of gene expression for biodosimetry.

Keywords: ICR mice, AKR/J mice, high- and low-dose-rate radiation, radiation-sensitive expressed genes, glucose metabolism

TS1a.5
Informativity Of Regulatory Proteins At Estimation Of Radiation-Induced Changes Of Immune Homeostasis In Nuclear Workers

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The objective of the analysis is to determine the informative value of the content of regulatory proteins in blood to estimate immune homeostasis in nuclear workers following chronic occupational radiation exposure. External γ-doses accumulated during a working career ranged within 0.01 – 4.9 Gy, and Pu body burden – within 0.03 – 35.1 kBq. Controls includes unexposed Ozersk residents of relevant age and gender. The age of monitored individuals was 60-80, and doses significantly exceeded threshold level of radiation load for nuclear workers (20 mSv/y and 1000 mSv for 50 years). These individuals included those hired at the nuclear facility in early years of its operation. Adaptive rearrangements at prolonged exposure are characterized by deterioration of organism reserve resources and regulation disruption due to changes in protein synthesis, which leads to the dysfunction of cells, tissues, and organs and subsequent onset of diseases. Quantitative estimate of protein concentration in blood serum of Mayak PA personnel were performed by immune-enzyme analysis. Analysis included ascertainment of the level of ~50 regulatory proteins regulating cell proliferation, differentiation and apoptosis: growth factors, multifunctional interleukins, pro- and anti-inflammatory cytokines, apoptosis and cell adhesion molecules. The number of effector and regulatory lymphocytes, activated cells and apoptosis-ready cells were studied with a flow cytofluorometer. Results showed that changes of protein status were related to both type and dose of radiation exposure. Significant differences from controls were found in the analysis of growth factors (EGF, TGF-β1, FGF, PDGF), multifunctional interleukins (IL-17A, IL-18) and anti-inflammatory cytokines IL-1β and INF-γ, IL2-R; pro-and anti-inflammatory cytokines demonstrate concentration imbalance which testifies to immunodeficiency. Nuclear workers' lymphocyte phenotyping showed change of expression of regulatory cells membrane proteins and increase in the number of activated forms of T-lymphocytes.

TS1a.6*
Possible Consequences of Inhomogeneous Suborgan Distribution of Dose and the Linear No-Threshold Dose-Effect Relationship

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The current system of radiation protection is based on the assumption that the risk of stochastic effects of radiation exposure is directly proportional to effective dose. Effective dose being the weighted sum of absorbed organ doses is independent of the spatial dose distribution within the organs. However, there are experiments suggesting that risk is a non-linear function of absorbed dose and may depend on the suborgan distribution of dose.

The objective of the present work is to study the role of inhomogeneous dose distribution in case of different dose–effect relationships with the example of radon progeny deposited in the lungs.

For this purpose, the following assumptions have been made:

• Regarding stochastic effects, the relevant biological targets are not organs but small tissue fragments (TFs).

• Risk is equal to the weighted sum of „local effects", which are the functions of doses absorbed by TFs.

• Weighting factors are proportional to the size of the TF.

• The sum of weighting factors of TFs is equal to the tissue weighting factor of the organ consisting of the particular TFs.

• Regarding radon progeny, the dose distribution in the lungs is identical with the dose distribution in the central airways.

Doses absorbed by TFs (with size of ~10^5 μm^2) of the central airways have been calculated from the deposition distribution of radon progeny. A linear and four different non-linear dose–effect relationships have been considered. Non-linear relations are also linear at moderate doses, but below a threshold dose they exhibit supralinear, sublinear, constant zero or hormetic shape.

Results show that the spatial dose distribution has no consequences if the dose–effect relationship is linear. If the dose–effect relationship is non-linear then the threshold dose between the linear and non-linear ranges is scaled down due to the inhomogeneous dose distribution of radon progeny within the lungs.

If there is a low dose range where the dose–effect relationship is not linear then expectedly the threshold of this dose range is lower for inhomogeneous than for homogeneous spatial dose distributions.

TS1b.1
Risk of Lung Cancer Death Associated to Radon Exposure Corrected for Measurement Error Among Uranium Miners

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In epidemiological studies, Measurement Error (ME) can substantially bias the estimation of risk parameters. A broad variety of methods for ME correction has been developed, but they have been rarely applied. The present work investigates the impact of ME on the estimated risk of lung cancer death associated to radon exposure in the French cohort of uranium miners.

The French cohort of uranium miners includes more than 5000 miners chronically exposed to radon with a follow-up duration of 30 years. ME associated to radon exposure has been characterized for each individual, taking into account the evolution of uranium extraction methods and of radiological monitoring over time. We carried out a simulation study to investigate the effects of ME on the estimated excess relative risk of lung cancer death per working level month (ERR/WLM) and to assess the performance of different methods for correcting these effects:

ME associated to radon exposure decreased over time, from more than 45% in the early 70's to about 10% in the late 80's. The nature of ME also changed over time from mostly Berkson to classical type. Simulation results showed that ME leads to an attenuation of the ERR towards the null, with substantial bias on ERR estimates in the order of 60%. Among the different ME correction methods considered, the simulation-extrapolation method (SIMEX) was the best performing method in our context. The application of this correction method allowed reducing the bias due to ME to less than 5%.

This work allows estimating the risk of lung cancer death associated to radon exposure among French uranium miners, after correction for ME. It illustrates the importance of ME correction in order to obtain reliable ERR estimates. Such risk estimates should prove of great interest in support of the determination of protection policies against radon.

TS1b.2
Cardiovascular And Cerebrovascular Diseases In The Extended Cohort Of MAYAK Nuclear Workers

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A second analysis of incidence and mortality from ischemic heart disease (IHD, 410-414 ICD-9 codes) and cerebrovascular diseases (CVD, 430-438 ICD-9 codes) in relation to exposure to external gamma rays and internal alpha-particle radiation taking non-radiation factors into account in an enlarged cohort of 18,763 workers (25.3% female) first employed at the Mayak Production Association between 1948 and 1972 and followed up to the end of 2005 has been performed. A statistically significant increasing trend in IHD incidence (ERR/Gy 0.10 with 95% CI: 0.04-0.15) was found with total external gamma-ray dose after adjusting for non-radiation factors, which reduced slightly when adjusting for internal liver dose. New findings in IHD incidence revealed a statistically significant decrease in IHD incidence among workers exposed to external gamma-rays doses of 0.2-0.5 Gy in relation to the external doses below 0.2 Gy. This decreased risk is heavily influenced by female workers. This finding has never been reported in other studies and the results should be treated with caution. There were no statistically significant increasing trends in IHD incidence with internal liver dose and in IHD mortality with external gamma-ray dose. The significantly increasing trend in IHD mortality with total absorbed dose to liver from internal alpha-particle radiation tended to be lower and statistically insignificant after restricting the follow-up to Ozyorsk or adjustment for external dose. After adjusting for non-radiation factors, there were significantly increasing trends in CVD incidence, but not mortality, with total absorbed dose from external gamma-rays (ERR/Gy 0.41 with 95% CI 0.32-0.50) and total absorbed dose to liver from internal alpha-particle radiation (ERR/Gy 0.09 with 95% CI 0.03-0.15). The CVD incidence was significantly higher among workers exposed to external gamma-rays in total absorbed dose >0.2 Gy compared to those exposed to lower doses; the data were consistent with a linear trend in risk with external dose. The CVD incidence was significantly higher among workers exposed to internal alpha-particle radiation in total absorbed dose to liver >0.025 Gy compared to those exposed to lower doses. The risk estimates obtained were consistent with our earlier study and are generally compatible with those from other large occupational studies, although the risk estimates for the CVD incidence are higher compared to those from the Japanese A-bomb survivors.

TS1b.3
Livelong Accumulated Radiation Exposure Dose from Medical Radiography and Nuclear Medicine in a Population Representative Sample

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The red bone marrow dose is the place of origin of leukemia – a group of diseases that can be caused by radiation. Compared to other diseases caused by radiation exposure leukemia develops after lower doses and with shorter latency following exposure. Thus the cumulative red bone marrow dose is an important factor when dealing with risk estimations and causes of leukemia.

The lifetime dose of the red bone marrow was estimated for a population based representative cohort (2811 subjects) of the NLL – a large population-based epidemiologic case control study conducted in Northern Germany (Hoffmann et al., Am. J. Ind. Med. 51 (2008) 246-257). The interviews were administered in a standardized, personal and computerized way considering number, calendar year and kind of examination as well as gender and age of the subjects. The calculations are based on the comprehensive quantification model suggested by von Boetticher and Hoffmann (Health Physics 92 (2007) 315-331) which include calendar year, age and kind of examination, gender of the subjects, technical development and real life conditions of radiological practice.

The number of radiologic examinations for diagnostic purposes increases continuously over lifetime in all cohorts. The rise appears to be less steep in childhood and young adults and becomes steeper in later life. Likewise, the number of examinations rises over consecutive cohorts and is highest in the most recent cohort. The red bone marrow dose decreases with later birth year. It depends on age but more so on calendar year. Until 1970 traditional examinations like conventional and mass screening examinations caused the main dose. They were replaced by technically advanced examinations mainly computer tomography and cardiac catheter. Remarkably the distribution of the red bone marrow dose over lifetime seems to depend more on availability of the technique of the type of examination than on age. It is significantly influenced by development of technique.

TS1b.4
Risk Of Radiation-Induced Cataract For Interventional Cardiologists: Results Of The O'CLOCStudy

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Interventional cardiologists are exposed to X-rays during their occupational activity. This exposure may induce early eye lens opacities known as radiation-induced cataracts, in particular posterior subcapsular cataracts. The O'CLOC study (Occupational Cataracts and Lens opacities in interventional Cardiology) was performed in France to test the existence of an increased risk of cataracts among interventional cardiologists.

O'CLOC study is a cross-sectional multicenter study including an exposed group of interventional cardiologists - ICs - and a comparable unexposed group of non medical workers. Individual information, including risk factors of cataract (age, diabetes, myopia, etc. ...) were collected during a telephone interview. A specific part of the questionnaire focused on occupational history in cardiology and procedures description (kind, frequency, use of radiation protection tools) in order to retrospectively assess cumulated eye exposure of ICs. All participants had a clinical eye examination performed by ophthalmologists working in the same centre based on the international standard lens opacities classification - LOCS III - that allowed screening of type (nuclear, cortical or posterior subcapsular) and stage of cataracts.P> The study included 106 ICs (mean age=51±7 yrs.) and 99 unexposed people (mean age =50±7 yrs.). For ICs, mean duration of activity was 21 years and eye lens dose cumulated during occupational life in cardiology ranged from 25 mSv to 1650 mSv (mean=454 ± 369 mSv). There was no significant difference between both exposed/unexposed groups in terms of sex ratio, BMI, smoking status, diabetes, myopia, corticosteroids use. Regarding nuclear and cortical lens opacities stage ≥1, no significant difference was observed: 61% for ICs vs. 69% for unexposed group, p=0.23, and 23% for ICs vs. 29% for unexposed group, p=0.29, respectively. In contrast, posterior subcapsular lens opacities (stage≥1) were significantly more frequent among interventional cardiologists (17% vs. 5%, p = 0.006), corresponding to a crude OR=3.9 [1.4 - 10.9] which remained significant even after adjustment for age, sex, BMI, smoking status, diabetes, myopia and corticosteroids use (OR= 3.8 [1.3 - 11.4], p=0.015).

A significant excess risk of posterior subcapsular cataract was observed in this study for interventional cardiologists and it is highly recommended that cardiologists use protective equipment against X-rays and wear lead glasses.

TS1b.5*
Study on the Prevalence of Thyroid Disease in Healthcare Workers at the Hospital of Pisa in Relation with Occupational Exposure to Ionizing Radiation

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This thesis analyzes the prevalence of thyroid disease in healthcare workers who have worked at the University Hospital of Pisa. They underwent a health surveillance protocol until 01/07/2009 with particular regard to occupational exposure to ionizing radiation.

The hospital provides potential radiological risk situations, in both traditional radiological areas (Radiology, Radiotherapy, Nuclear Medicine), and surgical wards as the Cardiovascular Hemodynamics, Orthopedics and Endoscopic Urology.

The radiation-induced biological thyroid effects in humans are divided into three groups: acute effects (thyroiditis, early hypothyroidism), no acute effects (late hypothyroidism), late stochastic effects (tumors). Data of health care workers were obtained by consulting Asped 2000: computerized medical records used by the University Hospital of Pisa for health surveillance of workers exposed to occupational risk. This population consisted of 6658 persons of which 4391 women and 2267 men. Of these, 546 persons were found to have thyroid disease. Radiological exposure interested 2226 persons. 213 of the 546 workers suffering from thyroid diseases were exposed to ionizing radiation. For thyroid diseases overall and for each type of thyroid disease the fraction of patients professionally exposed has been calculated. A statistical analysis was done to determine whether the exposure could be a risk factor for the development of these diseases.

For thyroid diseases in general the odds ratio resulted to be 1.30 with a 95% confidence interval between 1.09 and 1.55. Thyroiditis was present in 187 cases including 79 exposed subjects and 108 non-exposed subjects with an odds ratio of 1.47 (CI95%, from 1.10 to 1.97). No statistical significance was achieved for any of the other thyroid diseases analyzed (goiter, C-cell hyperplasia, hyperthyroidism, hypothyroidism, Graves' disease, nodular disease and cancer). Thyroid cancer was present in 37 cases including 14 exposed and 23 non-exposed. The odds ratio was 1.21 with (CI 95%, from 0.62 to 2.36). The odds ratio was calculated also for the specific papillary histotype which was 1.86 (CI 95%, from 0.9 to 3.87).

The data of this thesis show a significant prevalence of thyroid disease in the population of healthcare workers occupationally exposed to ionizing radiation, suggesting the need for furthering the investigation reguarding epidemiology and radioprotection.

TS1c.1
Radon Risk in Uranium Mining and ICRP

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In 2009, the ICRP issued a radon statement indicating that the dose conversion convention (DCC) for radon progeny would likely double and that the calculation of risk from radon should move to a fully dosimetric approach, from the long standing epidemiological approach. Both issues have important implications for uranium miners. This paper first examines the epidemiological basis for the ICRPs recommendations and provides a detailed analysis of the effect of smoking prevalence on lifetime excess absolute risk and consequently on the DCC. This paper concludes that at current smoking levels, a "nominal" DCC of the order of 6 to 7 mSv/WLM would seem to be both protective of miners and representative of current smoking conditions. The paper also examines the capability of current dosimetric models to address the risk from smoking and exposure to radon and observes that results of dosimetric models do not match sufficiently well with those from epidemiology. The paper also reviews the measurements needed to implement a dosimetric based system of protection for radon and currently available data. At this time, data for mines are very limited there needs to be further improvements in the modelling, measurement techniques, and understanding of modern workplace conditions

TS1c.2
A Risk Assessment of the Potential Impacts of Radon, Terrestrial Gamma and Cosmic Rays on Childhood Leukaemia in France

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Background and Aims Natural radioactivity (NR) is an ubiquitous phenomena and exhibits large geographic variations. Current risk models for radiation-induced leukaemia prediction, which are mainly issued from the epidemiological study of Hiroshima and Nagasaki (H&N) A-bomb survivors, imply that levels of NR could induce some leukaemia cases. This would especially be the case in children, which are known to be more radiosensitive than adults. This work estimated the percentage of childhood leukaemia that might be related to 3 sources of NR (radon, cosmic and terrestrial gamma rays) in France.

Methods: National rates of childhood leukaemia over period 1990-2004 were provided by the French registry of childhood malignancies. Mean doses to the red bone marrow that children would receive from radon, terrestrial gamma and cosmic rays in France were estimated. Risk models proposed by the United Scientific Committee for the Effects of Atomic Radiation (UNSCEAR) and by the US National Research Council (BEIR VII) to predict radiation-induced leukaemia cases were used.

Results: Overall, 6784 leukaemia cases were registered over the study period. Estimated annual red bone marrow doses for the average French child due to radon, terrestrial gamma and cosmic rays were 0.27, 0.49 and 0.28 mSv respectively. The percent of leukaemia cases that could be attributed to these combined exposures vary from 4 to 18 % according to the UNSCEAR model, depending on the model used for the transfer of risk from A-bomb survivors to French children (additive or multiplicative). It is about 11% according to the BEIR VII model, whatever the transfer mode considered.

Conclusions: These preliminary results suggest that a sizeable percentage of childhood leukaemia cases could be attributable to NR in France. This is in accordance with previous risk assessments conducted in the UK. However, the risk assessment approach entails several important uncertainties. Some are related to the transposition of risk models from acute (H&N) to chronic exposures and from external to less accurately known internal doses. The statistical precision of risk estimates issued from the H&N cohort should also be further considered in future risk estimates. A planned Inserm-IRSN epidemiological study of the relation between NR and childhood leukemia in France as part of the Geocap project will aim at reducing uncertainties by providing direct observation.

TS1c.3
A New Look At Ionizing Radiation Carcinogenesis

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The current framework for estimating the risk of cancer induction for exposure to ionizing radiation is, unfortunately, based on misunderstandings. Radiation induction of cancer is not a simple stochastic process as assumed by the International Commission on Radiological Protection but rather it involves numerous inter-relational cellular and radiative events. Also, it is not proportional to cumulative dose, but rather it is a precise function of life time average dose rate to the affected tissues. Studies that assume that it is proportional to cumulative dose can be quite misleading. At low average dose rates the time required to develop cancer may exceed the natural life span resulting in a life span virtual threshold of several sieverts. In sharp contrast is the study if the Japanese 1945 atomic bomb survivors. These survivors were exposed to up to several hundred times the normal average annual ionizing radiation dose from natural background, but it was delivered in only about one minute. All the cells of the body were irradiated and underwent some type of permanent reprogramming. Many years later and throughout life, some of the exposed survivors developed cancer and remarkably these cancers were of the same types as occurred among the control population, but at higher rates. This lifetime promotion of cancer rates was proportional to that original one-minute radiation dose. This promotion of cancer was independent of age at exposure or the time between exposure and cancer development. Except for early cases of leukemia that were caused by radiation damage to the blood-forming tissues, there were no apparent independent occurrences of unique radiation induced cancers. The current tissue weighting factors and risk models are based primarily on the promoted cancer types in those Japanese survivors and do not apply to radiation induced cancer. These findings suggest possible dose-rate revisions of radiation safety models and protection criteria for internal emitters and other protracted and repeated exposures to ionizing radiation.

TS1c.4
Genetic Hypersensitivity to Ionizing Radiation in Imaging and Treatment

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Keywords: Ionizing radiation, Genetic hypersensitivity, Gene profile predicting radiation sensitivity

Background: Exposure to medical radiation has increased over the past years significantly and it constitutes to a major part of exposure to radiation in high income countries. Genetic hypersensitivity to ionizing radiation has been observed in some genetic syndromes. On cellular level specific gene expression seems to correlate with cancer cell sensitivity to radiation.

Material and methods: Pubmed was searched for studies between the years 1990-2011 for analyzing in vitro or in vivo the sensitivity to ionizing radiation in genetic syndromes that predispose cancer development. Our review summarizes observations on radiosensitive phenotypes and cellular sensitivity based on gene expression.

Results and Conclusions: Eight syndromes with hereditary genetic sensitivity were identified. Additionally, studies on genetic profile with increased cancer cell's sensitivity have been published. Radiosensitive phenotypes are important to acknowledge in order to predict specific individual radiation sensitivity. In future the challenge is to manage the use of appropriate diagnostic imaging and to investigate the optimal fractionation of radiotherapy (RT) in patients with radiosensitive genotype and to apply the knowledge on cellular radiosensitivity. More research is needed about the hypersensitivity of those who are carriers of a disease gene linked with specific syndromes. In future, gene expression profiles may have a role in designing protocols for diagnostic imaging and treatment programmes taking into account individual genetically based radiation sensitivity.

TS1c.5
Dynamics of Hematopoiesis in Residents of Techa Riverside Villages Chronically Exposed to Ionizing Radiation: Clinical and Model

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A comprehensive approach to analysis of clinical data on dynamics of key hemopoietic cell lineages (granulocytopoiesis, thrombocytopoiesis, and erythrocytopoiesis) for members of the Techa River population who have been chronically exposed to radiation since 1949 due to contamination of the river basin with radioactive waste of the Mayak Production Association is suggested. The approach involves a goal-directed generalization and statistical processing of clinical data on the population groups of interest, and also a joint analysis of the data obtained and mathematical models. The latter describe the dynamics of the above-indicated cell systems in man under the conditions of radiation exposure these individuals were affected by. Using the models, the dynamics of the system of granulocytopoiesis, thrombocytopoiesis, and erythropiesis was studied in residents of the Techa riverside communities chronically exposed to radiation over the period from 1949 through 1956. Based on a joint analysis of the results of modeling, and the relevant clinical data, it became possible to trace the relationship between the changes in the indices of these systems and the changes in chronic exposure intensity over the above-indicated time period. The use of the granulocytopoiesis model allowed reproduction of the effect of prevalence of younger cells of granulocytic lineage in bone marrow observed in the course of examinations performed for a number of Techa riverside residents, and identification of the mechanism by which this effect had developed. Also, the study allowed tracing cause-effect relations which were conducive to a stable reduction in blood levels of granulocytes, thrombocytes, and erythrocytes in the population of the Techa River villages during the period of maximum radiation exposures. The effect of the level of granulopoiesis, thrombopoiesis, and erythropoiesis inhibition during the period of maximum exposures on the recovery of these systems in the subsequent period (period of reduced intensity of exposure) was evaluated. One more issue studied involved assessment of the significance of the contribution of non-radiation factors (age at first exposure, gender, and ethnicity) to the changes in the dynamics of the studied parameters in man under chronic exposure with a changing dose rate.

TS1c.6
High Congenital Malformations Rates in a Chornobyl Ionizing Radiation Impacted Population Isolate in Ukraine and Call for Research Co-Investigators

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Background: In 2000, we established a birth and congenital malformations (CM) population registries in Ukraine relying on methods used by a European network of CM monitoring systems (EUROCAT); in 2002, we noted elevated rates of neural tube defects (NTD), confirmed by further analysis of 2000-2006 data. Population rates of microcephaly, microphthalmia, teratomas, and conjoined twins were also found to be elevated, more so in a Population Isolate in Polissia (Prypiat river marshes and low lands in northern counties of the Rivne province). These counties are officially designated as Chornobyl Ionizing Radiation Impacted (CIR) and the native Polissia inhabitants or Polishchuks are a known Ukrainian ethnic sub-group with characteristics of a population isolate.

Objectives: To document and analyze population CM rates, temporal trends and to test strategies and feasibility to sub-categorize regions by county; village, family groups; levels of external and internal exposures to CIR (inhalation, ingestion, whole body CIR counts); life-style (alcohol use, occupation, dwelling); and isonomy levels (frequency of shared family surnames characteristic of settlements, a proxy measurement of inter-family relationships).

Results: Analyses of 145,437 pregnancy outcomes from 2000 to 2009 demonstrate persisting elevated population rates (per 10,000 live births) of NTD, microcephaly and a-microphthalmos. These rates are higher in Polissia vs. nonPolissia (26.3-16.4; 5.7-3, 3; 2.9-1.1 respectively) and are among the highest in Europe. Within Rivne, the highest NTD and microcephaly rates noted in the vicinity of two nuclear power plants (34.1-31.9; 12.2-11.2 respectively), but the number of observations were few (14-17; 5-6 respectively). The birth of 7 conjoined twin pairs and 11 teratomas, both quite rare events, is provocative. Regarding known causes of neural CM, CIR levels in soil, milk, and whole body counts (WBC), obtained from ambulatory patients and pregnant women, were highest in the three most northern Polissia counties (NP). Alcohol consumption during pregnancy, another cause of microcephaly, was less frequent in NP. Concerning genomic factors, family surname isonomy levels were highest in NP.

Conclusion: These observations are sufficiently compelling to call for case-control or other prospective investigations with an emphasis on NP Polishchuk families. Further categorizations of NP village populations by life-style, levels of internal CIR based on WBC, along with degrees of isonomy or other estimates of consanguinity can contribute to clarifying the relative impacts of CIR, alcohol and genomic factors causing the elevated CM rates observed, a task to be facilitated by a call for research co-investigators.

TS2a.1
Characterization of the Neutron Fields Around Cernavoda NPP

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In the environment near a nuclear reactor, a fuel container or a particle accelerator, mixed neutron/gamma fields are very common, necessitating routine neutron dosimetry. Accurate neutron dosimetry is complicated by the fact that the neutron effective dose is strongly dependent both on the neutron energy and the angular distribution of the neutron fluence. Neutron field characterization is indispensible if one wants to obtain a reliable estimate for the neutron dose. A measurement campaign in CANDU NPP in Cernavoda, Romania, was set up in November 2010 to characterize the neutron fields in four different locations and to investigate the behavior of different personal neutron dosemeters.

Neutron field characteristics, such as energy and angular distributions, were determined using different neutron monitors. The energy distribution was measured using a BTI Mycrospec and Nprobe combination, which provides an spectrum divided into 17 energy bins, spanning neutron energies from thermal till 20 MeV. This information is used to determine the average field specific h*(10), $h_p(10, 0°)$, $h_p(10,90°)$ and $h_p(10, 180°)$ fluence to dose conversion factors.

The total neutron fluence was calculated using information about the ambient dose rate and the average fluence to ambient dose conversion coefficient h*(10).

Where the ambient dose rate dH*(10)/dt was measured using different ambient monitors, such as Studsvik 2202D, Wendi II and Eberline NRD. The reference value was taken as the average value of the monitor readings, taking into account their energy response.

The angular distribution of the neutron fluence was determined using personal dosimeters. Therefore the detectors were placed in different angular orientations on a slab phantom. By combining the information on angular distribution and the average field specific hp(10, 0°), hp(10,90°) and hp(10, 180°) fluence to dose conversion coefficents, partial neutron dose rates, dHp(10, 0°)/dt, dHp(10, 90°)/dt and dHp(10,180°)/dt were estimated. The partial dose rates were combined together to the total dose rate dHp(10)/dt.

The calculated values of dHp(10)/dt in the four locations, were considered to be a reference value for the neutron personal dose equivalent rate. The readings of the personal detectors were compared with the readings of the personal monitors in order to propose field specific correction factors and to choose a suitable neutron dosimetry system at Cernavoda NPP.

TS2a.2
Radiation Dose to Interventional Radiology Staff – Can It Be Assessed by Only One Radiation Badge: Trunk, Head or Finger?

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Purpose To evaluate the relations between the trunk, head, and finger radiation badges measurements for interventional radiology staff and to assess whether radiation doses can be based on exposure of only one badge. Methods: The radiation doses of trunk, head and finger badges for three interventional radiologists, a nurse and a radiographer measured through six years were analyzed. The trunk badges were consistently worn behind the protective lead apron at the left upper chest height.

For the first three years of this study, the head badges were worn above the aprons, at the upper chest height, and during the last three years, they were placed above the thyroid protective shields.

Results: The mean values of the ratios between the trunk badges and head badges exposures were (4.4 +- 1.4)%, (3.0 +- 0.8)% and (4.1 +- 2.4)% for the three radiologists and (5.0 +- 3.0)% for the radiographer. Since the threshold value for the measurable radiation dose for the trunk badge in Israel is 0.1 mSv and for the years 2006 - 2010 the reported annual doses were zero for the nurse, the above analysis couldn't be performed.

Due to the change in the location of the head badges, the ratios of the exposures of the head badges to the finger badges were decreased by a factor of ~ 0.43 at average for the radiologists and 0.27 for the radiographer. For the nurse an increase by a factor of ~ 0.2 was observed.

Possible reasons causing the different values for the above ratios between the measured doses by the badges, such as full or partial protection provided by the lead aprons, type and extension of use of the upper shield, the location of the badges and different occupancies are discussed in the study.

Conclusions: Due to uncertainties described in the study, the radiation dose to interventional radiology staff can not reliably be evaluated based on the exposure measurements of a single radiation badge: trunk, head or finger.

TS2a.3
Guidelines to Optimize Extremity Monitoring and to Reduce Skin Doses in Nuclear Medicine. Results of the ORAMED Project

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ORAMED (www.oramed-fp7.eu) is a European collaborative project developed in 2008-2011 to enhance the safety and efficacy of the use of radiation in medicine, mainly in interventional procedures and in nuclear medicine. This paper focuses on summarising the project guidelines in order to optimize extremity monitoring and to reduce skin doses in nuclear medicine (NM).

NM procedures require handling of radiopharmaceuticals in contact with the extremities. NM radiopharmaceuticals are mostly photon emitters, but mixed photon/beta emitters are used for Positron Emission Tomography (PET) and pure beta emitters for many therapeutic applications. These characteristics lead to difficulties in establishing an appropriate monitoring program. On the one hand, the dosemeter has to be sensitive to a large range of radiation types and, on the other, the dosemeter should be worn close to the most exposed area on the hand. Monitoring of 124 workers from 32 hospitals in Europe highlighted that, in some cases, the maximum skin dose limit is exceeded and that, for the same type of work, there is a wide range of exposures. To complete the experimental observations, a Monte Carlo simulation of some selected typical NM scenarios was undertaken to quantify the influence of different radiation protection means. Based on the results of these studies, guidelines have been proposed to correctly estimate hand exposure in NM and to reduce hand doses to an acceptable level.

Main Guidelines:

1. Extremity monitoring is recommended for NM staff in charge of labelling or injection of radiopharmaceuticals. Dosemeters should be sensitive to workplace radiation fields.

2. The base of the index finger of the non-dominant hand with the sensitive part of the dosemeter placed towards the inside of the hand is the recommended monitoring position.

3. A ring dosemeter is preferable to a wrist dosemeter.

4. The maximum skin dose can be estimated by multiplying the reading of the ring dosemeter worn at the recommended position by a factor of 6.

5. Shielding of vials and syringes is essential to ensure low skin exposures. Minimum requirements are given in ORAMED website.

6. Any tool that increases the distance between the hands/fingers and the source is very effective for dose reduction.

7. Training and education in good practices are needed to reduce staff exposure.

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TS2a.4
An Assessment of Eye Doses in the UK, Ireland, USA and France.

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The ICRP has issued a draft report containing a proposal for the dose limit for occupational exposure to the lens of the eye to be reduced to 20mSv/y (from 150mSv/y). This new limit is likely to become the legal limit for occupational doses to the eye within a few years as countries renew their national legislation. In the meantime, regulatory authorities (for example the Health and Safety Executive (HSE) in the UK) have advised that employers should start to assess the likely significance of the reduction in dose limit in areas of significant risk of exposure to the lens of the eye. Significant occupational eye doses principally occur in the medical profession in Nuclear Medicine, Interventional Radiology and PET departments. But there is also the possibility of eye doses arising in other industries, for example, the nuclear industry and research.

As a leading supplier of personal dosimetry services, Landauer have worked with a number of clients in the UK, Ireland, USA and France to make a preliminary assessment of eye doses to employees in areas of higher risk of getting exposures above the proposed limit, especially as eye dose may become the limiting dose for some employees.

Approved eye dosemeters are not yet available, conversion factors for Hp(3) are being debated, standards for dosemeters and calibration procedures are not yet fully established. As a first step, we have reviewed conversion factors currently available (as outcome of the ORAMED (Optimisation of RAdiation protection of MEDical staff) project for example) and calibration techniques. We have used our currently available nanoDot™ dosemeter as an eye dosemeter for assessing the eye dose, which were read out on microStar™ readers. These nanoDots were worn by a number of staff in different departments in hospitals and also by employees in the nuclear industry. The dose reported for the nanoDots has been compared with whole body dose and information on the number of operations and duration of the operations, for the different types of operations and occupations, and compared with the whole body dose. The results have been annualised and compared with the current and future dose limits.

This paper will report on the techniques used for this study and the results obtained. It will discuss the implications for eye dosimetry in the future.

TS2a.5
The Status of Criticality Accident Dosimetry in the UK

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Criticality accident dosimetry is required under the Ionising Radiation Regulations 1999 in environments where there is a risk that persons may be exposed to a high dose of ionising radiation from a critical assembly. The infrequency of criticality accidents has resulted in a dwindling of expertise in the area of Criticality Accident Dosimetry (CAD) over the past decades.

New technologies and methodologies, and renewed regulatory interest in the area of criticality accidents, has highlighted a need to modernise CAD systems and the techniques used in dose assessment. The history of CAD is reviewed and the current state-of-the-art in the UK is examined and compared to other dosimetry services around the World.

TS2a.7*
Skin Dose Assessments Using Varskin.

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This paper describes the output of a research project to identify a suitable method of compliance with the requirements of IRR99 Regulation 23 "Dosimetry for Accidents etc". The assessment of skin doses from contaminated clothing has historically been provided as a service by the Sellafield ADS using Lithium Fluoride (LiF) powder thermoluminescent dosimetry. This is not a legal dosemeter and any dose assessment goes on the dose record as an estimate. There has been little demand for this service over the past several years and the LiF process has been discontinued on the Sellafield site.

There are several methods of carrying out skin dose assessments. This paper describes one such method and its potential for use on the Sellafield site; the computer code Varskin 3. Varskin 3 can be used to carry out a skin dose assessments; taking into account the isotopes present, source geometry, clothing attenuation and exposure time in order to estimate the dose to the individual.

This paper describes how the software can be used in a practical context to estimate skin doses received under accident situations, and therefore to determine the further action necessary to comply with IRR99 such as notification of overexposure (if applicable). It details the necessary input information required in order to run a calculation, and the appropriate questions to ask of a contaminated individual. It includes a step-by-step approach towards carrying out a contaminated clothing dose assessment, from the initial event and preliminary calculations, through to identifying the appropriate reporting mechanism, and explains how to interpret the Varskin output into an equivalent dose in mSv.

TS2a.8*
Modelling and Comparison of Hot Cell Shielding Capabilities during a Criticality Excursion

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A 25 cm thick lead-walled hot cell and an 87 cm magnetite high-density concrete walled hot cell were modelled using MCNP code to determine their respective shielding capabilities in the event of a criticality excursion producing 10^{17}, 10^{18} and 10,startsup>19 number of fissions respectively. Both cells consisted of a lead glass window with layers of different densities. It was assumed that a moderator ingress accident had taken place and that the fissile material present in the hot cell had become homogeneously dispersed in the water moderator. The fissile material was taken as 20% enriched uranium. The shielding capability, or lack thereof, of each type of hot cell was investigated and detector phantoms filled with tissue equivalent material were placed over a range of distances from the hot cell to determine the radiological dose consequences to operators and workers who may be present during a hypothetical criticality excursion. For the lead-walled hot cell it was found that neutrons streamed more easily through the lead walls than the lead glass window. This is due to the borosilicate content of the glass, of which the boron is a strong neutron absorber. However the retention is minimal and the total equivalent radiological dose during such an event would lead to severe deterministic effects and possible death. The total equivalent dose received through the high-density concrete wall at a given distance was approximately 4300 times lower than through the lead-walled hot cell. This is because the magnetite concrete is a better neutron shield than the lead. Therefore in the event of a criticality excursion producing a flash not exceeding 1019 fissions, no person close to the concrete-walled hot cell will suffer any deterministic effects of radiation exposure. It is therefore recommended that for any hot cell operations involving possible criticality, magnetite high-density concrete walls should be used as the material of construction rather than lead.

Technical sessions

TS2a.9*
Interpretation of Measured Dose Data in X-ray Imaging

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Radiation dose from an x-ray examination is needed for estimation of radiation risk to a patient. Organ and effective doses are risk related quantities but normally it is not possible to measure them directly. Therefore air kerma based measurable quantities are generally used for dosimetry. These quantities can be used for quality control and diagnostic reference levels but they are not directly risk related quantities and should not be used e.g. for optimization.

There are several possible methods to estimate risk related quantities for an x-ray examination but the accuracy of the final result is depending on the methods used for this estimation. The first level of estimation is to use tabulated values for that specific examination. These values are generally calculated for some group of devices and people. More accurate data can be achieved if measured data is used together with tabulated conversion factors. Nowadays these factors are typically based on Monte Carlo simulations. Accuracy is the better the more information can be used for choosing the correct conversion factor. However, the human models used for conversion factor calculation are typically average size and they do not take into account differences in patient size and structure. The best accuracy can be achieved when examination specific simulation is performed. There is already also some effort to do individual dose calculation which is based on Monte Carlo simulation and real computed tomography images of the individual.

As part of a coordinated research project (CRP E2.10.08) of the International Atomic Energy Agency, several people from different institutes calculated organ and effective doses from the same initial data. In this presentation results from the CRP study are introduced and discussed. Available methods for interpretation of measured dose data are reviewed and discussed together with the uncertainties.

TS2b.1
Routine Internal Dosimetry Monitoring And Assessment: The Practical Application Of International Standards And Guidance

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The monitoring and assessment of intakes of radionuclides is a complex process: a variety of methods have been developed. Recently considerable effort has been put into establishing more definitive guidelines and standards, with the aim of 'harmonising' the methods. Recent publications of specific relevance are the ISO International Standards on Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material and Dose assessment for the monitoring of workers for internal radiation exposure; and the IDEAS project and guidelines. These publications have sought to define some basic principles, objectives and methods; however, they still require to be incorporated into working procedures and applied in practice. The Radiation Dosimetry Department (RDD) of Nuvia is engaged in developing such procedures, and reviewing the practical challenges of applying them operationally. This paper reviews our experience, focussing on two of the main practical challenges.

The first relates to the processes for deciding when routine monitoring is required. Published advice is available, but this is largely subjective and refers to un-quantifiable terms such as significant risk or expected intakes. RDD have derived procedures which seek to be objective and transparent; however, some degree of subjectivity is unavoidable. In this situation the procedures require that any subjectivity should be supported by relevant and quantifiable evidence, although this need not be from a full routine dosimetry programme.

The second challenge relates to the assessment of dose and the influence of measurement uncertainties: of particular concern is the measurement of actinides in bioassay samples. Monitoring of potential exposures to ever lower levels relies on bioassay measurements which are very close to the detection limits. This means that uncertainties in the measurement are proportionately more significant. Current guidelines for dose assessment employ an algorithm, with decision points to direct the assessor to various stages of an assessment. This is a useful tool; however, problems can arise when significant measurement uncertainties are introduced into this procedure. The uncertainties propagate through the assessment process, not only impacting on the modelling and final doses, but also on the decision points within the algorithm. Thus there is a risk of a step-change in the assessment process due to purely random factors: i.e. two identical exposures can lead to two significantly different assessments due to the measurement uncertainties.

TS2b.2*
Evaluation of In Utero Doses from Maternal Ingestion of Strontium Radionuclides at the Techa River

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A cohort of persons exposed *in utero* due to radioactive contamination of the Techa River (Southern Urals, Russia) in the early 1950s represents a unique opportunity for studying radiation risks from chronic exposures in early life. Bone-seeking strontium radionuclides were the main contributors to haemopoietic tissue doses received in utero from maternal ingestion of the radionuclides before and during pregnancy. Numerous measurements of ^{90}Sr in human teeth, bones and the whole body have been compiled at the Urals Research Center for Radiation Medicine (URCRM) since the early 1950s and have been used for reconstruction of maternal intakes of the radionuclides and development of an age-dependent biokinetic model for strontium for women living near the Techa River. To evaluate doses from *in utero* exposure to strontium radionuclides, the biokinetic model for adult females was adapted for the period of pregnancy specifically for the Techa River population (see Fell *et al*; these proceedings) using methodology recommended by the International Commission for Radiological Protection (ICRP). This model for radionuclide transfer during pregnancy was validated by direct measurements of ^{90}Sr in maternal and foetal skeletons resulting from Techa River contamination and global fallout in Russia. In addition, dosimetric models for the in utero period were developed as a series of hybrid computational phantoms of foetuses of different gestational age specifically for the Techa River study. These phantoms were based on computed tomography (CT) and magnetic resonance imaging of preserved foetal specimens. Refined estimates of doses from *in utero* exposure to strontium radionuclides will be presented for a reference village located on the Techa River. The estimates will be compared with the doses calculated using standard models recommended by the ICRP in Publication 88 (2002) and differences will be addressed. Models presented in this study provide the most reliable estimates of doses from in utero exposure for the Techa River residents and will be used in companion epidemiological studies. This work has been funded by the European Commission Contract No. FP7-249675 “Epidemiological Studies of Exposed Southern Urals Populations” (SOLO).

TS2b.3
A Probabilistic Approach for the Assessment of Internal Dose to Chronic Lymphocytic Luekemia Precurson Cell

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Under the U.S. Energy Employees Occupational Illness Compensation Program Act (EEOICPA), the National Institute for Occupational Safety and Health (NIOSH) is responsible for reconstructing radiation doses to certain workers who developed cancer, based on their exposures received while employed in nuclear weapons-related activities for the U.S. Department of Energy or its predecessor agencies. The reconstructed exposure to the organ or tissue that developed cancer is then used by the U.S. Department of Labor to determine whether the cancer was at least as likely as not caused by the worker's weapons-related exposure. While the organ for which a dose needs to be reconstructed is obvious for solid tumors, the relevant tissue for tumors of the hematopoietic and lymphatic system is more difficult to define.

Under the original published regulations (U.S. 42 CFR Part 82), chronic lymphocytic leukemia (CLL), which is a form of lymphoma, was the only cancer not covered under the EEOICPA. Recently, however, NIOSH has taken steps aimed at amending the federal regulation to include CLL. If CLL does become a covered cancer, a method must be available to reconstruct doses to the relevant tissue(s) that contain the precursor cells for CLL. Based on a review of the scientific literature and input from several subject matter experts, it was concluded that it is possible to develop a procedure to calculate the dose to the type of B lymphocytes that are precursor cells for CLL.

Because the etiology of CLL could involve radiation damage to any precursor B lymphocytes that are distributed throughout the body, it was clear that a calculation of dose to a single, anatomical organ would not be appropriate. In light of this, an extensive literature review of the distribution of lymphocytes and precursor B lymphocytes in the body was conducted. This review identified quantitative estimates for B cell precursors in six discrete lymphoid organs/tissues, and in nine other lymphocyte-containing compartments. Uncertainty distributions have been developed for the number of precursor cells in each tissue. Using these data, a probabilistic model has been applied to estimate a weighted dose to these cells. This weighted dose can then be used with the existing Interactive Radio Epidemiology Program (IREP) to determine the probability that a worker's CLL was at least as likely as not caused by nuclear weapons-related exposure.

The findings and conclusions in this abstract have not been formally disseminated by NIOSH and should not be construed to represent any agency determination or policy.

TS2b.4
Individual Monitoring of Internal Exposures for Argentina Nuclear Medicine Workers

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The external individual monitoring for nuclear medicine workers is a requirement in Argentina, meanwhile the internal individual monitoring is not a requirement neither in our country nor in most of other countries in the world. However, the international discussion regarding the internal exposures of workers in these facilities has been installed and is reflected in the development of a new standard that was approved by ISO at the beginning of 2011.

The aim of this paper is to propose a method, feasible to implement routinely in nuclear medicine facilities, to control the internal exposures of workers to detect and assess ^{131} I intakes.

It describes a proposal for screening monitoring that will be performed at Fundación Escuela de Medicina Nuclear by local staff using the available surface contamination monitor. This relatively simple instrumentation, previously calibrated, is located in front of the thyroid to detect whether ^{131} I predetermined threshold has been exceeded, indicating that a potential intake could have occurred. In case of positive screening, the next step is the, well known, thyroid monitoring that should be performed to obtain data for the committed effective dose assessment

It is concluded that this proposal could contribute to control ^{131}I internal exposures in nuclear medicine workers.

TS2b.5
Development of mobile laboratories for Routine and Large Accident Monitoring of Internal Contamination

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The medical surveillance of workers exposed to a risk of internal contamination by radionuclides by *in vivo* monitoring will be generally preferred for X and gamma emitters of relatively short period while the analysis of 24 hour urines or the 72 hour faeces will often represent the examination of choice for alpha and beta emitters. Nevertheless, because the *in vivo* measurements require the patient to be physically present during the measurement, the analysis of urines is often preferred by the professionals of nuclear medicine, although it is not always adapted to exposures by short-lived emitters such as ^{99m}Tc. On the other hand, in the event of an accident involving radioactive material, there could potentially be a large number of people who require monitoring for internal contamination. If the release contains radionuclides which emit high-energy gamma rays then the most suitable means of providing this monitoring is whole body counting. The advantage of a mobile system over fixed *in vivo* monitoring facilities is that the latter may be to a considerable distance from the accident. Besides, the mobile system will allow members of the public who may have been exposed because of their proximity to the accident to be monitored with the minimum of delay and inconvenience. As already explained for medical surveillance, rapid monitoring is also important because many radionuclides which may be present are short-lived and the seriousness of the accident will need to be quickly assessed.

To answer these two challenges, the IRSN, the French institute for radiological protection and nuclear safety, has developed a float of mobile unit, unique in Europe, able to monitoring on-site up to 3500 people per day. This paper describes the development of these *in vivo* mobile laboratories. The specificities, calibration procedures and performances of these systems will be presented.

TS2b.6
Modeling Of DTPA Decorporation Therapy -- Still Puzzling After All These Years

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Incorporations of Pu/Am/Cm (An) can be treated by i.v. injections of Ca- or Zn- salts of di-ethylene-Triamin-Pentaacetic-Acid (DTPA). An enhanced urinary and fecal excretion An and thus a reduction of the body burden can be observed after the injections. Multiple injections are used in the decorporation therapies, which in some cases use total amounts as high as 500g of DTPA within several years without adverse side effects.

The principle behind the enhancement of the excretion is the in-vivo formation of stable complexes of the radionuclide with DTPA. These An-DTPA-chelates mask the An from the biokinetic processes in the body and are rapidly excreted. This basic idea was stated in the 1940s by Kety et al., several chelators including Citrates or EDTA have been studied. DTPA which has become available in the 1960s showed to be the most effective chelator and was used since then.

A modeling of the observed biokinetics is required for assessing the doses averted by the therapy. Primarily in the 1970s various studies in several species of experimental animals have been conducted to understand and improve DTPA therapy. The results of these and newer studies as well as human case studies after incidents have been used as database for modeling decorporation therapy. Today in the 2010s several case specific models exist in the literature as well as a generic empirical model. The latter can only describe the urinary excretion pattern as a mathematical function and be used for a rough assessment of the dose using a “reduced intake”. Even more than 50 years of using DTPA decorporation therapy no generic model exists, which can describe the biokinetics of the radionuclides under therapy and be used for accurate dose assessment. Several hypothesis and approaches in modeling are currently followed. One of the many problems for the understanding and modeling of DTPA decorporation therapy are the still unknown sites of chelation, i.e. which parts of the biokinetic system the An is removed from and with which efficacy. Another puzzling point is the identification of the bio-ligands and other molecules competing for the DTPA or the An and their influence on the therapy. The database still needs to be widened by targeted experiments to answer such more specific questions. The authors will summarize the problems and the still open questions and provide an overview of the current modeling efforts in DTPA decorporation therapy.

TS2b.7
Evaluation Of The Amount Of 210Po Ingested By The Spanish Population And Its Relation To Their Diet Habits

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Polonium-210 is a natural occurring radionuclide, belonging to the Uranium series, which is present in minute amounts in the different environmental compartments and that through its route along the trophic chain can finish incorporated in the human body via ingestion of waters and/or food. This radionuclide is highly radiotoxic, with the highest value between the natural radionuclides of the committed effective dose per unit intake via ingestion, and it is present in relatively high concentrations in the marine biota due to its enhanced bioaccumulation and its strong affinity for binding with certain internal tissues. Consequently, ^{210}Po it is an important contributor to the radiation dose received by the marine organisms as well as by the humans consuming seafood.

The Spanish population has the seafood as an important component in their diet. Expected higher committed effective doses via ingestion can be then expected in the Spanish population in relation with other European groups where the culture to include fish in their diet is not so much introduced, due to the higher intake of ^{210}Po associated to this food component. For that reason, we have estimated the contribution of this radionuclide to the committed effective dose by ingestion received by the Spanish population, by determining the ^{210}Po activity concentrations in an ample set of samples which can be considered representatives of the diet consumed in Spain. During several years, and every three months, a composite sample formed by several cooked foods and drinks, and representing the diet consumed by a person in a week, was collected from a typical Spanish restaurant, and its ^{210}Po content determined as a basis for dose estimation. The results obtained in this study will be presented and discussed in this work.

By other hand, data about the ^{210}Po levels in the edible parts of a great variety of marine organisms can be found in the literature. However, the great majority of these determinations correspond to raw edible products. Little is known about the effects of cooking on the ^{210}Po content of seafood which are normally cooked for human consumption. Then it is important to check if cooking can alter the ^{210}Po content in the seafood in order to refine the dose estimates to human consumers. Trying to cover this gap we have analyzed also the ^{210}Po content in the edible parts of several seafood products bought in commercial markets of our town and cooked following the more common recipes in our country. The obtained results have been compared with the obtained ones in aliquots of the same products but analyzed as raw materials. These results will be also presented and discussed in this work.

TS2b.8*
Estimation of Radionuclide Biokinetics Dependence on Intake Conditions for Internal Exposure

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Dose estimation of internal exposure is important, as well as that of external exposure, after the release of a large amount of radionuclides to the environment caused by a severe accident at a nuclear facility. Effective dose, at present, is the index of internal exposure, which is different from the external exposure that is estimated by simple and reliable operational quantities in practical situations. The circumstances of intake and the biokinetics of intake radionuclides should be considered for accurate dose estimation due to internal exposure. Although internal exposure of the public has attracted attention since past severe accidents such as those at Chernobyl and Fukushima, the intake conditions of the public are generally more complicated than those of radiation workers because the intake occurs not only by inhalation but also by ingestion and continues from several weeks to, in some cases, several years. For accurate internal dose estimations, biokinetics depending on these intake conditions must be taken into account. The biokinetics analysis computer code based on intake conditions of radiation workers developed in our previous study is, in the present work, upgraded to analyze biokinetic dependence on intake conditions of the public (pathway and period).

The latest biokinetic models recommended by the ICRP (International Commission on Radiological Protection), the Human Respiratory Tract Model (HRTM) and the Human Alimentary Tract Model (HATM), are referred to and combined with the developed code. Although the above biokinetic models representing biokinetics from intake by inhalation or ingestion to the blood are applicable to all radionuclides, the models representing biokinetics after leaving the bloodstream are nuclide-specific. Cesium and iodine, mainly released in a severe accident, are focused on in this work and those biokinetic models are also combined with HRTM and HATM. These nuclides are known to spread to the whole body or to the thyroid after intake. Biokinetic analyses are performed by solving differential equations representing all transitions of the combined models by numerical analyses with the Runge-Kutta method.

Biokinetics of Cs-137 and I-131 is revealed in some intake conditions and time dependence of remaining rates of Cs-137 to whole body and I-131 to thyroid would depend on intake pathway and period. Therefore, accurate internal dose estimation to the public requires attention to the presumable biokinetics based on intake conditions.

TS2b.9
What Studies of Radioactive Aerosols can tell us about the Translocation of Nanoparticles

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Nanotechnology has the potential to develop new materials and devices, with applications covering a wide range of fields from medicine to textiles. It is a fast developing technology with the global market in nano-enabled products expected to grow from $2.3 billion in 2007 to $81 billion by 2015. However, alongside the potential benefits of nanotechnology are concerns regarding possible health and environmental impacts.

Evidence from studies on air pollution, which indicate that the nanosized (diameter < 100 nm) particulate fraction is responsible for detrimental effects on the cardiovascular and respiratory system, have raised concerns that inhalation of similar sized engineered nanoparticles may have similar consequences.

A key question in relation to the toxicological properties of nanomaterials is - where are they transported to following entry into the body? Although some studies have been undertaken in this area there is limited information on nanoparticle translocation following inhalation. The experimental results to date indicate the importance of particle size and chemical properties to the resulting pattern of translocation.

A series of in vivo experiments undertaken in the 1970s to investigate the mobility of aerosol particles of plutonium and curium in a number of chemical forms provides some insight into the possible transport of nanoparticles within the body. The results from these studies have been reconsidered with a focus of the information they can provide about the pulmonary clearance, translocation and excretion behaviour of nanosized particles and the influence of physicochemical factors, such as charge, on this behaviour.

TS2c.1
Structural Genomic Damages In Plutonium Workers

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The research objective is assessment of structural genomic damages in plutonium workers. The study group included the Mayak nuclear workers exposed to chronic occupational exposure to incorporated ^{239}Pu and/or external gamma-rays. The external gamma-ray dose to red bone marrow (RBM) ranged within 0-2.7 Gy, absorbed dose to RBM from internal alpha-radiation to incorporated ^{239}Pu ranged within 0-0.8 Gy. The analysis was performed based on the culture of lymphocytes from peripheral blood. The yield of intra-chromosomal aberrations on stained slides was analyzed using in situ fluorescent hybridization, mBAND. Linear relationships were revealed between (a) the total yield of chromosomal aberrations (e.g. intra- and inter-chromosomal ones) and absorbed dose to red bone marrow from external gamma-rays, absorbed dose from internal alpha-radiation to incorporated ^{239}Pu; and (b) the yield of intra-chromosomal aberrations and absorbed dose to red bone marrow from ^{239}Pu and ^{239}Pu body burden. Thus, intra-chromosomal aberrations in peripheral blood lymphocytes are a specific biomarker of internal exposure and can be used to identify individuals exposed to internal alpha-radiation.

TS2c.2
Performance Of The Dicentric Assay In A Recent NATO Exercise Of Established And Emerging Biodosimetry Methods

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Accidents involving human exposure to radiation can cause severe health effects which may require extensive medical resources. Particularly in mass-casualty events, the rapid identification and classification of potentially overexposed individuals into medical treatment groups is of prime importance. For this purpose, clinical signs and symptoms and biological dosimetry methods are the two main approaches for assessing radiation exposure in situations where no dosimetry badge was worn.

The dicentric chromosome assay (DCA) is considered the "gold standard" method for biological dosimetry after an acute radiation exposure. However, several novel techniques are emerging which may be faster and have a higher throughput than the DCA and could thus become valuable dosimetric tools in the future.

This comprehensive study was organized under the umbrella of the NATO Research Task Group RTG-033 "Radiation Bioeffects and Countermeasures" in order to compare the performance of the two most validated techniques (DCA, cytokinesis block micronucleus assay) and of three candidate assays (premature chromosome condensation, gene expression, ƒxƒ{H2AX) for biodosimetry and radiation injury assessment. To this end, an inter-laboratory and inter-assay comparison exercise was performed. In a first step, blood samples exposed to known X-ray doses were provided for establishing calibration curves at each laboratory and for each assay. In a second step, ten coded blood samples irradiated with different X-ray doses were distributed among 15 institutions for triage-mode biodosimetry.

This presentation focuses particularly on the inter-laboratory comparison of the DCA and discusses as main parameters (1) the time required for providing dose estimates for the unknown samples, and (2) the statistical parameters (sources of variance) that describe the precision of the assay.

TS2c.3
The Dicentric Assay in Triage Mode as Reliable Biodosimetric Scoring Strategy for Population Triage in Large Scale Radiation Accidents

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Introduction: Mass casualty scenarios of radiation accidents require high throughput techniques of biological dosimetry for population triage to identify individuals for whom clinical treatment is indicated. To this end the dicentric assay in a triage mode is a very suitable technique. Within the MULTIBIODOSE EU FP7 project a network of eight biodosimetry laboratories is established with expertise in dose estimations based on the dicentric assay.

Results: In the first task the conventional dicentric assay was tested in the triage mode. Three types of irradiation scenarios were included: acute whole body and partial body exposure and protracted exposure. Blood samples from 33 healthy donors (> 10 donors / scenario) were irradiated in vitro with gamma rays, simulating the 3 different types of exposure and 3 different doses each. All the blood samples were irradiated at the University of Gent, Belgium, and then shipped to the participating laboratories. The dose estimates of acute whole body exposure show a good agreement with real irradiated doses (0.5, 2.0 and 4.0 Gy) for all labs. At partial body exposure, most labs can identify correctly the partial body doses at 4 and 6 Gy, but this was not possible at 2 Gy and indicates a need for more cells to be analysed. After protracted exposure, all labs performed these dose estimations well and received good results at 1.0 and 2.0 Gy.

Conclusions: The results obtained up to now within the MULTIBIODOSE project are very promising for application of the dicentric assay in the triage mode as a high throughput scoring strategy for biodosimetry in large scale accidents by a network of eight collaborating laboratories throughout Europe.

TS2c.4
Contribution of the Biological Dosimetry for Treatment Decisions in Patients with Differentiated Thyroid Carcinoma (DTC) under Radioiodine-131 Therapy

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Radioiodine-131 therapy is applied in patients with DTC, within the therapeutic scheme following thyroidectomy, for the ablation of thyroid remnants and treatment of metastatic disease. Several approaches for the selection of a therapeutic dose were used. In this work, the treatment protocol used incorporates the assessment by biological dosimetry (BD) for estimating doses to whole body and bone marrow.

The objective of the present work is to estimate the absorbed dose to the whole body and bone marrow, due to the therapeutic administration of ^{131}I in patients with DTC, by applying cytogenetic techniques, which include the evaluation of dose distribution in the body, for treatment decisions.

Materials and methods: 40 DTC patients (Pt) from treated with total thyroidectomy, followed by ^{131}I therapy, were assessed. The criteria for the inclusion of Pt involves: 1) cumulative activities from medium to high (exceeding 37.0 GBq -1000 mCi), 2) persistent/recurrent disease that would require the administration of new therapeutic doses and 3) hematological complications.

A prospective clinical follow-up was conducted, and was correlated with cytogenetic, hematological and endocrinology data.

For the cytogenetic studies, a blood sample was obtained before each patient treatment and another was obtained on day 8 after the administration of ^{131}I. Cytogenetic methods were applied to quantify chromosome aberrations for dose assessment.

Results and Conclusions: The risk of recurrent/persistent disease and the need for the administration of reiterative activities, generate the requirement of bone marrow status knowledge. The results of this work show that BD assessment have contributed to optimize the ^{131}I therapeutic administration in 5 out of the 40 patients evaluated with cumulative activities higher than 1000 mCi, and to decide the application of a complementary surgery in one case. For the remainder, the routine treatment protocol was applied as the doses estimated by BD confirmed that this further ^{131}I administration would result in a low risk of reaching the myelotoxicity threshold (2Gy). The assessment of dose distribution in the body was conducted to evaluate consistency with the clinical status. Patients with inhomogeneous distribution correlated with the presence of metastasis, diagnosed previously to the cytogenetic study. From a clinical point of view, the BD conducted on samples from Pt with previous treatments, before a new therapeutic administration, could allow the cytogenetic status assessment (radiation damage and repair capacity) to become a warning signal for reducing potential hematological complications. In cases with cumulative activities higher than 1000 mCi, it could be useful to indicate the need to consider therapeutic schemes alternative to the administration of ^{131}I, such as surgery, chemotherapy or radiotherapy, reducing morbidity.

TS2c.5
Retrospective Dosimetry on Human Nails using X-band EPR Spectrometry.

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After a nuclear accident it is important to soon after exposure determine the individual doses for triage. Electron paramagnetic resonance (EPR) spectroscopy provides a mean to determine absorbed doses by quantification of free radicals induced by ionizing radiation. A search for possible body materials for retrospective EPR- dosimetry is ongoing; tooth enamel and bone containing hydroxyl apatite are very good with high sensitivity and a high radical stability, however teeth have to be extracted and biopsies of bone are needed. Finger nails are easy to collect and contain keratin. Keratin has a high yield for creation of free radicals by ionizing radiation. Unfortunately free radicals are also easily created at cutting, causing a mechanically induced EPR signal.

So far three types of EPR signals can be identified in a nail spectrum; the background signal (BKS), the mechanically induced signal (MIS) and the radiation induced signal (RIS).The aim of the present investigation was to develop a method including preparations to use fingernails for retrospective dosimetry.

In a preliminary study the background signal was obtained for nails from 10 donors. A preparing procedure was developed including water preparation of cut pieces of nails. Further the mechanical stress was studied by repeated cutting of fingernails just before the measurements. Finally a dose response curve was obtained and an attempt was made to determine the absorbed dose to a sample irradiated with an unknown dose. The irradiations were performed with 6MV X-rays from a linear accelerator Varian Clinic 600. Preliminary results showed that the background signal from untreated nails varies a lot between individuals and that it is impossible to establish an averaged BKS from only 10 donors. The mechanically induced signal decayed within 24 hours and the solution treatment reduced the BKS significantly. Before 24 hours after irradiations the water treatment will completely remove the MIS. Both BKS and MIS increase with additional cuts of a whole nail. A linear dose response curve was obtained but for determination of the RIS the subtraction of the BKS failed probably because of averaged values from too few donors. The investigation will be completed with an averaged background from fifty donors and also a comparison between toe and fingernails from the same donor for the possibilities to use the toe nails for background signal when only the hands are exposed.

TS2c.6*
Assessment of Frequency of Dicentrics of Ukrainian Children from Parents Exposed to Radiation Fall-out After the Chernobyl Accident

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The accident of Chernobyl affected about 130 km north-west of Kyiv, 36,000 hectares of the territory covering 78 districts in 12 regions of Ukraine which have been contaminated with radionuclides with ^{137}Cs density exceeding 1 Ci/km^2. More than 1.8 million people inhabit the contaminated territories. Moreover, 502,377 children, residents of Ukraine, were born in the families where the parents have been exposed to the ionizing radiation. The aim of this study was to carry out a cytogenetical analysis of 55 Ukrainian children living in the areas around Chernobyl. Children were residents of Ukraine and they were born in the families where the parents have been exposed to the ionizing radiation due to nuclear accident.

Cytogenetical procedures were performed according to biological dosimetry assays. Analysis from a total of 53,477 metaphases scored in these children reflected a very low frequency of dicentrics, maybe due to the relatively low doses of exposure in living areas. The low frequency of dicentrics do not permit to estimate any absorved dose in these children.

TS2c.7
FISH Translocation Practice as a Retrospective Biodosimeter: a Review.

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Fluorescent in situ hybridisation technique (FISH) allows an easy detection of translocations and this method can be used in biological dosimetry to estimate a dose in some cases of accidental overexposure to ionising radiation. The purpose of this study, based on the 57 analysed cases, is to check whether this indicator of dose is appropriate and to identify its remaining limits. Translocations were detected on lymphocytes of patients who have been suspected of overexposure to ionising radiation in the past. Chromosomes 2, 4 and 12 were labelled using the 3 painting FISH technique.

Among the 57 cases, 33 cases presented a positive dose with translocations. The lowest positive dose measured was 0.3 Gy.

Between 2 and 6 months, the dose measured by translocations is higher than that measured by dicentrics so translocations estimated a dose accumulation. Over 6 months, dose estimation is only possible by translocations because dicentric dose estimation is equal to 0. We were able to measure an over exposition up to 30 years.

This technique is helpful to identify exposed people however the sensitivity of the technique is still higher than with the conventional cytogenetic technique bases on the scoring of dicentrics. In addition, no clear relation can be established between exposition and late pathologies developed by the patients.

TS2d.1
Improvement of Construction of Recombination Chamber for Mixed Radiation Dosimetry at Workplaces

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Recombination chambers have been used in dosimetry of mixed radiation fields for over 50 years. Their main advantage, in comparison with classic ionization chambers operated at saturation, is that the ion collection efficiency under conditions of initial recombination of ions depends on linear energy transfer (LET). Therefore, it was possible to define measurable quantities which depended on LET in the way similar to the dependence of quality factor Q(L).

Up to now, there were about 20 methods, about 30 types of chambers and about 15 various recombination dosimeters developed. Among them, there were chambers which could be used for direct determination of H*(10) and of the photon contribution to the absorbed dose in radiation fields of practically any composition and energy spectrum.

The experience gained from earlier designs and from the measurements of H*(10) in different radiation fields, makes it possible to introduce improvements to the most commonly used chamber of REM-2 type, in order to match better the dependence of its response on neutron energy (in the range up to 20 MeV) to H*(10). The main innovations in the design of the new chamber, preliminary denoted as REM-3 are as follows

1. Polypropylene was used as the electrode material instead of a tissue equivalent material used in REM-2 chamber. This raised the amount of hydrogen in the electrodes and therefore it can be expected that the neutron response will be increased to the value close to the photon response of the chamber.

2. The cylindrical polypropylene insert was introduced (this changes the wall contribution to the ionization of the gas in neutron fields and makes the energy dependence of the chamber response more flat).

3. Improved insulators effects in decreasing the signal stabilization time after a change of polarizing voltage.

The REM-3 chamber will be used as a main detector in the currently developed recombination dosimeter of new generation. Like the REM-2 chamber, also REM-3 has two sets of electrodes and can be used either in differential or summation mode for direct reading of H*(10) or the ambient absorbed dose D*(10), respectively. In the new dosimeter, the remote switch of the mode will be possible. In order to facilitate the use of the device at workplaces and at distant or hardly accessible locations, the option of internet connection (cable or Wi-Fi) between the dosimeter and recording/controlling computer will be available.

TS2d.2
Nordic Intercomparison Campaign for Whole Body Counters – Evaluation of the Performance of the Facilities and Inventory of Regional Resources

del Risco Norrlid, L*[1]; Halldorson, O[2]; Holm, S[3]; Huikari, J[4]; Isaksson, M[5]; Lind, B[6]

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Results of the regional intercomparison campaign conducted during 2010/2011 are presented and discussed. This activity was promoted in the framework of the Nordic Nuclear Safety Research (NKS) for regional cooperation in nuclear safety, radiation protection and emergency preparedness. The goals were to evaluate the quality status of whole body counting measurements by means of a proficiency test exercise, setting up an on-line library for the management of the use of calibration phantoms in the region and an inventory of the regional resources.

The St. Petersburg whole body phantom (also known as IRINA), jointly owned by the Nordic countries, was circulated for the measurements together with two sets of fully traceable radioactive material (Cs^{137} and K^{40}). This phantom can be built in six sizes and the choice for the phantom size was the adult size with 77,8 kg and 170,5 cm. Twenty one laboratories participated. The phantom circulated first among in-vivo laboratories situated at nuclear facilities, second priority was given to national authorities and laboratories with responsibilities within emergency response and lastly university hospitals or other research laboratories.

A web based library for regional phantoms was set up containing the information on every phantom and its ”home” site. The online data updated after the completion of every loan event makes possible for the users to check online regarding availability/waiting time for the phantoms to borrow.

The regional inventory of resources for in vivo measurements revealed that the whole body counting assets have been maintained compared to 2004, the last time an inventory of this kind was made. Both the field laboratories as the stationary ones are equipped with sophisticated whole-body counting systems with Ge-, NaI-detectors. The regional competence is good and retains experienced staff but a new generation is coming that needs training and exchange of experiences, which emphazises the importance of keeping the practice of intercomparison exercises.

TS2d.3
A Novel Dosimetry System for Military Use in Response of Nuclear Emergencies

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A novel dosimetry system capable of determining the absorbed dose to tissue (cGy) arising from detonated tactical nuclear weapons was developed with the intention of replacing the system used by the U.S. Army and addressing newer challenges related to modern nuclear events. In addition, the new system eliminates the need for a second dosimeter to be carried during operation other than war as is the case with the current system.

The system is composed of a portable and self contained new dosimeter (RadWatch™) and dosimeter reader (RadLight™). The ensemble assesses the absorbed dose to tissue (cGy) from neutrons and photons and the personal dose equivalent (mSv) from neutrons and photons at occupational dose in accordance to ANSI N13.11-2009.

The RadWatch™ dosimeter contains a plurality of Al_2O_3:C discs as active detection material. Each disc is placed under different cylindrical filters for improved angle and energy response and good energy discrimination. The slide containing the detector material has a radiofrequency identification chip (RFID) on which identification information, last read information and detector sensitivity data are recorded. The slide also contains a Al_2O_3:C,Mg fluorescent nuclear track detector (FNTD) as a redundant detector for neutron monitoring.

The dosimeter is using the Al_2O_3:C detectors to measure photons with energies greater than 70keV in addition to fusion and fission neutrons with energies greater than 0.5 MeV by assessing recoil protons using fine, homogeneous Al_2O_3:C crystalline powder. Neutrons with energies greater than 0.025 eV are assessed from recoil protons from the (n,α) reaction with Li^6 using solid crystal Al_2O_3:C,Mg fluorescent nuclear track detector (FNTD). The measured dose ranges are as follows: photons: 0.01cGy to more than 3,000 cGy and neutrons: 0.3 cGy to more than 3000 cGy with OSL; 0.5mSv to 0.5 Sv with FNTD.

The portable RadLight™ is a small battery operated instrument designed to prevent interference from dust and dirt and withstand severe environmental and operational conditions. The reader uses pulsed stimulation method (POSL) and reflection geometry operating at 1000 cycles per second with pulse duration of 50 microseconds. Luminescence is assessed following each pulse. The reader interrogates the RFID chip for element sensitivity which is critical in dose calculation. The dose results are stored on the RFID chip so that the dosimeter contains the results of the last analysis. A record of each reading and other pertinent information is stored in the reader memory and can be exported as required.

The dosimetric characteristics as of: energy response, angular dependence, fade, accuracy, precision, lower limit of detection, linearity, depletion rate as a function of number of reads were investigated for the RadWatch™ and RadLight™ system and presented in this paper.

TS2d.4
Design and Setup of a New HPGe Detector Based Body Counter Capable of Detecting Also Low Energy Photon Emitters

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Germanium detectors allow for an accurate detection of complex contamination cases involving multiple nuclides, but they have a downside compared to the previous-generation scintillators: the lower counting efficiency. This requires careful optimisation of the system to attain the best results. In this work, the complete redesign of the partial-body and whole-body counter previously installed at IVM (KIT, Karlsruhe) is described and the first results of its application are reported. The old system was using germanium detectors and phoswich scintillators, the new system uses coaxial high-purity germanium crystals with the front dead layer removed to extend the sensitivity to lower energies (10-2000 keV).

The first step of the work is the modelling of the detector using MCNPX,. The model was later compared to measurements of both point sources and phantoms loaded with radionuclides. The agreement achieved is within 5% for most of the reference cases. The second step of the work consists in the definition of the partial-body counting configurations. Different simulations of a voxel model of the human body (MeetMan, from the Visible Human Project) were used to determine the highest photon-flux regions of space around the phantom. The detectors were placed in these regions and the requirements for new mechanics to support the detectors were defined.

The definition of the whole-body counting configurations was also performed using MC simulations and using the calculated photon flux, but in this case different results for different organs, phantoms and energies were aggregated to calculate average values and standard deviation. These two new quantities were used to optimise the counting setups.

Once the system and the mechanics were ready, different tests were performed. First, a reference phantom was used to quantify the improvement in the detection limit compared to the previous system. Later, two subjects potentially contaminated with ^{210}Pb were measured on the skull. This test aimed to check the lowest-energies capabilities of the system (46 keV). A last test involved the measurement of subjects returning from Japan after the Fukushima accident, with mixed results.

All the steps of the routine operation will be handled by software written specifically for the purpose: calibration, measurements, analysis, saving of the data. The software integrates with the old database in use in the laboratory, but enhances it to provide more flexibility and future expansion.

TS2d.5
Wearing More Than One Dosemeter - How Do We Explain the Differences?

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Increasingly, radiation workers are wearing more than one dosemeter, either a passive and an active one supplied by their employer, or a combination of employer's and site operator's dosemeters. Electronic dosemeters now have a level of dosimetric performance which equals, and sometimes exceeds, that of passive dosemeters supplied by approved dosimetry services. As such, wearers are increasingly inclined to compare the results of various dosemeters issued to them and to be concerned when there are, to their eyes at least, significant differences between the results. This is particularly true for users who work at high levels of precision in their jobs and who find it difficult to appreciate the relatively low accuracy of field radiation measurement.

This paper goes into the various reasons why differences are generally inevitable. It covers from the simple - "Did you wear both dosemeters all the time" to the more subtle, such as the radiation fields to which the dosemeters have been exposed and the factors used to make corrections to the apparent recorded dose. The analysis uses data from a wide range of sources and gives various simple methods which can be used to investigate differences.

TS2d.6
Measurement of Radio-nuclides in Radioactive Aerosols Produced in a 120-GeV Proton Target Station

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High-energy proton beams traveling in air and beam sprays from the interaction of the beam with the target and related target station components produce radioactive aerosols in the accelerator target area. Those radioactive aerosols are produced either by direct activation by the beam and its secondaries and/or the subsequent attachment of the various radio-nuclides produced by other nuclear spallation reactions in the target, in the instruments around the target, air and other sources. The radio-nuclide composition of those radioactive aerosols and their source materials have scarcely been studied previously. In order to control external and internal exposure of the workers in a high-energy accelerator target area, it is important to measure the produced amount of radio-nuclides in the radioactive aerosols.

In this work, we determined the activity levels of the following twenty radio-nuclides in the radioactive aerosols; Be-7, Na-22, P-32, Sc-46, V-48, Cr-51, Mn-52, Mn-54, Co-56, Co-57, Co-58, Fe-59, Co-60, Se-75, Y-88, Ag-110m, Os-185, Au-195, Au-196 and Au-198. The aerosol samples were collected in the Fermilab Anti-proton target station (AP0), where 120-GeV proton beam interacts with an Inconel target. The radioactive aerosols were withdrawn by a pump and collected on filter paper. The filter paper was subjected to gamma-ray spectrometry. In case of measuring P-32, beta-ray spectrometry was performed using a liquid scintillation counter after appropriate radiochemical separation procedure. Based on the results, source materials of those radio-nuclides obtained will be discussed. Additionally, internal dose will be estimated from the activity levels of corresponding radio-nuclides.

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TS2d.7
Radon Exhalation from Mine Tailings Dams in South Africa

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In South Africa mining activities take place in Gauteng Province. Rocks taken from underground are milled and processed to extract gold. The uranium bearing tailings are disposed in dumpsites. These tailings dumps contain considerable amounts of radium (^{226}Ra) and have therefore been identified as large sources of radon (^{222}Rn). ^{222}Rn is a noble gas formed by the decay of ^{226}Ra which in turn is derived from radioactive decay of uranium (^{238}U). ^{222}Rn release from these tailings dumps in Gauteng pose health concerns because of the surrounding communities.

Measurements on ^{222}Rn gas concentrations and exhalations have been conducted at Kloof mine dump which is inactive. RAD7 from Durridge Co., was used to measure ^{222}Rn gas concentration in the tailings dump at five different spots from shallow to deep depth. The concentrations recorded ranged from 26.5 kBq m-^{3} to 472 kBq m-^{3}. Further, thirty four samples were taken from these spots. The soil samples were collected in the depth range 0-30 cm, placed in labeled plastic bags, sealed and then taken to the laboratory for analysis using HPGe. After analysis, the average activity concentrations were 308 ±12 Bq/kg, 255±12 Bq/kg and 18±1 Bq/kg for ^{238}U, ^{40}K and ^{232}Th respectively.

222Rn exhalation from the ground surface is influenced by <STARTSUP.226< SUP>Ra activity concentration and its distribution in soil grains, soil grain size, soil porosity, temperature, moisture and atmospheric pressure. At Kloof mine dump ^{222}Rn exhalation was mapped using a novel technique by means of a MEDUSA (Multi-Element Detector for Underwater Sediment Activity) γ-ray detection system. The MEDUSA detector uses a CsI(Na) crystal and was mounted on the front of a vehicle, 0.6 m off the ground. With this setup, the MEDUSA detector measures the average activity concentration in the top 30cm when accessible parts are traversed.

MEDUSA spectra were analyzed and activity concentrations for ^{238}U, ^{40}K and ^{232}Th were extracted using Full Spectrum Analysis. The field activity concentrations were (1) normalized by normalizations factors computed from ratios of MEDUSA to HPGe and (2) corrected for moisture content. Since radon exhalation does not affect ^{40}K and ^{232}Th activity concentrations therefore the ratio of ^{238}U and ^{40}K and/or ^{232}Th for the field (MEDUSA) to laboratory (HPGe) will give a measure of radon exhalation at a particular location in the dump. Applying this new technique yielded an average normalized radon flux of 0.105,,b0.015 Bq m-^{2}. s-^{1}.

TS2d.8
Use of Phoswich Detector for Simultaneous Monitoring of High Energy Photon and its Applications in In vivo Lung Counting

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A phoswich detector system with associated pulse shape discrimination (PSD) electronics is being used for monitoring of actinides in lungs by the measurement of low energy photons. The PSD electronics of the system is modified in order to simultaneously record both lower energy photon (LEP) spectrum and higher energy photon (HEP) spectrum. Phoswich system with modified PSD electronics was evaluated for its suitability to analyse the high energy gamma photon spectrum. The parameters like energy linearity, variation of FWHM with energy, efficiency linearity and room background are studied. During the evaluation process, presence of ^{137}Cs in the CsI detector portion of phoswich was detected. The HEP spectrum recording feature helped in identification of the interference from ^{41}Ar (a site specific interference at Kalpakkam) without any additional monitoring system. This feature also enabled us to quantify the interference of ^{41}Ar in LE regions. Muscle to fat ratio is one of the parameters required for in choosing the correct efficiency factor during lung counting of actinides. Measurement of ^{40}K in subjects enables one to estimate the muscle / fat composition. The ^{40}K measurement with the present system showed that activity of 100Bq can be achieved. This paper discusses the details of the PSD electronics for simultaneous monitoring of HEP and its utility in *in vivo* lung counting.

TS2e.1
The use of New Eye Lens Dosemeter for Medical Staff

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The publication of BSS recommends the use following operational quantities: Hp(10), Hp(3) and Hp(0.07) in radiation protection dosimetry. Typically two types of dosemeters: whole body dosemeter (measured doses in term Hp(10)) and finger dosemeter (measured doses in term Hp(0.07)) are used in radiation protection dosimetry.

In this study the personal dose equivalents were obtained using three different types of individual dosemeters with TL detectors and during normal procedures. Measurements were performed by the dosimetric service. Within this study the measurements during typical interventional radiology and nuclear medicine procedures were performed. Within this study the measurements in 7 Polish hospitals during typical medical procedures were performed. The doses to medical staff in were measured in terms of: the personal dose equivalent Hp(10) for whole body, Hp(0,07) for hands and Hp(3) for lens of the eye. For individual dosimetry thermoluminescence MCP-N (LiF:Mg,Cu,P) pellets, 4.5 mm in diameter and 0.9 mm thick were placed in a Rados individual dosimetry badge with three Al filters. For extremity ring dosimetry the MTS-N detector was inserted in a plastic ring holder that could be adjusted to any finger size. For eye-lens doses the new type of eye-lens dosemeter (developed by Radcard in frame of EU ORAMED project) with standard TL detector (4.5 mm diameter and 0.9 mm thickness) was tested.

One of the objective of this work was compare doses measured with the newly developed eye lens dosemeters to doses determined with the presently used personal dosemeters, worn on chest and finger. This realistic comparison will be useful for necessity of using the separate dosemeter in different medical procedures for assessment of Hp(3). The dosemeters are indented to measure doses at the depth of 3 mm, which corresponds to the depth of the eye-lens.

TS2e.2
Type Test Information Of The New Instadose Personal Dosimeter

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Introduction: Instadose™ is a small, rugged dosimeter based on patented direct ion stor-age technology. Instadose™ is currently NVLAP accredited for all photon test categories un-der ANSI/HPS N13.11-2001 and accredited in the United Kingdom under the Health and Safety Executive. The Instadose™ dosimeter was launched in June 2009 and continues to grow its client base. The technology provides radiation workers the ability to eliminate the need to return their personal dosimeter to a processor. This is accomplished by allowing any computer with internet access the ability to read and record the individual's doses using the computers USB drive.

Dosimeter Theory: Instadose™ utilizes the Direct Ion Storage (DIS) for its radiation de-tection. Detailed discussions of the technology operations will be discussed in this paper.

Test Data Review: Over the last couple years, many tests were conducted on the Insta-dose™ dosimeter. Many of the tests were conducted in accordance with the IEC 62387, but some were conducted to ensure a positive customer experience. Tests include:

- Energy response tests
- Angularity response tests
- Response at various temperatures
- Drop Tests
- Computer USB Power tests
- Low Dose Tests
- Pulsed radiation tests
- Dose Rate Tests
- Dose Linearity

This paper will discuss the results of each of these tests.

Operational Experiences: Since Instadose™ utilizes a unique form for receiving per-sonal radiation exposure by having the individual wearer perform the reading, there have been some operational experiences that were learned over the last couple years of implementation. Some of these include:

- How to ensure wearers read their dosimeter
- PC related issues (i.e. firewalls, proxy servers, USB ports)
- Temperature effects on the Instadose™ dosimeter

Details of each will be highlighted and discussed.

TS2e.3
A Personnel Neutron Albdo Dosimeter Badge using Aluminum Oxide Pellets

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Personnel neutron albedo dosimeter (PNAD) is mandatory for radiation workers at particle accelerator laboratories, high-energy medical linac and hadron therapy centres and nuclear reactor facilities. The novel PNAD developed by WPE Detector and Sensor Group basically consists of a pair of highly gamma sensitive α-Al_2O_3:C pellets commonly available as TLD-500 chips. The pellets were housed in two small lead pouches of 2.5 mm wall thickness. The first pellet was covered with 0.2 mm thick Gadolinium foil and the second one was kept blank. The pouch-pairs were attached to a 50 mm x 50 mm x 3 mm borated rubber pad and enclosed in a small PVC bag (70 mm x 95 mm) with mounting clip constituting the albedo dosimeter badge. The PNAD was attached to a 300 mm long, 25 mm diameter cylindrical polyethylene phantom and irradiated with neutrons from a ^{226}Ra/Be photoneutron source to dose levels up to 20 mSv. The borated pad side of the badge was facing the incoming neutron flux whereas the rear side sensing the albedo neutrons from the phantom. The pellets were evaluated using a Harshaw Model 3500 TLD Reader and a calibration (linear function) curve constructed. The aluminum oxide PNAD found to be three times more sensitive than conventional personnel dosimeter based on TLD-600 (^{6}LiF: Ti,Mg) and TLD-7600 (^{7}LiF: Ti,Mg) chips. Our paper highlights feasibility of

TS2e.4
A Personal Dosimetry System in a Box

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An increasing number of organisations, worldwide, are requiring to provide personal dosimetry monitoring to a small number of employees. Often these organisations are situated in remote areas for which shipping of large volumes of equipment and consumables is difficult and for whom automation is not a key driver. For such organisations Landauer has developed a complete personnel dosimetry laboratory package. The package is low cost, simple, accurate and easy to implement. The complete system can be supplied in a rugged container which is easy to ship via international couriers.

The complete personnel dosimetry laboratory package is based on Landauer's InLight™OSL technology. OSL features include:

• Reduced maintenance - no heating or gas, just gentle light.

• Fast throughput - 280 dosimeters per hour for lower program costs.

• Annealing on demand - erase the dose when required.

• Reanalysis - verification results without erasing the dose.

• Rugged design - resistant to shock, moisture, dirt, oil, etc.

• Long wear periods - up to 1 year for lower program costs.

The complete personnel dosimetry laboratory package contains everything needed to start-up and operate a low cost, accurate dosimetry laboratory with minimal support. This includes: the equipment and consumables required (microStar™ reader, annealer, dosemeters and calibration sets); software for the operation of the reader and dose record keeping/reporting; and the documentation required for Quality Assurance and validation/approval as required by national and/or IAEA requirements. Training is available at our regional centres including in: Paris, France and Chicago, USA, or at a mutually convenient third party site. Ongoing support can be achieved simply by shipping faulty equipment back to our offices for repair and return. Additional equipment and consumables are available for printing labels and other forms of dosimetry. The system is versatile so if, for example, a client wants to use their own record keeping/reporting software this is readily possible.

This paper will describe the system and demonstrate that it is possible to produce a low cost, reliable package to start a dosimetry system with measurement capabilities comparable to larger systems. It will also discuss the application of this system in a number of countries, principally in Africa.

TS2e.5
Characterization of a Research Reactor's Fast Neutron Irradiator Using Silicon Bipolar Transistors and Calcium Fluoride Thermoluminescent Dosimetry.

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An experimental characterization of the University of Massachusetts Lowell Research Reactor's Fast Neutron Irradiator was performed following the guidance of ASTM E1855-05: *Standard Test Method for Use of 2N2222A Silicon Bipolar Transistors as Neutron Spectrum Sensors and Displacement Damage Monitors.* The ultimate goal of this work was to determine the One MeV Equivalent Neutron Fluence for Silicon by correlating this value to the measured current gain degradation of bipolar transistors. This process involved calibrating the transistors in a well-known fast neutron environment, which was provided by the University of Massachusetts Lowell Van de Graaff Accelerator. Calcium Fluoride Thermoluminescent Dosimetry (TLD) was also used to measure the gamma dose rate to Silicon inside the irradiator. A technical challenge encountered during the TLD measurements led to the development of an experimental routine for determining the dose imparted to the TLD elements due to thermal neutron activation. The final results of this work verified expectations for the neutron fluence and resolved a previously unexplained discrepancy between the predicted gamma dose rate and that measured by an earlier ionization chamber measurement.

TS2e.6
What can you say when there is almost nothing? Decision thresholds associated with multiple measurements and their use for environmental monitoring.

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When sample activity is measured several times for various reasons, then with each measurement can be associated an individual decision threshold and limit of detection. Each measurement can be analyzed through its own decision threshold. The whole measurements can sometimes present contradictory results, certain measurements being lower than the decision threshold and other higher. The problem then arises to build a decision threshold and a detection limit taking into account all the individual results, and to decide if the radioactivity is finally detected or not. It is interesting to note that the global decision threshold, taking account all individual results, could enable the analyst to decide that the radioactivity is present whereas each individual results is negative in terms of individual decision threshold. We are able to show how these thresholds and these coherent limits cumulated can be determined in way according to the experimental conditions. In a general way a rigorous method of cumulating makes it possible to systematically decrease the decision threshold and limit of detection in terms of activity. This approach has interesting applications in gamma spectrometry with multi-emitters, radioactive surveys or periodical environmental measurements. On the basis of measurements realized by the IRSN within the framework of the national monitoring of the environment, we will see the potential impact of these methods on the final assessments

TS2f.1
Eurados Intercomparisons for Individual Monitoring Services: Results and Conclusions from the First Three Exercises

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The regular participation of individual monitoring services (IMS) in intercomparison exercises is now considered by many IMS to be a convenient and essential tool for validating the performance of their dosimetry systems. Participation can be used to assist the accreditation (or approval) of the IMS. Participation is strongly advised in the recently updated European Commission's Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation (RP-160, 2009) and is a requirement of ISO/IEC 17025.

In 2008, Eurados (the European Radiation Dosimetry Group) started to organise a self-sustained programme of regular intercomparisons with the aims of encouraging and facilitating the participation of IMS in intercomparisons. To date, two intercomparisons for whole body dosemeters (IC2008 and IC2010) and one for extremity dosemeters (IC2009) have been carried out.

The intercomparisons for whole body dosemeters were performed in terms of quantities Hp(10) and Hp(0,07) for different photon radiations. The majority of participating dosimetry systems used thermoluminescence (TLD) and film detectors but optically stimulated luminescence (OSL), radiophotoluminescence (RPL), direct ion storage (DIS) or active personal dosemeters (APD) systems were also represented.

The extremity dosemeters were irradiated with photon and beta radiations in terms of the quantity Hp(0,07). Most IMS participated with finger ring dosemeters but finger stall and wrist dosemeters were also represented.

For each intercomparison a novel irradiation plan was prepared with the aim of providing the participants with useful information on their dosimetry systems, ie linearity, reproducibility, and responses for energy, angular and mixed fields. The irradiation facilities were selected from accredited metrological laboratories in Europe.

The number of participants in all intercomparisons has shown a significant increasing year on year trend. In 2008 there were 52 IMS (62 dosimetry systems from 24 countries) and in 2010 there were 70 IMS (85 dosimetry systems from 30 countries). The extremity dosemeter intercomparison held in 2009 had 44 participating IMS (59 dosimetry systems from 18 countries). These figures clearly demonstrate the rising interest of IMS services in the EURADOS intercomparison programme.

The results of the intercomparison showed good performances from most of the participating IMS. However, areas for improvement were identified for some of the IMS. Many IMS participated at both IC2008 and IC2010 which allowed them to confirm the quality of their results, demonstrate improvements or, for few IMS, identify new issues for more thorough investigation.

This paper presents the development of the intercomparison programme, results and conclusions of the three intercomparisons already completed and sets out the scientific and operational case for regular IMS performance testing.

EURADOS believes that the intercomparison programme is a significant contribution to the harmonization of personal dosimetry in Europe.

TS2f.2
International Co-Operation, Basic Principles And Ongoing Developments In Radiation Protection Metrology And Measurements

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Assessment of external and internal exposure for radiation protection purposes needs reasonable physical, biological and ecological concepts. Reliable instruments and well-established measurement methods are the essential basis for high quality dose and activity measurements.

In this paper, international co-operation, basic principles and recent developments in radiation protection measurement techniques are given. Metrological aspects as traceability chains to assure traceability from national primary standards to end-user measurements are discussed together with the international and European metrological network in radionuclide metrology and dosimetry. The basic methods and practical implementation of uncertainty assessments in activity and dose measurements methods are presented. Finally main aspects and recent research projects in radiation protection metrology and measurements are discussed.

The paper provides a comprehensive evaluation of ongoing radionuclide metrology and dosimetry for radiation protection assessments. The results serve as state-of-the-art theoretical foundation and practical information for qualified RP experts and all users of measurement instruments in radiation protection.

TS2f.3
Radiation Protection Dosimetry in Pulsed Radiation Fields

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The application of pulsed radiation fields for research, security screening and medical investigations has increased remarkably in the last years. The testing of active per-sonal and area dosemeters for the operation in pulsed radiation fields is a necessity to judge the suitability of the dosemeter. Up to now, radiation protection dosemeters have only been tested in continuous fields, although they are used for measurements in pulsed radiation fields as well. As PTB has discovered, many of the conventional electronic dosemeters do not determine reliable dose values in these pulsed fields any more. The reasons for this are based on the measurement principle (mostly the counting technique) in combination with the characteristics of the pulsed radiation field (e.g. high dose rate during the short radiation pulse).

Similar problems occur during measurements in radiation fields that appear as pulsed fields for the dosemeter, e.g. as used for X-ray security scanners. The measuring conditions at X-ray scanners are very demanding. The pulse-like X-ray beam has a high dose rate of up to 4 sievert per hour. In combination with very short irradiation times of a few milliseconds, however, the resulting dose values are only in the order of the values produced by the natural environmental radiation within a few hours.

Thus, in cooperation with the Siemens company, a novel facility has been developed which will make it possible for the first time to adjust all parameters of pulsed X-radiation reference fields and to determine the performance limits of dosemeters with respect to pulsed radiation. Worldwide, it is the first facility of its kind.

The determination of reference fields is a basic requirement for the development, testing and calibration of radiation protection dosemeters as well as for the further development of radiation sources for the range of pulsed radiation. Therefore, a new international ISO standard for pulsed reference fields, dealing with the requirements for such reference fields, is in preparation.

For the active direct reading dosemeters, which use pulse counting techniques to determine the measured dose value, a concept of requirements and testing proce-dures has been developed. This concept is proposed as a new international IEC standard for the type testing of dosemeters.

TS2f.4
ISO/TC 85/SC2 Radiological Protection

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The international standardization organization ISO develops standards in the field of radiological protection for more than thirty years.

Within ISO/TC 85 *Nuclear energy, nuclear technologies and radiological protection,* subcommittee SC 2 develops standards to protect individuals (workers, patients members of the public) and the environment against all sources of ionising radiations in planned, existing or emergency situations linked to nuclear activities, medical activities, industrial activities, research activities and natural radiation sources (radon, cosmic radiation).

Twenty seven countries participate in this subcommittee involving about 200 experts. International organizations such as IAEA, ICRP, WHO, ILO, ICRU are associated to its work. 66 standards have been published and about 50 standards are in preparation.

The work carried out by its 11 working groups covers various needs for harmonization concerning metrology and ionizing radiation dosimetry, measurement and control methods, biomedical analyses, design of radiation generating sources and devices, equipment and systems for the protection of facilities, including remote techniques.

The main recent topics that should be highlighted are the following:

- the publication in March 2011 of ISO 27048 *Radiation protection — Dose assessment for the monitoring of workers for internal radiation exposure,*

- the finalization of a series of 10 standards on the measurement of radon,

- the establishment of a new working group “Control of goods and materials for radioactive substances” in a short term,

- a new project for characterizing reference pulsed radiations,

- the increasing need for guidelines and protocols in the medical field,

- the need for developing standardized procedures for monitoring dose for lens of the eyes.

The standards developed by SC2 represent a high level of technical consensus and benefit the various users of sources, occupational health physicians, radiological protection technicians and experts responsible for ensuring protection both within facilities and in the environment. They also enable regulatory authorities all over the world to facilitate the implementation of basic radiological protection standards established by relevant bodies at the international (e.g. IAEA) or the regional (e.g. European Commission) level.

TS2f.5
Characterization of an 241AmBe neutron irradiation facility by different spectrometric techniques

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An automated panoramic irradiator with a 3 Ci ^{241}Am-Be neutron source is installed in a bunker-type large room at the Universidad Politécnica de Madrid (UPM). It was recently modified and a neutron spectrometry campaign was organized to characterize the neutron fields in different measurement points along the irradiation bench. Four research groups working with different Bonner Sphere Spectrometers (BSS) and using different spectral unfolding codes took part to this exercise.

INFN–LNF used a BSS formed by 9 spheres plus bare detector, with cylindrical, almost point like, 6LiI(Eu) scintillator (4 mm x 4 mm, from Ludlum); UAZ-UPM employed a similar system but with only 6 spheres plus bare detector; UAB worked with a ^{3}He filled proportional counter at 8kPa filling pressure, cylindrical 9 mm x 10 mm (05NH1 from Eurisys) with 11 spheres configuration; and CIEMAT used 12 spheres with an spherical ^{3}He SP9 counter (Centronic Ltd., UK) with very high sensitivity due to the large diameter (3.2 cm) and the filling pressure of the order of 228 kPa.

Each group applied a different spectral unfolding method: INFN and UAB worked with FRUIT ver. 3.0 [1] with their own response matrixes; UAZ-UPM used the BUNKIUT unfolding code with the response matrix UTA4 [2] and CIEMAT employed the GRAVEL-MAXED-IQU package [3] with their own response matrix.

The paper shows the main results obtained in terms of neutron spectra at different distances from the source as well as H*(10) determined from the spectra. These values are compared with the readings of a common active survey-meter (LB 6411). In addition, the intensity of the source is estimated from the spectrometric measurements. The small differences in the results of the various groups are discussed.

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TS2f.6*
Radiation Protection of Patients: Status of Primary Standard Dosimetry of High-Energy Photon and Electron Beams in Austria

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In Austria, a Domen-type absorbed dose graphite calorimeter is used to realize the unit of absorbed dose to water. It was developed by the National Metrology Institute of Austria (BEV) in cooperation with the Research Centers Seibersdorf. The graphite calorimeter is designed for quasi-adiabatic and quasi-isothermal mode of operation. The absorbed dose conversion is done by two methods based on the photon-fluence scaling theorem. The graphite calorimeter was originally designated for determination of absorbed dose to water in ^{60}Co beams. The progress in radiation therapy required the development of the graphite calorimeter to enable primary standard dosimetry of high-energy photon and electron beams. Therefore a set of beam quality dependent conversion and correction factors was required. They were mainly obtained via Monte Carlo simulations with PENELOPE code and measurements. The determination of correction factors for ^{60}Co beams led to the re-evaluation of the absorbed dose rate to water reference value for ^{60}Co beams. For validation the BEV participated in the international key comparison for absorbed dose to water in ^{60}Co gamma radiation at the BIPM. To achieve beam quality specific correction factors it was necessary to consider the beam characteristics of irradiation facilities. This included Monte Carlo modelling of the BEV ^{60}Co therapy unit and of Varian Linac treatment heads. The determined photon energy spectra constitute the basis of beam models used for Monte Carlo simulations to obtain the required correction factors. Further concepts were developed for primary standard dosimetry of high-energy electron beams. A confirmation of the graphite calorimeter development and respectively of the implemented correction and conversion factors was done in the framework of an EURAMET project - intended for the direct comparison of absorbed dose primary standards in ^{60}Co and high-energy photon beams. The advance of the graphite calorimeter provides the methodical fundamentals to enable the BEV for the accomplishment of primary standard dosimetry of high-energy photon and electron beams. The improvement of the primary standard directly leads to an improvement of quality assurance measurements in Linac radiotherapy, i.e. directly related to the radiation protection of patient. Since the accurate knowledge of the applied dose is a main factor influencing the success of a radiotherapy and therefore of great importance for the treatment planning.

TS2g.1*
Library of Mesh and NURBS Female Phantoms for Pulmonary in Vivo Body Counting Studies

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The monitoring of workers with internal contamination risks is commonly done using in vivo spectrometry measurements. However, the physical phantoms used to calibrate the counting systems remain of limited anatomical realism. Moreover, until today no female model of the calibration phantom exists. Hence, realistic calibration coefficients are assessed using voxel phantoms and Monte Carlo calculations to optimize the monitoring of female workers. However, voxel construction is time consuming and its flexibility considerably limited. Therefore, 3D formats developed for computer graphics and design (Mesh and NURBS geometries), were considered. The flexibility of these representations is highlighted through the development of female thoracic phantoms with various chest girths (85-120) and cup sizes (A-F). The effect on counting efficiency of chest girth, cup size and internal organ volume was quantified for the typical AREVA NC germanium counting system.

As a result, 24 different thoracic female phantoms were created using the Rhinoceros 3D modulation software and starting from the ICRP reference female voxel phantom. For one particular chest girth, counting differences as much as 50% were observed between the A and the E cup. Moreover, for a given cup size, the counting efficiency variation with chest girth was quantified. The lung efficiency corrections, between 15 keV and 1.4 MeV, have then been tabulated for the 24 designed female torso models. Finally, the morphology induced variations of counting efficiency were put into equation and practical recommendations were given for routine calibration optimization when monitoring female workers.

To go much further towards a personalized numerical calibration and dosimetry, a case-base reasoning platform was next developed to select from the produced library, the most similar phantom of any female worker. Adaptation process, using artificial neural networks, is then undertaken to fit precisely the morphology of the worker. This platform has proven to be very efficient in the phantom selection and adaptation process. Future work will focus on enriching the case-base database with new and representative models and in upgrading the adaptation algorithm to adjust a set of organs and structures and reconstruct a realistic and personalized full body phantom.

TS2g.2
Impact of ICRP-89 Based Models on Dose Estimates for Radiopharmaceuticals and CT Exams

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Organ models based on NURBS (non-uniform rational B-splines), as used in computer graphics were developed by William Paul Segars, Duke University. These 4D NURBS-based cardiac-torso (NCAT) phantom are realistic and flexible models of the human anatomy and physiology and are used in medical imaging research and other applications, including radiation dosimetry. The RAdiation Dose Assessment Resource (RADAR) committee of the Society of Nuclear Medicine has adapted these flexible and easily scaled models to represent adults and children of the six standard ages and pregnant women at three stages of gestation, as defined in ICRP Publication 89, for use in internal and external dosimetry. These models serve as an update to the Cristy/Eckerman and Stabin et al. phantom series of the 1980's. Specific absorbed fractions (SAFs) and dose factors (DFs) for internal emitters, as defined in the RADAR dose assessment schema, were developed using Monte Carlo methods (Geant4) and used to update existing dose estimates for radiopharmaceuticals. The models were used as well in Geant4 routines to calculate doses to individuals represented by the models for various typical CT examinations. This work will present the calculations obtained to date, with direct comparisons to previous estimates, from various sources.

TS2g.3
Influence of Head Shape on Measured Activity of Actinides

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In vivo measurement of actinides activity in human skull is a valuable technique of internal dosimetry. Many articles were published on calibrations and some new facts were found. The most important finding was that the relation of measured head size and size of a calibration phantom has notable effect on measured activity; however real impact depends on the detectors geometry. Still opened and never studied issue is: How variation in the head shape influences measured activity. Current study tries to provide answer to this question by the means of Monte Carlo simulation and voxel phantoms.

TS2g.4
Comparison Of Internal And External Dose Conversion Factors Using ICRP Adult Male And Meetman Voxel Model Phantoms.

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The dose conversion factors enter directly in the evaluation of the effective dose in case of external irradiation of a body or in case of internal exposure. They can be calculated only making use of Monte Carlo methods and voxel model phantoms. In this work the differences in anatomy and in resolution among several voxel model phantoms, with a special emphasis on the MEET Man voxel model phantom, and the reference ICRP adult male are considered to account for the different values of the dose conversion factors.

MCNPX Monte Carlo code is employed with each voxel model phantom. Dose conversion factors are calculated for whole body irradiation with monoenergetic photon beams in anterior-posterior, posterior-anterior, left- and right-lateral direction and a in complete irradiation around the body (ISO). Those factors are calculated as a function of the photon energy, from 30 keV to 10 MeV, in terms of the kerma.

For the internal exposure scenarios, several organs are taken as source and the dose conversion factors are evaluated in the neighbouring organs. The source organs emit photons of fixed energy, in the energy range from10 keV to 10 MeV. Discrepancies in the dose conversions factors are observed and explained in term of anatomical differences or resolution of the phantoms. Thus this investigation gives an impression to inter-individual variations of the dose conversion factors.

TS2g.5
Age Dependence of Dose Rates in the Enamel of Teeth Contaminated by 90Sr

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From 1949 to 1956 as a result of the radioactive releases into rather small Techa River (Southern Ural, Russia) about 30000 riverside residents were exposed by both external and internal sources of radiation. One of the most dangerous radionuclides in the releases has been a long-lived ^{90}Sr. As osteotropic element the ^{90}Sr incorporates in calcified tissues of human body including teeth. Enamel is a natural solid-state detector of ionising radiation, which is widely used in the external dosimetry with Electron Paramagnetic Resonance spectroscopy. In the case with Techa River radiation situation ^{90}Sr incorporated in the teeth has an effect on the dose accumulated in the enamel additionally to external exposure. ^{90}Sr is beta emitter with path length in the bone tissues about 3 mm (in the approximation of continuous slowdown), that is comparable with the thickness of dental tissues. Therefore the internal dose component in the enamel is strongly depending on tooth geometry. Geometry of the tissues of tooth crowns changes with human age as a result of mechanical attrition, carious destructions and growth of secondary dentine. Therefore the dose rates in enamel due to internal exposure should be also age dependent. The age-related changes in size and shape are most expressed for incisor crowns and it is significant smaller for molars. The aim of presented study is estimation of age dependence for dose rates in tooth enamel due to ^{90}Sr incorporated in the different compartments of tooth crown, viz.: in enamel, primary crown dentin and secondary crown dentin. For this purpose the set of voxel phantoms of incisors and molars for humans from 1 to 70 years old were elaborated based on histometrical measurements of 69 incisors and 31 molars (extracted on medical indications in the restrict clinics of Southern Urals). Dose-rates in tooth enamel were calculated using Monte Carlo simulations of electron transport in tooth tissues with MCNP4c2 code. Obtained results allow to improve tooth dosimetry in the Techa riverside region.

TS2g.6
Absorbed Fractions for Multi-Region Models of the Kidneys in ICRP/ICRU Voxel Phantoms

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Kidney dosimetry is indispensable in internal dose evaluations since the kidneys appear to represent radioactivity uptake in both diagnostic and therapeutic nuclear medicine. The Medical Internal Radiation Dose (MIRD) Committee of the Society of Nuclear Medicine has presented multi-region kidney models and evaluated absorbed fractions (AFs)-fraction of energy emitted in a source region which is absorbed in some target regions- for regional kidney doses in the MIRD schema. However, it is needed to update the AFs for the kidneys since the MIRD kidney models, which are stylized models, do not reflect realistic anatomy. The International Commission on Radiological Protection (ICRP) has developed reference computational models i.e. ICRP/ICRU voxel models of the Reference Male and Reference Female, which have more realistic and detailed information about the kidney than the MIRD kidney models. The ICRP/ICRU kidney model consists of 3 regions for each kidney: cortex, medulla and pelvis. In the present study, the ICRP/ICRU kidney models were applied to evaluating AFs for the kidneys. Uniformly distributed photon sources with the energy range from 10 keV to 10 MeV were assumed to be in the cortex, medulla and pelvis. The radiation transport was simulated using the Monte Carlo code EGS4 in conjunction with an EGS4 user code, UCSAF. Consequently, it was found that the AFs with the ICRP/ICRU kidney models were consistent with those with the MIRD kidney model for adult. In the case of cross-irradiation AFs, the largest differences between the two kidney models (ICRP/ICRU and MIRD) were found to be 3.3 for the female and 2.6 for the male in the low-energy region. The AFs obtained in the present study would be useful for non-uniformly distributed source of photons in kidney dosimetry.

TS3a.1
20 years of ALARA Management, Research and Development at the Belgian Nuclear Research Centre SCK•CEN

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The Belgian Nuclear Research Centre SCK•CEN was created in the fifties. It performs research in the domains of nuclear safety and radiation protection; it produces radionuclides and offers services in its domains of activity. It operates, commissions and decommissions a number of large facilities such as research reactors and hot laboratories. After a large reorganisation ending in 1991, important changes were made to the safety management, including a systematic ALARA approach. A number of newly engaged staff members from the Health and Safety Department and from the operator's divisions were trained in the ALARA approach, and a case study was developed linked to a large dismantling project: dismantling of the first PWR reactor at the European continent. An ALARA management system including an ALARA-committee, an ALARA-procedure and an ALARA database was put into place. The organisation took into account the complex mixture of routine tasks linked to the larger facilities on the one hand, and many unique, innovative tasks characteristic of a research environment. Dose constraints were set at various levels. A dedicated tool called "VISIPLAN 3D ALARA planning tool" to assess doses prior to an operation in a radiation environment was developed and applied in a number of cases. Technological developments such as improved electronic dosimeters were implemented. Initially, a lot of effort was made in the further development of formal optimization techniques. Later on conceptual work leading to a holistic approach of radiation protection, nuclear and industrial safety, including aspects of waste management, was developed and growing attention was paid to cultural aspects of safety. At present, an extension towards enhancing an adequate security culture is being made.

The paper discusses the major steps in this evolution, and illustrates them with practical examples and outcome. It illustrates the flexibility needed to cope with a large number of circumstances typical for a research environment. Despite the aging facilities and the increase in service activities, the policy put into practice allows keeping maximal individual doses at a few mSv and the collective dose to the workforce and contractors to a very low level (~100 person.mSv/year). The design of a new research reactor MYRRHA creates a new challenge for our ALARA approach. Due attention must be given to dose reducing measures already embedded in the design. The experience gained in radiation protection in the past 20 years at the research centres is a valuable asset in the design process.

TS3a.2
The Critical Examination of Radiological Installations

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The Critical Examination (CE) is a legal requirement of Regulation 31(2) of IRR99, & places a duty on the installer/Supplier to demonstrate to the purchaser that a) the designed safety features & warning devices operate correctly, b) there is sufficient protection for persons from exposure to ionising radiation, & c) the equipment is safe to use in normal circumstances.

Unfortunately, there is no agreed standard for the CE, & the basic radiation safety elements can occasionally be confused or lost in the commissioning & acceptance testing. Additionally, some elements may be pre-existing (Barriers) or supplied & installed by sub-contactors (Warning devices & interlocks).

We have devised & tested a generic CE protocol that covers all radiological installations & radiation equipment. This provides a thorough examination & assessment of the following 3 core elements: Installation Examination (barriers, & associated safety design features, interlocks & warning devices), How the Radiation Equipment is Erected or Installed (safety design features, interlocks and warning devices), & Exposure Control of Radiation Equipment (safety design features, interlocks and warning devices).

We will demonstrate how this Critical Examination protocol facilitates the Standardisation of the CE, the training of staff, communication & the optimisation of radiological protection.

TS3a.3
Development and Dissemination of ALARA Culture

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The need to further develop and disseminate ALARA culture comes at a moment in time where we see an increase of the awareness of the risk, new exposure situations to be managed as applications of ionising radiations increase by introducing new techniques, and scientific knowledge of the health effects is constantly developing.

ALARA culture is at the heart of radiation protection culture. It is based on the scientific knowledge on health effects from ionising radiation together with the application of the precautionary principle, leading to the adoption of the linear dose-effect relationship without thresholds (LNT). It results in attitudes and behaviours of individuals and organisations, committed to always search for dose reduction potentialities taking into account that this remains reasonable.

Implementation of optimisation of radiation protection is an ongoing and iterative process, to keep the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposure As Low As Reasonably Achievable (ALARA) taking into account technical, economical and societal factors. This implementation requires qualitative and quantitative judgements and the involvement of all parties having an interest in or concern about an exposure situation. It often requires a profound decision about what is acceptable from an objective point of view rather than striving for “Zero-Dose”.

The paper, elaborated by a working group from the European ALARA Network (EAN) will discuss elements constituting ALARA culture, its practical implementation according to the various exposure situations, and ways to further develop and disseminate it.

TS3a.4
Development and Implementation of USNRC's Safety Culture Policy Statement for Radioactive Materials

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In June, 2011, the U.S. Nuclear Regulatory Commission (NRC) issued its final safety culture policy statement, which describes NRC's expectation that individuals and organizations performing regulated activities establish and maintain a positive safety culture commensurate with the safety and security significance of their activities and the nature and complexity of their organizations and functions. The policy statement was developed over a three-year period during which the agency engaged in extensive outreach with a broad range of stakeholders. By providing NRC's experiences and insights on safety culture, we believe there may be opportunities for the NRC to contribute as organizations (e.g., IRPA) embark on efforts to develop tools or standards that could favorably influence licensee efforts to develop a positive safety culture.

This paper describes the NRC staff's efforts to increase awareness of safety culture including a summary of the methods and processes used to engage a wide variety of stakeholders in developing the NRC safety culture policy statement. NRC staff held public workshops to develop the safety culture policy statement, and public meetings to solicit input on the draft policy statement. Members of NRC staff gave presentations at industry conferences, and provided information via publications and NRC's public website to make stakeholders aware of NRC's efforts in the area of safety culture and the development of the policy statement.

Now that the safety culture policy statement is entering the next phase of implementation, outreach, cooperation and interaction with, and among, external stakeholders will become even more important to its success. During this phase, the NRC staff will continue to engage stakeholders in a dialogue regarding the contents of the policy statement and the importance of a positive safety culture in their specific regulated activities. To increase awareness of safety culture, the NRC will continue to share information on safety culture with licensees and co-regulators via web, e-mails, publications, letters, inspections, licensee workshops, and conferences. NRC is also considering initiatives such as reviewing the NRC's current regulations from the perspective of assessing how potentially utilizing the safety culture traits could contribute to a positive safety culture, and potentially considering evaluating safety culture as a root cause in cases of significant poor performance.

TS3a.5
Improving the Radiation Protection Safety Culture in the UK

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Development of a good Radiological Protection (RP) Safety Culture in any organisation is essential to good radiological control and optimisation of dose. However, across the UK, as elsewhere, there is potential to improve the cultures in many areas of work. Since the mean dose uptake from medical exposure alone has now increased to 0.4mSv per year for every person in the UK (Health Protection Agency, January 2011) equivalent to about 24,000 person Sv, the risk of radiation induced cancers is significant. At a fatal cancer rate of about 5-6% per Sv, the potential impact of even small reductions in dose would be huge and could save many lives. Yet without active intervention, culture is very hard to change. It requires the embedding of change in values, attitude, awareness and behaviour throughout an organisation. In particular, culture needs to be led by the Senior management with strong input from the workforce.

SRP has set up a working group to examine the factors which influence RP Culture in the workplace and has proposed a series of measures we believe could assist a reduction in dose in many areas. These actions include proposed changes in UK training designed to improve knowledge and awareness at one level and ways to influence management and colleagues at the workplace.

We are seeking support from all Radiation Protection Practitioners to examine these proposals and where appropriate to use them to assist improvement in RP Safety Culture in their own workplace.

TS3a.6
Conditions and Means of Developing a Radiation Protection Practical Culture within the Population in Post-Accident Situations

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At the last IRPA conference in Buenos Aires (2008), the French nuclear safety authority (ASN) presented the approach implemented for the definition of a national doctrine related so the risk management during the post accidental period following a nuclear accident (so called "CODIRPA program"). The subject of the «Radiation Protection Practical Culture» was investigated in this framework, as identified as a key element of long-term rehabilitation of living conditions in territories contaminated by radioactivity. This culture aims to allow people living in the contaminated territories to:

• understand the risks associated with the radioactivity deposited in the environment and ways to limit their own exposure;

• apprehend, by the radiological measurement, the territories and food contamination levels ;

• be able to understand the relevance and evaluate the effectiveness of the implemented protective actions.

This reflection has helped to define criteria for the development of radiation protection practical culture in normal time and post-accident situation and to identify the means for the diffusion of radiological protection practical culture, which will be presented.

TS3b.1
IAEA's Education and Training Programme for Strengthening Radiation Protection in Member States

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IAEA's education & training programme for strengthening radiation protection in Member States is guided by the resolutions of its General Conference. The IAEA 'Strategic Approach to Education and Training in Radiation, Transport and Waste Safety', as endorsed by the General Conference, provides the overarching framework. The paper describes the aims and objectives of the strategy and its supporting activities such as the Post Graduate Educational Course on Radiation Protection and the Safety of Radiation Sources, training courses for Radiation Protection Officers, Train-the-Trainers workshops, Practice-specific and topical specific training courses. The paper also describes the key elements to guide Member States in developing a national strategy to ensure education and training needs in radiation protection are appropriately identified and optimally met by utilizing national, regional and international resources. The role of the IAEA Steering Committee on Education and Training is described, and importance of collaborating with regional training centres and other organizations is emphasized.

TS3b.2
Accreditation of Health Physics Academic Programs in the U.S.

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In 2003, the Health Physics Society entered into an agreement with the Applied Science Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc. (ABET) to accredit health physics and similarly named applied science programs in the U.S. Programs seeking accreditation must meet all requirements set forth in the ABET Policy and Procedures Manual, as well as those outlined in the following eight criteria: students, program educational objectives, student outcomes, continuous improvement, curriculum, faculty, facilities, and institutional support. Programs must also satisfy applicable program criteria developed by members of an accreditation subcommittee of the Health Physics Society. These program criteria were established to ensure graduates demonstrate competency in a number of curricular areas related to health physics, including radiation physics, radiation biology, radiation detection and measurements with a laboratory experience, internal and external radiation dosimetry, principles of radiation safety, and contemporary issues in health physics. Eight academic health physics programs at seven institutions have been accredited by ASAC/ABET since inception of this initiative. Faculty and other constituents at these institutions indicate health physics accreditation has positively impacted their programs and has led to opportunities to secure valuable resources and facilities for their program

TS3b.3
The Development And Implementation Of A System To Accredit Ionising Radiation Instrumentation Specialists.

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The United Kingdom's National Physical Laboratory's Ionising Radiation Metrology Forum has developed a new certificate for an Ionising Radiation Instrumentation Specialist (IRIS) under the Radiation Protection Advisers 2000 aegis. This was not intended to supplant the recognised role of the qualified person. It was designed for those involved in ionising radiation instrumentation who wished to demonstrate an advanced level of expertise and competence. An IRIS is expected to demonstrate significant expertise in monitoring methods, instrument limitations, calibration requirements and facilities, setting up of instruments and the provision of advice to the employer and Radiation Protection Adviser (RPA). Following the model of the RPA accreditation process, assessment is via a portfolio covering both theory and practice.

Evidence is required of a basic underpinning knowledge across a wide range of topics such as:

• Basic atomic and nuclear physics

• Interaction of radiation with matter

• Practical radiation fields

• International guidance requirements

• Signal processing and display

• Power supplies

• Understanding the effect the environment can have for both for calibration and routine operation

In addition demonstration of a more detailed understanding is required in the following areas:

• Statutory requirements relating to the selection use, maintenance or testing of Radiation instrumentation

• UK guidance pertaining to instrument calibration

• Measurement quantities and units

• Principles of operation of detector systems

• Types of facility and their essential attributes including traceability to National standards

• Typical instrument problems

• Detection and measurement and best monitoring methods

Finally evidence must be provided that demonstrates the use of a detailed understanding of the following areas and the practical implementation of this understanding in day to day workplace situations.

• Setting up instruments

- Energy thresholds

- HT

- Dead time

- Overload current

- Averaging times

- Alarms

• Advising the employer and RPA

- Advise on instrument selection

- Clear account of why an instrument has failed

- Advise on the implications of failure if the instrument was used

- Explanation of varying indications from different types of instrumentation

TS3b.4*
Enetrap II: WP5
Develop And Apply Mechanisms For The Evaluation Of Training Providers

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To maintain a high level of competency in Europe regarding radiation protection and to facilitate harmonisation and (mutual) recognition of Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs) quality assurance and quality control plays an important role. The ENETRAPII project (FP7-EURATOM) aims at developing European high-quality 'reference standards' and good practices for education and training in radiation protection.

In work package 5 (WP5) the quality issue is addressed. Therefore WP5 deals with the development and application of mechanisms for the evaluation of training material, training events and training providers by means of a transparent and objective methodology. The results can be used by regulatory authorities to benchmark their national radiation protection training programme and will be communicated to other networks, e.g. EUTERP.

The presentation will be about the comparison of training providers, through the use of quality criteria.

The presentation will address the development of a quality assurance protocol that is a key item in WP5 of ENETRAP2. For the comparison of training providers an inventory is carried out to find the key elements of quality assurance. This inventory has taken into account requirements by regulations and international standards, e.g. ISO 17024, EQAVET and topics addressed by stakeholders. The list of quality criteria,that is going to be used for the comparison of training providers is presented together with a first comparison of different training providers throughout Europe.

TS3b.5
Delivering a Radiation Protection Dividend: Systemic Capacity-Building for the Radiation Safety Profession in Africa

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Many African countries planning to enter the nuclear energy "family" have little or no experience of meeting associated radiation safety demands, whether operational or regulatory. Uses of radiation in medicine in the continent, whether for diagnostic or clinical purposes, are rapidly growing while the costs of equipment, and hence of access to services, are falling fast. In consequence, many patients and healthcare workers are facing a wide array of unfamiliar challenges, both operational and ethical, without any formal regulatory or professional framework for managing them safely. This, combined with heighted awareness of safety issues post Fukushima, means the already intense pressure on radiation safety professionals in such domains as NORM industries and security threatens to reach breaking point. To remedy this situation, the need for a systematic competency-based capacity-building programme for RP professional in Africa was captured in a Resolution of the Third Afrirpa Regional Conference (Nairobi, September 2010) approved both by African stakeholders, but also by IRPA, the International Atomic Energy Agency, the World Health Organization and the International Organization for Medical Physics. The goal is to meet recruitment and HR needs in the rapidly emerging radiation safety sector in a reliable, timely and sustainable manner, while also addressing stakeholder concerns in respect of promoting and meeting necessary professional and ethical standards.
The outcome is an RP "dividend" to society as a whole. The curriculum model is aligned to safety procedures and best practices such as Safety Integrity Level and Layer of Protection analysis; it emphasises proactive risk communication both with direct and indirect stakeholders; and it outlines disciplinary options and procedures for managers and responsible persons for dealing with unsafe or dangerous behaviour at work. In line with the resolution, an expert working group was set up to lead the programme. This paper reports on progress to date. It presents a five-tier development pathway starting from a generic foundation course, suitable for all RP professionals, accompanied by specialist courses by domain, activity or industry. Delivery options are discussed, including in-post, classroom and elearning. Part of the content has already been developed and delivered as MiLoRAD, based on extensive experience training radiation safety personnel in the United States.

TS3b.6
Radiation And Radiological Protection. Guidelines For Primary And Secondary Schools

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One of the tasks assigned to the Nuclear Safety Council (CSN) is to inform to the citizens in relation with topics in the area of its responsibility.

One way to report to the public about the uses of ionizing radiation, the risks and the measures of protection to apply is through the education system. The CSN has established an agreement with the Education and Science Ministry (MEC), competent organ in Spain in education, related to the knowledge transfer concerning the field of ionizing radiation. In the framework of that agreement, updating a document published by the Directorate General XI (environment, Nuclear safety and radiation protection) of the European Commission, entitled "radiation and radiation protection: course for primary and secondary schools", was carried out.

Due to the time elapsed since the edition of the above-mentioned document and, to update it to the current educational system in Spain, it was necessary to develop two new documents. A teaching guide for primary schools was issued (aimed at students between 6 and 12 years old) and a teaching guide for secondary schools (high school and vocational training), for students aged 12 to 18 years old.

The topic of ionizing radiation is not included in the curricular syllabus set out in the Spanish education system, so it can be included as a transverse topic to be taught by the teacher if convenient in a voluntary basis . The aim of these guides is to provide the teacher with tools to deal with this task.

A general objective for the teaching guide for primary schools is to stimulate student's interest in the physical phenomena that reveal the existence of radiation in daily life, as well as to introduce the different types of radiation (ionizing and non ionizing) from both natural and man-made sources. These issues are explained in a very intuitive and general way, due to the fact that pupils of this age have not yet studied the internal composition of matter.

The teaching guide for secondary schools is more ambitious, its general objectives are wider, and try to explain that the radiation is everywhere, what its origin is, the types of radiations, their characteristics, devices for detecting and measuring them, biological effects of radiation on the human body, measures for radiation protection, and its implementation in medicine, industry, research, security, etc.

TS3c.1
The Euratom Basic Safety Standards Directive

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The paper describes the basis for the Euratom Basic Safety Standards Directive and outlines progress to date with its development. The current draft of the Directive is compared and contrasted with the International Basic Safety Standards requirements level document approved by the IAEA Board of Governors on 12th September 20111, and a number of issues discussed. The procedure for finalising the Euratom BSS Directive is described and the progress with establishing the key points for the United Kingdom to take account of during negotiations is outlined.

TS3c.2
Ongoing efforts of HERCA on the Harmonisation of the Radiological Monitoring Systems for Outside Workers

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The association HERCA brings together the Heads of 46 European Radiological protection Competent Authorities from 28 countries. It consists of a Board of Heads and topical working groups composed of experts from the different Radiation Protection Authorities.

Its objectives are to build and maintain a network of chief radiation safety regulators in Europe, which promotes exchange of experience, expresses its consensus opinion on significant regulatory issues, and develops a common approach to radiological protection issues within the States of HERCA members. The association involves, as appropriate, the European Commission and other relevant stakeholders in its activities.

HERCA Working Group 1 (WG1) was created in 2007 to investigate on the practical implementation of the Directive 90/641/Euratom and on how a better harmonisation of the radioprotection systems for outside workers could be achieved. In 2008, a survey was lead about the practical transposition of the Directive within the Member States. It allowed to derive the commonalities and variations of the radiation monitoring systems for outside workers and to compare the content registered in the radiation passbooks to the required information in the Directive. A model of radiological passbook (see www.herca.org) was proposed by WG1, including the harmonisation of terminology and of the requirements on data content, with a distinction between mandatory fields and optional fields. The Radiation Passbook can be a paper based system but countries could also opt to use an electronic (possibly web-based) system instead of parts of the paper based system. The radiation passbook is one of the first major achievements of HERCA, in its aim of harmonisation at the European level.

After approval of the proposal by the Board of Directors, it was sent to the EC for its inclusion in the BSS recast. A proposal of inclusion in a generic way has been formulated. Additionally, HERCA invited all European national competent authorities and stakeholders to express their comments. These will be integrated in the passbook model. Furthermore, a guidance document on how to implement and use the passbook will be developed.

In 2010, WG1 has been given the new mandate to carry out a feasibility study for the transition to an electronic information exchange between countries for the radiological protection of workers. This work should be carried out in close collaboration with the EC and with ESOREX.

TS3c.3
Why an Effective National Regulatory Infrastructure is Essential for a Country's Radiation Protection System.

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The importance of strict regulatory control over all facilities and activities that may cause people to be exposed to radiation risks is essential to ensuring that people and the environment are protected from harmful effects of ionizing radiation. Regulatory control can only be guaranteed through the establishment of a governmental, legal and regulatory framework for safety. The IAEA's safety standards establish fundamental safety principles, requirements and measures to ensure the protection of people and the environment from harmful effects of ionizing radiation. The IAEA General Safety Requirements, GSR Part 1 "Governmental, Legal and Regulatory Framework for Safety" lays out the essential aspects of the governmental and legal framework for establishing a regulatory body to ensure the effective regulatory control of facilities and activities that may cause people to be exposed to radiation risks. Based on this standard, the paper elaborates on the importance of establishing a proper national regulatory infrastructure for the control of radiation sources in order to ensure a satisfactory national radiation protection and safety system in countries having no nuclear facilities and activities. The paper presents how the quality and robustness of a national regulatory framework impacts other aspects of radiation safety and the safety culture in the entire country, reaching down to operational details. It clarifies how fundamental elements such as legislation, regulations, regulatory guidance documents, and the independence, adequate funding, staffing and training of a national regulatory authority impact radiation protection and safety. The essential role of the regulatory authority in national coordination and international cooperation is also highlighted. A clear link is made as to how critical regulatory activities such as maintaining a national register of radiation sources and practices, the issuance of authorizations, and the performance of inspections and enforcement activities, when carried out adequately, contribute to ensuring the protection of people and the environment. An overview of IAEA assistance in strengthening regulatory infrastructures in Member States is provided.

TS3c.4
Radiation Protection Challenges in Kenya

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Kenya became a member state of the United Nation's nuclear watchdog, the International Atomic Energy Agency, in November 1965. Radiation Protection Law was enacted in 1982 largely to control the use of radiation sources in the medical field. The regulatory body, Radiation Protection Board, was established in 1986 to advise government on radiation protection and radioactive waste management among other functions. However, as use of radiation extended over time to agriculture, industry, research and other socio-economic sectors, the law has become increasingly inadequate.

Challenges have also emerged from advancing technology, improving safety standards and threats to radiological and nuclear security in terms of nuclear terrorism, illicit trafficking in radioactive and nuclear materials, among other malevolent acts. Further, environmental activities which technologically enhance Naturally Occurring Radioactive Materials (NORMS) are on the increase.

New challenges have also emerged - public radiation exposure from mobile telephone Base Transceiver Stations (BTSs); radioactive waste management, where generators of radioactive waste are stockpoiling the wastes without the necessary safety and security controls; extended use of radioactive materials and irradiating devices in various research programmes across all sectors of the economy and a Nuclear Power programme (NPP) initiated by the Government for electrical power generation in the next 10-15 years.

The regulatory body has therefore embarked on a comprehensive review of the legal framework for regulatory control of radiation sources, nuclear safety and radioactive waste management in order to address present and future challenges and to adhere to the internationally recognized best practices and principles. The legal review will also address institutional infrastructure and the respective mandates as well as development of the commensurate human and technical resource capacity.

The international community, networks of technical and scientific support organizations, professional societies and associations, and the academia, are expected to make significant contributions towards addressing the challenges in radiation protection, safety and security, currently facing emergent nuclear states such as Kenya.

TS3c.5
Considerations of Transfrontier Shipment of NORM Waste from the North Sea Oil and Gas Industries

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A liaison group was established in 2008 comprising competent authorities from Norway, the UK, Denmark and Germany, with responsibilities for regulating the accumulation and disposal of NORM wastes arising from the extraction of oil and gas in the North Sea area. This group has met on a regular basis to discuss issues of joint interest, including the increasing need to clarify the provisions for transboundary movement of NORM wastes from this industry. There are a number of regulatory issues associated with transfrontier movement of NORM wastes, which the liaison group is seeking to resolve. This paper provides an overview of the regulatory issues involved and an update on the liaison group's work in this area.

It has been recognized that many platforms in the North Sea area are reaching the end of their productive life and, although the precise timing is uncertain and will depend upon economic and other conditions, the volume of decommissioning wastes is likely to increase over the coming years. International and national policies related to the movement, treatment and final disposal of such wastes may influence the pattern of the decommissioning market and clarity on these points is essential.

The main instrument for placing controls on the transfrontier shipment of radioactive waste within the European Union is Directive 2006/117/Euratom. However, the scope of this directive relates to natural radionuclides only where they are produced from processing of natural sources for their `*radioactive, fissile or fertile properties*', and therefore does not apply to NORM waste from the oil and gas industry. The mechanism used for the transfrontier shipment of non-radioactive wastes in the EU is Regulation (EC) No. 1013/2006 but it is not clear if this regulation applies to NORM waste. In any case the provisions of this regulation do not relate to the radioactive characteristics of NORM waste. There is therefore a need to supplement these controls by more specific provisions.

There is a need to develop a consent process for the movement of NORM wastes from the decommissioning of oil and gas platforms in the North Sea area. This will involve further clarification of appropriate mechanisms and of national regulatory policies regarding exemption and disposal of NORM wastes.

TS3c.6
Regulatory Stantards to Control Radiological and Nuclear Fuel Cycle Facilities

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The nuclear activity regulation and control covers four main topics: radiation protection, nuclear safety, safeguards and physical protection. In Argentina, the National Nuclear Activity Law assigns these functions to the Nuclear Regulatory Authority (NRA).

Nuclear regulation issues in Argentina were developed since the beginnings of activities devoted to research, development and production belonging to the National Commission of Atomic Energy (CNEA) in the frame of international regulations.

Sixteen years ago nuclear activity regulation and control were separated from the activities of research, development and production, through the creation of the Regulatory Body, now the Nuclear Regulatory Authority (ARN).

In accordance with the provisions of the National Nuclear Law, the ARN has to "establish regulations relating to radiation and nuclear safety, physical protection and usage of nuclear materials, licensing and control of nuclear facilities, international safeguards and transport of nuclear materials and nuclear safety and physical protection aspects". Is this framework, ARN has Regulatory Standards to control the facilities and personnel licensing.

The purpose of this paper is to present the regulatory standards evolution regarding the control and monitoring of activity in radioactive and nuclear facilities in the areas of radiation protection and nuclear safety, with particular reference to nuclear fuel cycle facilities, particle accelerators, radioactive sources production plants, irradiation facilities, radioactive waste management facilities and mining.

Finally we analyze the current situation in the areas mentioned and discuss future prospects in this field.

TS3d.1
NEA Stakeholder Involvement in the Development of ICRP Recommendations

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Beginning with its creation in 1957, what became the Committee on Radiation Protection and Public Health (CRPPH) of the OECD Nuclear Energy Agency has been interested in the development of recommendations by the ICRP. A significant manifestation of this interest began in 1999 when the ICRP opened discussions on what was to become ICRP Publication 103. To most effectively participate in discussions with the ICRP, the CRPPH organised a series of international meetings to discuss the ICRP's evolving approach to radiological protection policy. To formulate more concrete input, the CRPPH created in 2002 the Expert Group on the Implications of ICRP Recommendations (EGIR). The EGIR discussed each draft recommendation provided by the ICRP, providing detailed comments and proposed changes supported by clear rationale. The CRPPH also employed the EGIR to provide a similarly detailed level of NEA input to the development of the new International Basic Safety Standards. Recognising the value of this work, in May 2009 the CRPPH agreed that the EGIR had become a very useful process for the Committee. As such, the EGIR became a generic tool for the Committee to assess the implications of any draft text that the CRPPH deems should be reviewed. In recognition of this change, the group's name was changed to the Expert Group on the Implications of Recommendations (EGIR).

This paper will discuss the difficulties and benefits of establishing such a group within the confines of an international organisation, and will describe some of the principle accomplishments that the NEA has been able to achieve through this active stakeholder involvement.

TS3d.2
Dose Constraints and other Policy and Practical Issues in Occupational Radiation Protection

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The Expert Group on Occupational Exposure (EGOE) acts on behalf of the Committee on Radiation Protection and Public Health (CRPPH) of the OECD Nuclear Energy Agency. One of its mandates is to analyse the implementing of radiation protection principles into occupational radiation protec-tion frameworks of workers. In particular, it focuses on the concept of dose constraints and some other policy and practical issues in occupational radiation protection in the nuclear sector.

ICRP Publication 103 regards the concept of dose constraints as a key factor in optimisation. In occupational exposure, dose constraints are demanded as individual, source related upper bounds below which exposures should be kept as low as reasonably achievable. This concept has also been adopted in the revised Basic Safety Standards of the IAEA and the European BSS.

EGOE analysed the perception and practical implementation of the dose constraint concept in several member states of the OECD. It also performed a survey on the use of dose constraints as a tool for optimisation of occupational radiation protection in the nuclear and parts of the non-nuclear sector. The report which was approved for publication by the CRPPH revealed that dose constraints are widely used, albeit often in a far more complex way then proposed by ICRP. Many, mainly European countries, follow the concept very closely. In the USA, constraints are used if appropriate and embedded in or subordinated to a total risk management. Japan, however, prefer to seek target doses below their national dose limits.

The dose constraint concept raises many open questions during the practical implementation process and requires guidance and close communication between regulators, licensees, and radiation protection managers.

Under the aspect of globalisation and worldwide workforce transfer, EGOE identified several policy and practical issues that pose a challenge to future occupational radiation protection:

• policy making: same international requirements lead often to different national implementa-tions and practices,

• knowledge transfer and education between generations and nations,

• itinerant workers: implications of different national dose limits, transnational dose tracking and balancing, international radiation passbook,

• Management of high radiation risk jobs and jobs with combined workplace risks (radiation, toxic, chemical, ...),

• International information exchange on good practices and lessons learnt.

Based on the mandate and approval of the CRPPH, the expert group will work on these topics dur-ing the next two years to prepare another report.

TS3d.3
Findings from a Workshop on the Practical Implementation of the new ICRP Recommendations: a Contribution of the NERIS Platform

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In 2010, the NERIS Platform was established to combine organisations from the operational, the research and the stakeholder community interested in nuclear and radiological emergency response and recovery. By the end of 2011, 37 organisations from 20 countries have already joined the Platform which comprises national and local authorities, technical support organisations, professional organisations, research institutes, universities and non-governmental organisations.

One of the NERIS Platform working groups is focused on the practical implementation of the new ICRP recommendations: how they can be applied in the national context; and how they can be integrated into existing Decision Support Systems for emergency and recovery preparedness and management. This challenge is also tackled with a European research project, NERIS-TP. To support this activity, the ICRP working group of the NERIS Platform has organised a working group meeting in 2010 and an international workshop in Bratislava in February 2012. This Workshop will provide a forum for discussion and sharing of experiences on the implementation of the ICRP Recommendations for the protection of people in emergency exposure situations and living in long-term contaminated areas after a nuclear accident or a radiation emergency. International, European and national perspectives will be presented. Furthermore, the workshop will provide an opportunity to explore the methodological and computational aspects related to the practical introduction of these recommendations in the existing decision support tools used in European Countries.

This paper presents the main findings of the workshop with particular emphasis on the methodological aspects and computational tools that might be implemented into the decision support tools ARGOS and RODOS in the frame of the NERIS-TP project.

TS3d.4*
The Influence of ICRP 103 on Current Actions of the U.S. Environmental Protection Agency

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The U.S. Environmental Protection Agency (EPA) is considering adopting certain recommendations from ICRP Publication 103 into new regulations and guidance documents. When some of the older EPA regulations were issued, the dose assessment tools of the day calculated doses to adult organs and to the whole body, with only minimal consideration given to gender differences. Newer dosimetry models allow us to account for age and gender differences in calculating organ doses from both external sources and from intakes of radionuclides. While the reference person as defined in ICRP 103 is adequate for occupational protection purposes, EPA is keenly interested in the proposed age-specific reference individuals under consideration by the ICRP. Updating regulations and guidance to be consistent with these age-specific reference individuals will provide a more defensible standard of protection for all members of society. In addition, adopting the ICRP 103 approach for setting reference levels and dose constraints will bring more transparency and coherence to the optimization process and better demonstrate that ALARA goals are being met. However, it will be important to ensure that the selected reference levels and dose constraints appropriately take into account age and gender differences.

TS3d.5
What Resources Were Needed to Implement ICRP 60, and What Resources May Be Needed to Implement ICRP 103?

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National and international organisations are currently considering the implementation of the 2007 ICRP Recommendations, ICRP 103. Information on the resources required to implement ICRP Recommendations is of interest, particularly to the United States where pertinent federal legislation had been revised just before the release of ICRP 60, and ICRP 60 was never implemented formally.

A survey of resources spent on the implementation of ICRP 60 and anticipated to be needed to implement ICRP 103, on behalf of the Committee on Radiation Protection and Public Health of the OECD Nuclear Energy Agency, yielded information from regulatory agencies in 11 member countries and some operators/licensees in four countries.

Little quantitative, monetary information is available. The qualitative information obtained indicates that in most countries, the cost of implementing ICRP 60 were regarded as relatively modest (or at least tolerable), both by regulators and after some initial concerns by operators. The cost of implementing ICRP 103 is expected to be smaller where ICRP 60 is already implemented, since the nominal risk and the dose limits remain essentially unchanged.

Important factors contributing to this relatively sympathetic perception of the ICRP 60 implementation costs appear to be:

· Considerable lead times (up to 10 years or more from initial discussions to legally binding obligations), permitting ample time to explain the recommendations and allowing licensees an orderly and timely re-organisation of their operations;

· Considerable efforts on information, discussions, training, and consultation with licensees and professionals before any binding decisions were taken (however, the efforts involving the general public were often less comprehensive than probably expected today);

· At least some stakeholders felt, after the comprehensive consultations, that the recommendations ‘made sense’;

· Legislation and regulations were often updated in connection with scheduled revisions for other reasons rather than ‘ad hoc’, thus reducing the administrative costs;

· In some cases, costs were balanced in part by savings due to improved working conditions in areas with high radiation levels;

· Constructive discussions (e.g., on realistic modelling of shielding requirements) between regulators and operators evaded some costs that had initially worried operators.

TS4a.1
Stakeholder Engagement: The UK Experience

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The UK has a strong tradition of Stakeholder Engagement in decision making in Radiological Protection and in wider societal and environmental matters. This allowed the UK's Society for Radiological Protection (SRP) to take a prominent role, along with the French and Spanish Societies, in developing the Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement adopted by IRPA at IRPA 12. These are currently being advocated for adoption by Associate Societies to aid their members in promoting the participation of all relevant parties in decision making in order to improve the sustainability of any final decisions. Some 4 years on, IRPA 13 will be an important focal point for Societies to feed back experience and progress on integrating the principles into everyday RP practice. This paper describes the UK experience.

It will review the actions taken to promote the use of the Guiding Principles set against the context of the historical development of Stakeholder Engagement in the UK. Importantly it will look at the professional and societal drivers that encourage processes with Stakeholder Engagement at their heart. Equally it will look at the threats to the spread of this inclusive process, particularly in terms of smaller organisations and intra-organisational issues. The paper will also look at commonality with elements in the developing concept of RP Culture and the work of the long established ALARA Networks.

Use will be made of practical experience gleaned from UK stakeholders, analysis of relevant research and surveys. A range of case studies, some presented as papers in their own right at the Congress, will be summarised to examine the current state of play in the UK. Particular attention will be given to how Stakeholder Engagement is an integral element of the emergency preparedness framework that is common for dealing with all UK emergencies; from naturally occurring flooding, through accidents such as nuclear ones, to deliberate incidents such as terrorist attacks. Experience from the Polonium Poisoning incident in London in 2006 will be used to highlight some aspects of Stakeholder Engagement in an emergency response.

TS4a.3
Early Stakeholder Involvement in Environmental Rulemaking for Uranium

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This paper will illustrate how EPA's Radiation Protection Division (RPD) draws upon the Agency's strong legacy in stakeholder outreach as well as incorporating new "social media" tools to enhance its efforts to involve the public in decision-making regarding environmental rules (regulations) pertaining to the uranium fuel cycle.

U.S. law prescribes a defined public participation process as part of the formal rulemaking process. To enhance the transparency of its rulemaking, RPD wanted to engage the stakeholders in a two-way dialogue that is less formal than the prescribed process. RPD therefore initiated an expanded, voluntary outreach campaign to engage the public in its internal review of existing regulations, before the start of an official rulemaking with its prescribed process. RPD also made plans to pursue an optional legal process, the *Advanced Notice of Public Rulemaking*, that allows the affected industries and members of the public to provide responses to a series of scope and technical questions before a new regulation is developed.

RPD's outreach strategy involved the integration of communication staff into the technical regulatory development teams. The teams collaborated in the development of a strategic communications plan to identify and reach stakeholders and affected parties. RPD employed an overarching tactic of taking its messages and presentations to stakeholders at their own venues, such as trade association meetings, environmental meetings and meetings of Native American tribes. Specific tactics were developed to target stakeholders in rural, economically distressed areas and to engage certain technical communities. RPD also made use of social media tools such as an on-line discussion forum (or "blog") to get a dialog going with industry and affected populations.

Outreach efforts are still ongoing. To date, the public has provided input on exposure pathways, risk assessment, and statistical approaches. This information will be evaluated and used in the development of any upcoming revisions to the existing regulations.

TS4a.4
Activities of the Moroccan Association of Radiation Protection as one African Experience in the Field of Associative Work.

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The establishment of Moroccan Radiation Protection Association since 2002 aims to:

· Encourage activities and information exchange in the field of radiation protection and related areas;

· Assist in informing both the public and the professionals concerned about the problems and requirements related to radiation protection for the protection of man and the environment;

· Promote professional training in radiation protection.

The use of nuclear technology in medicine, agriculture and industry is very advanced in Morocco. This technological progress has been accompanied by fairly detailed legislation and significant involvement on the part of Morocco in international conventions and agreements.

The AMR has an important role to make sensitive the various national operators in the field of the nuclear power as regards the protection of ionizing radiations and the installation of the culture of the radioprotection in the national educational system. the AMR organizes regularly annual manifestations and expects to organize more international meetings to facilitate more exchange of experiences and information in the field of the radioprotection.

In this communication, we present the main Activities of the AMR since its inception in 2002, and its role in raising awareness and educating the public, professionals and politicians.

TS4a.5
Fukushima Facts: Science, Journalism and the Way Events are Perceived.

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This paper attempts to show, first, a theoretical framework for the interpretation of journalism, and secondly, an analysis of the Argentine press communications regarding the Fukushima accident.

We understand that the objective facts related to the events which occurred at Fukushima Daiichi have a different logic from the logic that is employed by the media as a means of communication. In this regard, we believe that the public perception of what happened during the Japanese events differs from the objective interpretation of the facts. We wonder how much influence the press had in relation to this discoursive duality, as well as which precise press mechanisms took place to make this possible.

We analyzed the main Argentine daily newspapers, both the cover as well as the inside articles, from the point of view developed by the Bulgarian author Julia Kristeva, who elevates the journalistic writing as literature. At the same time, Hayden White provides an analysis of scientific texts (historiographical) in relation to the writing of fiction. We use these categories to understand the kind of writing that took place in the media when referring to the Fukushima issue. At the same time, we recover the notion of ideology that some French structuralists pose in their works.

The key point is to know how events like Fukushima may be addressed to improve communication with stakeholders and society in general.

TS4b.1
Public Participation in Decision Making on Nuclear Installations

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Public participation is nowadays an imperative for the formulation and implementation of good policies in the environmental and health domains, including radiological protection. It has also become a key determinant in decision making processes related to the development of science and technology. However, practice shows that when offered the opportunity to participate, the public frequently refrains from active participation.

Public involvement may take place at different levels, depending on the objectives and the desired influence on the final decision: from communicating information, consulting and dialogue, up to stakeholder engagement on complex issue or partnership.

The goal of this paper was to determine predictors for the intention to participate in decision making processes related to new nuclear installations. Among the potential predictors analysed are attitudes, subjective norms, descriptive norms, moral norms, past behaviour, environmental constraints and specific knowledge.

The study is based on empirical data from a large scale opinion survey in Belgium between 25/05/2011 and 24/06/2011. The method employed was CAPI ("Computer Assisted Personal Interview"). The population sample consisted of 1020 respondents and it is representative for Belgium adult population (18+) with respect to gender, age, region, province, habitat and social class.

Results show that moral norms are the strongest predictor for the intention to take part in public involvement activities, other influential predictors being attitudes, subjective norms, descriptive norms and time constraints. At the same time, the analysis reveals that financial benefits from participation do not seem to influence people's intention to participate in decision processes related to new nuclear installations.

This proves that long term programmes of stakeholder involvement are necessary and confirms the need for society engagement.

TS4b.2
Comparison Between Two Local-National Forums for Emergency and Recovery Strategies

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The Norwegian Radiation Protection Authority and the County Governors of Østfold and Nordland took an initiative to strengthen the counties› preparedness within late phase emergencies after a nuclear accident/incident. We wanted to test local-national forums where emergency and recovery strategies could be elaborated and cooperation mechanism explored, involving all actors that would be affected by radioactive contamination accidents/incidents. The idea was to arrange thematic sessions where authorities and stakeholders at all levels and sectors were involved. The participants in the seminars included national, regional and local authorities, farmers associations, food industries, health sectors and others.

After some introductory sessions with presentations on radioecology, the emergency preparedness organisation and the responsibilities of the different authorities, there was table-top exercises performed in smaller groups. The most important challenges identified in the discussions were the various roles and responsibilities for all involved actors and the need for sampling/analyses and recovery strategies.

The seminars brought up many questions and the need for follow-up activities to support the development of emergency plans in the local communities was evident. As the forum in Nordland has experience with countermeasures due to the Chernobyl accident while the forum in Østfold has not, there were evident differences between the forums.

The presentation will focus on important challenges for local preparedness and response in the future, how the national authorities can assist the municipalities in improving their capabilities and different needs depending on earlier experience.

TS4b.3
Maximizing Public Engagement in Radiological Monitoring as a Means of Furthering Public Understanding of Ionizing Radiation

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The recent accident at the Fukushima Daiichi nuclear power plant resulting from the massive earthquake and subsequent tsunami helped to highlight the persistence of public fears about ionizing radiation, as well as the need to develop and implement better communications strategies both prior to and in the wake of such accidents. The Community Environmental Monitoring Program (CEMP), established in 1981, meets nearly all of the principles for stakeholder engagement identified by the International Radiation Protection Association. The CEMP goes beyond the traditional model of public involvement often defined by town hall meetings, community advisory groups, and opportunities for written feedback, by providing a hands-on role for members of the public in the operation and communication of monitoring results collected from a network of 29 radiation monitoring stations installed at communities and ranches surrounding the Nevada National Security Site (NNSS), the area where the United States conducted the majority of its continental nuclear tests in the past. The CEMP stations are located across southern Nevada, southwestern Utah, and southeastern California, and help provide assurance to the public that no radioactive releases of health concern are occurring from the NNSS to off-site communities.

Members of the general public who are residents of towns where the stations are located, many of whom are teachers at local public schools and colleges, are tasked with collecting regular air samples and also are trained to become knowledgeable points of contact in their communities on issues concerning the NNSS and on ionizing radiation and nuclear technologies in general. Developing a significant role for members of the public in the monitoring process can provide for the creation of a network of informal communicators and knowledgeable lay-experts whose personal involvement can help defuse distrust of the monitoring results by the public at large, while helping to address some of the fear and misconceptions associated with ionizing radiation.

TS4b.4
Stakeholder-Managed Independent Review: A Local Committee's Initiative to Assess the Radiological Impact of the Soulaines LILW Disposal Facility

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In France, each nuclear or radioactive waste management facility has a "local information committee" (CLI) composed of local elected officials, representatives of civil society or environmental organizations and unions, and qualified experts. The 2006 national law on Transparency and Nuclear Safety strengthened the role of CLIs to include the ability to engage environmental analyses. Such an initiative was taken by the CLI associated with the Aube Disposal Centre (CSA) at Soulaines (located in the Champagne region east of Paris and operated by the national waste management agency Andra). In 2007 the elected Regional Council of Champagne-Ardennes financed a dose rate measurement campaign at the site perimeter. Independent laboratory CRIIRAD demonstrated the existence of "hotspots" outside the fence (although levels of radioactivity remained within regulatory limits). The Soulaines CLI responded to local concerns and increased its credibility by launching a bidding process for independent investigation of the facility's radiological impact. The authorities and the operator were kept informed and they cooperated, notably by opening the facility for sampling from the piezometers located within the facility perimeter. This unprecedented move may be attributed to the rigor of the CLI's study protocol. It also reflected Andra's willingness to help the CLI construct its own independent public information. The protocol approved by the CLI covered radionuclides not usually measured and included 3 samples at each place: one for the independent laboratory (ACRO), one for the operator (Andra) and one as a possible reference, should any discrepancy in results appear (this did not occur). The process was managed by the CLI with attention to optimising the cost of data delivery. The CLI made final assessment results public, thereby establishing a baseline and informing the population about the degree of "environmental pressure" exercised upon the ecosystem by the facility. While no unacceptable environmental impact was found, the assessment exercise was valuable in and of itself and it established the CLI as an active seeker of information on behalf of the local population. Mr. Philippe Dallemagne is Mayor of Soulaines-Dhuys, President of the Community of Communes of Soulaines and President of the CLI de Soulaines.

TS4b.5
Moral Emotions and Risky Technologies: Including Moral Emotions In Risk Communication And Political Decision Making

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Risky technologies such as nuclear energy often give rise to heated and emotional debates (Slovic 2000, 2010). However, emotions are generally excluded from communication and political decision making about risky technologies, since they are seen as irrational states (Sunstein 2005) that should at most be taken into account for instrumental reasons in order to create support for a position (Loewenstein et al. 2001). Such an approach is based on a deficient conception of emotions. Emotions can have cognitive aspects (Scherer 1984, Lazarus 1991, Solomon 1993, Nussbaum 2001) and they enable us to be practically rational (cf. Damasio 1994, Roberts 2003). Moral emotions such as sympathy and indignation are necessary in order to judge ethical aspects of technological risks, such as justice, fairness and autonomy (Roeser 2006). Risk policy should include the moral emotions of stakeholders.

Little research has been done yet on how to genuinely, non-instrumentally include moral emotions in risk communication and risk policy about nuclear power. Although moral emotions are not explicitly taken into account in current approaches for risk politics, they might already play an implicit role. It might be possible to adjust these approaches in order to give moral emotions an explicit role. Moral emotions can be legitimate, even necessary sources of insight concerning the moral acceptability of risks. In this paper, various policy making approaches concerning risky technologies will be compared and the extent to which they do or are able to incorporate moral emotions will be assessed. Main proposal of this paper is to take an emotional deliberation approach to technological risk caused by nuclear power, by taking emotions as starting point of discussion. This approach will contribute to morally better political decisions about risks and a better understanding between laypeople and experts.

TS4b.6
Tools and Techniques for Effective Message Mapping and Radiological Risk Communications with the Public During Radiological Emergencies

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The accident at the Three Mile Island Unit 2 nuclear power plant in March 1979 highlighted the need for effective communication with the public, media, and local and State emergency response officials. The accident led to an overhaul of emergency planning regulations and guidance in the United States. Based on existing U.S. Nuclear Regulatory Commission regulations and guidance, each nuclear power plant licensee and local response organization is responsible for developing their own media and communication plans for a radiological event. This has resulted in a wide range of facilities and equipment available to support public communications during an emergency and a lack of consistency throughout the industry and offsite officials in reporting events.

There has been great emphasis on □grisk□h communications and □ggood□h communications in professional journals, at meetings, workshops, and conventions. While these efforts to improve communications are long overdue, in so many cases there is a lacking of the necessary tools to make them effective. The USNRC has recently developed a guidance document (NUREG/CR-7033) to provide tools and techniques for USNRC licensees and others to use to develop effective radiological risk communications. This session will provide an overview of risk communications techniques including message mapping and templates and provide a □ghands on□h opportunity on to how to use the tools to develop and use pre□]scripted messages as part of a successful radiological risk communications strategy.

TS5a.1
The Urgent Need to Apply the ICRP Criteria to Non Ionizing Radiation

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Although the IARC has classified EMF as a possible carcinogen, the main reference organization (ICNIRP) does not promote the principle of justification neither the principle of optimization because he considers it not practicable, and bases its recommendations solely on the application of exposure limits, developing a policy that is closer to promotion than to the protection against radiation.. Nor does the ICNIRP recommends the use of dose constraints. This policy determines that the public is not adequately protected or even informed to protect themselves. There is no doubt that the widespread use of the ICRP philosophy would improve the protection of the public and employees of any risks derived from exposure to electromagnetic fields. The Principle of Precaution establishes that "when an activity represents a threat or damage for the human health or the environment, it is necessary to take measurements of precaution even when it could not have demonstrated the cause-effect relationship in a scientific and conclusive form". This declaration implies acting even in presence of uncertainty, deriving the responsibility and the safety to who creates the risk, to analyze the possible alternatives and to use participative methods to take decisions. This presents practically two dilemmas:

· How to perform a cost-benefit analysis when the relation cause-effect is not even established for the health of the exposed persons? (In case of ionizing radiations a factor α is in use, that represents the economic cost of the dose received by a person)

· Which criterion must to be used in case of ionizing radiation act synergically with non ionizing radiation? How to integrate the quantitative optimization criterion with a qualitative criterion of precaution? It will have to appear some temporary hypotheses in order to be able to perform the quantitative evaluations. One possible solution is to consider the results of the Interphone study that show an increase in the highest decile in the frequency of glioma (1.4) and meningioma (1.15). In the case of the low frequencies we can consider that the exposure can increase the risk of leukaemia in children. The use of such hypothesis of work to perform the cost - benefit studies allow us to compare different alternatives for the systems of communication to reduce the human exposure and establish criteria to limit the use of the mobile phones to groups of persons, especially the children and teenagers, to the as low as possible level. The precautionary approach must be used until more detailed information on health effects becomes available. KEYWORDS: precautionary approach; non ionizing radiation.

TS5a.2
Implantable Cardioverter Defibrillator and 50 Hz Magnetic Field Exposure in the Workplace

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Introduction: When a worker is implanted with an implanted defibrillator (ICD), occupational physician has to define his work aptitude. The implant may be perturbed by magnetic field, and the risk has to be evaluated. The objective of this paper is to illustrate the application of a methodology to do this risk assessment. EDF had to manage 3 cases of workers implanted with an ICD since 2005: the first worked in a hydroelectric plant, the second in a nuclear power plant and the third in a high voltage substation. In these circumstances the workers are potentially exposed to higher magnetic fields than the general public. These three examples illustrate our approach to define the work fitness.

Materials and Methods: We performed an assessment of the ICD functioning at various workplaces. The protocol consists in measuring magnetic field in the presence of implanted worker. A pluridisciplinary team should perform the study:

- the occupational physician
- the employee
- the cardiologist with cardiac reanimation material
- the ICD constructor to question the ICD with the telemetry material
- the engineer to perform magnetic field measurements

All areas where the worker could work or even cross have to be visited and the ICD has to be questioned in all situations. To limit possible interferences for the worker, the measurements should begin with the areas of lowest magnetic field, which correspond to daily life exposure.

Results: In the hydroelectric power plant, the occupational physician decided to perform directly measurements with the patient. In the different areas, the magnetic field has been measured from 0 to 650µT at the ICD location. No dysfunction of the ICD has been observed with the bipolar mode. In the nuclear power plant, the occupational physician decided to perform measurement without the patient in a first step. The magnetic field measured was lower than 200µT. In the areas where the magnetic field is lower than 10µT, no additional assessment is needed. Measurements of magnetic field with the patient and the telemetry material have to be performed in the other areas. In the high voltage substation, the occupational physician decided to perform directly measurements with the patient. In the different areas, the magnetic field has been measured from 0 to 80µT at the ICD location. No dysfunction of the ICD has been seen.

Conclusion: Theses three examples of workplace assessment show different way to conduct a particular risk assessment for implanted cardiac devices. They demonstrate the interest of measuring magnetic field and questioning the implant in the same time in order to evaluate risks of 50Hz magnetic field interference and to help the occupational physician to define the work aptitude.

TS5a.3
Paradigm Change for Optical Radiation – Temporary Blinding from Optical Radiation as Part of the Risk Assessment

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Up to now only deterministic risks are treated in a risk assessment concerning optical radiation. Although the European Directive on artificial optical radiation 2006/25/EC states that indirect effects from e. g. temporary blinding shall be included in the risk assessment no quantitative data are thus far available.

As a result of a research project quantitative relationships have been determined in order to be used for laser radiation and high-brightness light emitting diodes of various colors, respectively. A logarithmic dependence of the duration of impairment of several visual functions, like visual acuity, especially the capability to read, as a function of the applied optical energy has been experimentally found and will be explained. In addition threshold values are derived from experimental results achieved in a study with about 200 volunteers and almost 2000 irradiations. Last not least a proposal to classify artificial sources of visible optical radiation based on the capability to impair vision temporarily is presented.

TS5a.4
Laser and LED Retina Hazard Assessment with an eye Simulator

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Optical radiation entering the eye is focused on the retina and produces a focal spot of relatively high energy/power density, depending naturally on the amount of energy or power entering the eye. The size of this focal spot is the critical factor in determining the hazard classification of an optical source.

For laser beams and some other light sources this focal spot is extremely small and hence - the high optical hazard of point sources like laser radiation.

Hazard classification of laser products is commonly conducted by computational methods, assuming the laser source specifications as provided by the device manufacturer are correct.

At the 2009 International Laser Safety Conference we presented a new method of measuring the spot size on the retina by using an eye simulator consisting of a gradual index lens and a beam profiler and its application to the analysis of a laser beam defined by the device manufacturer as a "totally diffused beam".

In this paper we present other applications of the method and measurement results of different point and extended sources, such as a LED array, a laser beam through a telescope and a bulb projector. We then compare this measurement method to computational methods according to IEC safety standards of light and laser sources (IEC 60825 2nd ed. 2007-03, Safety of laser products – Part 1: Equipment classification and requirements and IEC 62471 1st ed. 2007, Photobiological safety of lamps and lamp systems).

We also include a new calculation method for multiple spots on the retina.

TS5a.5

Measurements of the Magnitude and Direction of the Electric Field of a Mobile Phone in the Near Field

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The interaction of mobile phone radiation with humans has been the subject of considerable research for many years. The efforts have been directed primarily to investigating the magnitude of the electric field of the microwave radiation. However the direction of the electric field has also been associated with the effectiveness of its interaction with a living cell. In this work measurements are presented of both the magnitude and the direction of the electric field vector of a commonly used mobile phone in the near field. In particular measurements have been taken at distances from 1 cm to 12 cm from the surface of the mobile phone, next to the patch antenna, both in the forward direction (towards the skin) and backwards (towards the hand). The EP600 3-dimensional electric field probe has been used for the measurements. It is concluded that at distances practically in contact with the mobile phone, the magnitude of the electric field in the forward direction (towards the skin) is up to four times weaker than it is backwards (towards the hand). It is also concluded that the direction of the electric field of the microwave radiation deviates substantially from the far field geometry (being perpendicular to the propagation direction, parallel to the skin) and turns towards the skin, direction which has been associated with an enhanced interaction with the cell.

TS6a.1
Updating the UNSCEAR Methodology for Estimating Human Exposures due to Radioactive Discharges

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As part of its continuing review and assessment of the sources and effects of ionizing radiation, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) developed a methodology for assessing the radiological impact of routine releases from nuclear installations. This approach has been used to undertake assessments of the global radiological impact of such installations every few years, using the latest available data on discharges of radioactive material and dose conversion factors derived for a range of standard installations. At its fifty-sixth session in 2009, the Scientific Committee approved a programme of work to update this methodology. This paper provides a report on progress and an overview of key features of this project.

Using the current UNSCEAR methodology, collective effective dose commitments had been assessed for local, regional and global exposures with an emphasis on determining an overall estimate of the radiological impact of the nuclear fuel cycle, primarily on the basis of sector-specific factors that were normalized to the level of power production. The ongoing review has considered whether these quantities adequately convey the radiological impact of nuclear fuel cycle activities, and whether they are at a level of detail consistent with the Committee's mandate and strategic objectives. The implications of developments in computing capabilities and dose assessment methodologies were also reviewed in order to help select a level of complexity that is commensurate with the objectives of the UNSCEAR assessments, the availability of discharge data and the way in which the results are foreseen to be used.

To date, this work has involved a detailed review of the basis for the methodology applied in previous UNSCEAR assessments of the radiological impact of discharges from nuclear installations and from non-nuclear sources of electrical energy. The review has also considered other published methodologies used by national and international bodies for assessing the radiological impact of such discharges. On the basis of this review and lessons identified from past assessments, a proposed updated methodology for assessing the radiological impact of discharges from installations associated with electrical energy production is due to be presented to the Scientific Committee in May 2012. The methodology is to be consistent with the Committee's strategic objectives, and provide the basis for more accurate assessments, and for providing information on collective and individual dose distributions and their uncertainties.

TS6a.2
Radiation Protection Aspects of Water Chemistry and Source-Term Management with a view of an ISOE Expert Group

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Information System on Occupational Exposure (ISOE) provides a forum for radiation protection profession-als from nuclear electricity utilities and national regulatory authorities world-wide to share dose management information and operational experience to improve the optimisation of worker radiological protection at nuclear power plants. The ISOE programme, with its participating utilities and regulatory authorities, is a key organisation in developing safe, sustainable and socially acceptable strategies for emerging issues in the field of occupational radiation protection.

Water chemistry approaches in different design of NPPs vary in results and consequences in terms of radia-tion protection performance. It was suggested that radiation protection aspects of primary system water chemistry and source-term management could be discussed in detail by the participation of ISOE utilities with an establishment of an expert group. The Expert Group on Water Chemistry and Source-Term Man-agement (EGWC) has been mandated to address the experience of various ISOE utilities with various water chemistry regimes to explore if experience exchange could help to improve radiation protection perform-ances. It is also necessary to note that water chemistry should not be viewed only from the context of radia-tion protection issues, but also from the context of operational and safety issues, and it was proposed to be grouped into a few of the most commonly used water chemistry approaches (e.g. zinc injection, pH control, iron injection, hydrogen water chemistry, etc.) to focus the exchange of experience discussions.

The expert group is planning to focus on:

• Description of strategies and techniques aiming to limit the level of activity in the primary coolant (pre-vention of contamination);

• Description of strategies and techniques for the decrease of activity in the primary coolant or circuit de-contamination (remediation of contamination);

• Performance indicators to assess results from the above strategies and techniques; measurement tech-niques and performance assessment (monitoring), and

• Management of iodine, xenon and alpha risks.

The outcome of the work will be a new ISOE publication which is planned to include information and prac-tical experience available in the nuclear industry on addressing operational aspects of primary water chemis-try and source-term management of nuclear reactors with special emphasis on effects on the management of occupational exposures, identify factors and aspects which play key roles in achieving good practices in water chemistry management and analysis on impact on worker doses and operational costs.

TS6a.3
An Update on the UK Generic Design Process for Potential Nuclear New Build Reactors - the AREVA EPR and the Westinghouse AP1000

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The Office for Nuclear Regulation (ONR)'s mission in completing the Generic Design Assessment (GDA) process on Nuclear New Build is to reassure the public that the new reactor designs are safe, secure and environmentally acceptable before any major construction is started. ONR is independent of industry and the UK nuclear policy-makers in government.

Subject to timely and acceptable responses from the industry vendors to the GDA Issues identified by ONR and Environment Agency in July 2011, by May 2012 the GDA process should be on course for ONR providing AREVA/EDF with a Design Acceptance Confirmation (DAC) for the AREVA EPR in December 2012. The position with Westinghouse is presently unclear as it negotiates for contracts with potential UK operators.

Along with provision of a Nuclear Site Licence and other regulatory requirements, that DAC for the AREVA/EDF EPR would be required before ONR could consider issuing its Consent for the start of construction of the nuclear island at NNB Genco's Hinkley Point C site, where NNB Genco's plans are to build two EPRs.

GDA is a unique process, and has not been undertaken anywhere else in the world. We have so far spent over 47000 days of effort on GDA, the vendors have submitted over 7000 documents, and we have raised and had answered over 3000 question. The incident in Japan in March 2011 has, of course, now added to what needs to be considered during GDA. The regulatory costs of GDA are borne by the vendors.

GDA has been undertaken jointly between ONR and the Environment Agency, in an open and transparent way, with a comprehensive website, routine ebulletin information to many thousand registered recipients, a public comments process, and with Quarterly Progress Reports published on our website. The international position is also important, as Nuclear New Build is a global issue, so collaboration between international regulators forms an important part of GDA as international regulators strive for harmonisation of designs across the world.

So, at IRPA13, Kevin Allars, the ONR Director of Nuclear New Build, will update on progress so far on GDA, and will expand on what the regulators are likely to be doing on any further assessment of new designs, and also on progress for construction activity in the UK.

TS6a.4
Radiological Protection Aspects of the Generic Design Assessment of Potential New Nuclear Reactors in the UK

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The Office for Nuclear Regulation is undertaking the Generic Design Assessment (GDA) of two nuclear reactor designs as part of a phased regulatory process to prepare for potential new nuclear build. Radiological protection is one of the technical areas that we are examining in detail, and in this paper we present our approach to the radiological protection assessment of the EDF and AREVA UK EPR and Westinghouse AP1000 reactor designs.

We will present the process that we have followed, the challenges involved with assessing reactor designs prior to the site specific phase, and the outcomes of our work. We examined the claims, supporting arguments and detailed evidence provided in the Requesting Parties' safety documentation and covered topics including the minimisation of radiation sources, the adequacy of radiation shielding, the effectiveness of measures to control radioactive contamination, and the adequacy of measures intended to restrict the exposure of workers during accidents. In June 2011 we concluded that both designs ensure that engineered features would restrict exposures to workers to ionising radiation so far as is reasonably practicable during normal operation.

Predicted doses to members of the public are very low and the approach to optimising radiation exposures of workers when carrying out high dose work activities was judged to be adequate. In our presentation, we will summarise the key Assessment Findings, which are matters where the lack of detailed information has limited the extent of our assessment. These will require further assessment during the site specific phase as the additional details become available as the design progresses. We will also describe the GDA Issues, which are matters of particular significance and will require resolution before ONR would agree to the commencement of nuclear island safety related construction of either reactor design in the UK. One GDA Issue, associated with the substantiation of bulk shielding and the radiological zoning scheme has been identified for the EPR design, and one GDA Issue, associated with criticality control of the spent fuel pool has been identified for the AP1000 design.

TS6a.5 The Evaluation of the Radiological Impact for a New Nuclear Facility on a Multi-facility Site

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Pelindaba is the hub of South Africa's nuclear technology development. It is home to SAFARI-1, and NTP PTY Ltd: the major international commercial isotope producer which includes Molybdenum-99. Pelindaba is south of the Hartebeespoort Dam in the North West Province of South Africa, approximately 27km west of Pretoria. It stretches over 2362 hectares in area, and houses multiple nuclear and chemical facilities. This paper explores the site characterisation of the preferred location for a new facility on the multi-facility Pelindaba site.

In general, siting involves a selection process and site characterisation. A preferred site is selected on the basis of safety and other considerations e.g. economic viability. Characterisation ensures the site is indeed viable as the preferred site. When a new facility is erected on an existing multi-facility site, this process is adapted slightly: a location on the site is identified through the selection process and then the on-site location is characterised, utilising knowledge of the multi-facility site and some location specific investigations. Siting is undergirded by the regulatory requirements imposed by the South African National Nuclear Regulator (NNR).

The site characterisation for the new facility location is a combination of data gathering of existing information and performing location specific investigations. Site specific investigations include: environmental impact, nearby facilities, geology and geotechnical characterisation, and ambient radiation levels. External events are identified through the site characterisation. Finally, the site characterisation culminates with the radiological impact assessment: a dose assessment and a risk assessment. The assessment detail is determined by the hazard graded approach. Site characteristics such as meteorology, demography and land-use of the region are utilised, and where necessary data is extrapolated. Some results are presented. Finally, the paper provides an overview of the licensing process and the relevant experience with the NNR, regarding the new facility's location selection and characterisation.

It is paramount that any new facility is safe for the workforce on Pelindaba and the public in the vicinity. A quality siting process is the first step in ensuring a safe facility. It establishes a thorough knowledge and understanding of the site so that the relevant hazards and site conditions are incorporated into the facility design.

TS6a.6
Assessment Of The Impact On The Irish Public Arising From Liquid Discharges From Potential New Build Power Plants In The United Kingdom

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The impact of any potential increase in radioactive effluent discharges into the Irish marine environment arising from new build Nuclear Power Plants (NPP's) in the United Kingdom is of considerable concern to the Irish public.

In order to address these concerns, the Radiological Protection Institute of Ireland carried out a comprehensive assessment of the impact nuclear new build may have on the Irish public. The results of this assessment are presented here and investigates:

1. The radioactivity concentrations in the Irish Sea arising from routine and non-routine liquid discharges.

2. The committed effective dose to the Irish population arising from these routine and non-routine discharges.

As this assessment was concerned with liquid discharges into the Irish marine environment only potential new build sites located on the west coast of the UK were assessed.

The radioactivity concentrations in the Irish Sea arising from routine liquid discharges are determined using the DORIS model in the PC-CREAM-08 software, which is based on the EC's Consequences of Releases to the Environment: Assessment Methodology (CREAM). The build up of radioactivity concentrations over 70 years in the Irish Sea are calculated and are based on the appropriate predicted annual discharges from the routine operation of a NPP.

The radioactivity concentrations in the Irish Sea arising from a non-routine discharge cannot be determined in the same way as those for routine discharges. Instead, a three dimensional Princeton Oceanographic Model of the Irish Sea is used to simulate releases of a conservative radionuclide tracer from each of the proposed NPP sites. This model was validated for simulation of the transport of a conservative radionuclide tracer. Radioactivity levels in seawater on the east coast of Ireland are computed by the model.

The dose to the Irish population arising from routine discharges are determined using the ASSESSOR module of PC-CREAM-08. The dose arising from a non-routine discharge is determined by firstly identifying the non-routine discharge scenario from the new build sites that gives rise to the largest radioactivity in seawater concentrations on the east coast of Ireland. Once identified, the dose arising from the predicted seawater activity concentrations at the monitoring location of interest is calculated using the CREAM methodology in conjunction with appropriate habits data.

TS6a.7
Industrial Radiography at Nuclear Power Plants

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In recent years, several incidents involving industrial radiography have occurred at nuclear power plants (NPPs) in Sweden. Therefore, the Swedish Radiation Safety Authority (SSM) decided to inspect the activity involving industrial radiography in 2010 at all three sites with reactors in operation. During the inspections, the Author-ity also reviewed the work of the licensees relating to industrial radiography. SSM was especially interested in how the NPP and the executing company cooperated before, during and after the radiographing work. An industrial radiography activity in an NPP differs from other radiography activities because one normally works in an environment with dose rates above background and sometimes with high dose rates.

Almost all industrial radiography actions in an NPP during an outage are classified as "open radiography" under SSMFS 2008:25 (the Swedish Radiation Safety Au-thority's Regulations and General Advice on Radiography). During the outage, sev-eral persons not involved in the radiography normally work day and night close to the radiography working area. It is important to limit this access so that no unauthor-ized people can enter the area where radiation from the radiography equipment is present. This is one reason why it is essential that an NPP and a radiography com-pany cooperate in radiation protection issues.

During the inspections, SSM had two teams working, one team for the NPP and another team for the radiography company. The two teams maintained close contact for comparison of the information received during the inspections. The views about how the cooperation was performed in reality sometimes differed between the personnel from the NPP and the radiography company.

The outcome from these inspections can be summarized as follows:

• Cooperation in radiation protection issues is essential and could be strengthened and started at an early stage

• Pre-Job-Briefing and Post-Job-Debriefing are good tools for improving ra-diation protection

• The instructions for the working procedures could be more clearly written and worded in more detail in order to avoid misunderstandings

• Improvements are needed to follow valid procedures and instructions

• Experience feedback could be strengthened

• Improvements are needed to ensure that the foremen have the regulated adequate training

• Corrective actions proposed earlier should be implemented

The Authority is presently monitoring implementation of the corrective action pro-grammes of the NPPs and the radiography companies.

TS6b.1 Radiation Protection during Decommissioning of Nuclear Facilities – Experiences and Challenges

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Decommissioning is the last phase of the life cycle of any nuclear facility. Today more than 450 facilities (nuclear power plants, research reactors) are finally shut down, un-der decommissioning or decommissioning has been already completed resulting in dif-ferent technical and radiological end-states. As especially more and more nuclear power plants reach the end of their technical life time and thus will be finally shut down the number of decommissioning projects will increase in the next years. For example, of the 442 nuclear power reactors in the world in operation in 2006, 88 have been in operation for 30-40 years, 200 for 20-30 years, 109 for 10-20 years, and 45 for less than 10 years. Radiation protection of workers and the public – together with the man-agement of radioactive waste and of spent fuel (if any is available) – is the central chal-lenge during each decommissioning project. Depending on a manifold of influencing parameter, e.g. radiological inventory, complexity of the nuclear facility, decommission-ing strategy or approach to structure the project, measure of radiation protection are different and specific for each individual decommissioning project.

Within this contribution to the IRPA 2012 an overview on experiences on radiation pro-tection and best practice concluded from past decommissioning projects will be given and an outlook on future challenges in radiation protection during decommissioning will be provided. A special emphasis will be laid on the selection of decommissioning tech-niques, i.e. dismantling and decontamination technique, and on international activities to collection radiation protection experiences related.

TS6b.2
Radiological Protection During the Dismantling of Nuclear Facilities

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ENRESA is the national company in charge of radioactive waste management in Spain. The company was set up in 1984, and one of its missions is the dismantling of nuclear facilities. ENRESA has carried out the dismantling of the Vandellós 1 nuclear power plant, several research installations and a pool type experimental reactor and is currently initiating the dismantling of the José Cabrera nuclear power plant, a pressurised water reactor facility.

From the point of view of radiological protection, the dismantling of a facility presents a series of characteristics that set it aside from normal operation, such as for example the continuous variation of the type and level of the radiological and conventional risks and the fact that activities are performed on equipment and systems that have not been acted on previously. In addition, certain of the protection systems are left out of service and have to be replaced with mobile systems. It is also important to point out that many of the workers participating in dismantling projects are not accustomed to this type of work and may even not have worked before with ionising radiations.

During dismantling there is also an increase in the risk of internal incorporation of alpha emitters, which are much more restrictive and difficult to determine than beta-gamma emitters, this implying the need to increase protective measures and to establish controls to determine as soon as possible whether any such incorporation has occurred.

This article describes the radiological protection programmes implemented by ENRESA for dismantling projects and the organisation and resources available for their performance. There is also an analysis of the ALARA techniques implemented to prevent the incorporation of alpha emitters and the dispersal of contamination, as well as of the incorporation controls established. Finally, the results obtained are analysed, in terms of dose.

TS6b.3
Harwell's Liquid Effluent Treatment Plant: Past, Present and Future Challenges in Radiation Protection

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A variety of research, development and nuclear operations were carried out at Harwell (UK) over many decades. As part of this, a Liquid Effluent Treatment Plant (LETP) was built just north of the main site to process and sentence radioactive waste effluent. Harwell and LETP are now subject to a decommissioning programme which involves (i) dealing with and sentencing historical waste and (ii) the demolition of facilities and buildings.

LETP currently handles a number of liquid wastes such as carboys with old laboratory waste and waste sludges held in a number of tanks. The facility contains a number of plants which are used to address this waste legacy. This includes a Carboy Washing Facility (used to process lower levels of waste in carboys) and two effluent / sludge Encapsulation Plants utilised to encapsulate low level and 'elevated' level wastes. As well as processing these historic wastes, a number of older delay tanks and pumphouses have recently been subject to Post Operational Clean Out (POCO) operations and demolition.

Further to this, a new Replacement Effluent Treatment Plant (RETP) is being built to replace LETP in dealing with liquid wastes generated during remaining work on the main Harwell Site. The RETP is being constructed in an old delay tank system which was first subjected to POCO operations to remove legacy waste and address contamination.

Radiation protection staff support all operations and LETP's radiochemical laboratories are essential in identifying waste fingerprints. The latter is particularly important as a wide range of radionuclides have been used at Harwell during its sixty year history and record keeping in the early days of the nuclear industry did not meet today's high standards.

This paper provides an overview of past, present and future operations and challenges. It stresses the importance of the associated radiation protection principles and practices used at LETP and RETP. For example, Risk Assessments and "HAZOP" studies are used to identify and address risks. ALARP measures and Safe Systems of Work are developed and implemented. Suitably Qualified and Experienced Personnel (SQEP) carry out all work. The plant holds a variety of instrumentation including hand held monitors, gamma-alarms and activity-in-air alarms. Both external and internal doses are measured using suitable dosimetry. While work is strictly controlled, contingency planning and emergency response training are carried out.

TS6b.4 Pharmaceutical-Producing Cyclotron Characterization, Removal, and Disposition

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The increased availability of Position Emission Tomography (PET) scanning for diagnostic investigation has led to an increased demand for radionuclide and radiopharmaceutical production. To sufficiently meet this demand, pharmaceutical-producing cyclotron facilities continually strive to produce larger quantities of product while keeping costs and occupational doses as low as reasonably achievable. The advanced age of some cyclotrons requires facilities to remove and dispose of older machines in order to facilitate the purchase of new state-of-the-art equipment. Removal and disposition of these older machines requires considerable planning, as the materials are radioactive as a consequence of their use, possibly located inside a massive concrete vault, and typically located in a remote part of a facility. A Scanditronix MC17 cyclotron was removed from the University of Iowa Hospital in the summer of 2011 and transported to Clive, Utah where it was disposed as low-level radioactive waste. This allowed the purchase and subsequent placement of a GE PETtrace 880 cyclotron. This replacement was necessary to make radionuclides and radiopharmaceuticals for the facilities four PET scanners. Overview of the disposition project from a health physics perspective is provided. Discussions are accompanied by photo documentation and include waste characterization activities using in-situ counting systems, preparation of the cyclotron for removal, vault wall demolition, ancillary equipment removal and packaging, movement of cyclotron through the hospital, removal of wastes via crane, and conveyance loading and transport. Radiological, health and safety, waste management, and logistic aspects of the project are discussed.

TS6b.5
Final Radiological Release of the Radiochemical Laboratory at the Joint Research Centre in Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry.

It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

One of the first JRC-ISPRA's radiological facilities to be released from regulatory controls, in 2010, was the Radiochemical Hot Laboratory (RCHL). This facility has been used, since the sixties, to perform radiochemical separation and analyses on many radioactive samples obtained through irradiation in other JRC-ISPRA's nuclear facilities, including the two research reactors ISPRA-1 and ESSOR.

Radioisotopes found in RCHL during its decommissioning process were alpha, beta and gamma emitters, including the majority of the most interesting hard-to-measure radionuclides.

An extensive radiological characterisation campaign, composed of a first phase of non-destructive analyses and a second phase of more detailed destructive analyses, was performed in RCHL between 2008 and 2009. Homogeneous groups and nuclide vectors were then properly defined, according to the results of the characterisation campaigns.

A final decontamination campaign was performed before the facility's final radiological release.

A thorough final radiological survey was performed after RCHL final decontamination, examining hundreds of samples and direct analyses, with the aim of describing in a complete way the final radiological status of the facility.

At the end of this process, the RCHL was released from regulatory control, and was destined to non-radiological activities.

This report covers the pre-characterisation, characterisation, decontamination and final radiological survey processes, leading to the final radiological release of the facility.

TS6c.1
Radiation Protection Challenges for Exposures to Naturally Occurring Radioactive Material (NORM)

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Technological and regulatory developments concerning exposure to naturally occurring radioactive material (NORM) during the last two decades have resulted in progress towards achieving broad international consensus on managing exposure to NORM. However, the standards and regulatory approaches being adopted at the national level still needs to be harmonized especially in developing countries with limited regulatory resources. The new International Basic Safety Standards (the BSS) published by the IAEA in 2011 provides requirements reflecting the concept of planned, existing and emergency exposure situations and are in line with the 2007 Recommendations of the ICRP. Exposure to natural sources continues to be generally subject to the requirements for *existing exposure situations*. Major radiation protection challenges for NORM are — Differences in standards and regulatory approaches between countries, and even within individual countries; the need for an industry-specific approach - no single approach to the control of exposure to NORM was appropriate for all industrial processes involved; resurgence of uranium mining industries and fast expanding worldwide exploration activities for uranium; the identification of situations that could be classified as either existing exposure situations or planned exposure situations and how such exposures should be optimized using, as appropriate, reference levels or dose constraints; adoption of a very conservative and cautious approach, resulting in undue attention being given to industrial processes and residues for which there was no real evidence of the need for control; the need for an evidence-based approach to the making of policy and regulatory decisions; problems of interpretation of the 2007 recommendations of the ICRP, particularly concerning the distinction between existing exposure situations and planned exposure situations; differences in interpretation of the standards, especially with respect to the concepts of exclusion, exemption and clearance; exposure of workers; radon in workplaces; transport issues; NORM residue recycling and use; management of NORM residues designated as wastes; legacy situations and shortage of trained radiation protection professionals in the industry. The paper also summarizes the International Standards and guidance on NORM with a focus on the new BSS and other industry specific safety reports of the IAEA.

TS6c.2
Estimates of Effective Doses Among Czech Uranium Miners

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Czech uranium mining started on industrial base in the 1890s. It is estimated that the total production has been 110 000 t of uranium and the uranium industry has employed nearly 100 000 underground workers. Radiation doses in uranium mines include contribution form inhalation of radon and uranium dust and from external gamma radiation.

The Czech uranium mine at Rozna is still operated. The presentation includes an estimation of radiation doses, which is based on measurements of physical and chemical characteristics of the mining aerosol conducted recently in the mine. The main parameters were: size, chemical solubility in lung fluid, and amount of Rn gas emanating from uranium particles. The mean size of particles in terms of AMAD was in the range 5-9 μm. Study of kinetics of dissolution of uranium collected on filters from personal dosemeters ALGADE estimated rapidly dissolved fraction of 0.142 and 0.177 for U-238 and U-234, respectively. Fraction of Rn gas emanating from uranium particles was estimated by measuring activity ratios of radon progeny and Ra-226. This fraction, which determines how the gross long lived alpha activity is distributed into radionuclides of the uranium series, were in the range 32% - 63% with the mean of 44%.

Based on these parameters, committed effective doses from long lived radionuclides in uranium dust were calculated using the IMBA software. In conditions at mine Rozna in 2000-2009, mean annual effective doses are 1.9 mSv from long lived radionuclides, 4.1 mSv from radon and its progeny (using conversion 1WLM=10mSv) and 2.2 mSv from external gamma radiation.

This work was supported by the Czech State Office for Nuclear Safety, R&D project VZ 60022490.

TS6c.3
Problems Experienced when dealing with the Decommissioning of NORM Contaminated Oil Production Installations and Vessels.

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The radiological significance of high activity levels of NORM deposits in the oil and gas industry were first identified as an issue for the industry in 1981 in the UK. Since then the problem has been identified throughout the world wherever oil production takes place. In several countries oil production facilities and platforms are now requiring decommissioning and Floating Production Storage and Offloading (FPSO) vessels are requiring their first refurbishment program involving major engineering demolition work to be carried out on them. In several countries, by necessity, this is being carried out by a local labour force with no experience at all of working with NORM contaminated materials, sometimes with little national legislation regarding ionising radiations being in place, to a very time restricted work schedule and large pressures to keep costs to a minimum. Further problems regarding trans-frontier movements of radioactive materials have to be addressed when FPSOs have to be moved from their country of origin to a second country where the rebuilding program is carried out, particularly when the second country has a well developed national legislation in place regarding NORM and inspectors to implement it.

The presentation will describe the initial problems of identifying the levels of activity in Installations and FPSOs and the levels of activity and doserates that have been measured in and around pipework and inside storage tanks in Europe, South America and Africa. The methodology adopted to estimate the total amount of waste that may be present on an installation or vessel will be also be outlined.

The work procedures that were put in place for the work force carrying out will be discussed and the problems, success and lack of success in implementing them described. Practical solutions to these problems following from our experiences and discussion with the experienced RPSs sent out to supervise the work will be suggested. These solutions are being applied to projects now being planned. Some experience of the implementation of these solutions may also be available for presentation.

TS6c.4
Dose Assessments Uncertainties for NORM Management in Conventional Hazardous Waste Disposals

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Naturally Ocurring Radioactive Materials (NORM) are generated in huge quantities in several industries – called NORM industries for this reason - and their management has been formerly carried out under considerations of industrial non radioactive wastes. As the concentration of non radioactive toxics in several of those materials is relatively high, they were treated as toxic materials. This implies that the materials must be previously conditioned using conventional methods (drying, incineration, inerting treatments, etc.) and that the waste disposal itself must be prepared to isolate the toxics from the environment for long periods of time. Spanish regulation for these conventional toxical waste disposals include conditions that assure adequate isolation.

After the 96/29 European Directive (the European BSS), radiological implications on NORM industries and their residual materials must be considered. One option that can be considered for the disposal of NORM with activity concentrations above the unconditional clearance level is the use of the same hazardous waste disposals.

This work analyses the radiological implications of the management of NORM under these ‘conventional’ considerations, emphasising in activity concentrations slightly over unconditional clearance levels – from 1 Bq g^{-1} up to 10 Bq g^{-1}. Generic dose assessments are usually carried out under highly conservative hypothesis. However, in this work uncertainties are also included to consider possible variations due to climate factors or other parameters used in the models.

TS6c.5
A Prospective Radiological Risk Assessment for a Phosphate Industry Project

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Radiological Risk Assessment (RRA) seeks to predict the future consequences for human health of possible decisions regarding radioactive materials in the environment; and that it seeks to inform decision-making. An environmental risk assessment in the planning phase of the project (prospective RRA) enhances the understanding of the risks of the project. And, if the risks are known, the best way to deal with it can be planned and their effects can be avoided or mitigated. Consequently, the costs related to liabilities and rework can be minimized and the benefits for environmental safety are maximized. The Santa Quitéria Project is currently the biggest Brazilian uranium mine project. A peculiarity of this project is the enhanced concentrations of uranium and of phosphate in the ore and the mining and processing of both by two different enterprises. A private company will be responsible for the production of phosphoric acid and a state owned company will be responsible for the production yellow cake. At full capacity, the plant will generate 10% of Brazil's total annual phosphoric acid production and 1,500 tons of yellow cake per year. The chemical processing, by which phosphoric acid is produced, generates phosphogypsum (PG) as a by-product. The ratio of phosphogypsum to phosphoric acid will be around 5 to 1. After all the phosphate has been extracted and processed, it is expected that some 37 million tons of phosphogypsum containing 13 Bq/g of radium 226 will be produced. Aiming to assess the potential radiological risk of this PG stack on the workers and surrounding inhabitants, a generic assessment was carried out with RESRAD offsite and onsite codes. A hypothetical farmer scenario was used to calculate potential dose out of the project boundary and over the stack piles, after the shutdown of the project. The annual exposure dose for workers during the facility operation was also evaluated. In a conservative approach the potential public dose was estimated around 2.5 mSv/y. This study identified the rainfall erosion index, the geometric shape of the PG stack and the fish consumption rate as the main parameters for the dose assessment, in which an improvement of information and understanding could improve the quality of the dose assessment. The worker dose estimation stressed the need for action plan to mitigate worker exposures on the stack. In addition, the onsite public dose pointed out the importance of a planning for remediation of the area after the shutdown of the plant, in order to assure that public and environment health will not be affected by the presence of the PG stack.

TS6c.6
Radioactivity in Raw Materials and Waste from NORM industries in China

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A nationwide campaign for investigation of radioactivity resulting from exploitation of thirteen resources in NORM industries had been conducted during the First China Pollution Sources Census (FCPSC) from early 2008 to 2009 in China. 11000 enterprises were censored in 2007. In which, 1433 enterprises are monitored in more detail, they either produce ores, raw materials, or wastes with that γdose rate on 1 meter distance is over 50 nGy/h of local background level. These resources are of minerals or elements including rare earths, tantalum/niobium, zirconium, tin, lead/zinc, copper, iron, phosphate, coal, aluminium and vanadium. The resources in which the average concentration of ^{238}U, ^{226}Ra or ^{232}Th is more than 10000 Bq/kg are rare earths, tantalum/niobium and zirconium. But the industries of coal mining and coal users, phosphate are considered significantly radiological impact because of their production of waste. China is the biggest producer of the REO in the world. Mining and mineral processing for products of rare earths is considered to be the most serious NORM problem. Data from 69 rare earths plants show that the radioactivity concentrations of raw materials are on the average of 5782Bq/kg for ^{232}Th, 2529Bq/kg for ^{226}Ra and 3972 Bq/kg for ^{238}U. The radioactivity concentrations varying in solid wastes are similar to those in the raw materials.

The amount of coal production in China accounts for about 45% of the total amount of world. According to the statistic data of Chinese coal mines, the average concentration of ^{238}U,^{226}Ra,^{232}Th in coals is 79 .5 Bq/kg, 73 .9 Bq/kg and 40.3 Bq/kg respectively, but the result of the FCPSC in 550 mining enterprises and 168 coal users shows that the average concentration of ^{238}U,^{226}Ra,^{232}Th in coals is 383 Bq/kg, 212 Bq/kg and 51 Bq/kg , while in solid waste is 225 Bq/kg, 326 Bq/kg and 91 Bq/kg respectively.

About 7.8x10^6 t/a of P_2O_5 is produced by China and accounts for 17% of the total amount of the world. Activity concentrations in phosphate rocks range from 10 to 150 Bq/kg for ^{232}Th and 100 to 300 Bq/kg for ^{238}U in most of China, but 1500 to 4000 Bq/kg for ^{238}U in some other areas.

TS6d.2
Improving the Security of Radioactive Sources in Industrial Radiography in South East Asia

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This paper describes the need and new requirements to ensure the security of radioactive sources in the practice of industrial radiography. We describe the discussions and issues arising during the September 2010 South East Asia regional workshop held in Sydney on the application of security measures to industrial radiography practices. The workshop provided the perspectives of both radiation regulators and industry practitioners from some countries in South East Asia. We describe the outputs of the workshop, how they were developed, and make suggestions for further consideration and application of security measures in the practice of industrial radiography. Examples of uptake of the outcomes of the workshop by the Philippines Society for Non-Destructive Testing and the World Institute for Nuclear Security are provided.

TS6d.3
Search for Non-registered Radioactive Sources - an Important Part of the National Inspection Programme

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According to the HASS directive the EU countries are obliged to conduct campaigns to identify orphans sources and to have in place emergency preparedness system. Actions mentioned are necessary in order to prevent the exposure of persons handling such sources not knowing characteristics of sources and to prevent contamination of the environment. Additional threat is caused by malevolent actions with orphan sources, because they can be easily acquired and used. Furthermore, economic impacts when sources are melted or found at scrap yards resulted in defence systems prepared by regulatory authorities and industry. The systems are established at state borders or within industrial objects. They are based on equipments specially designed for detection of orphan sources. Furthermore, international databases of incidents with such sources exist, e.g. IAEA database.

A necessary update of state database of sources is based on defence systems mentioned and on documentation related to sources in a state. However, the documentation available to a regulatory authority can have a systematic drawback. Namely, according to the experiences of the Slovenian Nuclear Safety Administration (SNSA), who conducted a systematic inspection campaign focused on non-registered sources, majority of sources found have never been under the regulatory control in the past. In general, owners of non-registered sources were not aware they are handling sources. The reasons for such uncontrolled use of sources can be different, e.g. military safety standards were different than civil ones or the staff at institutes often underestimated risks.

From 2004 when the SNSA prevention campaign started around thousand of sources were identified mainly through systematic inspection programme which included research and educational institutions and military objects. Till 2011 more than 100 inspections were conducted based on a special methodology. A whole spectrum of well known radioisotopes was identified starting with various uranium compounds. Physical states of sources were very different, some of them causing also the contamination of workplaces or the environment. Also unconventional sources were found. As a rule no documentation related to sources was available but owners were known. Risks associated with sources found are analyzed based on different criteria, e.g. radiotoxicity, potential contamination, radiation fields. Solutions regarding radiation safety are given. Lessons learnt from the SNSA campaign focused on non-registered sources which could become orphan sources in a near future, are systematically presented and can be used for establishing action plans in other states.

TS6d.4
Radiation Safety at the PRIMA facility: A Review of Shielding Solutions and Personnel Dose Assessment

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The Neutral Beam Test Facility (NBTF), also called PRIMA (acronym for Padova Research on ITER Megavolt Accelerator) consists of two separate development test beds currently under construction in Padua (Italy): the ion source test facility, named SPIDER (Source for Production of Ion of Deuterium Extracted from Rf plasma) and the megavolt test facility, called MITICA (acronym for Megavolt ITER Injector & Concept Advancement). Both injectors accelerate negative deuterium and hydrogen ions with a maximum energy of 1 MeV for MITICA and 100 keV for SPIDER, and a maximum beam current of 40 A for both the experiments. Accelerated ions are stopped on a.CuCrZr alloy calorimeter where an intense neutron field is generated following to D-D and D-T reactions.

In the present paper, a systematic review of the radiation safety analysis for both injectors is presented. The shielding design is described, including special shielding solutions planned with the aim of allowing personnel access for inspection and maintenance of the injector. In addition, the major results regarding the activation level of the corrosion products (ACPs) generated inside the cooling loops are reported, as a function of the neutron yield, time campaign and pulse duration. Furthermore, personnel classification, tritium inventory and dispersion are also presented and discussed in the paper.

Our analysis indicates that the radiation safety system for the PRIMA facility is appropriate in maintaining the individual doses for workers and population well below the Italian (and internationally stated) regulatory limits.

Tritium diffusion from the facility is not an issue from the radiation protection point of view. Even considering the most conservative scenario, the dose rate per year to the reference group (population) is about three orders of magnitude lower than the dose limit.

Furthermore, our results indicate that for SPIDER, even considering the maximum workload, the contribution of ACPs to external exposure is negligible. On the other hand, due to the higher neutron yield, ACPs produced on MITICA cooling loops may significantly contribute to external exposure of workers.

Radiation shielding and radiation protection criteria were assessed in order to meet the Italian regulatory limit for non radiation workers (1 mSv/yr). Our analysis and project evaluations confirm that this limit is never exceeded during operating phases of the injectors.

TS6d.5
Current Practice of Occupational Radiation Protection in Industrial Radiography

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In 2009 the IAEA launched the Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR) – a project aimed at improving occupational radiation protection in those areas of radiation use in medicine, industry and research where non-trivial occupational exposures occur. As part of ISEMIR, a working group on industrial radiography (WGIR) was established in 2010.

Three questionnaires were developed by WGIR to gain insight into occupational radiation protection in industrial radiography world-wide – one addressed to individual industrial radiographers, another to non-destructive testing (NDT) companies, and a third to national or state regulatory bodies. Each questionnaire addressed the topics of training in radiation protection, incidents, safety of the radiographer, the public and sources, inspections, emergency plans, and individual monitoring.

The questionnaires were distributed widely over a one year period. Responses were received from 432 industrial radiographers from 31 countries, 95 NDT companies from 29 countries, and 59 regulatory bodies. Findings will be presented and discussed.

Initial training of industrial radiographers in radiation protection appears to be well established, with a high prevalence of practical training being included. Requirements for refresher training are less well established. Approximately 20% of industrial radiographers have had an accident, near miss or deviation in the last 5 years, with an approximate incidence of 8 accidents per 1000 operators per year. There was about one notification of an accident per regulatory body per year.

All regulatory bodies required individual monitoring with passive dosimeters, 80% also requiring the use of active dosimeters. All NDT companies provided passive dosimeters, and over 90% also provided active dosimeters. The average annual effective dose for industrial radiographers in 2009, as reported by the radiographers, was 3.4 mSv, with a reported maximum of 30 mSv. Regulatory body data gave an average of 2.9 mSv, with a maximum of 158 mSv. Approximately 4% of operators reported a maximum monthly dose in 2009 exceeding 5 mSv, while the percentage from the regulatory body data was 2%. An estimate of 2.9 ± 1.2 μSv for the mean occupational dose per radiographic exposure was derived from operator workload data. Differences in the level of NDT training, the type of sources being used, the activity of sources, the use of collimation, or the incidence of events did not have a statistically significant effect on this estimate.

The results from the survey are being used to: design the ISEMIR database that will be used by end-users to improve their implementation of optimization in occupational radiation protection in industrial radiography; and to develop a "roadmap" tool that enables NDT companies to assess their own performance in radiation protection against accepted practice.

TS6d.6* Probabilistic Radiological Risk Assessments for Radiation Facilities with Vague Information

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The International Commission on Radiological Protection(ICRP) recommended that in the design of equipment and procedures and in the planning of their application, attention should also be paid to accidental and unintended exposure. The objectives of this article are to provide streamlined technique, including the Delphi approach, Bayesian update and two-dimensional Monte Carlo analysis(2D MCA), and to provide information through the investigation of factors in risk model which supports risk assessment for the radiological risk assessment in operation of such radiation facilities with vague information. According to IEC 60300-3-9, the main stages of risk management consist of risk analysis, risk evaluation and risk reduction/control. The scope of this study is restricted to risk assessment. Focus was placed on the framing of probabilistic risk assessment(PRA) procedure applicable to a system for which information on risk contributing factors is vagueness. Incorporation of the Delphi panel method and the Bayesian update into PRA for dealing very uncertain factors was addressed in particular. The PRA methodology established through this study for facilities with vague information on risk contributing factors was applied for risk assessment for field radiography. Task analysis was performed for operations and scenarios based on the risk ranking and relative frequency were constructed for each task in field radiography. The risks for the worker and the public member were estimated by dividing into the normal and accident situations. It is expected that the procedures established in this study, certain refinements, will open the way leading to quantification of risks and their uncertainties in similar systems with vague risk information, particularly other type of radiation facilities.

Key words: Radiological risk assessment, radiation facility, Delphi panel method, Bayesian update, 2D MCA

TS6d.7
The Safety Case for Transporting Spent Nuclear Fuel

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The transportation safety case for transporting spent nuclear fuel is a requirement for licensing. It has both qualitative and semi-quantitative aspects.

The qualitative aspects include transportation regulations, radiation dose limits, role of the transportation package in transportation, transportation package certification process, training, emergency response, the performance of the transportation package in accidents, and the evaluation of past transportation accidents.

The quantitative aspects support the qualitative descriptions. Radiation doses accrued by members of the public and by workers are calculated using the code RADTRAN. Dose from both routine, incident-free highway transportation and from highway transportation accidents are part of the safety case and will be compared with both background doses and the regulatory safety criteria.

The radiation doses from routine transportation are calculated for:

· The maximally exposed member of the public.

· Doses to vehicle escorts.

· Doses to vehicle crew

Collective doses to populations are calculated for representative routes. Collective dose depends on the number of people affected as well as on the extent of the radiation from the source to which reference groups are exposed.

Accidents involving loss of gamma shielding and loss of confinement integrity are discussed, as are accidents in which there is no impact on the cargo.

TS7a.2
IAEA Quality Audits in Radiotherapy

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Quality audits in radiotherapy have proven to be a useful tool for quality assessment and practice improvement in radiation oncology centres. The IAEA/WHO TLD postal dose audit service has been in operation for over four decades and checked the calibration of approximately 8500 radiotherapy beams in 1800 hospitals in 122 countries. Several discrepancies in radiotherapy dosimetry have been discovered and rectified. Generally, throughout the time, radiotherapy centres have improved their ability to deliver the dose accurately. The percentage of acceptable TLD results has increased from 50% in early years of the TLD service to 95% at present. However, there are still shortcomings that impede quality of clinical dosimetry that need to be addressed.

Another dosimetry audit programme developed by the IAEA uses the end-to-end approach, i.e. it assesses the entire workflow for conformal radiotherapy techniques, from patient data acquisition and computerized treatment planning to dose delivery. It is based on a semi-anthropomorphic phantom circulated among radiotherapy centres. The experience gained in this programme has highlighted the fact that proper attention must be paid to basic aspects of dosimetry and treatment planning.

The IAEA's comprehensive clinical audits by the Quality Assurance Team for Radiation Oncology (QUATRO) assess overall practices in radiotherapy centres including the infrastructure, patient and equipment procedures, quality assurance programmes, radiation protection, staffing levels and professional training of the local radiotherapy staff. To-date QUATRO has conducted over 60 audits on request, in radiotherapy centres of Central and Eastern Europe, Asia, Africa, and Latin America. Some centres have been acknowledged for the adequate level of practices; in other centres auditors identified gaps in technology, human resources or procedures, allowing the audited centres to document areas for improvement. Overall, QUATRO audits have contributed to improvements at centres, but also have identified common issues to be addressed internationally. An example is the training of radiation therapists in Central and Eastern Europe, now being implemented through the IAEA's cooperation with the European Society for Therapeutic Radiology and Oncology.

QUATRO, in addition, offers assistance in the resolution of suspected or actual dose misadministrations in radiotherapy. It includes the follow-up of inconsistent results detected by the IAEA/WHO TLD postal dose audit service. This way radiotherapy centres are offered help at a very early stage in the problem-solving process, focusing on prevention of incidents or accidents in radiotherapy.

TS7a.3
Peripheral Doses in Children Undergoing Gamma Knife Radiosurgery

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Radiotherapy treatments typically involve the delivery of doses of tens of Gray to the target volume, whilst delivering lower doses to all other parts of the body. The carcinogenic properties of ionising radiation thus lead to a probability of inducing a second cancer in the irradiated patient. Factors contributing to the recently renewed concern about the radiation induced secondary cancer include improved cancer survival rate, younger patients population as well as emerging treatment modalities that can potentially elevate secondary exposures to healthy tissues distant from the target volume. Gamma Knife radiosurgery stereotactically delivers a high single dose of external radiation to a small well-defined intracranial lesions. Due to a large amount of dose delivered in a single fraction (10 - 30 Gy) in stereotactic radiosurgery, dose outside the treatment volume is an important issue. The aim of study was to measure the out-of-field doses during the Leksell Gamma Knife Model C radiosurgery for children. The children population was chosen due to their higher susceptibility to radiation. Also, due to smaller size of their bodies, the larger doses are expected to all out-of-field tissues and organs than for adults for the same irradiation conditions. The purpose was to identify doses delivered to the eye lens, thyroid glands, breasts, sternum, upper abdomen and gonads from the doses measured with dosimeters placed on the some positions on the surface of the patients. The relation of the organ doses and doses on the surface was determined by measurements using the anthropomorphic phantom (CIRS, ten-year old child). Additionally, surface doses were measured on the patients; there were 5 patients between 4 and 14 years old. At the every point of measurement two types of thermoluminescent dosimeters were placed, LiF:Mg,Ti and LiF:Mg,Cu,P and two radiophotoluminescent glass dosimeters (GD-352M). The agreement between three types of dosimeters was on average within 6 %. Doses on the patients have shown large dissipation for the same positions above specified organs. This is due to different influential parameters (position and volume of the target, height and weight of patient, irradiation dose). For example, doses to the eyes and gonads varied from 0.7% to 2.55% and from 0.05% to 0.22% of the mean target dose, respectively. Results of organ dose measurements in the phantom and on the surface of the phantom show uncertainty of about 20 % of the organ dose estimations from the surface dose measurements.

TS7a.4
Comparison of Primary Doses Obtained in Three 6 MV Photon Beams Using a Small Attenuator

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OBJECTIVES: It is a common technique in radiotherapy treatment planning systems to simplify the calculations by splitting the radiation beam into two components: namely the primary and scattered components. The primary component is the radiation which arrives at the point of interest without having had any interactions. The scattered component is the radiation which arrives at the point of interest having undergone at least one interaction. The contributions of the two components are evaluated separately and then summed to give the dose at the point of interest. It is of vital importance to determine these components as accurately as possible, as any error will have an impact on the dose the patient receives. Usually the primary dose is obtained experimentally by extrapolating the ionization measured within the medium to zero field size. This approach offers the opportunity to obtain the primary component of dose without the need for an uncertain non-linear extrapolation. It is based on a paper by Nizin & Kase from 1988.

DESIGN & METHOD: The total dose in a broad beam can be described as the sum of the primary and scattered dose components ($D_T = D_p + D_s$). A small diameter central axis absorber (denoted by superscript i) is placed between the source of radiation and the point of interest, resulting in additional attenuation of primary photons without appreciably changing the scattered component of the beam ($D^I_T = D^I_P + D_s$). For a specified depth d in a phantom, the ratio of primary components is independent of field size: D_p / D^I_P = constant = C_D.

Thus: $D_p (d) = [1 – 1/ CD(d)]^{-1} \cdot [D_T (d,S) - D^I_T (d,S)]$ CD can be measured by a series of ionization measurements with and without the attenuator in a narrow beam. The value of CD together with the total doses with and without the central axis attenuator in the beam enables one to calculate the primary dose component of the beam. Measurements were done in Philips SL75-5, Siemens Mevatron KD2 and Varian 2300 Clinac 6MV photon beams. Lead attenuators of 1 cm and 2 cm thickness were used.

RESULTS: The values for the primary doses at d_{max} in a 10 cm x 10 cm field ranged from 0.925 Gy/100MU to 0.943 Gy/100MU with uncertainties ranging from 3.3% to 5.2%.

CONCLUSION: The obtained values of the primary dose component compare well with the values currently in use on the treatment planning systems as well as with Monte Carlo simulations. One can thus conclude that this method has the potential to provide an independent measurable verification of calculations of primary dose.

TS7a.5
Multi-institutional Study for IMRT Dose Quality Assurance in Korea

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To ensure the safe implementation of IMRT in Korea, we performed a multi-institutional study for IMRT dose quality assurance (DQA). Ten institutions were grouped into the LINAC (7) and TOMO (3) groups to determine a confidence limit of DQA measurements. A custom-made acryl phantom for LINAC and a cheese phantom for TOMO were used to measure a point dose using an ion chamber as well as planar dose distributions using a film. The mock programs for the prostate and head & neck cases employed in AAPM TG-119 were modified according to the anatomy of Korean patients. The five mock programs drawn on CT images of the two phantoms were centrally distributed to all participating institutions. Per-field measurements were performed by only the LINAC group using a 2D detection array or film, but composite fields were measured by the all institutions using a film. Composite-field measurements were applied to all mock programs except for multi-target cases. We followed the confidence limit concept of AAPM TG-119. The ratio of measured and planned doses was used for the point dose analysis. The planar dose distributions were assessed at the gamma criteria of 3%/3mm. For high dose point measurements, the average differences between the measured and planned doses for the LINAC and TOMO groups were -0.007±0.012 and -0.005±0.014, respectively. The average confidence limit (mean + 1.96) was determined to be 0.031 for both groups. For low dose point measurements, the average differences were -0.010±0.019 and -0.001±0.025 for the LINAC and TOMO groups, respectively. The average confidence limit was 0.048 and 0.050 for the LINAC and TOMO groups, respectively. For head and neck cases, the per-field passing rate averaged over the LINAC group was 98.2±2.6% and the confidence limit was 93.1%. The composite-field gamma passing rate averaged over the LINAC group was 94.7±3.1% and a confidence limit was 89.6%. For the TOMO group, the average composite-field gamma passing rate was 96.3±3.2% and the confidence limit was 90.0%. In this study, there was no significant difference between LINAC and TOMO groups. A tolerance level of ±3% and an action level of ±5% could be suggested for high dose point measurements while a tolerance level of ±5% and an action level ±7% for low dose point measurements. In the planar dose measurements, a tolerance level of 93% and 90% could be applied for per-field and composite field measurements at the criteria of 3%/3 mm, respectively. The action level of 87% and 85% could be applied for per-field and composite field measurements at the same criteria, respectively.

TS7a.6
Treatment Errors And Near-Misses In A Radiotherapy Department

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Background: Radiotherapy is a multi-step and complex treatment modality requiring the linkage of many different systems and staff groups and therefore lending itself to potentially significant dose delivery errors. Despite significant technological and process control advancements, errors in radiotherapy persist and risk reduction measures are therefore a necessary consideration.

Purpose: To analyse causes of significant errors in a busy radiotherapy department.

Materials and Methods: A number of significant radiotherapy incidents were investigated utilising Root Cause Analysis. Specific errors were classified into “root (first) causes”, “main causes” and “contributory factors” and the associated dosimetric considerations were quantified.

Furthermore, near-miss errors detected in the checking processes within physics planning services were analysed for about 1300 treatments and a classification method was developed to facilitate risk analysis.

Results: The “root (first) causes” for most of the incidents were human factors. Process control and management system issues were identified as the “main causes” for most of the incidents.

Within physics planning services, an average of about 0.5 errors (near-misses) per treatment were detected. About half of the errors were identified as significant near misses in terms of the potential impact on treatment delivery. Of these, about 20% were transcription mis-entries, 10% were planning errors, 5% were dose miscalculations, 8% were erroneous independent MU check calculations and 12% were in-vivo dose miscalculations.

Conclusions: Risk reduction through improved use of available technologies for error detection is suggested. The number of errors detected by the checking processes is high and should be reduced.

TS7b.1
Challenges in Nuclear Medicine Radiation Dosimetry

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In spite of considerable progress, many advances remain to be achieved in the estimation of organ absorbed doses and in the prediction of biological effects from radiopharmaceuticals.

In *patients* undergoing diagnostic procedures, the biokinetics of the radionuclide has to be determined for a limited number of representative patients. When radiopharmaceuticals are used for therapy, it is essential to determine the *individual*l kinetics to be able to calculate the absorbed doses to critical normal organs/ tissues with high accuracy.

For pharmaceuticals based on radionuclides emitting single photons, the planar conjugate view method has been the way to investigate the activity content in organs and tissues and its time variation. The accuracy of this technique is limited by the lack of knowledge of the source-organ thickness and the difficulties to correct for organ overlap. SPECT is a way to solve some of these problems, but to get acceptable statistics in the images very long acquisition times are needed. In SPECT/CT, the CT images are used, not only for identification of anatomical details but also as a basis for attenuation correction. In a similar way, PET/CT is used for patient specific 3D image based internal dosimetry using the patient´s own anatomy and spatial distribution of activity as a function of time.

The transition from stylized reference phantoms to voxel phantoms may lead to improved dose estimates. New phantoms, e.g. the non-uniform rational B-spline (NURBS) can represent a broader population of nuclear medicine patients, but still the dose estimates are valid only for the phantom and not for the individual patient. Therefore, the real challenge – at least for the therapeutic situation - is to describe the patient by imaging (CT, MRI) and then make individual calculations.

In recent years, there has been an increasing interest in combining biologically specific targeting agents (antibodies, peptides, etc.) with short-range alpha particle or Auger electron emitters. It is a challenge to develop a dosimetry that predicts the biological effects of these particle emitters.

In vivo measurements when using photon and beta particle emitting radionuclides have been done using small TLDs, OSL dosemeters or diodes. New possibilities may be opened using quantum dot (QD) dosemeters, with physical dimensions of a few nm.

For *staff* exposure, it is important to take into account the increasing use of PET agents for imaging. It is also important to investigate the occupational exposure from a number of old and new radiopharmaceuticals for therapy and how these affects both the effective dose and the dose to fingers, hands and the lens of the eye.

TS7b.2
Impact of the New Reconstruction Algorithm trueX at Siemens PET/CT-scanners

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PURPOSE: Aim of this study was to compare the differences between the new reconstruction algorithm TrueX and conventional 2-dimensional (2D) and 3-dimensional (3D) OSEM in a phantom study.

METHODS: Thereby measurements were carried out with a Siemens Biograph 64 TruePoint PET/CT Scanner and a self constructed performance phantom. The Phantom consists of eight communicating cylinders (inner Phantom) with different diameters, which are surrounded by a phantom body. The measurements were carried out with four different activity concentrations (8:1, 6:1, 4:1 and 2:1) of F-18. For analyzing purposes a TrueX, a 2D OSEM and a 3D OSEM reconstruction algorithm with four iterations and 8 subsets were used. Furthermore each of them was reconstructed with a Gauss and a Allpass Convolution Kernel. For evaluation purposes IDL, a C++ based interpreter language for visualization and statistical evaluation, was used with a maximum line volume method.

RESULTS: The results demonstrate that 2D OSEM and 3D OSEM display the true activity concentration within 10 %, in the contrary trueX overestimate the true activity concentration up to 25 %. No significant difference could be identified between 2D and 3D OSEM.

CONCLUSION: The advantage of TrueX for diagnostic belongs to lesions about 11 mm in diameter, in which 2D OSEM and 3D OSEM display activity concentration and consequently the evaluated SUV not sufficiently. For scientific purpose 2D or 3D OSEM is the most useful reconstruction algorithm, because of the minimal deviation from the real activity concentration for diameters of more than 11 mm.

Key words: iterative reconstruction, OSEM, TrueX, PET-CT, IDL

TS7b.3
Iodine 131 Treatment for Patients on Hemodialysis: Radiation Safety Considerations

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Background: Radioactive iodine 131 therapy may be necessary for thyroid cancer treatment. Usually, for patients with normal renal function, iodine is mainly eliminated through the kidneys. For patient with renal failure however, iodine will be eliminated by dialysis, potentially exposing medical staff and contaminating the dialysis equipment.

Objective: To present an evaluation of the radio contamination level and the medical staff exposure during dialysis of patients treated with iodine 131.

Method: Iodine 131 (activity of 1.85 GBq) was administered to the patient following dialysis. Approximately 48 hours later, the patient was asked to return for another 4 hours of dialysis. Staff training was provided and shielding and contamination protections were put in place before the procedure. Dose rate measurements were performed on the patient before, during and after that second round of dialysis. The contamination of the treatment area and of the dialysis equipment was also measured.

Results: Pre-dialysis dose rate measurements indicated that biological removal is negligible in terms of biological elimination of iodine 131. Post dialysis dose rate measurements (taken 2 m from the patient) yielded a value of 6 mSv / h and allowed the determination of the collected activity during dialysis (approximately 1.11 GBq). During dialysis, the maximum dose rate in the room next to the dialysis one was measured to be 7 uSv/h 7 minutes into the procedure and 2.4 uSv/h 60 minutes into it. Behind the near patient shielding (inside the dialysis room), the dose rate was under 0.75 uSv/h after 5 minutes of treatment and 1.07 uSv/h after 60 minutes. This increase in dose rate is due to the larger fraction of the blood volume on the other side of shielding. No contamination of treatment area (bedding, floor) was found. Only a tissue and napkin used by the patient was contaminated. As expected, the dialysis equipment showed signs of internal contamination. Washing cycles are made to diminish this contamination and the very low level of contamination that remains after those washing cycles is considered attached, therefore not dangerous for the other patients.

Conclusion: Iodine 131 treatments can be administered safely and effectively for patients who are receiving hemodialysis. There is no significant risk of contamination of the dialysis equipment and medical staff maximum exposure is evaluated to be 0.05 mSv. The treatment procedure must be under supervision of a member of the radiation safety team and the medical staff must be previously trained.

TS7b.4
Personalised Dosimetry in 90y-Microspheres Therapy of Liver Cancer Using the Oedipe Software and SPECT/CT Images

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Hepatocellular carcinoma is the most frequent primary liver cancer and the third cause of cancer death. Nearly 700,000 new cancers are diagnosed each year worldwide. A recent technique called selective internal radiation therapy is used to treat locally unresectable liver tumors by injecting radioactive microspheres labelled with ^{90}Y into the hepatic artery. Treatment planning consists in determining the activity to be injected to the patient where a compromise must be found between a maximum dose to the tumor and minimum to the healthy liver. The two conventional methods of dosimetry, the Body Surface Area method and the Partition model, are based either on an empirical approach where the activity is adjust according to the tumor and patient size, either on the MIRD approach where the tolerance dose to the liver must be respected. However, these dosimetric techniques consider a uniform repartition of the radionuclide. Therefore, in collaboration with the Hôpital Européen Georges Pompidou (Paris, France), we have developed a personalized dosimetry taking into account the heterogeneity of the activity distribution using patient SPECT images. The anatomy and tumor of the patient were segmented using the CT and PET images respectively. The dose calculations were performed at the voxel scale with the OEDIPE software, French acronym for "tool for personalised internal dose assessment" developed at IRSN, associated to the MCNPX Monte Carlo code. The mean doses were compared to the classic methodologies. To go further, isodose curves superimposed on the anatomical images were obtained and dose volume histograms were analysed to determine the optimal activity to be injected in order to optimize the treatment efficiency.

TS7b.5
Optimization of a Routine Method for Bone Marrow Estimation in 177Lu-EDTMP Therapy- Experience in Uruguay.

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Patients suffering from breast, lung and prostate cancer usually develop metastases or secondary cancerous lesions in bone. These lesions lead to pain and lack of mobility that conventional treatments not always give expected results. The use of systemic therapies with radionuclides is a good alternative to bone pain palliation to provide a higher quality of life. ^{177}Lu-EDTMP is an excellent alternative due to its radiopharmaceutical and nuclear decay characteristics (β- , t ½ 6.73 d). Dosimetry estimations is mandatory to avoid haematological toxicity resulting from absorbed dose delivered to bone marrow.

The purpose of this work was to optimize an image quantification method to improve bone-marrow and whole-body dosimetry in ^{177}LuEDTMP therapy. To perform this work a Mediso Gamma Cammera of 2 heads was used. A 5 mCi tracer dose of the radiopharmaceutical of interest was administered to patients, both anterior and posterior whole body images were acquired at 1, 6, 24 hours post administration according to the following conditions:

• 3/8 “, rectangular field,

• medium energy collimator

• window centered in the peak of energy (±15%)

• matrix 128 x 128

Scattering corrections were performed using triple-energy-window (TEW) method and attenuation correction of the patient was performed by transmission using a ^{57}Co flood according to conjugate view method. To determine the numbers disintegrations in red marrow, regions of interest were drawn over the lumbar spine or sacrum, as large proportions of the red marrow are situated in these regions.

The first images at 1 h were acquired without patient micturition and these counts were considered as 100% of injected activity. Percentages of reminding activity in the same ROIs were plotted in OLINDA/EXM to determine the absorbed dose in red marrow and main lesions.Mean bone marrow dose was 0.95± 0.2 mGy/MBq and mean whole body doses were 0.19 ± 0.07 mGy/MBq. These results are explained because of the rapid urinary elimination of the radiopharmaceutical. This method revealed to be efficient, easy to implement in routine and reliable to guarantee adequate bone marrow dose estimation before therapy with radionuclides.

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TS7b.6
Organ Dose Reconstruction for Hyperthyroid Patients Treated with 131I

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An organ dose reconstruction for hyperthyroid patients was performed to support the epidemiological analysis for the Thyrotoxicosis Therapy Follow-up Study (TTFUS). The aim of the epidemiological study was to evaluate the long-term effects of treatment of about 23,000 hyperthyroid patients with 131I. That population constitutes the largest group of hyperthyroid patients ever examined in a single study. In a previous evaluation, performed in the 1980s, the organ doses were estimated using the dose coefficients from ICRP Publication 53. The current dose assessment is based on the available measurements of 131I in thyroid, blood and urine of these patients that were made at various times after iodine administration.

A comprehensive biokinetic model, with ten compartments representing the thyroid, iodide (I-), protein-bound iodine (PBI), salivary glands, alimentary tract, urine and feces, was developed to reflect the measured concentrations of 131I in the body. Using the SAAM II computer code, the transfer rates between compartments were derived for 150 of 178 patients with at least 4 measurements of time-dependent activities in thyroid and blood (I- and PBI). Organ doses were then calculated using a biokinetic internal dose computer code (*KINDOSE* - internally developed at NCI). *KINDOSE* calculated the dose coefficients derived from the biokinetic model. In general, the dose coefficients (mGy/MBq) were correlated with the 24-h thyroid uptake, the values of which ranged from 30 to 100% of the administered activity. Equations were developed to relate organ dose coefficients (mGy MBq^{-1}) to percent thyroid uptake; they were applied to estimate organ doses for the hyperthyroid patients in the TTFUS. The overall average organ doses were 110 Gy for the thyroid; 2.3 Gy for the salivary glands; 1.2 Gy for stomach wall, and below 1 Gy for all other organs and tissues.

TS7c.1
Strengthening Justification of Medical Exposure in Diagnostic Imaging

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The use of radiation in medicine has increased dramatically in recent times. In some countries the population dose from medical exposures now rivals that from natural background. Scientific studies show a significant and widespread practice of inappropriate examinations in diagnostic imaging, where much of this arises from health systems' deficiencies and a lack of knowledge. There is a need to strengthen the implementation of the principle of justification.

The International Commission on Radiological Protection first presented the three-level approach to justification in medical exposures in the mid-90s, and this approach continues today. It is at the third level of justification, the use of a given radiological procedure for a given patient, that there needs to be more effective implementation, particularly in diagnostic imaging. The transfer of the concept to day-to-day practice has proved difficult due to several factors, including the respective role and responsibilities of the referrer and the radiological medical practitioner, conflicts of interest - financial or defensive medicine, societal or cultural differences in the practice of medicine - particularly the relationship of radiology with other areas of medicine, and simply the logistics of a busy imaging department. Further, the patient is having increasing "ownership" of their medical care, and self-presentation is another factor.

The International Atomic Energy Agency (IAEA) has recently revised the International Basic Safety Standards (BSS) and the new requirements in the area of justification of medical exposures are intended to provide the framework for effective implementation in the real world.

At the same time, the IAEA has also explored this issue through a series of consultancies. Means for ensuring effective implementation of justification in medical decision making were grouped under three practical issues: *Awareness*: devising means of effectively communicating about radiation risk to the relevant persons, including patients, public and physicians; *Appropriateness:* devising means of ensuring that those referred for radiological examinations really need them; and *Audit:* the audit of the effectiveness of the referral and related processes. These are the 3 A's of strengthening justification.

Recent media releases over the levels of unnecessary diagnostic medical exposures and the potential for some patients to received quite significant doses during their lifetime has provided impetus to the idea of tracking patient doses. Clinical context is crucial in each instance of justification for a patient, including information from previous radiological procedures. It has been argued that cumulative dose should be part of this information.

TS7c.2
Justification and Medical Exposures: Context and Implementation Issues in Practice

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The benefits of medical radiology are not in doubt; it has greatly enhanced the effectiveness of medical practice. However, they come at a price and radiology (particularly CT scanning) now accounts for over 98% of manmade human radiation exposure. Good practice in radiology relies on the principle that each examination is justified for each patient. A recent joint IAEA/EC workshop concluded that "There is a significant and systemic practice of inappropriate examination in radiology." It found doctors/health professionals generally have poor awareness of radiation risks and consistently underestimate them. Audit reveals that 20-50% of examinations are routinely not justified, and the figure can be as high as 60-77%. Paradoxically, a citizen upon becoming a patient loses the protection of a dose limit, and entrusts their care to physicians who seldom know the dose or risk to which they are exposed. The background and context for these observations are reviewed as are issues likely to facilitate or impede possible solutions. In particular issues presented will include awareness of dose and risk, the IAEA 3A's campaign, and the parallel, competing impact of Health Technology Assessment (HTA) initiatives.

TS7c.3
DEBATE: 'The rapid expansion of CT can be adequately justified through the existing framework of referral criteria'

Remedios, Denis*; Huda, Walter*

Dr Denis Remedios (proposing the motion) and Dr Walter Huda (opposing the motion) will take the audience through a debate on the use of referral guidelines, both global and national, in the justification of CT imaging; and whether these are sufficient for the purpose or whether a stronger emphasis should be required on the quantification of the radiation risks involved to enable individual patient justification.

TS7d.1
Quality Control and Patient Dosimetry on line for Computed Tomography

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The aim of this work is to present the functionalities and first results of an automatic system on quality control and patient dosimetry for diagnostic radiology, recently updated, and its application to computed tomography (CT) in a big university hospital.

The system is directly connected to the PACS (Picture Archive an Communication System) of the hospital and extracts useful information contained in the DICOM headers and Radiation Dose Structured Reports (RDSRs). But it could also be directly connected to the X-ray systems.

The full process is automatic and was tested during the past 6 months for 11,500 procedures in three 64 multislice CT units. The hospital performs around 300,000 diagnostic procedures per year (50,000 are CT exams). Data from all the modalities have been captured with only a small number of errors (less than 0.1%).

The system allows not only to extract, archive and process, in a relational data base, the parameters contained in the DICOM headers and RDSRs, but also to manage all the additional information contained in such headers for a quality control "on line" of the operational procedures. Information is gathered at four levels: patient (e.g. demographic data), procedure (e.g. X-rays system, name of the procedure classified following the criteria of the national Society of Diagnostic Radiology, etc), series (e.g. number of images per series) and images (e.g. radiographic and geometry parameters). Combining all this information, several trigger conditions can be implemented to generate alarms and to launch corrective actions in cases such as individual dose values per examination higher than 3 times the diagnostic reference level (DRL), median values of the last 30 procedures higher than the DRL, acquisition rotation time and kV out of the established protocols, patients with several CT exams in a short period of time, etc. For other modalities, trigger conditions like low compression in mammography or low kV in chest images can also be used. When alarms are produced, an automatic e-mail is sent to the Medical Physics Service to determine if a corrective action is needed.

The system allows export of data for statistical process. A personal patient dose record can be built, initially limited to the examinations performed at the hospital, but with the capability of further connection with other hospitals and outpatient centers using the same system.

Patient dose data are verified and corrected by the Medical Physics Service before issuing any formal patient dose report.

Mean and median Dose Length Product (DLP) values for the most common CT procedures are presented and compared with the existing references available, to decide if optimization actions are required to refine some clinical protocols. Effective doses have also been estimated from the DLP values, using the conversion factors based on the current Dose Datamed European Guidelines.

TS7d.2
Radiation Dose Optimization Approach At Dubai Health Authority Hospitals: The Control Of Patient CT Radiation Exposures During 2008-2010

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Introduction: A systematic approach in recording, observing and controlling CT doses were followed at Dubai Health Authority (DHA) radiology departments. In this paper, we are presenting the experience of Dubai Hospital in managing CT doses which resulted in a remarkable control of patient doses during a period of 3 years (2008-2010).

Method: Radiation doses generated from the 4MDCT Ge LightSpeed unit at Dubai Hospital are evaluated annually through the DHA Quality Control program. Dose measurements in terms of weighted CT Dose Index $CTDI_w$ (mGy) were frequently monitored using Head (16 cm diameter) and Body (32 cm diameter) ACR Accredited Cylindrical PMMA CT phantoms, Nero mAx 8000 meter and 10 cm pencil ion chamber.

Patient radiation doses in terms of Dose Length Product (DLP, mGy.cm) and volume CT Dose Index ($CTDI_{vol}$, mGy) along with patient and imaging parameters (Age, weight, kVp, mA, pitch, slice width, No. of slices, IQ, … ect) were manually recorded during 2008 for the common CT examinations: Head, Chest and Abdomen and Pelvis scans. In 2009-2010, these CT dose data were recorded within the Radiology Information System (RIS) and the Picture Archive and Communication System (PACS). CT Effective Doses (ED mSv) were also estimated in this work. Data accuracy verifications were followed and presented in this paper.

Results: The total number of adult patients undergone common CT examinations in this study was 6528 (558, 2617 and 3353 in 2008, 2009 and 2010, respectively) while pediatric group was 404 (55, 184 and 165 in 2008, 2009 & 2010, respectively). The doses results (DLP, $CTDI_{vol}$ and ED) in this study were analyzed as average and 3rd quartile for adult and pediatric patient groups and were compared to the initial Dose Reference Levels (DRLs) established for the DHA hospitals. The positive outcome of this radiation exposure study is manifested in the significant CT dose reduction for adult and pediatric patient groups with no noticeable drop in image quality. In compare to the local DRLs, adult doses were reduced by about 52%, 17.5% and 31% for head, chest and abdomen and pelvis examinations, respectively. For the pediatric group, the doses were reduced by about 46%, 38.6% and 48.6% for head, chest and abdomen and pelvis examinations, respectively. This has led to the introduction of new local DRLs. There were variations in the total number of patients for each common CT examination over the 3 years of this study. Hence, to avoid bias analysis, further investigations were considered.

Discussions and Conclusions: Radiation dose exposure control obtained in this study and technical actions to achieve it were discussed and found to be promising. Study limitations and future further considerations, such as the introduction of new local DRLs, were discussed in this paper. The RIS/PACS approach to record patient doses is effective and provides advantage of obtaining evidence on patient individual cumulative doses and population exposures.

Key words: CT Doses, CT Radiation Doses, Patient Radiation Doses, Control of Patient Radiation Doses, Control of Radiation Exposure. Dose Length Product (DLP), volume CT Dose Index (CTDIvol) and Effective Doses (ED).

TS7d.3
An Effective Method of Patient Radiation Safety Assessment in a University Medical Center

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A Radiology dose assessment group was started in 2008 at the Penn State Hershey Medical Center. The group consisting of the Radiation Safety Officer, a Senior Clinical Radiology faculty member, an Imaging physicist and a CT Physicist began the initial assessment by reviewing CT protocols throughout the Medical Center. Affected stakeholders are invited to meetings and brainstorming sessions which are designed to encourage open dialogue.

Progress has been substantial. Midway through 2011, CT protocols have been standardized across all CT scanners and locked down so all changes are reviewed, weight- stratified pediatric protocols have been developed, neurological radiology protocols have been optimized with dose reductions as high as 70% and a low-dose follow up shunt protocol has been developed and applied. In addition, a statistical analysis of repeat CT patients was completed and a standing report of repeat CT patients was implemented. New, reduced kVp pediatric protocols were put in place resulting in approximately 20% lower dose. Finally, average adult brain, chest, and abdomen/pelvis CT doses were identified for comparison with national averages and published data.

The role of the facility's radiation safety culture and the inclusion of both the senior clinical Radiology faculty and affected stakeholders are critical to the success of this process.

TS7d.4
Latin American Results in Diagnostic Mammography under IAEA Programme: Radiological Protection of Patients in Medical Exposures (TSA3)

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Latin American countries (Argentina, Brazil, Chile, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Paraguay, Uruguay and Venezuela) working under IAEA Technical Cooperation Programme *TSA3 Radiological Protection of Patients in Medical Exposures* have joined efforts in the optimization of radiation protection in mammography practice. Through surveys of image quality and patient doses, the region has a unique database of dose reference levels for analog and digital equipments that will direct future optimization activities, towards the early detection of breast cancer among asymptomatic women.

During RLA9/057 (2007-2009) 20 institutions participated in a dose survey that included verification by the radiologist of European image quality criteria for each patient; in this phase only analog equipment was included. Regional training on methodology and measurement equipment was addressed in May 2007. Mean Glandular Dose (MGD) was estimated using the incident kerma in air and relevant conversion coefficients for both projections (CC and MLO). For phase two, RLA9/067 (2010-2011), it was decided to include also digital systems in order to see their impact in future dose optimization activities. Any new country that joined the project received training in the activities through IAEA expert missions. 32 new institutions participated (12 analog and 20 digital equipment).

A total of 2600 patient doses were collected during this study. 87% fulfilled 80% of image quality criteria and from them MGD (mGy) for both projections were estimated for each institution and country. Regional results (75 percentile in mGy) show for CC and MLO respectively: RLA9/057 (analog) 2.68 and 3.18; RLA/067: 2.57 and 3.15 (analog) and 2.69 and 2.90 (digital). Regarding only digital equipment for CC and MLO respectively, CR systems showed 2.59 and 2.93 and DR systems 2.78 and 3.04. Evaluation of image criteria for digital systems showed a higher score on an overall basis.

Based on the BSS reference dose (3mGy), it can be observed that there is enough room to start optimization processes in LA; several countries or even particular institutions have values much higher than the 3mGy. Main issues to address are: lack of well established QA programs for mammography, not enough medical physicists with training in mammography, an increase in patient doses with the introduction of digital equipment and to create awareness on radiation risk and optimization strategies.

TS7d.5
A New Method for Dosimetry and Image Quality Assurance in Mammography and Breast Tomosynthesis

de las Heras Gala, H*[1]; Schöfer, F[1]; Tiller, B[1]; Chevalier del Río, M[2]; Zwettler, G[3]; Semturs, F[3]

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Introduction and purpose: The latest developments in breast imaging technology have underlined the need for appropriate dosimetry and image evaluation methods for routine quality assurance. We are presenting the so called Quart phantom together with an evaluation method to address this need for digital x-ray mammography as well as breast tomosynthesis. We compare our dose measurements to the ESE readings from the console and standard ion chamber measurements, and the image quality evaluation to the known CDMAM phantom test, which receives criticism because of its high cost in terms of price, evaluation time with human readout, as well as number of exposures and related data storage needs with automatic readout.

Materials and Methods: The presented method is based on the visual evaluation of Landolt C's included into the Quart phantom, which are constructed to be equivalent to microcalcifications inside the breast. The image quality assessment produces a score as a function of the average glandular dose (AGD), and can measure detectability in a wide range of background attenuation. Additionally, the Quart phantom contains objects for a software-based evaluation of resolution and contrast-to-noise ratio, and specific objects to be used for quality control of digital breast tomosynthesis. To compare the method with the CDMAM test, images were obtained with FFDM flat panel systems from Siemens, GE and Hologic in a series of gradually reduced doses and evaluated following the specific protocol of each methodology. In-depth dose is measured by insertion of a small calibrated detector in the specifically designed slot of the phantom.

Results: A threshold score equal or above 18 (maximum possible score being 42) has been identified with a passed CDMAM test on acceptable values, showing the equivalence of both methods. However, the lower variability of the new method has shown that an acceptable uncertainty is achieved with the acquisition and evaluation of 5 images or less. The detector does not affect the automatic exposure control although it is placed inside the phantom.

Conclusion: The suggested method can increase the efficiency of quality assurance checks in digital mammography. The Quart test is consistent with the CDMAM test, but it covers a wider range of system aspects and it is less expensive in terms of manufacture costs, operator time and evaluation effort.

TS7d.6* Implementation of Acceptability Criteria for Medical Radiological Equipment in Belgium

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Introduction: In Belgium it is obliged by law for a holder of a radiological facility that a medical physics expert performs quality control of all x-ray equipment in the facility. Since 2001, the Belgian legislation referred to the European guidance document Radiation Protection 91 for acceptability criteria. These criteria included criteria for medical diagnostic x-ray equipment, but did not contain any criteria on digital detectors, and few criteria for the evaluation of image quality. A strong need for up-to-date acceptability criteria existed in order to implement quality control by the medical physicist in radiology.

Materials & Methods: By demand of the Belgian Federal Agency for Nuclear Control (FANC), the Belgian Hospital Physicist Association (BHPA) drafted a document containing the acceptability criteria for medical radiological equipment. The criteria in this document were determined by internationally benchmarking and experimental test results. Using this document as a basis, the Federal Agency for Nuclear Control (FANC) investigated how these recommendations could be put into a mandatory format, in collaboration with the involved stakeholders.

Results: The final document of the BHPA, published in 2007, contains extensive criteria and testing methodologies for general diagnostic X-ray equipment, such as tele-operated tables, ceiling mounted systems. The FANC redrafted the document into a regulatory format, adding a chapter on the application of the criteria. The legislative document was implemented in September 2011 as a FANC Decree laying down the acceptability criteria for medical radiological equipment.

Discussion & Conclusion: The determination of acceptability criteria was an extensive process which involved a broad benchmarking and stakeholder involvement. The process however proved to be efficient, and is currently followed in Belgium for the determination of other acceptability criteria. Several drafted documents containing acceptability criteria will be implemented into Belgian legislation (e.g. fluoroscopy systems, CT).

With the aid of many medical physicists in Belgium, FANC will closely follow-up the implementation of the acceptability criteria and the status of the radiological equipment. The feedback provided by the medical physics experts will allow to further improve the existing acceptability criteria to maintain an up-to-date status. The Federal Agency will, together with the certified medical physicists, continue to strive towards optimization in Belgium for radiological equipment.

TS7d.7
Radiation Protection of the Australian Public via the Introduction of a National Diagnostic Reference Level Scheme.

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The growth of diagnostic imaging using ionizing radiation is steadily increasing worldwide. The estimated growth of multi-detector computed tomography (MDCT) scanning is approximately 9% per annum. In 2008 the estimated annual caput effective dose to the Australian population was 0.8 mSv, this has increased to an estimated 1.2 mSv in 2010.

Diagnostic imaging is required to be undertaken using the constraints of appropriate referral, justification and optimisation strategies to ensure a positive risk-benefit outcome for the patient. While the radiation insult from the high dose imaging procedures may give rise to some limited increase in stochastic risk and the expression of deterministic damage particularly in the case of high dose interventions, the additional risk to the patient remains supportable when compared to the risk of not having the investigation(s). However, there may be an impact at the national level contributing to an increase of radiation risk at a population health level.

Australia currently does not have a state/territory or national patient medical record system. It is therefore very difficult to gain any complete and accurate information on a patient's exposure history as they move across medical institutions. In the absence of this information, one compensatory strategy is to support the imaging practices in ensuring that the doses that are delived are within a reasonable range when compared to that of their peers. This support can be achieved with the application of diagnostic reference levels at a national level. The ARPANSA national DRL is the 75th percentile (third quartile) of the spread of the median doses of common protocols from a national survey of imaging practices. A local practice reference level (PRL) is defined as the median value of the spread of doses for common protocols surveyed at the local radiology practice for 20 patients. The development of DRLs will be derived from a nationwide survey of local PRLs which, it is assumed, have produced images of acceptable diagnostic quality as defined by the reporting specialist.

It is expected that significant outliers, greater than the 75th percentile, will undertake a review of their protocols and implement an optimisation strategy to reduce their doses if not clinically justified.

It is envisaged that future practice submissions to the NDRL survey should reflect an appropriate dose reduction.

While the initial work has been centred around MDCT, ARPANSA will commence surveys into other imaging modalities. These include interventional radiology, PET/CT, nuclear medicine, mammography and general radiography.

Key Words

Diagnostic reference level, caput dose, optimisation

TS7e.1
Challenges in Paediatric Interventional Fluoroscoppy

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Interventional fluoroscopy procedures are commonly performed on pediatric patients in Radiology and Cardiology. Due to their complexity, these procedures result in large patient radiation doses. Due to the size of these doses and the sensitivity of pediatric patients to ionizing radiation, these doses must be carefully managed.

This lecture addresses the challenge of reducing the entrance skin dose to the pediatric patient during interventional fluoroscopic procedures while maintaining good image quality regardless of the patient's size. This is achieved by working with the manufacturer of the fluoroscope to appropriately configure and leverage the design features of the imager. First, one must deliver the necessary radiation level to the image receptor, dictated by the selected image processing and acceptable level of quantum mottle in the image. Second, the appropriate radiation level at the image receptor must be properly adjusted as pulse rates, Field of View, and filter thicknesses change during the examination. Finally, the high voltage, tube current, pulse width, and filter thickness must be appropriately adjusted as a function of patient size to properly reduce the entrance skin dose as the radiation level to the imager is properly maintained.

Learning Objectives:

1. Understand basic radiation doses required at image receptors as a function of selected image processing.
2. Understand appropriate changes to image receptor doses as a function of pulse rates, Field of View, and added filtration.
3. Understand appropriate levels of high voltage, tube current, pulse width, and filter thicknesses during pediatric fluoroscopy.

TS7e.2
International Project on Individual Monitoring and Radiation Exposure Levels in Interventional Cardiology

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Introduction: IAEA has launched the Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR) project. The Working Group on Interventional Cardiology (WGIC) started a 3-year activity to assess levels of exposure and methods applied for individual monitoring and to setup an international database of occupational exposures.

Methods: Two worldwide surveys have been addressed to national regulatory bodies (RB) and interventional cardiologists (IC) to collect information and staff doses from a hospital sample.

Results: 200 ICs from 32 countries and 81 RBs from 55 countries responded. Concerning dosimetry: 72% of ICs use personal dosimeters, and 36% always two; 26% knew their doses.

Only 57% of RBs define number and position of dosimeters for the staff monitoring requiring: 40% one dosimeter, 83% dosimeter be worn over the apron and 20% two dosimeters. Less than 40% of RBs could provide doses.

Preliminary doses from 20 hospitals in 15 countries are: mean (maximum) Hp(10) over apron 7.6 (42.3), 6.1 (26.3) and 3.4 (14.6) mSv/y, respectively for hemodinamists, electrophysiologists and nurses.

Conclusions: Survey results proof poor compliance with staff monitoring recommendations in a large fraction of cathlabs, the need for staff monitoring harmonization and staff education. The large majority of IC doses are of poor quality, while those of nurses are generally of acceptable quality. Quality indexes have been developed to identify poor data for the purpose to automatically analyse doses will be provided to the designed and under-development international database.

TS7e.3 Monitoring the Eye Lens

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To prevent the induction of cataracts by ionizing radiation (photons or betas), the International Commission on Radiological Protection (ICRP) has lowered the annual dose limit for the eye lens from 150 mSv down to 20 mSv for occupational exposures. Thus, protecting the eye and monitoring the lens dose to prevent exceeding the dose limit is more necessary than formerly assumed.

It was investigated which type of dosemeter (which dose quantity) is suitable to monitor the eye lens dose in which type of application to give guidelines on monitoring the lens dose when necessary.

Results: $H_p(0.07)$ dosemeters are constructed to monitor the local skin dose in 0.07 mm depth as the radiation-sensitive epidermis lies about 0.07 mm below the surface. In pure photon radiation fields, e.g. in interventional radiology, $H_p(0.07)$ dosemeters are appropriate to monitor the lens dose when worn near the eye and if the back of their case consists of thin plastic. In beta radiation fields, e.g. in nuclear medicine, $H_p(0.07)$ dosemeters may overestimate the lens dose by a factor of 100 or more. Thus, they are unsuitable here.

$H_p(3)$ dosemeters are constructed to monitor the lens dose as the radiation-sensitive part of the lens lies about 3 mm within the eye. Only very few $H_p(3)$ dosemeters exist, but, by construction, they should monitor the lens dose also in beta fields correctly. However, this has not yet been demonstrated.

$H_p(10)$ dosemeters are constructed to monitor the whole body dose as the inner organs are assumed to lie about 10 mm within the trunk. $H_p(10)$ dosemeters usually underestimate the lens dose and are, thus, unsuitable.

Conclusions: Protection measures such as lead glass shields or glasses should be used. In case exposures cannot be avoided, appropriate dosemeters must be worn near the eye behind devices used to shield the eyes but not behind a shield worn on the trunk (e.g. a lead apron).

Literature:

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TS7e.4
Paediatric Computed Tomography Exposure and Radiation-Induced Cancer: The French Ongoing Cohort of Childhood CT Scan

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Background and aims

The increased use of computed tomography (CT) scans for paediatric patients raises the question of a possible impact of such ionising radiation (IR) exposure on the occurrence of secondary leukaemia and cancers. We describe the preliminary results of an ongoing cohort study of children exposed to CT in France, performed in collaboration with the "Societe Francophone d'Imagerie Pediatrique et Prenatale". This cohort will be included in the European collaborative EPI-CT project with 8 other national cohorts.

Materiel and Methods

In 19 of the most important French paediatric radiology departments, demographic and IR exposure information concerning children less than 5 years, who underwent at least one CT scan between 2000 and 2006, were collected. Inclusion of patients will continue from 2007 to 2013 according to the EPI-CT project. Absorbed organ doses were calculated with the "CT-expo" software.

Results

Until now, 28,190 children free of cancer or leukaemia at the first CT scan examination have been included. Age at first CT scan exposure was less than 1 year for 42% of the population. The mean number of CT examination per child was 1.5 (min 1, max 30) and concerned head in 66% of the cases, thorax in 22%, abdomen and pelvis in 10% and other localisations in 2%. Highest cumulated organ doses were observed for brain and lens during head exposure and mean absorbed doses were 27 mGy (range: 2.8 - 478 mGy) and 30 mGy (0.5 - 620 mGy), respectively.

Conclusion

This cohort allows to better characterizing organ doses associated with CT scan exposure in childhood. Relatively high doses to radiosensitive organs (lenses, ovaries, breast, etc…) have been observed, as well as large dose ranges according to the protocols used. The follow-up of the cohort will be based on cancer incidence up to age 15 to quantify a possible excess paediatric cancer risk.

TS7e.5
Basic Recommendations for Interventional Procedures

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Introduction:

Given the importance of the risks involved in Interventional Cardiology the Argentine College of Interventional Cardioangiólogos (CACI) has appointed a task force composed of cardiologists and specialists in Medical Radiation Protection for establishing recommendations in order to prevent deterministic effects systematically and control stochastic risks for the patient and the attending physician team.

Objective:

To determine the courses of action and appropriate techniques to ensure that doses are as low as possible (optimization of practice) without affecting the therapeutic goals or the quality of the procedures. Methods: We evaluated various procedures under controlled conditions in a number of services Hemodynamics of the City of Buenos Aires, determining the radiation dose to the patient and staff, for different working conditions and operating parameters. It was estimated in each case the peak skin dose, the alarm values for deterministic effects and patient follow-up. We estimated the “patient-specific factors” that determine the onset of effects and risk assessed procedures inherent complexity.

Results:

Once the data collection work in different operating conditions dosimetric established several sets of recommendations for different stages of intervention and different recipients as follows:

1) What the cardiologist should know before entering the operating room:

2) What the cardiologist should check before starting a film sequence.

3) Criteria to be applied during a film sequence.

4) What must register the wizard at the end of an intervention.

5) The measures to be taken by the Director of Hospital

6) The measures to be taken by the competent authority

7) Factors to minimize dose to the patient and physician.

8) How to estimate the dose in the staff involved.

9) The Proper use of protective gear.

The set of recommendations resulted in the publication of leaflets and posters aimed at medical staff, technicians and nurses.

Conclusions:

It is highly recommended to conduct a periodic monitoraje radiation fields across Hemodynamic service to determine the most appropriate operating parameters to optimize practice.

It was found the suitability of the presence of a radiation protection specialist services Hemodynamics.

KEYWORDS:

Radiological Protection of the Patient, Interventional Radiology, Reference Levels, Doses.

TS7e.6
Randomized Comparison of Occupational Dose between Radial and Femoral Access for Percutaneous Coronary Intervention, Radifemoproc

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Background: Some trials have shown controversial results regarding the radiation protection aspects comparing radial (RA) vs. femoral access (FA) for percutaneous coronary intervention (PCI). We aimed to assess whether radial access has or not more radiation exposure to the first operator than femoral access.

Methods: Between July 2010 and February 2011 136 patients (P) (42 female) were randomly assigned to RA (71 P) or FA for PCI in our center in Montevideo, Uruguay. The endpoint was the first operator over the apron dosimetry (FOD) located at the thyroid collar. This position may be extrapolated to the eye lens dose. We included all consecutive P submitted to PCI excluding previous CABG and cardiogenic shock. The FOD was measured with electronic dosimeter DMC 2000 X de RadPro International GmbH, Wermelskirchen-Germany.

Results: The mean age was 61.2 y/o (60.3 RA and 62.5 FA), the mean weight was 79.5 kg in RA and 78 kg in FA. Primary PCI was 52% in RA and 40% in FA, average number of vessels treated were 1.2 in both groups and the number of stents/P were 1,7 in RA and 1.6 in FA. The radioscopy time was 16.5 minutes (m) in RA and 15.8 in FA. The cine series recorded were 21.7 in RA and 21.4 in FA. The number of images were 1979 in RA and 1892 in FA. The dye volume was 188 in RA and 199 in FA. The whole PCI time was 72 m in RA and 66 m in FA. In all the above data there were no statistical differences. The FOD was 69.4 microsieverts in RA and 49.9 in FA ($p=0.02$)

Conclusions: There were no statistical differences between both groups related to time of intervention, vessels treated, stents implanted, dye volume, radioscopy time, cine series and images recorded. However we observed a statistical higher FOD in RA compared to FA. This finding may be explained because of the difficulty in optimizing the position of the ceiling suspend protective screen.

TS7e.7*
Estimation of Occupational Radiation Dose Levels of Interventional Cardiologists at the Philippine Heart Center

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The highest doses recorded for radiation workers in the hospital setting are for those who are occupationally exposed during fluoroscopically guided procedures. The aim of this study is to estimate the effective dose, *E* to interventional cardiology (IC) operators at the cardiac catheterization laboratory of the Philippine Heart Center by the use of a digital electronic personal dosimeter (EPD). Clinical data and technical factors were gathered from 40 coroangiogram (CA), 14 percutaneous transluminal intervention (PCI), and 10 double set-up (DSU) procedures. Estimated *E* from these procedures is 1.42/2.27-4.54 mSv for CA, 0.172/0-0.804 mSv for PCI, and 1.94/0.582-5.85 mSv for DSU. These values were found to be similar to the values found in literature. This is the same for the *E*/DAP values of 0.108 μSv/Gy.cm^2 for CA, 0.010 μSv/Gy.cm^2 for PCI, and 0.136 μSv/Gy.cm^2 for DSU. The estimated weighted annual dose for a busy interventional cardiologist is 3.53/2.852-11.19 mSv, which is lower than the dose limit given by the BSS.

TS8a.1
ICRP Recommendations on Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste

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In August 2011 the ICRP published a draft report on "Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste" for public consultation. This paper describes the recommendations made in the final version of this report, to be published in 2012, together with an overview of the comments received during the consultation period and how these were addressed.

The report explains how the 2007 ICRP System of Radiological Protection described in ICRP Publication 103 can be applied in the context of the geological disposal of long-lived solid radioactive waste. The report is written as a self standing document. It describes the different stages in the lifetime of a geological disposal facility and addresses the application of relevant radiological protection principles for each stage depending on the various exposure situations that can be encountered. In particular, the crucial factor that influences the application of the protection system over the different phases in the lifetime of a disposal facility is the level of oversight that is present. The level of oversight affects the capability to reduce or avoid exposures. Three main timeframes have to be considered for the purpose of radiological protection: time of direct oversight when the disposal facility is being implemented and active oversight is taking place; time of indirect oversight when the disposal facility is sealed and indirect oversight is being exercised to provide additional assurance on behalf of the society; time of no oversight when oversight is no longer exercised because memory is lost.

TS8a.3
Radiological Assessments in Support of the UK Review of Exemption Orders for Radioactive Waste

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In 2009 and 2010, as part of the better regulation initiative, the Department of Energy and Climate Change (DECC) and the Devolved Administrations consulted on a new exemption orders regime under the Radioactive Substances Act 1993 and the Environmental Permitting regulations (EPR) 2010. The overall aim was to have a simpler set of exemption orders, informed by risk, that are more easily linked to the European Basic Safety Standards Directive (BSSD).

As part of the work to support the review of the exemption orders, DECC asked HPA to advise on radiological protection and health related aspects of the proposed regime. The new regime contains exclusion levels (activity concentrations below which the waste is not considered to be radioactive) and exemption levels (total activity or activity concentration levels below which a permit for radioactive waste disposal is not required). DECC asked HPA to perform a number of radiological assessments to ensure that the exclusion and exemption levels for radioactive wastes in the new regime took into account the associated risk to health. HPA also advised on the use of internationally agreed exemption levels in the new regime.

HPA performed specific radiological assessments to determine: suitable exemption levels for large volumes of solid wastes containing naturally occurring radionuclides (NORM); suitable exemption levels for aqueous liquids; suitable exclusion levels for NORM gases and NORM liquids to compliment internationally agreed values for NORM solids; and suitable exclusion levels for non-aqueous liquids. The paper describes these radiological assessments, giving details of the scenarios and important parameter values and presenting selected results.

The results from the HPA's radiological assessments are cited in the single Exemption Order that comes into effect in the autumn of 2011, replacing the previous Exemption Order regime.

TS8a.4
Comparison of Provisions for Exclusion and Exemption of NORM Radionuclides Associated with the Oil and Gas Industry in the North Sea

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A liaison group was established in 2008 comprising competent authorities from Norway, the UK, Denmark and Germany, with responsibilities for regulating the accumulation and disposal of NORM wastes arising from the extraction of oil and gas in the North Sea area. This group has met on a regular basis to discuss issues of joint interest, and provided a valuable forum for discussing the implications of new legislation that was being developed in parallel in the UK and Norway. This joint working allowed greater harmonization of approach and where differences were necessary for these to be explained and understood. The regulatory provisions for clearance and exemption for NORM radionuclides in these countries have become closer as a result of the recent changes in legislation and associated regulations.

There are some differences in the clearance values adopted, depending on whether EC RP 122 Part II or the IAEA RS-G-1.7 criteria were adopted as a basis for clearance. There are also differences in the way that the different countries approach exclusion for liquids, for example, in the UK, specific exclusion criteria have been derived for NORM containing liquids.

In both the UKL and Norway, under certain conditions, it is also possible that wastes containing activity concentrations in excess of clearance levels may be exempted from the full permitting requirements, e.g. by complying with rules set out in legislation. This paper provides a comparison of the provisions for clearance and exemption associated with NORM radionuclides in the UK, Norway and Denmark and looks at the different “exemptions” available. Similarities and differences are highlighted and potential implications for the oil and gas industry are explored.

TS8a.5
Optimization of Management of Liquid Radioactive Waste Generated in Research and Education Centers

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The correct adaptation and disposal of the radioactive waste generated is one of the most important issues in the management of radioactive installations of the research and education centres.

Some technical guidelines have been published in Spain with the aim to improve the management of this waste. However, some issues had not been resolved completely, therefore four important research and education centres started one research project, in 2008, with a grant of ENRESA (National Company of radioactive waste in Spain) trying to resolve them.

The radiological and chemical characterization of the generated waste has been carried out in the indicated project, and the management model for different waste has been proposed (solid and liquid waste, scintillation vials full of scintillation solution and uranyle salt waste). This work shows the proposed management for aqueous and organic liquid waste considering it as one the most important issues of the project.

The results obtained of liquid waste characterization show very low activities; therefore this waste could be clearance in different techniques.

The aqueous liquid waste could be directly discharged through the normal sewerage system. The management protocol proposed clearly shows the necessary calculations to determine the maximum discharge concentration for the aqueous liquid waste that does not exceed the annual limit on intake for ingestion for members of the public.

Regarding the organic liquid waste, the discharge via the sewer system is not possible taking into account their chemical composition. In this case the disposal way proposed is the incineration. The management protocol for organic liquid shows the necessary calculations to determine the reference levels applicable to the incineration of this waste than not exceeding the constrain dose of 10 ìSv per year in an individual member of the public. This model proposes that the hazardous waste company perform the incineration.

The present objective is to show the management model proposed in a technical guide facilitating the management waste to the radiation protection professionals of the research and education field.

TS8b.1
The Importance And Uncertainties Of Parameters Related To The Radiological Analysis Of NORM For Use In Public Dose Assessments

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Public dose assessments have to relate sources of radioactivity and radiation to the amount of radioactivity to which members of the public are exposed through external or internal exposure. The assessment methodology is normally based on mathematical atmospheric and aquatic transfer models which rely on standardised parameters and the results of full nuclide analyses. Since the waiting period for the latter can be in the order of 6 months, the radiological assessment places stress on the timelines of EIA processes. An alternative approach is therefore needed. In this study the assessment methodologies for various exposure pathways were evaluated to compare the importance and uncertainty of various parameters and the errors introduced through simplification and reduction of analyses, particularly comparing it with model, scenario and other parameter uncertainties.

Important findings relate to the use of gross activities for inhalation dose assessments, the dominance of uranium in drinking water due to its solubility and chemical toxicity and the large uncertainty in soil-to-plant concentration factors in the determination of doses from food ingestion, mainly due to the inclusion of the uncertainties of K*d* values in these factors.

As a case study a public dose assessment of a uranium mine was performed using the current and the proposed methodology and the results are discussed as a conclusion.

TS8b.2
Doses to Public Arising From the Use of Radioisotopes in Radionuclide Laboratories and Hospitals in Finland

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In the study, the radiation doses to the public caused by emissions from radionuclide laboratories and hospitals that use radionuclides in treatment of patients are assessed. The study has been made in part to support regulation renewal. Emission limits do not apply to medical use of radioisotopes, so to that extent the results are mainly for informational purposes.

In Finland, radionuclide laboratories are exempted from a waste management plan, if the doses caused by the radiation practice to the representative person of the public are less than 10 µSv / year. One of the aims of this study was to determine, as accurately as possible, the emissions [Bq/a], which cause a 10 µSv annual dose.

Screening calculations are commonly used in assessing the radiation doses caused by gaseous and liquid discharges due to radiation practices. In this study, two kinds of discharges were considered. These were radioactive waste sent to a waste incineration plant and liquid discharges into sewage system. When sent to waste incineration plant, radionuclides can end up in either flue gases discharged into air, or in ash, which is deposited at landfill sites. Liquid discharges enter the waste water system and are separated between processed water and sludge. Doses to both workers and representative persons were assessed. The considered exposure pathways include e.g. direct exposure to flue gas and consumption of affected foodstuffs.

The calculation is mainly based on models developed by IAEA. A model by the Swedish Radiation Protection Authority was also applied, specifically when modeling the seepage of radionuclides from a landfill site into ground water.

For the calculation, an Excel-spreadsheet that utilizes macros was developed. The template allows one to calculate the radionuclide concentrations and doses in different situations. The purpose was to achieve results that are as realistic as possible. However, if this was impossible due to e.g. lack of information, a conservative approach was selected. For example, the half life is not always fully taken into account, resulting in an overestimation of radionuclide concentration.

The assessment was done for three cities; Turku, Tampere and Seinäjoki. Cities were selected on the basis that there are a large hospitals that use radioisotopes and different waste treatment systems. For example, in Turku the processed wastewater is discharged into sea, in Tampere into a lake and in Seinäjoki into a river. Although the calculations were based on city-specific information, the model is not restricted to the chosen cities.

TS8b.3
Radiological Protection Challenges of Retrieval of Legacy Intermediate Level Wastes (ILW) at the Solid Waste Plant B462 RSRL Harwell

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Originally the United Kingdom Atomic Energy Authority (UKAEA) was involved in all kinds of Research and Development (R&D) into nuclear energy, including running a number of research nuclear reactors of differing types. The UKAEA site at Harwell, Oxfordshire was established in 1946, but the last reactor at Harwell ceased operation in 1990, therefore changing the focus of UKAEA towards decommissioning and radioactive waste management. Since 2009, the nuclear site licence and radioactive waste disposal authorisation for Harwell has been held by Research Sites Restoration Ltd (RSRL), who have been tasked with decommissioning the sites at both Harwell and Winfrith in Dorset on behalf of the UK Nuclear Decommissioning Authority (NDA).

The solid waste facility, B462, within the Harwell nuclear licensed site has been receiving wastes from this nuclear research for the last 50 years. One of the ongoing key projects involves the retrieval, repackaging, and storage of legacy Intermediate Level Wastes (ILW) from below ground storage tubes. The radioactive waste containers stored within the vertical storage tubes before 1988 were constructed of mild steel, and in a number of forms including “common or garden” paint cans and fruit tins. More recently, stainless steel receptacles with engineered sealing and release mechanisms have been utilised. The mild steel construction of some of the older stored wastes, sometimes limited control of waste container contents and the unexpected longevity of storage has caused some of these cans to have corroded and even disintegrated spilling their contents into the tubes. Radioactive wastes in this condition obviously increase the challenge of safe and controlled retrievals. New facilities have been provided to improve the throughput and effectiveness of retrieving and re-packaging of the historic ILW. For example, a second retrieval machine, RM2, has been designed to enable the recovery of over 6500 of these waste cans and their contents, whatever their condition. RM2 became fully functional in 2009.

This paper describes the work already undertaken to safely extract these historic wastes, focussing on the practical radiological protection challenges faced. Topics covered will include the radiation protection practices appropriate when dealing with issues such as waste deterioration, as well as the contamination control issues which arise a) at interfaces between modern engineered retrieval machines and simply engineered storage tubes, b) during access to multiple tubes and c) during the movement of machinery to enable further tubes to be emptied.

TS8b.4
Disposal Activities Within The IAEA Division Of Radiation, Transport And Waste Safety

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Within the Division of Radiation, Transport and Waste Safety of the IAEA activities related to disposal of radioactive waste concentrate on three main areas:

• Development of international safety standards

• Application of safety standards

• International harmonization projects on safety cases for different types of disposal

Following the recent publication of safety requirements on disposal of radioactive waste the development of safety standards aims at completing the series of facility specific safety guides (near surface disposal and geological disposal) and finalizing the series of thematic safety guides on the safety case and safety assessment and on monitoring and surveillance of radioactive waste disposal facilities. One of the main activities on the application of safety standards is linked to the assistance provided to Member States. Training missions, fellowships, scientific visits are organized to strengthen capabilities of member states in the development or review of the safety of radioactive waste disposal facilities. In addition, on the request of the Member States, assistance is provided through the organization of peer reviews on parts of radioactive waste management programmes.

Finally two International harmonization projects on disposal of radioactive waste are implemented by the division:

• A project related to the demonstration of safety of near surface disposal facilities (PRISM) and

• A project on the demonstration of safety of geological disposal facilities (GEOSAF).

International harmonization projects provide a forum to exchange ideas and experience in carrying out safety assessments and developing safety cases, with a view to improving methodology and working towards harmonized approaches to safety demonstration.

TS8b.5
Radiological Impact Assessment in the LLWR's 2011 Environmental Safety Case

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The Low Level Waste Repository (LLWR) is the United Kingdom's principal facility for the disposal of LLW. The LLWR submitted an Environmental Safety Case (ESC) to the Environment Agency on the 1st May 2011. The ESC is a major submission that will decide the future use of the LLWR and has important implications for the success of the UK's LLW Strategy and operational and decommissioning programmes.

The 2011 ESC addresses a wide range of aspects relating to environmental safety. It covers environmental management, safety culture and regulatory and stakeholder engagement; system characterisation and understanding; optimisation and site plans; and impact assessment and waste acceptance.

This paper focuses on a number of new or innovative aspects of the optimisation studies, the radiological impact assessments and the approach to waste acceptance.

Optimisation is a key principle of radiological protection and it is a key regulatory requirement that all aspects of the design, operation and closure of the repository relevant to radiological safety are optimised, i.e. doses and risks are as low as reasonably achievable (ALARA). Detailed modelling and assessment results have been used in decision making on the need for remediation of past disposals and on balancing the requirements of short- and long-term protection in the engineering design.

Radiological impact assessments have been undertaken for the period of active management of the facility and afterwards, covering a range of pathways, including direct irradiation, radioactive gas and dust, surface water bodies, groundwater, coastal erosion and inadvertent human intrusion.

For the groundwater pathway, the highest risks are calculated assuming that a well is constructed and water abstracted. An improved approach and model for assessing the risks from a well has been developed.

Similarly, improved approaches have been developed for assessing the impacts from the release of C-14 labelled gas and radon. For radon, the new approach uses empirical relationships between the concentrations of Ra-226 and Rn-222 in soil and R-222 in dwellings for appropriate ground conditions.

An unusual aspect of the LLWR is that it will be subject to coastal erosion on a timescale of hundreds to thousands of years. New assessment methodologies have been developed, based on extensive studies of coastal evolution, including modelling.

A new assessment of the impacts on non-human biota has also been undertaken, using the ERICA methodology.

New arrangements for waste acceptance have been identified using the assumptions and assessment results of the ESC, which will ensure the LLWR is managed within the safe envelope of the ESC. The new arrangements include waste acceptance criteria, approach to capacity management and emplacement strategies. The 'sum-of-fractions' methodology has been used.

TS9a.1
Preparedness and Response to Radiological Emergencies

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Radiological emergencies, caused by various reasons, will be faced by societies also in the future. Therefore all nations must have arrangements to response to these emergencies. Especially after the accident at the Chernobyl nuclear power plant in 1986 major progress was made internationally and nationally in management of response to and recovery from nuclear and radiological emergencies. Notwithstanding the broadly adequate provisions now in place in most countries and internationally, complacency would be misplaced and continuing vigilance remains important. Improvements, of a technical, organisational or political nature, are still needed in emergency management.

The Fukushima accident put these issues on the forefront of political debate and public opinion will certainly increase the need for developing preparedness strategies for emergency response and recovery all over the world in the following years. Radiological emergency may come about not only through an accident but also through nuclear terrorism or other malicious acts with radioactive materials. Addressing these challenges requires that nations set up arrangements to secure their territory from malicious and illegal acts and to protect their citizens' health and welfare from harmful effects of radiation. Safety and security arrangements have common goals and the systems and measures used to achieve these goals need to be complementary. Therefore, a well-coordinated approach in nuclear safety and security is essential.

TS9a.2
Promoting Use of Local Volunteer Radiation Professionals in Emergency Response to Assist in Population Monitoring and Public Shelter Operations

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A major nuclear or radiological incident will impact not only the community directly affected but also nearly every community in the country as potentially millions of displaced persons will seek assistance to address their health needs, screen them for radioactive contamination, and provide them with adequate shelter and assistance in relocation. In the United States, state and local agencies are responsible for public health and safety during radiological events. In the aftermath of a radiological accident or terrorist activity, state and local resources would be quickly overwhelmed by the large number of citizens needing to be monitored for contamination. One method of supplementing state and local resources is through the use of local trained and registered volunteer radiation professionals who could perform population monitoring and other assistance at community reception centers as well as support operations at public shelters.

Volunteer radiation professionals can include health physicists, medical physicists, radiation protection technologists, nuclear medicine technologists, and others who have training in radiation measurement. During 2010-2011, the Conference of Radiation Control Program Directors coordinated with the Centers for Disease Control and Prevention in a program to evaluate the feasibility of incorporating volunteer radiation professionals into existing volunteer registries (e.g., Emergency System for Advance Registration of Volunteer Health Professionals, Medical Reserve Corps, state volunteer registries, etc.). This program was piloted in seven state and local jurisdictions. CRCPD is providing outreach and further partnering with additional state and local radiation control programs and response agencies, as well as local chapters of radiation professional societies to promote recruitment and training of radiation professionals in additional jurisdictions and building a cadre of radiation professionals that could be used during a major radiological emergency. This presentation will describe the outcomes of the pilot program and the status of the current efforts.

TS9a.3
Radiological Emergency Preparedness and Response Training and Capability Development in South East Asia

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This paper describes the collaborative and systematic approach to training for nuclear and radiological emergency preparedness and response to ensure adequate measures are in place to detect, respond to and mitigate the consequences of any attempted, or actual, malicious use of radioactive sources or nuclear sabotage. The work is motivated by radiological and nuclear security concerns, including the response to security incidents. We describe the outcomes of ANSTO's cooperation with South East Asian counterparts in Thailand, the Philippines, Malaysia and Indonesia. The standards and criteria being applied are discussed, along with the methods, design and conduct of workshops, table-top and field exercises. The following elements of this training will be presented: (a) identifying the priority areas for training through needs analysis; (b) strengthening individual professional expertise through a structured approach to training; and (c) enhancing individual agency and national nuclear and radiological emergency preparedness and response arrangements and capabilities. The implications for effective and sustainable emergency response to any nuclear or radiological incidents are discussed, along with the significance of emergency preparedness and response at the nexus of nuclear safety and security.

TS9a.4
Implementation of an Awareness Tool to Post-Accidental Issues for Local Actors

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As part of their partnership agreement signed in 2003, the Institute for Radiological Protection and Nuclear Safety (IRSN) and ANCCLI (National Association of Local Liaison Committees) decided in late 2009 to launch an action on the preparation of local actors to post-accidental situations. This shared commitment has resulted in the establishment of a working group involving representatives of the IRSN and the Standing Group "Territory and Nuclear Post-Accidental phase" of ANCCLI.

The purpose of this group is to develop a tool to educate and train local people about the post-accidental consequences of an event affecting a French nuclear facility but also to prepare them for an accidental situation by identifying post-accidental issues of their territory.

The tool, called OPAL, provides map information on the medium-term consequences of generic accidents. The data can be exported and overlaid with local information layers via any geographic information system. They will enable Local Liaison Committees to create maps with which they can illustrate the challenges of post-accidental management in territories.

Parallel challenge for IRSN is to acquire a better understanding of territorial issues related to post-accident and, depending on the availability of information, to collect local data for characterization of the environment around French nuclear sites.

The work has been organized in three phases spread over a period of three years: a first stage consisted in identifying needs and characteristics of the tool (input parameters, outputs, desired performances ...), a second phase has permitted to build the tool and to create the associated post-accidental database, and the third phase consists now in implementing OPAL on pilot areas around Golfech, Gravelines, Saclay and Marcoule nuclear facilities before a gradual extension to all the sites identified by the working group.

The objective of this presentation will be to trace the origin and objectives of this action, to detail the first two phases of the project and to develop the first feedbacks following the implementation of the tool on pilot areas.

Keywords: Post-accidental, Local Liaison Committees, Territory, Cartographic tool

TS9a.5
MOIRA-PLUS use in Decision Making on the Long-term Management of Contaminated Freshwater Bodies and Catchments

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Abstract. In the mid-long-term after a nuclear accident, the contamination of drinking water sources, fish and other aquatic foodstuffs, irrigation supplies and people's exposure during recreational activities may create considerable public concern, even though dose assessment may in certain situations indicate lesser importance than for other sources, as clearly experienced in the aftermath of past accidents. In such circumstances there are a number of available countermeasure options, ranging from specific chemical treatment of lakes to bans on fish ingestion or on the use of water for crop irrigation. The potential actions can be broadly grouped into four main categories, chemical, biological, physical and social. In some cases a combination of actions may be the optimal strategy and a decision support system (DSS) like MOIRA-PLUS can be of great help to optimise a decision. A further option is of course not to take any remedial actions, although this may also have significant socio-economic repercussions which should be adequately evaluated.

MOIRA-PLUS is designed to allow for a reliable assessment of the long-term evolution of the radiological situation and of feasible alternative rehabilitation strategies, including an objective evaluation of their social, economic and ecological impacts in a rational and comprehensive manner. MOIRA-PLUS also features a decision analysis methodology, making use of multi-attribute analysis, which can take into account the preferences and needs of different types of stakeholders.

The main functions and elements of the system are described summarily. Also the conclusions from end-user's experiences with the system are discussed, including exercises involving the organizations responsible for emergency management and the affected services, as well as different local and regional stakeholders. MOIRA-PLUS has proven to be a mature system, user friendly and relatively easy to set up. It can help to better decision-making by enabling a realistic evaluation of the complete impacts of possible recovery strategies. Also, the interaction with stakeholders has allowed identifying improvements of the system that have been recently implemented.

Keywords: Decision support systems; MOIRA DSS; freshwater ecosystems; long-term contamination; Countermeasures

TS9b.1 Biodosimetric Response to Radiation Emergencies: Accidental Exposures in Latin America- Examples of Recent Responses Under IAEA-RANET System

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Radiation accidents are rare and have a very low reproducibility rate. Each accident can be considered as a unique event with its own characteristics, thus do not permit to derive a generalized biomedical approach and management. Victims of radiological accidents require prompt diagnosis and treatment of medical and surgical conditions as well as conditions related to radiation exposure and or radioactive contamination. Regarding medical care of overexposed victims, improvements in diagnosis and treatment have been made in the last years. Additionally, dosimetry evaluation has acquired a new role to guide medical treatment. Dose assessment is performed not only early post-exposure by physical dosimetry calculation (scenario reconstruction) but also from evaluation of serial blood counts with differential and the medical history (timing and severity of prodromal signs and symptoms). A medically significant dose should be subsequently confirmed or discarded by chromosome aberration assay, the current gold standard for biodosimetry.

The Response Assistance Network (RANET), which supports practical implementation of Assistance Convention, is a system of Competent Authorities capable and willing to provide, upon request, specialized assistance, in principal, on a regional basis to nuclear accidents or radiological emergencies, timely and effectively. The biological dosimetry laboratory of the Argentinean Nuclear Regulatory Authority (ARN) joined the RANET system on September 2008.

The objective of the present work is to give an overview of two assistances on biological dosimetry, performed by the ARN biological dosimetry laboratory in the Latin American Region under IAEA-RANET system (2009-2010).

TS9b.2
A New Strategy for the Delimitation of the Post-Accidental Zoning after a Nuclear Accident

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At the last IRPA conference in Buenos Aires (2008), the French nuclear safety authority (ASN) presented the approach implemented for the definition of a national doctrine related so the risk management during the post accidental period following a nuclear accident (so called "CODIRPA program"). 4 years later, ASN proposes to present the strategy which has been built, with stakeholders involved in the CODIRPA program, for the delimitation of the post-accidental zoning likely to be used by authorities few days after the end of the release. This zoning , based on predictive dose and modelling which should be provided by IRSN, offers a specific frame to decide on different issues as the relocation, the cleaning of urban areas, the waste management, the ban of foods consumption and trade and the population census needed for the surveillance of health's population and financial compensation. The main findings of the international seminary hold in Paris in 2011, May will also be presented.

TS9b.3
The Calculation of Dose to Externally Contaminated Livestock and Animal Triage for Livestock Handling and Processing

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Nuclear or radiological events or the malevolent use of radioactive material may result in a significant release of radioactive materials to the environment. The contamination of livestock animals in agricultural areas in close proximity to the release site may cause significant technical, logistic, and economic difficulties for the affected region.

Rapid and effective response to a large amount of contaminated agricultural products, such as livestock, by the Competent Authority will require a prepared and effective plan for handling and processing of these products. A protocol outlining the evaluation of and procedures for handling and processing radioactively contaminated livestock has been developed, to ensure safe animal food production and economic stability in the livestock industry in the wake of such a nuclear or radiological event. An evaluation of the salvageability of the contaminated livestock has been performed based on the degree of exposure, the cost of decontamination, expected demand for food products, and economic impact to the owner / producer, in order to serve as a basis for animal triage for the further handling and processing of affected livestock.

As salvageability is defined in terms of dose to the animal, a mathematically rigorous formalism to assess the animal dose has been developed. The general approach outlined in ICRP 108 is used for the mathematical description of the relevant exposure and contamination scenarios.

TS9b.4
Canadian Radiation Emergency Medical Management Guide

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Following a radiological or nuclear emergency, such as the recent one that occurred in Fukushima, Japan, a large population might need to be monitored for potential radiation exposure or contamination. For those who suffered radiation injuries or radioactive contamination, timely medical treatment and long-term follow-up may be necessary. A group of European agencies, together with the WHO, have developed a comprehensive tool called the TMT Handbook for triaging, monitoring, and treating people exposed to radiation or contaminated with radioactive materials, while the USA has developed several guidance documents or resource centres for monitoring and treatment, such as the CDC Population Monitoring Guide, the REAC/TS pocket book, and the REMM.

The Canadian Radiation Emergency Medical Management Guide is being developed for use by medical staff in hospitals, personnel working in public health, and emergency management staff in the federal, provincial, and municipal agencies. It will focus on population monitoring and medical management of a large population during an emergency. The guide will take the Canadian context into consideration, including the challenge associated with cold weather and pockets of expertise spread over a vast area.

TS9b.5
MULTIBIODOSE: multi-disciplinary biodosimetric tools to manage high scale radiological casualties

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In the event of a large scale radiological emergency biological dosimetry is an essential tool that can provide timely assessment of radiation exposure to the general population and enable the identification of those exposed people, who should receive immediate medical treatment. A number of biodosimetric tools are potentially available, but they must be adapted and tested for a large-scale emergency scenario. These methods differ in their specificity and sensitivity to radiation, the stability of signal and speed of performance. A large scale radiological emergency can take different forms. Based on the emergency scenario different biodosimetric tools should be applied so that the dosimetric information can be made available with optimal speed and precision. The aim of this multi-disciplinary collaborative project is to analyse a variety of biodosimetric tools and adapt them to different mass casualty scenarios. The following biodosimetric tools will be established, improved and/or validated: the dicentric assay, the micronucleus assay, the gamma-H2AX assay, the skin speckle assay and the blood serum protein expression assay. In addition EPR/OSL dosimetry in components of pocket electronic devises is investigated. The assays were chosen because they complement each other with respect to sensitivity, specificity to radiation and the exposure scenario as well as speed of performance.

The project involves the key European players with extensive experience in biological dosimetry. Training is carried out and automation and commercialisation pursued. An operational guide will be developed and disseminated among emergency preparedness and radiation protection organisations.

The final deliverable of this project will be establishment of a biodosimetric network that is fully functional and ready to respond in case of a mass casualty situation. Thus, the project will strengthen the European security capabilities by achieving tangible results.

The project is funded by the FP7 Security program. URL: http://www.multibiodose.eu.

TS9c.1
Nuclear Security for the 2010 FIFA World Cup in South Africa: Part 2: Summary of Logistics and Results

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“The largest nuclear security operation ever undertaken” - Vince McLelland, NNSA, US DOE, South Africa, 2010.

The concept of operation was to establish source detection capabilities, radionuclide identification, effective communication infrastructure and technical decision protocols to support radiological, emergency and medical response functionaries through three lines of defence at each monitoring point; all in limited time with limited resources.

The logistics of the nuclear security arrangements for the 2010 FIFA World Cup in South Africa will be presented, with details on:

· Training courses presented,

· Exercises conducted,

· Instrumentation and equipment employed,

· Personnel involved,

· Deployment and adjudication protocols.

Results of the preparatory work and actual venue surveillances will be presented:

· Background mapping of large areas with specialised radiation instrumentation which revealed some interesting facts,

· Problems with instrumentation encountered,

· Anomalies and incidents recorded.

During the event 26 medical, 43 NORM, 4 industrial and 15 false hits were recorded, adjudicated and acted upon. This presentation will include details on these hits (nuclides, radiation levels, etc).

TS9c.2
INEX 4 Exercise on Consequence Management and the Transition to Recovery

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The INEX series of international nuclear emergency exercises, organized under the OECD Nuclear Energy Agency's (NEA) Working Party on Nuclear Emergency Matters (WPNEM), have proven successful in test-ing, investigating and improving national and international response arrangements for nuclear accidents and radiological emergencies. Previous INEX exercises focused largely upon national and international aspects of early phase management of nuclear power plants emergencies. Starting with INEX 3 (2005-2006), the international community began looking at issue in longer-term consequence management. In order to build on the momentum of INEX 3 and the work of various INEX 3 follow-up activities, the WPNEM launched in 2008 the development cycle for a new INEX 4 international emergency exercise.

INEX 4 focuses on issues in consequence management and transition to recovery in response to malicious acts involving the release of radioactive materials in an urban setting. Recognizing that the arrangements for managing these events may vary between countries, the goal of INEX 4 is to provide a basis for enhancing emergency management through the exchange of exercise experiences from participating countries and identification of good practices and common issues.

To enable a consistent review of the exercise outcomes, the WPNEM developed a common INEX 4 framework and baseline scenario to allow participating countires to address the same challenges and topical areas in consequence management and transition to recovery. Planning teams used these materials to prepare their national exercise addressing the following INEX 4 topical areas:

- Decision-making on protection strategies;
- Public health;
- Monitoring and assessment capability;
- Safety and security of populations and infrastructure, and
- Planning for recovery.

As a consequence management exercise, the INEX 4 design specifically excluded the early crisis phase. Each participating country performed its own exercise evaluation using a common questionnaire, with the intent to share, as appropriate, its experience internationally.

Twenty three countries, including 5 non-NEA countries, have conducted or plan to conduct an INEX 4 exer-cise. While the timeline of the exercise has been modified due to Fukushima Dai-ichi nuclear accident, an early evaluation of completed exercises indicates that one area of focus will likely be the transition from the crisis phase to consequence management phase and continuity of the response. In order to facilitate mutual understanding of national decisions in nuclear emergency management, the WPNEM will address lessons learned from both the INEX 4 series and the Fukushima Dai-ichi accident in the INEX 4 evaluation work-shop. The presentation will summarise some of these findings to date.

TS9c.3
Lessons From Three Major Fires In The UK Non-Nuclear Sector

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Three major fires have occurred in radiation employer's (non-nuclear sector) premises in the UK during the last 10 years. The fires involved radioactive materials in the form of large quantities of unsealed materials, bulk storage of ionising chamber smoke detector sealed sources, and anti-static bars in a manufacturing environment. Fortunately none involved physical injuries to employees but the costs of clean-up, decontamination, demolition, re-construction, and loss of business were significant. This presentation summarises the incidents themselves through a series of photographs, discusses the common factors and outcomes, and identifies the data from which various professional groups may be able to evaluate and develop some of the possible lessons that may be learned. These groups include industries with known ignition sources, equipment manufacturers, employers using radioactive materials, emergency responders and civil contingencies, the insurance industry, and radiation protection professionals such as radiation experts, supervisors, and regulators.

TS9c.4
Revisiting the Dose Calculation Methodologies in European Decision Support Systems

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In order to avoid repeating the mistakes and failures encountered in the aftermath of the Chernobyl accident, where countermeasures were implemented on a hit-and-miss basis, it is essential to use the best possible supporting instruments in reaching decisions on justification and optimisation of intervention. The European ARGOS and RODOS standard systems are developed for this purpose, and offer excellent overview options for studying conceivable contaminating incidents before they happen, and developing a targeted and effective operational preparedness across Europe. They are also ideally equipped to enable best estimates of the consequences during and after the occurrence of an incident, helping to secure the best possible use of perhaps limited resources available within given timeframes, and to avoid wrong, and sometimes irreversible, decisions from being made. It should however also be noted that the dose calculation methodologies applied in some of the modules of the decision support systems are still based on the knowledge platform that was available several decades ago and only relate to the types of threats that were of concern at that time. Terrorist attacks involving dispersion of radioactive contaminants (e.g., 'dirty bombs') may lead to contaminants with characteristics that can not be adequately represented by the current dose estimation methodologies in the European decision support systems. In relation to nuclear power plant accidents, for instance a revision of the parameterisation in the ingestion dose calculation module is recommended on the basis of recent investigations, and in general a better representation of physicochemical forms of contaminants would lead to much more reliable dose estimates.

TS9c.5
Nuclear Security and Emergencies in Case of Malevolent Acts Against Nuclear Power Plants

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The European Commission, through the Seventh Research Framework Programme European Security Area, has commissioned (CAST, GA No.: 218070, Call FP7-SEC-2007-1, more details www.castproject.eu) to an international consortium analysis of the current situation and development of training programs focused on security for emergency response services of a catastrophic nature. The CAST project, Comparative Assessment of security-centered curricula for training first responders on disaster management in the EU, has worked for 2 years (2009-2011) in the development of the following areas: Managing Catastrophic Emergency, Terrorist Threats, Terrorism Catastrophe, Catastrophic Releases, Organization of response teams, Best Practices, Training Human Factors and Virtual Reality, Technology Implementation and Training Plans. The main results of the research carried out would be a standardized curriculum development for first responders in catastrophic emergencies, and the generation of proposals to overcome differences on training for disaster management between EU member states and the best worldwide practices identified.

This article summarizes the work done in analyzing the state of the art in facing terrorist attacks on nuclear installations and its potential serious consequences, and the review of best practices in the world. With this aim, it is carried out a review of key areas related to hostile acts against nuclear plants; firstly, an introduction to and classification of threat scenarios, are presented. The paper continues summarizing the risks and key vulnerabilities of nuclear facilities in a generic way. Once the situation has been set in relation to the threat, the main methodology defined to cope with it, e.g. Design Basis Threat, is briefly summarized. Some of the main aspects related to the application are also considered.

After defining the threat and the methodology to tackle it, the following step is the analysis of situation in case of emergency caused by security events, the authors can eventually discuss the specific characteristics of emergencies caused by hostile acts and the main areas in which emergency training should be focused in order to successfully cope with the specific characteristics of such events.

The work identifies the operational and logistical problems that first responders might find when arriving at the scene of a severe incident at a nuclear power plant. Topics such as situation awareness, on site staff dosimetry, evacuation, people and vehicles decontamination and environment impact control are included.

TS10a.1 Management of Operational and Existing Exposure Situations Due to NORM and Natural Radiation: Radiation Protection and Scientific Challenges

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Almost every country has NORM industries and existing exposure situations (legacy sites) from past operations, and many materials (mineral ores, commodities, products, waste and residues) containing NORM that require some level of management to avoid unnecessary exposures. An example of a legacy situation is the South Alligator River Valley (Northern Territory, Australia) where there are a number of abandoned uranium mine sites. The radiation protection community has to develop procedures for managing a very wide range of situations in a systematic way, based on sound, defensible principles, and consistent with international best practice. Ideally, these should include an internationally harmonised regulatory approach to avoid trade issues (commodities and products). Experience in NORM industries and in dealing with management of NORM wastes and residues and legacy sites also suggests that regulation of NORM should be based on a graded approach (level of regulatory control based on assessed risk). NORM management procedures have to be cost-effective, particularly in view of the large quantities of material involved. Stakeholder involvement is critically important, because lifestyles, jobs, etc, can be affected by regulatory and management decisions. Finally any approach that is adopted should solve today's problems in a way that does not leave worse problems for the future.

TS10a.2*
Comparisons of Carrington-Class Solar Particle Event Radiation Exposure Estimates on Mars utilizing the CAM, CAF, MAX, and FAX Human Body Models

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Estimating space radiation health risks for astronauts on the surface of Mars requires computational models for the space radiation environment, particle transport, and human body. In this work, estimates of radiation exposures as a function of altitude are made for solar particle event proton radiation environments comparable to the Carrington event of 1859. The proton energy distribution for this Carrington-type event is assumed to be similar to that of the Band Function fit of the February 1956 event. In this work, the deterministic radiation transport code HZETRN (High charge (Z) and Energy TRaNsport) 2010, which was originally developed at NASA Langley Research Center, is used. Exposure estimates for aluminum shield areal densities, similar to those provided by a spacesuit, surface lander, and permanent habitat, are calculated as a function of altitude in the Mars atmosphere. Four human body models are utilized, namely the Computerized Anatomical Man (CAM), Computerized Anatomical Female (CAF), Male Adult voXel (MAX), and Female Adult voXel (FAX) models. Comparisons between the CAM and MAX model organ exposures, and similarly for CAF and FAX, are made since there are differences in the mass and location of various organs for the human body models. In addition, comparisons of the predicted organ exposures are made with current NASA Permissible Exposure Limits (PELs).

TS10a.3
Exposure Caused By Natural Radionuclides In Building Materials: Current Practice And Regulation And Future Radiation Protection Requirements

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Due to increasing indoor habitation of persons - in average about 80 % of time persons stay indoor - external and internal exposure caused by natural radionuclides in building materials are of increasing importance. Additional the rising production of building materials using industrial by-products and residual materials from NORM industry necessitate the consideration and regulation of this radiation protection issue in regard to chronically public exposure.

Generally, indoor exposure from building material originates from radionuclides of the natural decay chains U-238, Th-232, U-235 plus progenies like Rn-222 and Rn-220 as well as the primordial radionuclide K-40. External radiation exposure by gamma-radiation and beta particles emission plus internal exposure due to inhalation of radon cause chronic exposure of the public.

In this paper current radiation protection concepts and practice of dose modelling, dose assessment, risk assessment, and radioactivity measurement methods including metrology and calibration of instruments are given. Examples of building material evaluations are discussed with regard to approaches for future requirements of radiation protection regulations and standards.

The research results in this radiation protection issue provide a state-of-the-art basis for harmonised guidelines and future standards to limit chronically public exposure in existing indoor exposure situations due to radioactivity of building materials.

TS10a.4
Distribution pattern of NORM on Red Sea Shore Sediments in Relation to Non-Nuclear Industries

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The Red Sea is a deep semi-enclosed and narrow basin that has intensive non-industrial activities on and near its shore. Oil exploration, phosphate mining and trading, navigation activities and intensive touristic activities are considered as non-nuclear pollution sources. They could impose serious radiological and ecological impacts on the Red Sea marine environment. Both oil and phosphate related activities could increase the concentration of Naturally Occurring Radioactive Materials – NORM such as uranium-238 series, thorium-232 series and potassium-40. Forty representative shore sediment samples were collected from the Egyptian Red Sea shore, from Shuqeir to Marsa Alam City region. Activity concentration of ^{238}U, ^{232}Th, ^{40}K, ^{210}Pb and ^{210}Po were measured using gamma-ray spectrometry, alpha particle spectrometry and ICP-MS analytical techniques. Previous study showed the possible impact of industrial activities on the activity concentration of NORM in shore sediment. This study will investigate such relation and the distribution pattern of NORM in more details.

Keywords: NORM; Red Sea; shore sediment; non-nuclear

TS10a.5
Rapid Method for Determination of Po isotopes in Biological Matter

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A short review of the existing analytical procedures for determination of Po-210, showing their advantages and disadvantages, is presented.

The criteria for selecting the proper method, according to the scope and type of matrix in study are summarised.

The rapid method which is described here consists of total digestion, auto deposition and measurement by means of alpha spectrometry. The classical method in this very simple form as presented here is result of studying the possible interferences and validating the method. The application of this method in analyzing the Po-210 concentration in fresh water wild fish caught in some lakes in Austria is discussed.

The corresponding ingestion dose to the public, due to Po-210 intake through consumption of this kind of fish is estimated.

TS10a.6
Necessity of World Wide Regulation for Radioactive Consumer Products in Current Markets

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Introduction; Many radioactive consumer products (RCP) to which radioactive materials were intentionally added, for example cosmetics and personal jewelry, are sold in current markets of Japan and some parts of Asia. However, there are prohibitions on intentional addition of radioactive materials for consumer products in some countries. Also, ICRP-103 mentioned 6 kinds of radioactive consumer products make unjustified exposure. The purpose of this study is to analyze radioactive concentration in RCP, to estimate exposure doses from the normal use of them, and to discuss the justification of the existence of RCP.

Experimental procedures; Samples were 26 kinds of RCP sold in Japan and 2 kinds of RCP sold in Korea. The gamma-ray spectrometry of the samples was performed by using a HPGe detector, a multi-channel analyzer and an analysis software of LabSOCS (CANBERRA). Estimation of external radiation exposure by the RCP was calculated by using the equations mentioned in the "NORM guideline" regulated by Japanese Government. Also radon concentration emitted from 3 samples was measured by using a scintillation Lucas cell (PMT-TEL, Pylon) or a pico rad (PICO-RAD™; ACCUSTAR LABS Co.). Estimation of internal radiation exposure was calculated from the radon concentration. Also, cosmetics of RCP were analyzed by SEM-EDX (Model JSM 6700F) to confirm the sizes of radioactive materials.

Results and discussions; The concentrations of ^{232}Th and ^{238}U added in RCP were extremely different among products; from 0.1 ppm to 32% of ^{232}Th and from 0.8 ppm to 1.7% of ^{238}U. Both of the concentration and the amount of radioactive materials were less than Japanese regulation limit values, so all of them were defined as "RCP". All the external exposures were low to be not worried about health risks from the RCP because their exposure doses were under 1 mSv y^{-1} at their normal use. However, the RCP might be used for long time, much amounts or multiple use. At that time, the external exposure would be higher than the estimation for normal use. Also, the concentrations of Rn emitted from the 3 kinds of RCP were not low. When the pillow of RCP used every day in a small room (25 m^3), for exampl, the internal exposure was estimated about 6 mSv per year. Furthermore, it is considered that there are risks of internal exposure when use the RCP cosmetics, because their particle sizes were under 2.5 μm in some cases. It was clear that some of the RCP were the items which are no justification to add the radioactive materials for consumer products identified by EURATOM, IAEA and ICRP.

Conclusions; There are many RCP sold in current markets. In some cases, the internal exposure might be high by using the RCP, and every one can buy the RCP through the Internet. Justification is the most important thought for RCP. So it is considered that a regulation unified at world level is necessary for commercially-available RCP from all over the world.

TS10b.1
A Quarter of a Century with Chernobyl Contamination – Norwegian Experiences

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The 1986 Chernobyl accident had long-term consequences for livelihood and food production in rural areas as remote as Scandinavia. In central and southern Norway, the Chernobyl fallout continuously calls for application of countermeasures in animal production (i.e., sheep and goat farming and reindeer husbandry), even a quarter of a century after the accident. Reindeer husbandry suffers particularly from the situation due to of the vulnerability of reindeer to radiocaesium fallout and because of the Sámi's cultural dependence on reindeer meat as their staple food. South Sámis have during the last 10-15 years been as contaminated by ^{137}Cs as people living in the most affected areas of Ukraine, Belarus and Russia. Countermeasures applied in reindeer herding and Sámi households as a consequence of the Chernobyl accident include: Change of slaughter season from winter to early autumn, clean feeding, application of caesium binders, live monitoring of animals, replacement of the herder's own contaminated meat by reindeer meat from less contaminated areas, replacement of reindeer meat by other food, various methods directed at culinary preparation of meat, dietary advices and whole body monitoring of herders.

This presentation will focus on applicability and acceptability of various measures applied in Norway after the Chernobyl fallout, on implementation and the importance of involving stakeholders in decision making. It is believed that many of the Norwegian experiences may be valuable in an event of serious and long-lasting contamination situations in other western countries and democracies.

TS10b.2
Key Radiation Protection Issues In Regulatory Supervision Of Nuclear Legacies

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Safe management of nuclear legacies arising from past activities is a critical issue in maintaining confidence in the continuing and future use of radioactive materials. Effective and efficient regulatory supervision of nuclear legacy management is a critical part of that process. The Norwegian Radiation Protection Authority plays an active role in bi-lateral regulatory cooperation projects with parallel authorities in the Russian Federation and with countries in central Asia, as part of the Norwegian Plan of Action to improve radiation and nuclear safety. NRPA is also very active within the IAEA International Working Forum on Regulatory Supervision of Legacy Sites. Based on this experience and by reference to specific legacy sites and circumstances, this paper will present key radiation protection issues necessary for the optimization of the regulations. This includes radiological characterisation of old and potential accident source terms, mechanisms of radionuclide migration and accumulation, evaluation of exposure conditions in the short and long term, and effects of long-term exposure. Consideration will also be given to the issue of radiation risk communication, important in the support of good decision making and the avoidance of the creation of new nuclear legacies.

TS10b.3
CORPORE, A Tool for Interpreting Whole Body Monitoring Results

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In long-term contaminated territories, the interpretation of whole body monitoring results is not straightforward. In these territories, years after an accident, the ingestion of contaminated foodstuffs becomes the preponderant root of exposure. However, the individual ingestion profiles are multiple and complex, and it is generally difficult to check that the actual doses received by individuals comply with the long-term dose objective stated by the ICRP for existing exposure situations (1 mSv/y). In this context, the challenge is to identify, together with the exposed people, the food products that are the main sources of their contamination in order to find options to reducing their individual doses ALARA.

Within the ETHOS and CORE projects implemented in Belarusian villages contaminated by the Chernobyl accident, a software prototype, named CORPORE, was developed by CEPN, with the support of the Norwegian Radiation Protection Authority (NRPA). This tool provides a quick and simple interpretation of the whole body measurements of the inhabitants. Actually, from the results of the whole body measurement and according to the age of the person, it is possible to assess the quantity of radioactivity ingested daily (Bq/d) through food assuming averaged diets and/or specific ingestion profiles: the model was developed to address both a daily mean ingestion and episodic ingestions (e.g. much higher contamination ingested only once or twice between two consecutive whole body measurement campaigns).

This tool was used by local health professionals to develop a practical radiation protection culture among the population. Thus, in territories contaminated by the Chernobyl accident where the highest doses are now received due to a seasonal consumption of mushrooms, berries or game meat, CORPORE helped health professionals and radiametrists in discussing with and informing people about the radiological risks they are exposed to. In Norway, where the Sami people is also still facing to the management of the Chernobyl accident consequences – the reindeer meat being the main source of its contamination – the tool was used by NRPA at the occasion of periodic whole body measurement campaigns, to try to find rooms for manoeuvre with the people, case by case, for reducing their internal doses.

There is no doubt that in Japan, after the Fukushima accident, the people that have not been evacuated or those that will come back home in the future will have a similar questioning.

TS10b.4
Optimising Decision Making For Late-Phase Recovery From Nuclear Or Radiological Terrorism Incidents In The US

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In March 2008 the U.S. Department of Homeland Security (DHS) issued its final Protective Action Guides (PAGs) for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) incidents. These provide recommendations for protection of public health in the early, intermediate and late phases of response to an RDD or IND, and discuss approaches to the implementation of the necessary actions. However, whilst the DHS guidance provides a general description of the goals of the late recovery phase, they do not describe the complex optimisation approach to decision making during the process of achieving these multifaceted goals.

In an effort to more fully define the process and procedures to be used in optimising the late-phase recovery and site restoration following an RDD or IND incident, DHS has funded the National Council on Radiation Protection and Measurements (NCRP) to prepare a comprehensive report that addresses all aspects of the optimisation process. The preparation of the NCRP report entitled 'Optimising Decision Making for Late-Phase Recovery from Nuclear or Radiological Terrorism Incidents', is a three year (2010 -2013) effort by a scientific committee designated as SC5-1. Members of SC5-1 represent a broad range of expertise, including homeland security, health physics, risk and decision analysis, economics, environmental remediation, radioactive waste management and communication. Stakeholders at the local, state and federal levels will hold discussions with members of SC5-1 during the course of preparing the report.

TS10b.5
Regulatory Supervision and Assessment of the Radiation Situation in the Areas of the Former Military Technical Bases

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Remediation of the sites for SNF and RW temporary storage (STS) at Andreeva Bay and Gremikha village on the Kola Peninsula and in the Primorsky Territory in the Far East is an important component of the regulatory functions of the Federal Medical Biological Agency (FMBA of Russia). Burnasyan Federal Medical Biophysical Centre is involved in the technical support of this activity of FMBA of Russia. The main directions of the study:

· Radiological threat assessment to identify the priority directions of regulation;

· Detailed analysis of the radiation situation on sites, at the territories and near the STS. Radiation control and monitoring of the environmental conditions

· Development of the computer maps and geo-information system

· Review of the projects on STS remediation including SNF and RW management.

Completion of the mentioned field, practical and theoretical works terminated with development of the set of regulatory documents to assure radiation protection and safety of workers, public and environment, as well as documents to regulate the SNF and RW management on the STS sites.

FMBA of Russia and NRPA paid the special attention to operations connected with the SNF removal from the STS, including non-conditioned spent fuel assemblies, and future gathering of the SNF spills from the former fuel pools. Over 2008 - 2010, three first SNF parties have been removed by Serebryanka tanker. At that, real doses to workers were a bit higher than 1% of the predicted values and did not exceed the reference levels. So, these operations could not and did not result in additional doses to the public.

TS10b.6
Challenges in The Nuclear Legacy Regulation

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The beginning of XXI century marks the documented milestone of the necessity recognition to regulate the nuclear legacy all over the world and in Russia, in particular.

The nuclear legacy covers such military and industrial facilities, which do not comply with the up-to-date requirements for nuclear and radiation safety, and sites contaminated following the past nuclear activities and uranium mining. In terms of the environmental safety, the most significant are consequences of the defense activity and large-scale radiological accidents: legacy contaminations in the Urals - Techa River and Kyshtym (past activity of the PA "Mayak"), sites for SNF and RW temporary storage originated from the dismantled nuclear submarines in the Russian Northwest and Far East. The nuclear legacy includes numerous territories in Russia and ex-Soviet republics (abandoned tailing dumps etc.) affected by the uranium mining and milling facilities.

The main current problem is the lack of comprehensive regulatory and legal framework in the existing legislation on the nuclear legacy management to implement principles aimed at prevention of harmful impact of such legacy sites on the environment and human health, reduction of the burden to the next generations.

FMBA of Russia plays an active role in the nuclear legacy regulation, which consists mainly of limiting generation of new nuclear legacy specific problems or, in other words, elimination of new nuclear legacy appearance. The basis for the nuclear legacy regulation is its regulatory and legal support including the radioactive waste classification, requirements for limiting contents of the fissile materials in wastes, long-term storage and final isolation of waste. IAEA approves such approach and many states follow this approach.

The FMBA's position on this issue has actively been represented at the IAEA International Forum on the regulatory supervision of the nuclear legacy sites. Russia was invited to lead the working group "Enhancement of the regulatory infrastructure" of the Forum. This working group will consider the regulatory experience in the legacy management and regulatory supervision of the legacy in order to provide recommendations on improvement of the regulatory infrastructure and the legal regulatory basis taking the suitability of different approaches for different national circumstances into account.

TS10b.7
Guidance on the Assessment of Exposure from Land Contaminated with Heterogeneously Distributed Radioactive Material

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Most, if not all, assessments of radioactively contaminated land will consider situations where the level of contamination is not uniform across an area (heterogeneous contamination). There may be variability in the radionuclides present, in the activity concentration within the ground, and contamination may be by discrete radioactive objects. This paper describes new guidance developed by the Health Protection Agency (HPA) on assessing the radiological implications of land contaminated by a heterogeneous distribution of radioactivity. This new guidance builds on previous advice given by HPA and one of its predecessor organisations, the National Radiological Protection Board (NRPB). Situations involving the redevelopment of land for future use (planned exposure situations) and situations where people are already being exposed (existing exposure situations) are considered.

It is important to recognise that every site has unique features that need to be explicitly considered when performing a radiological assessment. It is, therefore, not possible to specify a generic assessment methodology. However, some over-arching guidance has been given reflecting the general approach that could be followed in most situations. Guidance has been given on: defining the reason for the assessment; defining the source term; defining the exposure scenarios, exposure pathways and exposed groups; and interpreting the results of the assessment. The radiological assessment of land contaminated by discrete radioactive objects poses particular difficulties and specific guidance has been given for this situation. In all cases, care should be taken to avoid the use of overly cautious assumptions to compensate for the level of uncertainty.

When assessing the radiological consequences of contamination by discrete radioactive objects it is important that both the dose and the probability of receiving that dose are taken into account, and presented separately. This aids interpretation of the results, particularly in situations where deterministic effects could be received but where the probability of the dose being received is low. Where exposure leads to stochastic effects, and the risk to health can be considered to be proportional to the magnitude of the dose, then the overall risk to health can be calculated by multiplying the probability of receiving the dose, the effective dose and the health risk factor.

TS10b.8 Radiological Characterisation and Decommissioning in the UK Non-nuclear Industry: Project Experience, Challenges and Solutions

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National Physical Laboratory

RPS Radiological Services were commissioned to provide investigation and remediation support services for the redevelopment of the UK National Physical Laboratory (NPL) site. This is an important national facility dealing with the setting of standards for measurement including those associated with radioisotope measurement and traceable calibration standards. The site radiological characterisation plan was developed having investigated the long history of work with radioactive substances at the site (approximately 100 years), the multitude of radionuclides used and the extensive use of radium post WWII. The site presented the potential to have radiological contamination in many locations.

Key to the characterisation was liaison with the radiological laboratory to ensure correlation between field survey findings and reported data with cost savings achieved through nuclide screening techniques. A number of interesting radiological findings were identified which demonstrated some unexpected past practices.

Submissions were made to the Environment Agency to justify sentencing of bulk building fabric as Exempt to achieve significant cost and programme savings.

The remediation works generated over 50 drums of LLW which were disposed of appropriately. VLLW and exempt waste were disposed of to landfill.

A turnkey service was provided to the client for the Environmental Permit with submission to the Environment Agency correlating the site characterisation works, radioactive wastes and records of disposal to achieve Permit surrender.

University of Southampton

The University of Southampton had a requirement for radiological survey and characterisation works associated with a large former Biosciences building. This work was typical of the University and Pharmaceutical sector but unusually large scale, with approximately 1000 rooms.

The building survey was designed using the US EPA Data Quality Objectives. Programme requirements associated with sentencing decisions of materials to be soft stripped was undertaken on a sample by sample basis which required a more dynamic approach to the work. No LLW was identified during the building characterisation though nearly 50m^3 of VLLW was generated.

Characterisation of the external pipe work and tanks associated with the effluent discharge system identified exempt, VLLW and LLW with remediation of ground contamination required. Characterisation of the internal effluent discharge system resulted in a total of 17 different waste types being generated which included mercury containing pipe work.

Arrangements were made for Exempt and VLLW to be disposed of direct to landfill and LLW was disposed of to a suitable recipient following cost benefit assessment.

TS10c.1
Recent Developments in the Regulatory Control of Radon Exposure in Spain

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Radon is a well-established lung carcinogen and, consequently, many countries have developed strategies for controlling its concentration indoors. Spain transposed EC Directive 96/29 in 2001 by Royal Decree RD 783/2001, addressing, among others, those work activities that may result in increased radon exposure of workers or public. Nonetheless, because of an unclear definition of the competent authorities, the Decree was never enforced in practice, except for a few cases of particular radiological concern.

In order to unblock the situation, an amendment to the Decree was passed in 2010 (RD 1439/2010), and further regulations, including activity concentration criterion and methodological guidance, were issued by CSN in order to facilitate the application of the Decree. In addition, recommendations were made on radon exposure in existing and new dwellings updating and expanding upon previous guidelines from 2007. All new legislation is in line with the newest epidemiological evidences and ICRP new approach on radon. The concept of reference level has been used, with an emphasis on optimisation below it, and values of 600 Bq/m3 and 300 Bq/m3 for, respectively, workplaces and dwellings have been set.

Furthermore, a key issue in national or regional strategies to reduce exposure is the identification of areas most at risk for high radon levels indoors. As a first approach, CSN developed a predictive radon exposure risk map based on the measurements of ambient gamma dose rate averaged on grid cells of approximately 6 km × 4 km. This map was combined with available measurements in dwellings (around 14,000) and geological information to define such risk areas. On the one hand, all work activities within them have the legal obligation to conduct studies on their radon levels; on the other hand, resources for measuring and mitigating domestic radon levels must be allocated there as a matter of priority.

In this work, we give an overview on the current Spanish framework for the control of radon exposure and present the methodology followed to identify risk areas. Possible criterion applied to define them and the influence of factors, such as seismic risk or permeability, are also discussed.

TS10c.2
The Effect of New Building Concepts on Indoor Radon

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The building sector is at present responsible for more than 40% of EU energy consumption. New technologies have been implemented in new houses and are continually under development, which substantially improve the energy performance in buildings, reducing the conventional energy demand in new and existing buildings. New building concepts all aim at a new approach for the design, construction and operation of new and/or refurbished buildings in order to reach a high level of energy efficiency and sustainability. Various terms exist for those building concepts like green building, low energy house, passive house, triple zero house, eco-building, etc.

Within the EU-project RADPAR the effect of such new building concepts on indoor radon levels were investigated in detail. First, the construction, heating, and ventilation technologies used in modern dwellings were identified and subsequently their potential effect on indoor radon was assessed. To complement and to verify the findings a survey in 25 passive houses in radon prone areas in Austria was conducted. In another 11 passive houses more detailed radon measurements were made by means of active devices. In general, the results were below 300 Bq/m^3, in the majority of houses even below 100 Bq/m^3. However, in a few houses high radon concentrations were found.

The main results of this study are: (i) the high standard of airtightness of the building shell of new building concepts is basically beneficial with respect to low radon levels, (ii) controlled mechanical ventilation has principally a positive effect on radon indoors, (iii) however, certain design features or bad practice may cause high radon levels, e.g. leaky earth tubes of ground-coupled heat exchangers, improper sealing of penetrations of geothermal heat pumps, switching off mechanical ventilation in summer, use of air wells for preheating of outside air.

The paper gives detailed information on construction, heating and ventilation technologies specific to new building concepts and their relevance to radon. As a result of this study, recommendations are set up to avoid an adverse effect of these new technologies on indoor radon levels.

TS10c.3
Radon prevention and remediation in EU countries, RADPAR questionnaire study

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Radon control technologies aim at reduction of indoor radon concentrations in existing buildings and in new construction through remedial and preventive measures. A questionnaire was prepared and sent to all RADPAR EU DG SANCO project partners in 14 different countries.

The number of dwellings with elevated indoor radon concentration ranges typically from dozens of thousands to a million. The percentage of these houses already remediated varies from zero to 15%. Preventive measures in new construction have been taken from a small number of houses to over half a million houses. The research data on current situation, number of houses with preventive measures and the efficiency of these measures is currently still quite inadequate.

The most efficient remediation method is the active sub-slab depressurization (SSD) and radon well, for which the reduction of radon concentration is typically 60–95%. Other methods, such as sealing entry routes and improving ventilation in living spaces, in cellar or in crawl space, are less effective: reduction of radon concentration is typically 10–60%. The efficiencies of prevention techniques are analogous to those of remediation techniques. Active SSD is the most efficient prevention technique. The efficiency of passive SSD and passive radon piping is lower, typically 20–50%. However, wide use of such systems can be recommended. Both radon proof insulation of the base floor with a membrane and sealing pipe penetrations reduces radon concentration on average by 50%.

TS10c.4
Short and Long- Term Radon Measurements in Domestic Premises: Reporting results in terms of the HPA Action and Target Levels

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In the UK, the Action Level for radon gas in domestic buildings has stood at 200 Bq.m^{-3} for many years. Some years ago, our group made an extensive study of 7-day, 1-month and 3-month measurements in thirty-four un-remediated dwellings in a high-radon area over a full year. It was shown that one-week exposures were less reliable indicators of the long-term radon level, but that this variability was related to the changes in radon level, due to occupancy, weather changes and other influences. Our analysis reported the confidence limits for each detection period, and recommended a protocol for reporting. Short-term measurements can be reliable indicators in low-radon areas or for new properties, but in high-radon areas, the use of three-month exposures is indicated.

In 2010 the HPA recommended the introduction of a lower target level of 100 Bq.m^{-3}, with the intention of encouraging those most at risk from radon to consider remediation of their homes, even if the long-term average is between 100 and 200 Bq.m^{-3}. Our group has reviewed the results of the previous survey in relation to the new target level, and will report on the limits of confidence established for establishing whether a short term result is over the target level, and proposes a reporting scheme.

TS10c.5
Reverse Seasonal Variations Of Indoor Radon Concentration

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Radon concentration in indoor air of buildings, such as dwellings, schools, workplaces etc., is generally higher in autumn-winter season than in spring-summer period. This behaviour, however, is not quantitatively equal in all the buildings, and a quite large distribution of the winter/summer ratio actually occours, depending on several factors, including building characteristics, living habits, weather conditions. In a fraction of cases, radon concentration in summer could be higher than in winter. These "reverse" seasonal variations are particularly important if measurements of few months carried out in winter period are used to estimate the annual average, giving rise to a significant underestimate of the actual value. Some quite extreme reverse seasonal variations have been observed in a small town near Rome, Italy. In one of such cases, radon concentration, indoor and outdoor concentration were monitored The results of such measurements will be reported and analysed. Moreover, possible implications on measurement protocols and regulations will be discussed.

TS10c.6
Role Of Residential Radon In Childhood Leukaemia Incidence: The Geocap Program.

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Introduction: Childhood acute leukaemia (AL) etiology is still largely unknown. The main environmental exposures currently investigated are exposures to pesticides, hydrocarbon, ionizing and non ionizing radiation. The Geocap program investigates potential links between Childhood AL and several environmental exposures, among which domestic exposure to radon.

Materials and Methods: The Geocap approach consists in the comparison of residential exposure of children who suffer from AL in France to contemporaneous controls who are representative of the French population under the age of 15 years. Overall, 2 760 AL cases were recorded in the Inserm French National Registry of Childhood Haematological malignancies between 2002 and 2007. A random selection procedure led to gather yearly control groups (30 000 controls over the same period).

Cases and controls home addresses were geocoded, blindly with respect to their case or control status. IRSN mapped with an accurate geographic resolution (500 to 1000 m) the estimated geogenic radon potential (GRP), i.e. the capacity of geological units to produce radon and to facilitate its transfer to the atmosphere.. A first work aimed at validating the GRP map by comparison with a national sample of radon concentration measurements carried out in 10 843 houses by IRSN between 1982 and 2003, among these, 8 136 were geocoded at the address point

Results: Mean radon concentration increased along with growing GRP and this relation persisted after adjustment for known building characteristics (e.g.: material, floor). Considering contextual information on GRP surrounding measurement points rather than using punctual GRP alone, improved radon concentration prediction.

Conclusion: Preliminary results demonstrate the usefulness of the GRP for prediction of home exposure to radon and the added value of contextual information for such predictions will be further explored. Studying the statistical distribution of predicted radon concentration among the 30 000 Geocap controls will provide information on children exposure to radon in France. Finally, the comparison of this distribution to that observed among the AL cases will allow to document further the association between radon exposure and AL incidence among children.

TS10c.7
A Long-term Programme to Measure and Mitigate Radon Gas in English Schools - Progress Review and Lessons Learned

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Radon gas is the single largest source of radiation exposure to the UK population. It is the second largest cause of lung cancer after smoking. However, exposures are extremely variable and depend on multiple factors including the local geology, building construction and usage.

Radon measurements have been carried out in UK schools since the 1980s. After discussions at a national level in 2007, which concerned the radon exposure of children and radiation protection legislation, a countrywide, co-ordinated programme was developed to measure and promote the reduction of radon in schools. This paper describes the first concerted national radon campaign within a single occupational sector.

After detailed discussion with stakeholders including the Health and Safety Executive (HSE), a phased programme running over several years was proposed, with the following stated aims:

· To improve health protection by giving duty holders in schools the knowledge and awareness to ensure that no individual is exposed to excessive levels of radon gas

· To help duty holders plan and implement radon gas measurements

· To help duty holders understand the radon results and act upon them appropriately.

As the programme moves through its third year, this paper reviews the progress to date of the campaign, the successes and challenges, and the lessons learned. It covers the challenges of working with diverse customers, each having their own governance, priorities, and processes at a time when some aspects of the British education system are changing. For some schools, their radon situation is sufficient for them to become radiation employers under the Ionising Radiations Regulations 1999. One of the greatest issues with schools is addressing the concerns of parents and school governors when a new source of radiation exposure is revealed within their buildings; one to which students - children - and staff have been exposed for many years. Lastly, the paper discusses what changes can be made to enhance future programmes of this nature, both in the education other occupational sectors.

TS11a.1
Radiological Protection of Flora and Fauna Throughout Australia – Developing a National Approach

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Australia's longstanding approach to radiation protection of non-human biota (flora and fauna) has been to assume that if humans are adequately protected then other species are also protected. However, the 2007 Recommendations of the ICRP defined environmental protection objectives distinct from those for humans, and subsequently established a framework within which radiation exposures to flora and fauna from radionuclides released to the environment can be assessed. The framework uses reference organisms in order to estimate dose rates to living organisms which are representative of those within a contaminated environment.

The use of the reference organism approach to assess radiation exposures to flora and fauna has been explored by various Australian industries and operators. Some jurisdictions have issued guidelines supporting the reference organism approach for assessment of the non-human environment, whilst others are yet to take action. This demonstrates that there is a need for uniform guidance in order to encourage a National approach to the radiological protection of non-human biota that is consistent with Best International Practise.

In order to provide definitive guidance, a National Safety Guide is being produced in collaboration with expert representatives from Government and Industry. The types of planned, existing and emergency radiation practices in Australia to which specific advice on radiation protection on non-human biota may apply is likely to include;

- Radioactive waste management facilities,
- Mining and processing of radioactive ores,
- Other NORM-producing industries (e.g. offshore oil and gas),
- Research reactor operations,
- Hospital discharges of nuclear medicine wastes.

Australia is host to a variety flora and fauna with unique characteristics. It is important that strategies for the assessment of these unique species are captured in any National approach. These may involve the definition of specific reference organisms based on the ICRP's reference animals and plants. Relevant parallel projects collating concentration ratio data and determining data gaps in Australian environments provide a valuable resource for inclusion in the Safety Guide,

This paper will discuss the current status of the Safety Guide, future plans and timescales, as well as the specific challenges and risks involved in this project.

TS11a.2
Modelling radiation dose effects to wildlife populations

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A continuous, dual life stage, logistic model for generic populations of wildlife is presented in order to assess the non-stochastic effects of low LET radiation on repairable radiation damage, impairment of reproductive ability and mortality. Population change is modelled as a function of survival, fecundity, natural mortality and small density (allee) effects. Radiation-induced damages in young and adult life stages are modelled by means of a recovery compartment representing the organism's repairing system, with application of an allometric approach to extrapolate radiation-induced lethality rates for each life stage over a wide mass range.

Our study provides a simple, model-directed approach to understanding radiation effects on wildlife populations. The model equations are formulated generically by considering the organism's mass and a small number of species-dependent life history parameters. The potential of the model to infer screening values for the protection of non-human biota from ionising radiation in the presence of natural stressors is highlighted by two examples. First, model testing against radiation effects data for fish populations are presented. Then, simulations of population response to chronic irradiation for four mammal species (mouse, rabbit, dog and deer) are discussed in order to illustrate trends with mass for different organisms.

Taken together, model results suggest that radiation effects are more harmful for larger organisms which lower reproduction rates. For small mammal and fish populations, dose rates less than 10^{-2} Gy d^{-1} are not generally predicted to be fatal to the population. For large mammals, chronic exposure at this level is predicted to be harmful. At low exposure rates, similar to the ERICA screening value (2.4×10^{-4} Gy d^{-1}), long-term effects on the survivability of populations are negligible, supporting the appropriateness of this screening value for use in radiological assessments.

Keywords: Logistic, Population Model, Radiation Effects, Repair Mechanism

TS11a.3
Emerging Issues in Radiation Protection of Biota– The Impact of Non-Targeted Radiobiological Effects

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Ever since the acceptance that non-targeted effects (NTE) can be measured in unirradiated cells or distant progeny of irradiated cells, the discussion has developed about the relevance of these effects for radiobiology and radiation protection, particularly of non-human biota since they increase the complexity of the radiation response and allow for outcomes which are not as predictable as they were under the "old rules". For the purposes of this presentation, NTE are defined as effects not associated with DNA lesions due to energy deposition in the cell showing the effect and so include genomic instability and bystander effects. Specific examples which will be presented are (i) the data showing that bystander mechanisms are either on or off and that the "on" threshold appears to be at a very low dose (mGy range), (ii) the data suggesting that adaptive responses are induced not only in neighbouring cells but in organisms which receive bystander signals and (iii) the data showing that chronic exposures to alpha or gamma irradiation lead to complex responses in organisms which can be adaptive and protective, (iv) evidence suggesting that mixed contaminant exposures which include radiation can have sub-additive or synergistic effects. Apart from the practical relevance of NTE a major area of interest is the intrinsic relevance of these mechanisms in biology. Arguments will be made in this presentation, that NTE may call into question not only radiation effects paradigms such as the linear-non-threshold model (LNT), but may also have relevance to wider mechanisms in cancer biology, population ecology and evolutionary biology concerning process of selection, the transmission of heritable traits, the relevance of "social" interactions between cells, organisms and populations and the mechanism by which cells/organisms respond rapidly to environmental stress. This presentation will also argue that a key consequence of findings in NTE biology is that at any given level of organization, from gene to ecosystem – communication of stress signals and heritability of stress adaptations provide the bridges linking one hierarchical level to the next and enable the rapid propagation of change triggered by stress at one level, resulting in change at a higher (or lower?) level.

TS11a.4
Inhibition of DNA Double-Strand Break Repair in Zebrafish and Links with Effects on Reproduction and Development

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Uranium is a natural radioelement widely distributed throughout the environment. Background concentrations ranging from ~ ng/L to ~mg/L in surface water may be modified due to various anthropogenic processes, such as military, agricultural and industrial uses. These concentrations may have an impact on several aquatic species, and particularly fish, considerered generally as sensitive animals.

In this context, a research program was undertaken to study uranium effects on the zebrafish, Danio rerio. This species has been largely used as a test species in different research fields including genetics, study of the nervous system, cancer research and ecotoxicology.

The objective of the present work is to summarize all the genotoxic effects observed in zebrafish exposed to uranium, both in vivo to study effects on reproductive cells and consequences on ecologically relevant endpoints (reproduction, development), and in vitro to study DNA damage and repair mechanisms.

Zebrafish were exposed to waterborne depleted uranium during reproduction studies, as adults or as embryos and larvae.

Genotoxicity was assessed using the alkaline comet assay, which shows the amount of single strand breaks (SSBs), in several tissues (gills, hepatocytes, blood, germ cells). Germ cells were the most sensitive to uranium, and particularly male germ cells, with significant DNA damages observed from 20 µg U/L. This genotoxicity in gonads was correlated to a decrease of the reproductive ability. Additionally, DNA damages were observed in embryos of 24 and 48 h post-fecundation, correlated to an increase of larvae mortality.

Since unrepaired DNA damages were still observed in gonads after a one month-depuration, DNA double strand breaks (DSBs), considered as less repairable than SSBs, were studied. DBSs were evidenced both in vivo in male germ cells and in vitro in embryonic cells (ZF4). These breaks trigger the phosphorylation of H2AX proteins. We showed that the DNA-PK kinase activity, essential for the major DSB-repair pathways, i.e. non-homologous end-joining (NHEJ), was altered by the presence of uranium. Such a result suggests an impact of uranium upon the reparability of DSBs and the potential activation of alternative DSBs repair pathway leading to the propagation of possible misrepaired DSBs. This result may explain, at least partly, data observed on uranium effect on embryo survival and reproductive output.

TS11a.5
Assessment of the Radiological Impact and Associated Risk to Non-human Biota at Decommissioned Niobium (Nb) Mining Site in Norway

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An environmental risk assessment to evaluate the impact on non-human biota from elevated levels of terrestrial radionuclides (^{232}Th, ^{238}U and daughters) at decommissioned niobium (Nb) mining site (TENORM) was performed in present study. The mining activities related to ferro-niobium production in this area were conducted in period between 1953 and1965, while currently mechanical workshop exists at part of the site. High levels of radiation parameters (e.g., gamma dose rates, thoron and radon in the air, soil radionuclides levels) have recently been found on certain parts of this freely assessable site. Thus, a potentially increased associated radiation risk for humans was estimated. However, the assessment of impact on the environment and risk for non-human species has not been until now. Based on maximal soil activity concentrations of ^{232}Th (5650 Bq kg^{-1}), ^{228}Ra (5700 Bq kg-1), ^{228}Th (5300 Bq kg^{-1}), ^{238}U (1200 Bq kg^{-1}), ^{226}Ra (900 Bq kg-1) and ^{210}Pb (2700 Bq kg^{-1}), the significant external hazard index is estimated. Elevated gamma dose rates, 2.3 – 9.5 µGy h^{-1}, positively correlated with soil radioactivity levels was also observed. The information on mobility and transport of radionuclides is provided in addition.

The Erica Tool, a software programme developed within EC EURATOM funded ERICA project to assess radiological risk to biota, was used in calculation of total dose rates for set of reference organisms (4 – 147 µGy h^{-1}). The radiological risk (0.3 – 15) was estimated by comparison of calculated organism dose rate with ERICA default screening level of 10 µGy h^{-1} , given as a level below which no effect has been seen from ionizing radiation. Major contribution to total dose rate, for most of the organisms, was from exposure to ^{228}Th and $^{226, 228}$Ra isotopes. The most exposed organism group was found to be group of lichen and bryophytes, while trees were at insignificant radiological risk. Based on overall obtained results, the further investigations (uptake, transfer factors) is suggested in order to estimate weather the intervention action to protect the environment is needed.

TS11a.6
Review of Environmental Radiological Monitoring Programmes and Development of an Environmental Radiological Monitoring Guide

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The environmental radiological monitoring programme is a highly valuable complement for ensuring radiation protection of both the environment and the public. Since its beginnings, the Nuclear Regulatory Authority of Argentina (ARN) has been carrying out full environmental monitoring programs routinely at nuclear fuel cycle facilities within the country. This monitoring is carried out independently of the facilities´ own environmental monitoring. Over the last years the ARN has been reviewing both, the facilities' and its own monitoring programs, so that the operators' environmental performance is most efficiently controlled through the regulator's auditing and verification monitoring. As a result of this, the objectives of the environmental monitoring have been reformulated, new sampling criteria have been established, and both, operator and regulator responsabilities, have been reinforced, in terms of environmental monitoring. As a corollary of all this work, the need for an environmental monitoring guide has been recognized. Therefore, an ARN environmental monitoring regulatory guide is currently under production, in line with the latest ICRP recommendations, which will unify technical criteria concerning the development of environmental sampling programmes. The objective of this paper is to summarize the activities previous to the development of an environmental regulatory guide, and to present what we consider is necessary to be included in such a guide.

TS12a.1
Assessment of Atmospheric Dispersion for the Fukushima Dai-ichi Nuclear Power Plant Accident

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Dispersion of radioactive material released to the atmosphere from the Fukushima Dai-ichi Nuclear Power Plant Accident in Japan was modelled in real time to advice the French Government. The technical crisis centre of the Institute for Radioprotection and Nuclear Safety (IRSN) was activated to provide on a daily basis, the diagnosis of the different reactors, forecast their status and evaluate the radiological consequences of these different scenarios.

Since March 11, IRSN improved the assessment of the environmental contamination due to the Fukushima accident. The source term is still highly uncertain in terms of quantity and timing. This paper presents the approach which justifies the release scenario by coupling monitoring data with atmospheric simulations. Four different period of release were identified. For each event, a description of the atmospheric dispersion at local scale (50 km range), country-scale and world scale dispersion as well as doses assessment will be proposed. Uncertainties about the source term and the meteorological conditions will be discussed.

TS12a.2
Measurements and Dispersion Calculations by the Deutscher Wetterdienst Regarding the Release of Radionuclides at Fukushima-Daiichi Nuclear Power Plant

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In Germany, surveillance of radioactivity in the atmosphere has been a special task of the Deutscher Wetterdienst (German Meteorological Service) since 1955. This also involves the computation of dispersion forecasts which provide information about the transport and measurements. Airborne radionuclides are continuously measured at 48 measuring sites in Germany while precipitation samples are collected and measured at 40 sites. In addition, aircraft measurements supply information on radionuclide concentrations in the upper atmosphere.

Shortly after the release of radionuclides due to the explosion at the Fukushima Daiichi nuclear power plant, continuous calculation of dispersion forecasts was started at the Deutscher Wetterdienst. The results were published on the Internet, with graphs describing the pathways of possibly contaminated air parcels.. Two weeks after the event, the volatile radionuclides Xe-133, I-131, I-131 and Te-132 arrived in Europe and could easily be measured over Germany at magnitudes of several mBq/m3 using nuclide specific measuring and monitoring systems. In addition, I-131 was also detected by aircraft measurements.

The paper gives a detailed description of how the dispersion calculations were presented on the Internet, how the measuring results for airborne radionuclides and radionuclides in precipitation were obtained and how the Deutscher Wetterdienst communicated and cooperated with other national and international bodies and institutions.

TS12a.3*
Monitoring of Radionuclides in the Air in the Czech Republic After the Fukushima NPP Accident

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The system of the monitoring performed by the Radiation Monitoring Network after the Fukushima accident proved the ability of the network to react flexibly to any deviation from the standard situation. Results of the air monitoring all over the CR after the Fukushima accident are reported. The first rise of activities was detected on March 23 - 24 with activities amounting to units of $mBq.m^{-3}$. Increased activities were measurable until the beginning of June. Effective environmental half-lives of iodine and caesium in the atmosphere were 4 and 7 days, respectively. Found ratio of gaseous to aerosol forms of iodine typically ranged from 2 to 6. $^{137}Cs/^{134}Cs$ ratio equalled 1. The estimate of committed effective dose due to inhalation of radionuclides released from damaged Fukushima NPP is lower than $4x10^{-5}mSv$ for an adult living in CR.

TS12a.4
Operational Use of Atmospheric Dispersion Models in Denmark Supporting Decision Making During the Fukushima Daiichi Accident

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As in many countries far from Japan, the response in Denmark to the accident at the Fukushima Daiichi nuclear power plant in 2011 was more challenging than anticipated. The demand for general information to the press and to the Danish public, including the embassy in Tokyo, citizens in Japan and ship traffic in the area, soon become an obvious challenge to the preparedness. Accordingly, accurate prediction of risk areas was a high priority.

At the onset of the accident, the ARGOS decision-support system (DSS) was operational for East Asia regarding only long-range atmospheric dispersion calculation. However, in a very short time it became possible also to carry out short-range modelling when high-resolution data for orography and land use was uploaded to the system together with high-quality numerical weather prediction (NWP) model data.

For emergency response in Denmark, both short- and long-range atmospheric dispersion models were applied in real time during the accident. The models employed are the RIMPUFF and DERMA models, respectively, which are in operational use for Danish nuclear emergency preparedness. Whereas the RIMPUFF model is integrated in ARGOS, the DERMA model is run at the DMI high-performance computing facility and interfaced with ARGOS using automatic procedures. In order to carry out detailed atmospheric dispersion modelling, NWP model data were extracted in real time at highest spatial and temporal resolution from the global NWP model run at the European Centre for Medium-Range Weather Forecasts (ECMWF). The data obtained cover a geographical domain of about 6,500 km times 6,500 km at a resolution of 12 km. In addition, coarser global coverage data were available. In real time, the models were applied using source terms which were either best guesses at that time or hypothetical worst-case scenarios. Later, refined source terms were derived by e.g. fitting model results to aerial monitoring data. Results of the two atmospheric dispersion models are presented in comparison with the monitoring data.

Conclusions: For emergency response in Denmark, it was possible to use the existing ARGOS system for the Fukushima accident with minor data adjustments. The combination of long- and short-range atmospheric dispersion models proved to be an important tool for estimating risk areas not only for Japan, but also for the Danish ship transport to and from Japan during the accident.

TS12a.5
Comparison Of Dispersion Model Outputs And Radioactivity Measurements Made In Ireland Following The Fukushima Accident

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The Great East Japan Earthquake on 11 March 2011 generated a series of large tsunami waves that struck the east coast and resulted in extensive destruction. The Fukushima Dai-ichi nuclear power plant lost the ability to maintain adequate reactor and spent fuel pool cooling and water circulation. Subsequently, volatile fission products including iodine and caesium were released to the environment. The majority of the atmospheric releases took place between March 12 and March 22, with a maximum release phase from March 14 to March 16. Traces of iodine-131 from Fukushima were first detected in Europe (Iceland) on 23rd March; in Ireland, iodine-131 was first detected on air particulates collected on a high-volume air sampler during 26-27 March. Within 15 days of the accident accident, radioactive material released from Fukushima had spread all across the northern hemisphere.

The Radiological Protection Institute of Ireland (RPII) employs atmospheric dispersion models (ADMs) to predict the movement and deposition of radionuclides in the environment. This is of particular use in the case of unplanned atmospheric release of radionuclides before field measurements are not available. The RPII uses the Hybrid Single-Particle Lagrangian Integrated Trajectory (HySplit) model to assess the long range (>200 km) dispersion of radionuclides. The ADM was run using estimates available at the time of the quantities of radioactivity released from Fukushima Dai-ichi and with a combination of archive (Global Data Assimilation System, GDAS) and forecast (Global Forecasting System, GFS) meteorological data. The dispersion model was used to predict the arrival time in Ireland of the Fukushima radioactive plume, as well as air concentrations and duration of the radioactive plume over Ireland.

This paper will outline the HySplit model set-up used to predict the movement of the Fukushima plume. It will also compare the model predictions with measured air concentrations, demonstrating that the model predictions were broadly in agreement with the magnitude and timing of the observed radionuclide concentrations.

TS12b.1
Public Reaction to the Fukushima Accident in Korea and its Implications in Nuclear Safety and Risk Communication

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Although Korea is the next country to Japan, the prevailing wind directions directed east at the time of major releases from the Fukushima nuclear power plant made the contaminated air reach Korea after traveling very long distance. The measured activity concentrations in Korea were merely in the ranges of 1 mBq/m3 in air and a few Bq/L in the rain water.

However various over-reactions were observed in Korea. Extensive coverage of media lasted several weeks and people were very nervous. Quite a large number of people bought masks and excess bottles of drinking water. Due to rumors on protective capacity against radioiodine, brown seaweed and sun-dried salt was sold out. Foodstuffs produced in Japan, regardless of the specific area of their production, were refused by the consumers. All kinds of story flew in the network space.

If the prevailing wind directed the opposite, radiological damage to the Japanese society could hit extreme. The worst scenario may result in significant contamination of virtually all territory. Indeed the consequence might be far pessimistic: difficulties in food supplies, severe blow to export of goods and tourism led by 'stigma', social disruption caused by fear, shortage of electricity due to forced shutdown of operating nuclear reactors, and escape of foreign capitals, which are enough to lead a country into crisis. It should be noted that such severe impacts result not from real effect of radiation but from socio-psychological amplification of fear. Stigma is particularly the culprit. Misunderstanding of radiation effects of the general public plays the key role of propagation.

Among the lessons learned, two points are of particular worth to be emphasized: prevention of release of radionuclides having long half-lives and reform of public perception on radiation health risk.

The impact of release of noble gases or radionuclides with short half-lives will vanish soon, but that of long-lived radionuclides, typically Cs-137, can last decades. If nuclear accidents are not absolutely preventable, all means should be employed to restrict environmental release of the long-lived radionuclides of particulate form, particularly Cs-137. Introduction of the filtered vent system should be positively considered.

Given that use of nuclear power is a valuable asset in the era facing threat of climate change, the potential of social amplification should be neutralized by all means. Radiation protection community should at least share responsibility for reforming public perception of radiation risk. An active, innovative, effective and touching strategy of communication is needed in international scale because stigma deploys its power in the global trade.

TS12b.2
Responding to Public Fears on Transboundary Radioactive Contamination from Fukushima Daiichi Accident

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The consequences of the Fukushima Daiichi disaster go beyond Japan and beyond technological factors. Since Chernobyl, this accident is arguably the only other accident that had a major impact on the Malaysian public, testing the preparedness and response of Malaysian government in allaying all of its public's concerns. The national radiological response center, established in 2004 was required to operate 24/7 to address Malaysian's public concerns against transboundary radioactive contamination from the Fukushima Daiichi nuclear accident. The effects of nuclear accidents respect no borders and noting the planned nuclear power program within the South East Asian's region, Malaysia's ERP should be enhanced as the final boundary to safety. Valuable lessons were learnt in responding to public fears on Fukushima Daiichi accident and these lessons should put Malaysia on the right track forward.

Keywords: emergency response, transboundary, fukushima daiichi

TS12b.3
Content Analysis of the Media Reporting on the Fukushima Nuclear Accident in three European Countries

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The nuclear accident in Japan has predictably induced enormous media coverage. In general, mass media play a dominant role in communication on nuclear emergency issues. It is the prominent information channel for the general public, acting as the ''watch-dog'' of the society. Analysing the media content allows gaining a better insight into the way that a nuclear accident is reflected in nowadays society. It also provides useful lessons to be learned for risk communication in nuclear emergencies.

The goal of this study was to analyze and compare media reporting on the Fukushima nuclear accident in three European countries: Italy, Belgium and Slovenia. The political debate on nuclear energy in these countries was - at the time before the accident occurred- very different: from vivid discussions to no discussions at all.

The newspapers included in the analysis were *''Le Soir''* and *''De Standaard''* in Belgium; *''Corriere della Sera''* and *''La Repubblica''* in Italy and *''Dnevnik''* and *''Delo''* in Slovenia. The articles coded were directly or indirectly related to the Fukushima nuclear accident and were published between the 11th of March, 2011, until 11th of May, 2011.

The paper reports on quantitative aspects, such as the number of articles published and the main isssues addressed, as well as on qualitative aspects such as the connotation of the articles with respect to the nuclear energy. Differences and similarities across the three countries as regards the media discourse and content are highlighted and analysed.

TS12b.4
Japanese Earthquake And Tsunami: Implications For The UK Nuclear Industry

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On 11 March 2011 Japan suffered its worst recorded earthquake, known as the Tokuhu event. The ensuing tsunami resulted in a serious nuclear accident at the Fukushima Dai-ichi reactor site. Governments around the world watched with concern. The accident has since been rated as 7 (the highest level) on the International and Radiological Nuclear Event Scale.

In the United Kingdom the situation was kept under review at the highest level within Government with a focus on protecting UK citizens in Japan. The UK Government asked HM Chief Inspector of Nuclear Installations to co-operate and co-ordinate with international colleagues in examining the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. An interim report of this review was published in May 2011 with a final report in the autumn of 2011.

This paper will summarise the key findings of these reports with particular emphasis on those relating to radiological protection and emergency preparedness and response.

TS12b.5
Radiation Protection and Emergency Preparedness Aspects of the U.S. Nuclear Energy Industry Response to the Fukushima Dai-ichi Accident

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Immediately following the events of March 11, 2011, the U.S. nuclear energy industry mobilized its resources to respond to the Fukushima Dai-ichi accident. Industry emergency response centers were activated in Washington, DC, and Atlanta, Georgia, and a U.S. industry support team was deployed to Tokyo to interface directly with the Tokyo Electric Power Company (TEPCO). U.S. nuclear power stations augmented their environmental monitoring programs to better monitor for radioactivity transported across the Pacific Ocean and coordinated real-time data sharing with federal and state agencies through a web-based data management system.

The immediate industry priorities were to provide technical and material support to TEPCO to help stabilize the reactor units and to facilitate accurate and timely communications within the industry and with government agencies, national and international media and press, and the public regarding developments and implications of the accident. A wide variety of web-based applications, including social media, were employed throughout this effort.

The industry launched a nation-wide review to verify each station's capability and readiness to safely respond to a wide range of extreme events. For the longer term, the Electric Power Research Institute (EPRI), Institute of Nuclear Power Operations (INPO), and Nuclear Energy Institute (NEI), in conjunction with senior utility executives, created a joint leadership task force and plan to ensure that lessons learned from the Fukushima Dai-ichi accident are identified and response actions are effectively coordinated and implemented throughout the industry –including specific enhancements to radiation protection and emergency preparedness.

TS12b.6
Decontamination and Recovery Aspects of the Fukushima Accident

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As a result of the Fukushima reactor accident many countries and international organisations have offered assistance to the Japanese government to address radiological consequences of this tragic situation. The OECD Nuclear Energy Agency, conscious of the need to provide its expertise to the Japanese government while appropriately managing national and international resources, organised a workshop in October 2011 to address aspects of decontamination and recovery in the affected Japanese areas. Experts from other NEA member countries with direct experience in addressing contamination events participated in the conference and exchanged experience with their Japanese counterparts. The topics addressed included the use and evolution of protective criteria for affected populations; the management of areas contaminated with alpha-emitting radionuclides; the management of contaminated foodstuffs for internal use, for import and for export; and the decontamination of agricultural lands. Approaches, mechanisms and experience with the appropriate involvement of affected populations in all of these aspects were also discussed.

This paper will provide an overview of the topics that were discussed, and of the outcomes and ways forward that were devised as a result of these discussions.

TS12b.7
The IAEA's Incident And Emergency Centre: Response To The Accident At Tepco's Fukushima Daiichi Nuclear Power Station

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The IAEA's central role under the international emergency preparedness and response framework includes: prompt notification of the emergency to Member States and international organizations; exchange and/or provision of official (authenticated and verified) information to Member States and international organizations; coordination of international assistance, upon request of the State concerned; and provision and/or coordination of public information that is timely, accurate and appropriate. In addition, the IAEA plays a central role in coordinating the inter-agency response under the Joint Radiation Emergency Management Plan of the International Organizations. The IAEA discharges its role through its Incident and Emergency System (IES) consisting of a 24-hour a day contact point and an operational focal point, the Incident and Emergency Centre (IEC).

At 05:46 UTC (coordinated universal time) on 11 March 2011 an earthquake of magnitude 9.0 occurred off the east coast of Honshu, Japan. At 06:42 UTC the Emergency Response Manager of the IEC was notified, by the External Event Specialist on-call, of the earthquake and of the potential for damage at four nuclear power plants on the north-east coast of Japan, as well as the potential for a tsunami. Since that moment, the IEC started to implement its functions in response to the event.

The article will discuss in detail the actions of the IAEA's IEC in fulfilling the Agency's role in response to the accident at TEPCO's Fukushima Daiichi Nuclear Power Station.

TS12c.1
Key Issues on Radiological Protection from Radioactive Waste Management in Existing Exposure Situation

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In the environmental rehabilitation process after the accident at Fukushima-Daiichi nuclear power station, radioactive wastes have to be appropriately managed in existing exposure situation as a result of contamination with radionuclides released from the damaged reactors. However, the available radiological protection system for radioactive waste management has been constructed only for planned exposure situation, in which compliance with the dose limit of 1 mSv/y for public exposure should be demonstrated. In view of the principle of optimisation it is not be practicable to apply the available system for planned exposure situation to the rehabilitation process in the contaminated area because the radiation level would be reduced using a reference level selected from the band of 1 – 20 mSv/y in existing exposure situation. In this paper, we discuss some key issues to establish a concept of radiological protection from radioactive waste management in existing exposure situation; definition and selection of a reference level for radioactive waste management in existing exposure situation, application of long-term institutional control for radioactive waste management and consideration of half-lives of radionuclides in the wastes in the safety assessment.

TS12c.2
Comparative Analysis Of The Radionuclide Composition In Fallout After The Chernobyl And The Fukushima Accidents

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The nuclear accident occurred at Fukushima Dai-ichi Nuclear Power Station (NPS) (March 11, 2011) similar to the accident at the Chernobyl NPS (April 26, 1986) is related to the level 7 of the INES. It is of interest to make a comparative analysis of radionuclide composition of fallout following the both accidents. Results of spectrometric measurements of more than 200 soil samples taken 25-70 days after the Chernobyl accident and of 5 soil samples taken 17-18 days after the Fukushima accident were used in that preliminary analysis. Two areas following the Chernobyl accident were considered: (1) the near zone of fallout – the Belarusian part of the central spot extended up to 60 km around the Chernobyl NPS formed due to dry deposition on April 26-27, 1986 and (2) the far zone of fallout – the "Gomel-Mogilev" spot centered 200 km to the north-northeast of the damaged reactor formed due to mainly wet deposition on April 28-29, 1986. In the case of Fukushima accident the preliminary data published by Japanese specialists (Imanaka et al 2011) who collected soil samples in the near zone at distances (30-45) km from the Fukushima NPS at the north part on the northwestern radioactive trace mainly formed on March 15, 2011 were considered.

Comparative analysis has been done with respect to refractory radionuclides (^{95}Zr, ^{95}Nb, ^{141}Ce, ^{144}Ce), as well as of the following radionuclides 131I, ^{103}Ru, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{140}La, ^{140}Ba and the results of such comparison have been discussed.

With respect to exposure to the public the most important radionuclides are ^{131}I and ^{137}Cs. For the both accidents the specific activity of ^{131}I exceeds that of ^{137}Cs in the considered soil samples by a factor of (6-36) for the major part of the Chernobyl samples and by a factor of (8-13) for the Fukushima samples (the ratios are decay-corrected to the corresponding dates of the accidents). It is worth noting that despite of very limited number of the considered Fukushima soil samples there is a clear tendency that the ratio of $^{131}I/^{137}Cs$ decreases with the increase of the ground deposition density of ^{137}Cs. This tendency was revealed earlier for the areas contaminated following the Chernobyl accident (spectrometric measurements of more than 1000 soil samples were analyzed). The above tendency (confirmed for the Fukushima accident) is important for reconstruction of ^{131}I fallout based on the results of ^{137}Cs measurements carried out at late dates after the Fukushima accident.

TS12c.3
Practical Retrospective Dosimetry: Looking Back to Chernobyl with a View Forward at Fukushima

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Chernobyl accident, which occurred on April 26, 1986 at NPP located less than 150 km north of Kiev, is the largest nuclear accident ever. Unprecedented scale of the accident was determined not only by the amount of released activity, but also by a number of population and workers involved and, therefore, exposed to enhanced doses of ionizing radiation.

Population of the 30-km exclusion zone numbering about 116,000 persons of all ages and both genders was evacuated within days and weeks after the accident, emergency workers called 'liquidators of the accident' (males age 20-50) were involved into clean-up and recovery for 5 years and their number is estimated as 600,000, about 300,000 are Ukrainian citizens.

Due to unexpected and excessively large scale accident, none of residents had personal dosimeters, personal dosimetry of liquidators was not total, dosimetry techniques and practices were far from the optimum.

As a result, an acute need for retrospective dose assessment was dictated by radiation protection and research considerations. This need was responded by implementation of wide scale dose reconstruction efforts, which covered main exposed cohorts and encompassed broad variety of newly developed methods: analytical (time-and-motion), modeling, biological and physical (EPR spectroscopy of teeth, TL of quartz).

In most cases, particular needs called for development of new techniques and approaches. These approaches were quite different, yet all were aimed at reconstruction of individual doses to the subjects exposed after Chernobyl accident and paid special attention to assessment of associated uncertainties. The dose estimates were used for evaluation of impact of the accident on evacuated population and residents of contaminated areas downwind Chernobyl as well as for analytical epidemiological studies and estimation of risk factors. Although these tasks constituted a challenge, most of the aims were achieved and now dose reconstruction approaches and techniques were brought to the new qualitative level.

Though each dose reconstruction effort is unique and is determined by the needs of a particular study, the accumulated experience could be applied for broad variety of retrospective and emergency dosimetry applications. Situation in Fukushima area has many similarities with Chernobyl and, therefore, our approaches can be applied for dose reconstruction and verification of main cohorts involved in Fukushima Dai-ichi NPP.

TS12c.4
Assessment on the 66th Day of Projected External Dose for Populations Living in the North-West Fallout Zone of the Fukushima Nuclear Accident

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Since the beginning of the accident that occurred the 11th of March 2011 at the Dai-ichi nuclear power plant in Japan, the French Institute for Radiological Protection and Nuclear Safety (IRSN) has been strongly committed to perform a real-time evaluation of stakes and consequences of the situation based on partially-available information with the objective of responding concerns of French authorities, including French Embassy in Tokyo, and the public.

Thus the 8th of April 2011, 28 days after the beginning of the accident, IRSN published on its website a first map of doses likely to be received by the population (projected doses) living in the area of the damaged nuclear power plant for the year following the accident. Similar maps were published within the following weeks, notably those of the Department of Energy of the United States of America and of the Ministry of Science and Technology of Japan.

The projected doses as well as the geographic and demographic distribution of the Japanese populations living around the nuclear power plant allowed IRSN to assess the impact of evacuation measures (in terms of dose and range of concerned population) depending on reference level adopted for evacuation and the delay of its implementation.

The paper will present the drawing up of projected dose maps based on source term assessments and measurements done around the plant, and also the assessments of range of concerned population and surface depending on the reference level adopted for the evacuation and the delay of its implementation. A comparison with the Chernobyl accident and with the evacuation measures taken by Japanese authorities will conclude the presentation.

TS12c.5
Radiation and Radioactivity Monitoring in the Surrounding Environment after Fukushima Daiichi Nuclear Power Plant accident 1. Overview

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After the explosion of power plants on March 14, radiation survey has been done with the airplanes by DOE (Department of Energy), USA and MEXT (Ministry of Education, Culture, Science, Sports and Technology) in the area of about 100 km distance from the power plant. At the end of May, MEXT started the committee on radiation and radioactivity mapping in this area, behavior of radioactive materials in the forest and their transfer to the river. Twice from June to July, radio-activities of soils were measured at many local points over 2000 points, every 2 km in the area of 80 km and every 10 km in the area from 80 to 100 km from the power plant, and monitored radiation levels at those points by about 90 organizations. The car survey has also been done along the road by these groups. It was found that the explosion of power plants on March 15 to 16 emitted a large amount of radioisotopes of I-131, Te-132, Cs-134 and Cs-137 etc. in the atmosphere. Volatile Iodine isotopes were predominant, about 100 times larger than Cesium isotopes, but now after two months, Cs isotopes became dominant. Strontium isotopes of Sr-89, Sr-90 were about 1/1000 to Cs isotopes due to higher melting and boiling points than Cs isotopes. Some research groups continue to monitor the behavior of these isotopes in the forest and their transfer into the river and the well. The time-sequential variation of these deposited radioisotopes will continue to monitor.

TS12c.6
Estimation of Internal Exposure Dose of the Population Caused by Inhaled Radioactive Materials Released in Early Stage of Fukushima Nuclear Disaster

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In early stage of Fukushima nuclear disaster large amount of radioactive materials had been released to the area more than 100 km far from the Fukushima nuclear power plants. But, on account of the malfunction of the emergency monitoring system there existed less information about the airborne radioactive materials until 20th of March, while the measurements of the radioactive materials deposited on the green vegetables and drinking water were started on 18th of March. This is one of the reasons why the estimation of internal exposure dose of the population did not performed for long time.

By taking into consideration of the importance of the internal exposure, estimation of internal dose of the population living in northwestward of the nuclear power plants has been carried out here on the basis of the airborne radioactive materials estimated using concentrations of those on the green vegitables. The doses were estimated on the assumption that the people were staying at outdoor for three hours during the radioactive plume were passing through.

The highest concentration of airborne radioactive materials, which would be occurred on around 15th of March, could be determined by extrapolating the data obtained after 18th of March. The results apparently indicate that the internal exposures of the people exceeded 1 mSv by only 3 hours of inhalation of air, though they depended on where the people were living in.

List of Poster Areas

P01.01
On the question of interpopulation transfer of risk coefficients

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Scientific and Technical Center of Radiation and Chemical Safety and Hygiene FMBA Russia, It is known that even under normal conditions in the cells there are numerous spontaneous DNA damages and that irradiation adds a certain amount of such damages. The vast majority of DNA lesions, spontaneous and radiation-induced, are eliminated by the cellular repair systems. However, a certain fraction may remain and can cause malignant transformation of irradiated cells or its descendants. Since the carcinogenic effect of radiation, how believed, arise due to radiation damages, which had not been eliminated, then under protracted exposure would be expected increase the rate of such injuries and to increase of the mortality rate from cancer by a constant factor. However in fact such an effect is observed after acute exposure, while this factor under protracted exposure increases with age approximately exponentially.

This contradiction can be explained by assuming that the effect of ionizing radiation is manifested to a greater degree in the suppression of the repair systems than in the formation of additional DNA damages which lead to malignant transformation of cell. Reducing the effectiveness of repair systems causes an increase in the number of spontaneous lesions, which pass into the category of potentially cancerous. The cumulative dose under protracted exposure increases with age, the efficiency of repair is reduced, resulting in rises of the transition probability the spontaneous damages in the potentially cancerous damage and, respectively, the mortality rate from cancer increases with age by a factor proportional to the cumulative dose. Acute exposure causing a step-like reducing of repair systems efficiency, so the mortality rate at all ages after irradiation is different from the mortality rate prior to irradiation by a factor, which depended from dose but not from age. If account is taken additional damage, produced by radiation, then pattern is complicating, but not fundamentally changed.

The experiment that could verify the proposed hypothesis is to determine what impact will from radiation exposure on dependence of the probability of a mutation (or another cellular effect) from dose of any nonradiation carcinogen. Increase in the slope of such dependence would be evidence damage of repair systems. Proportionality of the slope to the radiation dose would be a direct confirmation of the hypothesis

Proposed mechanism of damage cell leading to cancer makes a logical widely practiced transfer risk coefficient for cancers of various localization between different population.

P01.02
The Relative Biological Effectiveness of 131I Beta Particles Compared to Gamma Radiation

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In this research a new approach was considered to determine relative biological effectiveness (RBE) for a specific radiation. RBE, in this study, was defined for ^{131}I beta particles, based on 1.25 MeV gamma photons of ^{60}Co source as reference radiation and DNA damages in U87MG Glioblastoma cells as a biological end effect were analyzed by alkaline comet assay technique. Comet assay revealed that there is a linear relationship between length of tail moment in cells and absorbed dose from beta particles. In this experiment the predicted RBE was 1.16. Beta particles with average energy of 180 KeV was about 16% more effective than 1.25 MeV photons to produce single strand breaks in Glioblastoma cells DNA. This was partly due to the linear energy transfer differences and partly to the secondary electrons that translate DNA damages at the microdosimetry level.

Key words: RBE, Glioblastoma, Spheroid, microdosimetry

P01.03
Do the Auger Electron Emitters I-123 and I-125 Show Differences in their Cyto- and Genotoxic Potential?

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The Auger effect is not yet fully understood in respect to dose and dose rate and hence no radiation quality factor is defined for radiation protection purposes. Therefore, we studied the Auger electron emitters (AEE) I-123 and I-125 which are characterized by a different half-life (13.2 h vs. 59.4 d) and by different average numbers of Auger electrons emitted per decay (ratio I-123/I-125 - 1:2). The biological response in mammalian cells labelled with various activity concentrations of 5-(123) iodine-2'-deoxyuridine (I-123-UdR) and (5-(125)iodine-2'-deoxyuridine (I-125-UdR) was thoroughly investigated to further elucidate the biological effectiveness of these particular electron emitters.

SCL-II cells were synchronized in G1-cell cycle phase, subsequently labelled with I-123- respectively I-125-UdR and the cellular uptake and DNA incorporation of I-UdR was determined. Chromatin damage was quantified by the alkaline Comet assay, apoptosis induction assessed by the Annexin V/PI assay employing flow cytometry and micronucleus formation was quantified using the Cytochalasin-B micronucleus assay at various times post-labelling. Cs-137 y-rays served as reference radiation.

I-125-UdR caused pronounced apoptosis when compared to I-123-UdR. In contrast micronucleus induction and chromatin damage were very similar for both radionuclides. Both AEE caused a pronounced and long-lasting G2/M cell cycle arrest. On average one decay of I-125 every 120 seconds in the DNA of a single cell is sufficient to induce a permanent G2/M cell cycle arrest in SCL-II cells. Albeit of a lower dose rate, I-125-UdR is more cytotoxic in comparison with I-123-UdR.

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P01.04
Effect of Gamma Irradiation on the Biophysical and Protection Properties of Melanin

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Abstract:

Melanins are natural pigments distributed in the living organisms and they are responsible for the pigmentation of the surface structure. In the present work gel exclusion chromatography, spectrophotometric and dielectric relaxation techniques were used to characterize DOPA melanin before and after irradiation with 60Co gamma rays in the range of 5-50 Gy. The results show that the studied melanin is composed of two structural groups. The extinction absorption coefficient and relative permittivity and conductivity of melanin sample increased after irradiation with rays and showed to be done dependent. These increases were attributed to the formation of melanin aggregation and crosslinks which result from the growing number of the formed free radicals by radiation.

It was concluded from the results that melanin goes through some structural changes after irradiation with the gamma doses demonstrated. Further studies were recommended to investigate and evaluate whether these changes could affect its efficiency as a radio protector against gamma doses.

Keywords:

melanin structure, gamma irradiation, gel chromatography, absorption spectra, relative permittivity and conductivity.

P01.05
The Role of V.A.C., Acellular Matrices, Enzymatic Debridement and Stem Cells Therapy as Adjuntive Treatment for C.R.S

Portas, M*[1]; Di Giorgio, M[2]; Coppola, A[1]; Giongrande, J C[1]; De Lellis, M[1]; Mansilla, E[3]; Drago, H[1]; Ortega, J C[1]

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Chronic or non-healing wounds can develop after radiotherapy, interventional procedures and accidental overexposures to ionizing radiation, and are the cause of considerable morbidity and health costs. The purpose of this paper is to describe different adjunctive treatments that were implemented to achieve a faster and more physiologic healing process.

Methods: In the frame of an agreement between the Nuclear Regulatory Authority and the Burn Hospital of Buenos Aires, 160 patients with localized radiation injuries were assisted. Most of the cases were due to medical exposures and were handled by the Radiopathology Committee at the Burn Hospital. Description: Patients displaying acute and/or late cutaneous reactions were classified according to the toxicity criteria of the Radiation Therapy Oncology Group (RTOG) and the European Organization for Research and Treatment of cancer (EORTC), grades 0 to 4. All cases were treated with the established protocol (topic administration of trolamine and silver sulfadiazine with lidocaine, associated with systemic administration of pentoxiphiline and anti-oxidants). Mild cases (dry and wet epithelitis and the further deepening of the lesion) were additionally treated with topical antibiotics ointments to prevent infection and with hydrating creams to prevent dehydration of the damaged skin. For the most severe cases, grade 4, other adjunctive treatments such as enzymatic debridement with collagenase or papain were employed. Two cases required VAC treatment (Vacuum Assisted Closure) due to deep tissue compromise and the presence of abundant detritus, together with a clinical bad status that did not allow surgery. Thus, it was indicated the use of a local exhaust system connected to an alternating pressure pump, allowing drainage of dead material, which prevented granulation tissue from growing. In these patients, 20 to 40 sessions of hyperbaric oxygen therapy were administered. When the wound bed was in suitable conditions, temporary skin covers with polymeric films, renewable as many times as necessary, were used, creating an accelerated healing environment while avoiding dehydration and infection. Further resources such as the use of acellular matrix and stem cell therapy are the novel proposed approaches.

Conclusions: Aggressive treatment is not indicated in poorly perfused tissues, deep tissue compromise involving muscles, with associated ischemia reperfusion phenomena and circulating free radicals. The therapeutic response observed supports that the closure of the lesion should be done preserving the dermal matrix and the usefulness of enzymatic debridants instead of the surgical removal of necrotic tissue. Given the characteristics of these lesions, their cyclic evolution and tendency to chronification, a regular monitoring of all injuries, even those categorized as cured, is strongly recommended.

P01.06
Radiation Injuries in Fluoroscopically Guided Interventional Procedures

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The incidence of fluoroscopically induced injuries is small compared with the number of procedures performed. Nevertheless, as such procedures can deliver high doses to patient skin; some patients develop Cutaneous Radiation Syndrome (CRS). Physical and patient-related factors that contribute to an increased clinical toxicity include: location of the irradiated skin, high individual radiosensitivity, obesity and smoking habit.

The purpose of this work is to review the diagnosis, treatment and follow up of 8 cases with fluoroscopically induced injuries treated in the Burn Hospital of Argentina.

Material and methods: In the frame of an agreement between the Nuclear Regulatory Authority and the Burn Hospital of Buenos Aires, a research project for diagnostic and therapeutic approach of CRS was conducted since 1997 to the present time. One hundred and sixty patients with localized radiation injuries were assisted, from which 8 (3 women and 5 men) corresponded to interventional procedures. Patients displaying acute and/or late cutaneous reactions were classified according to the toxicity criteria of the Radiation Therapy Oncology Group (RTOG) and the European Organization for Research and Treatment of cancer (EORTC), grades 0 to 4. Lesions occurring within 90 days after exposure were consider acute reactions, whilst those appearing after the 90 days, were considered delayed reactions.

Two patients developed CRS grade 3 and 4 patients developed grade 4. All cases were treated with the established protocol (topic administration of trolamine and silver sulfadiazine with lidocaine, associated with systemic administration of pentoxiphylline and anti-oxidants). For closed lesions the local topic superoxide dismutase (SOD) instead of silver sulfadiazine. Lidocaine provides local anesthesia, diminishing the pain; vitamin E and SOD reduce free radicals toxicity; silver sulfadiazine acts as a local bacteriostatic agent, and pentoxifylline prevents ischemia-reperfusion phenomena. Three cases radiation damage also extend to muscle. In one case, with the worst prognosis, 40 sessions of hyperbaric oxygen therapy was applied due to the severity of the injury. The evaluated patients with oval back lesions, from 10 to 20 cm, around the scapular region showed remission of signs and symptoms with the treatment. Four patients experienced spontaneous venous type bleeding that resolved with local compression .The area appeared as cured with no skin disruption.

Conclusions: Prognosis was serious in all cases. In those cases that interrupted the prescribed treatment, severe pain and lesions reappeared. Due to the cyclic evolution and tendency to chronification of these lesions we emphasize the importance of long term follow up, including both clinical and psychological aspects. According to diagnosis, a radiation origin should be considered for all skin lesions occurring within few weeks/ month of fluoroscopically guided procedures unless a definitive alternative diagnosis is established.

P01.07
A Ne Look at the Environmental Health Impact of Radon and its Daughters in Light of Combustion Products

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Today, lung cancer is the leading human malignant disease in both women and men. Radon is a recognized cause of lung cancer in uranium miners indicating a relation to environmental factors such as combustion products (CP). Recently, we found ^{210}Po, an environmental radon (ERn) daughter, to be in/or on diesel particulate matter (DPM) in the size range of 0.2-1.0 µm. In 1989 we reported that the exhalation of stored ERn is increased after eating when radon-free air was inhaled (Lykken & Ong, 1989). Thereafter, we reported that the ERn daughters, ^{210}Pb, ^{210}Bi and ^{210}Po , accrue selectively in the human brain proteins in AD and brain lipids in PD, and that hippocampus and amygdala are primary targets of radon and its daughter's deposition in the AD human brain (Momĉilović et al., 2006). Moreover, we detected increased levels of the ERn daughter ^{210}Po in nerve myelin and in cancerous breast and prostate tissues. These data indicate that ERn and/or its daughters are inhaled into the human body, and retained in the human body where they follow specific kinetics of tissue distribution (affinity for and solubility in the fatty tissue and body fluids for ERn).

There are numerous misconceptions about the biological role of ERn due to over-simplification of complex issues to find simple answers or, over reduction, even if not *reduction ad absurdum.* Thus, it is said that radon as a noble gas is chemically inert and does not react chemically within the body, that inhaled radon is exhaled with no net deposition within the body, and that energy released from radioactive decay during its brief residence is too small to be an environmental hazard in a non-occupational setting. However, radon can react through weak van der Waals bonds. Our seasonality report on ERn exposure showed that radon in the body tracks ERn exposure (Momĉilović & Lykken, 2007). Moreover, ERn decays from a noble gas into metallic radioactive elements of the uranium decay chain and the 4 α particles released in decay to stable ^{206}Pb would kill and damage at least 400 surrounding cells.

We found that CP contains ^{210}Po and that the emitted α particles from CP may be a contributing factor in the world-wide epidemics of the lung cancer and diseases of the central nervous system.

Lykken, G.I. and Ong, W.C., Hlth Phys 1989, 57:161-162; Momĉilović, B., Lykken, G.I. and Cooley, M., Mol Neurodegen 2006, 1:11 doi: 10.1186/1750-1326; Momĉilović, B., and Lykken, G.I. Hlth Phys 2007, 92(5):484-487

P01.08
Comparison of Absorbed Radiation Doses Following a Chronic Contamination through Ingestion of Either 137-Cesium or 90-Strontium

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The IRSN research program ENVIRHOM is dedicated to the study of non-cancerous effects of chronic ingestion of low concentrations of radionuclides. These studies showed that chronic ingestion of ^{137}Cs induces modifications in several physiological systems, although most of the observed modifications are at the molecular level, without any major consequence on the health status of animals. Thus it is of outstanding importance to know the absorbed radiation dose due to the chronic ingestion of radionuclides in order to facilitate the interpretation of the observed biological effects.

We used the dose conversion factors (DCF) proposed in the publication 108 of ICRP for two radionuclides of interest in our program, ^{137}Cs and ^{90}Sr . Concentration of radionuclides in organs of contaminated mice were obtained from previously published biokinetic studies both for ^{137}Cs and for ^{90}Sr . These studies were made with drinking water containing 20 KBq.l-1 of either ^{137}Cs or ^{90}Sr given ad libitum from mating of parents until the age of sacrifice of offspring.

We used the specific DCF expressed in (µgy/day)/(Bq/kg) for ^{137}Cs and ^{90}Sr proposed by ICRP publication 108. Results indicate that, for ^{137}Cs , the absorbed radiation dose vary between 3.4 ± 0.1 mGy at birth up to 10.7 ± 0.1 mGy at 20 week-old, without any significant difference between males and females. For animals ingesting ^{90}Sr , the absorbed radiation dose vary from 0.6 ± 0.1 mGy at birth up to 10.6 ± 0.1 mGy at 20 week-old, with significantly higher absorbed doses to the females as compared to males. There is a linear evolution of the absorbed dose in animals ingesting ^{137}Cs . By contrast, the absorbed dose increases more rapidly after the age of 6 weeks i.e., after the bone growth in ^{90}Sr ingesting animals. These absorbed radiation doses calculated with DCF were compared with a dose calculation based upon the use of specific fraction of absorbed energy as defined by others. This shows a good correlation between the results of the two methods. This suggests that the hypothesis used in order to apply the DCF from ICRP 108 to our mouse model of chronic ingestion (especially the hypotheses about the mouse body mass and radionuclides distribution) do not induce uncertainty on the absorbed dose calculation. Overall, the use of DCF allows obtaining in an easy way a good estimate of absorbed dose in experimental models of chronic ingestion of radionuclides by rats and mice.

P01.10
Antioxidant Status in Chicken Embryo Liver after Low Dose Gamma Irradiation

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It is well known that ionizing radiation at high doses has harmful biological effects. However, at low doses and low dose rates, radiation can stimulate induction of antioxidant defence system. In the avian there is lack of results on antioxidant status in organs of chicken after low dose egg irradiation. This study was performed to investigate the effect of low-dose gamma-irradiation upon activity of glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), catalase (CAT) and level of glutathione (GSH) and lipid peroxide concentration (MDA) in liver of commercial meat chicken line embryo. Fertilized eggs were irradiated with the dose of 0.05, 0.15, 0.3 and 0.5 Gy gamma radiation (source ^{60}Co) on the 19th day of incubation. Along with the irradiated chick embryos, there was a control group of non-irradiated chick embryos. The antioxidant parameters were measured in liver on 1, 3, 6, 12 and 24 hour after eggs irradiation. All parameters were measured spectrophotometrically except intensity of lipid peroxidation which was assessed by HPLC. The acute irradiation of chicken embryos to different doses of gamma radiation resulted in increase in the MDA concentration on the 3th hour after irradiation with doses of 0.15 and 0.30 Gy as well as in decrease in the MDA concentration on the 24th hour after irradiation with the same doses. The SOD and CAT activity were significantly increased on the 1st hour after irradiation with dose of 0.5 Gy while the activity of SOD was increased on the 12th hour after irradiation with doses of 0.15, 0.30 and 0.5 Gy. The GSH level was increased on the 24th hour after irradiation with doses of 0.05, 0.15 and 0.30 while at the same time after irradiation the CAT activity was decreased with doses of 0.05, 0.15 and 0.30. The obtained results suggest that oxidative/antioxidative balance in chicken embryo liver was impaired after irradiation with different low doses of gamma radiation especially at the dose of 0.3 Gy.

P01.11
Radioprotective and Anti-Carcinogenic Potentials of Mentha Piperita Linn.: Evaluation of cytotoxicity

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Peppermint (Mentha piperita) is on the FDA's GRAS list (generally recognized as safe). It is one of the world's oldest medicinal herbs. It belongs to the family Lamiaceae, a natural hybrid between spearmint (Mentha spicata) and water mint (Mentha aquatica). Peppermint is considered mainly to have antiseptic and antimicrobial activity but is also considered by herbalists as an astringent, antipruritic, antispasmodic, antiemetic, carminative, diaphoretic, mild bitter, analgesic, anticatarrhal, rubefacient, stimulant, and emmenagogue. We studied the anti-carcinogenic and radioprotective potentials of Mentha piperita Linn. in Swiss albino mice. M. Piperita leaf extract provide protection against radiation-induced alterations in intestinal mucosa, testis, haematological constituents, modulates values of serum acid and alkaline phosphatises activities, chromosomal and haematopoietic damage in bone marrow. The anticarcinogenic effects of Mentha piperita Linn leaf extract have been screened in Swiss albino mice against DMBA-induced skin papillomagenesis using two-stage mouse tumor model. To evaluate the possible molecular mechanisms underlying the cytotoxicity and anticarcinogenic potential of M. Piperita leaf extracts (petroleum ether, benzene, chloroform, ethyl acetate, methanol, and water extracts) on 6 human cancer and 2 normal cell lines were examined. The chloroform and ethyl acetate extracts of M. Piperita showed significant dose- and time-dependent anticarcinogenic activity leading to G1 cell cycle arrest and mitochondrial-mediated apoptosis, perturbation of oxidative balance, upregulation of Bax gene, elevated expression of p53 and p21 in the treated cells, acquisition of senescence phenotype, while inducing pro-inflammatory cytokines response. These results provide the first evidence of direct anticarcinogenic activity of M. Piperita leaf extracts. Further, bioassay-directed isolation of the active constituents might provide basis for mechanistic and translational studies for designing novel anticancer drugs to be used alone or as adjuvant for prevention of tumor progression and/or treatment of human malignancies.

Key words: Mentha piperita, cytotoxicity, anti-carcinogenic and radioprotective potentials, radiation-induced alterations.

P01.12
Radioprotective Activity And Genotoxic Effects Of Curcumin In Human Lymphocytes Cultures

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Curcumin is a major polyphenolic compound of the rhizomes of turmeric (Curcuma longa). This gold spice had been used for thousands of years in Asian and folk medicine as an anti-inflammatory agent and to treat several health disorders related with liver and abdominal pain, anorexia, rheumatism, diabetes, runny nose, cough and sinusitis.

The aim of the study was to assess radioprotective activity and genotoxic effects of curcumin. Firstly, to evaluate the genetic damage induced by curcumin, increasing concentrations (0-500 µg/mL) of this compound were added to human peripheral blood. Cytogenetic alterations such as chromosomal aberrations (CAs) and sister chromatid exchanges (SCE), were analyzed. Moreover, the use of the cell proliferation kinetics (CPK) and mitotic index (MI) were used to assess the cyto and genotoxic effect of different concentrations of curcumin. Secondly, radioprotective activity was carried out by the pre-treatment of human lymphocytes at concentrations from 0 to 500 µg mL-1 of *curcumin* and then exposed to 2 Gy γ-rays. The results showed that curcumin reduced radiation-induced chromosomal damage compared with cells with any treatment. Maximum damage protection was observed at the concentration of 5 µg mL-1. These assays were applied in order to establish a safe *in vitro* dose to be used as a radioprotector agent.

Keywords: curcumin, radioprotector, γ-radiation, genotoxicity, cultures

P01.126
HOTDOSE: A Software Package to Calculate Dose Probability Distributions for Hot Particle Inhalation

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HOTDOSE is a software package that implements ICRP biokinetic and dosimetric models for estimation of probability distribution doses due to the inhalation of a hot particle. HOTDOSE estimates the dose for inhaled hot particles for selected physical properties such as diameter, density and shape factor. The hot particles are considered to be non-soluble and move randomly in the different ICRP 66 compartments according to their half-times ($T_{1/2}$). In each compartment the residence time of the hot particle is estimated randomly according to a Poisson distribution, with an expected number of occurrences during the given interval, $\lambda = Ln2/T_{1/2}$, using the Monte Carlo method. The number of decays in each compartment is calculated according to activity and, therefore, the dose can be estimated using ICRP recommendations. The doses of many hot particles have been calculated for a variety of radionuclides in order to obtain the dose probability distribution. Results of dose probability distributions will be presented.

P01.13
Statistical Evaluation of Subtle Effect of Continuous Low Dose rate Gamma-Irradiation on Murine Inflammatory Reaction

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Because linear non-threshold model (LNT) is based on epidemiological data of atomic bomb survivors exposed on high dose/high dose-rate radiation, evaluation in low dose /low dose-rate range is necessary to apply LNT for risk estimation legal restrictions concerns. While the accumulation of data could increase the statistical power, it is hard to take a large sample in the experiments with the complex biological reactions. Here we statistically synthesize data from identical experiments, and analyze effect of continuous low dose rate gamma-irradiation on murine immune system to detect the subtle effects that cannot be detected by usual experimental approach. Mice immunized with allogenic antigens were continuously irradiated with dose-rate between 0.003-0.2 mGy/h during the experiment for 17 days, and expression profile for 30 genes in spleen were quantified. Results obtained from 10 independent experiments were statistically synthesized through meta-analysis. Although we could find no large change more than 2-fold or less than half, several responses were detected with statistical significance. Among them, reduction of gene expression in CD80 and iNOS was evident, implying the trend of suppressed inflammation in low dose-rate environment. Expression of p53 downstream targets such as p21 and mdm2 was significantly reduced. Continuous low dose rate irradiation significantly reduced footpad swelling evoked by concanavalin A, and suppressed pulmonary metastasis of Lewis lung carcinoma that is know to depend on inflammatory response. These results suggest that biological responses on continuous low dose/low dose-rate radiation have properties different from those on high dose/high dose-rate radiation. We propose that epidemiological strategy is necessary in the risk estimation for low dose/low dose-rate radiation even in experimental approach. We also discuss statistical issues related to evaluation of biological effects of exposure to low dose/low dose rate radiation, with the aim of combining biology and epidemiology from the point of view of statistical analysis.

P01.14
Pre-clinical Evaluation of 188Re(V)oxo Complexes as Potential Agents for Melanoma Therapy

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Melanoma is a disease with increasing incidence during the last years. As there are no effective treatments for patients in advanced stages it is essential to develop new therapeutic options. Nuclear medicine offers an alternative to external radiotherapy by using ^{188}Re. This radionuclide has adequate physical and chemical properties to develop radiopharmaceuticals for systemic therapy. Our research group has developed oxotechnetium and oxorhenium “3+1” mixed ligand complexes of high affinity for melanoma tumor cells.

In vivo biodistribution studies were performed in C57 mice (n=3)(8-10 weeks) bearing melanoma induced by subcutaneous inoculation of B16-F1 cells. The product was injected in the peritumoral area (74-370 KBq).

Animals showed significant uptake in tumors (24.0 „b 2.3 %ID/g) at 2 hours post-injection. Other organs that showed significant uptake were blood, liver ,and bladder.

Results of biodistribution were used for dosimetric evaluation using MIRD concept calculation code SAAM II and S values for ^{188}Re in mice model kindly provided by Dr M .Stabin. Dose to tumor was 1.56 Gy/MBq.

Efective doses in organs of main interest.

Organ	Efective dose (mSv/MBq)
Large Bowel	6.14E-03
Red Marrow	5.20E-03
Kidney	2.12E-03
Urinary Bladder	2.90E-02

According to dosimetric results, therapeutic efficacy was evaluated in three groups of animals, (n=5 each). They received a either a single dose of 11.1 MBq , 22.2 MBq or 2 doses of 11. 1 MBq respectively in the peritumoral area. A control group was also included. Studies of effect of treatment on tumor growth showed significantly lower average sizes in all treated groups compared with the control. Effects on animal survival were evaluated by Kaplan-Meier curves, resulting in a greater chance of survival for those who received a single dose of 11.1 MBq.

These early studies show promising results which indicate a positive impact of the treatment on murine melanoma in all cases evaluated. Further therapeutic studies will be performed in order to corroborate these initial findings.

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P01.15
Cognitive and Cerebrovascular Effects Induced by Low Dose Ionising Radiation "CEREBRAD EU project"

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CEREBRAD will test the hypothesis of the currently accepted linear-no-threshold (LNT) dose response relationship for cognitive and cerebrovascular diseases and thus will address the long-term health detriment of radiation on the central nervous system. This area of radiation late effects has so far not been examined rigorously using modern biological and epidemiological approaches. We have designed CEREBRAD to deliver the knowledge required for future modelling studies of the dose-response relationship of the brain to be able to assess the LNT model for cerebrovascular diseases.

The main concern of the consortium is to be able to more accurately portray in the future the risk of low doses below 100 mGy delivered to a young child. This will be achieved by using knowledge from epidemiological investigations and experimental studies in animal models. The CEREBRAD consortium will investigate the impact of low vs high doses of ionising radiation (below and above 100 mGy) using animal models to determine if there is a harmful effect to the brain after exposure at different stages of development from the prenatal (in utero) to the postnatal (after birth) period.

We will study the initial and late events occurring after irradiation of brain tissue at the cellular and molecular levels, as well as delivering appropriate know-how required for future modelling investigations. Key questions addressed by the CEREBRAD project are:

• Key Question 1:

Are the epidemiological data sufficiently robust in estimating the risk of cognitive and cerebrovascular effects below 500 mGy?

• Key Question 2:

Is the shape of the dose-response curve for cognitive and cerebrovascular effects at different stages of brain development described by a linear-no-threshold relationship?

• Key Question 3:

How to reduce the uncertainties of dose reconstruction in the brain?

• Key Question 4:

What are the underlying biological mechanisms for the non-cancer effects of radiation on the brain?

P01.16
Accumulation of Man-Made Radionuclides by Mushrooms Nearby the Site for SNF and RW Temporary Storage in Andreeva Bay of Kola Peninsula

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Disposal of and use of wastes containing natural radioactive material (NORM) or technologically enhanced natural radioactive material (TENORM) with excessive natural background as a building material is very important in the supervision body activity.

At the present time, the residents of Octyabrsky village are under resettlement. This village is located just near the Priargunsky mining and chemical combine (Ltd. «PPGHO»), one of the oldest uranium mines in our country.

The vacated wooden houses in the village are demolished and partly used as a building material.

To address the issue of potential radiation hazard of the wooden beams originating from demolition of houses in Octyabrsky village, the contents of the natural radionuclides (^{40}K, ^{232}Th, ^{226}Ra, ^{238}U) are being determined in samples of the wooden beams of houses.

The NORM contents in the wooden house samples are higher, on average, than their content in the reference sample of the fresh wood shavings, but the range of values is rather large.

According to the classification of waste containing the natural radionuclides, its evaluation is based on the effective specific activity.

At the effective specific activity lower 1.5 kBq/kg and gamma dose rate lower 70 μR/h, the material is not considered as waste and can be used in building by 1 -3 classes depending upon A_{eff} value.

At 1.5 kBq/kg < A_{eff} ≤ 4 kBq/kg (4 class), the wooden beams might be used for the purpose of the industrial building, if sum of ratios between the radionuclide specific activity and its specific activity of minimum significance is lower than unit.

The material classified as the waste containing the natural radionuclides has A_{eff} higher 1.5 kBq /kg, and its usage for the purpose of house-building and road construction is forbidden.

As for the ash classification and its future usage, such usage is unreasonable, because, according to the provided material, more than 50% of ash samples, are considered as radioactive waste containing natural radionuclides.

All materials originated from demolition of houses in Octyabrsky village are subjected to the obligatory radiation control.
The decision to use the wooden beams shall enter into force after agreement with the State Sanitary and Epidemiological Supervision bodies.

P01.17
Indices Of Blood Lipids In Workers Exposing Long-Term Radiation In A Range Of Low Doses

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The purpose. Evaluation of low-dose ionizing radiation influence to blood lipid status of Siberian Group of Chemical Enterprises male personnel exposing occupational radiatiation.

Materials and Methods. The object of research is male workers of 45-55 years old who exposed long-term ionizing radiation in the range of low doses in the process of their occupational activity. Two groups of workers were formed: main and control group. They were compared by "traditional" risk factors of cardiovascular diseases: arterial hypertension of I and II degree in association with obesity, smoking habit, increased psych-oemotional overload, dyslipidemia, hypodynamia, hereditary diseases, shift work. Both workers with arterial hypertension and workers with normal blood pressure were involved in our study. Variational series median (Me) of the cumulative external radiation dose was 100.43 mSv (interquartile range was 63.82; 147.08 mSv) and contents of Plutonium (^{239}Pu) was 444 nKu (333; 899.1 nKu). The control group workers have the following values of the same indexes: 19.03 mSv, (12.06; 29.61) mSv and 370 nKu, (111; 407) ($p < 0.05$), respectively. Evaluation of the following blood lipid indices were made in both groups: total cholesterol level, low density lipoprotein cholesterol level (LDL Cholesterol), very low density lipoprotein cholesterol level (VLDL Cholesterol), high density lipoprotein cholesterol level (HDL Cholesterol), lipoprotein (a) level.

Results. When analyzing the blood lipid indices with respect to physical activity of workers, such index as the lipoprotein (a) level was soundly higher in the main group than in the control group ($p = 0.011$). When compared the blood lipid indices relatively to body weight values, the total cholesterol level and lipoprotein (a) level were definitely higher in the main group consisting of workers with normal body weight rather than in the control group that was comprised of workers having obesity of I and II degrees ($p = 0.048$ and $p= 0.045$ in relation to total cholesterol level, respectively; $p = 0.021$ and $p = 0.022$ in relation to lipoprotein (a) level, respectively). Important result of this analysis consists in the following: in the control group, dyslipidemia intensity increases with growth of body weight, while in the main group, intensity of dyslipidemia becomes evident in workers with normal weight.

P01.18
The Cytogenetic Abnormalities of Blood Lymphocytes in the Cohort of Siberian Group of Chemical Enterprises Personnel

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The purpose. The main aim of this study was to analyze the data on the frequency and spectrum of cytogenetic abnormalities in the cohort of Siberian Group of Chemical Enterprises (SGCE) employees, considering their age and sex, type of radiation and external irradiation dose.

Materials and methods. The standard analysis of the frequency and spectrum of CA was performed. There were studied the samples obtained from 650 SGCE employees exposed to the long-term external irradiation. Some of the employees were exposed to internal α-irradiation due to incorporated ^{239}Pu and combined external and internal irradiation. All members of cohort were divided into groups in accordance with type of radiation: production control group – non-exposed to radiation; group with internal α-irradiation; group exposed to external irradiation and group exposed to combined irradiation.

Results. The decrease of total number of aberrant metaphases, single and pair chromosome breakpoints, pair acentric fragments and chromosomes of type "cross" (which are considered as the result of translocations) have been observed in combined irradiation as compared with external irradiation.

There was studied dose dependence of cytogenetic abnormalities in all SGCE workers exposed to only external irradiation (n = 250, average dose of 278.8 ± 18.0 mSv, median of 209.3 mSv, interquartile range of 82.3-404.2 mSv). There was shown that the dose dependence of quantity of aberrant cells, chromosome and chromatid abnormalities in SGCE workers is non-linear. In case of irradiation dose is to 10 mSv there has been observed the significant decreasing the number of aberrant cells, chromosome and chromatid abnormalities as compared with the control group, this corresponds to the phenomenon of the radiation hormesis. There was not significant mutagenic activity on human genome if the chronic irradiation doses are less 40 mSv. There has been observed significant rising of a quantity of aberrant metaphases and chromosome and chromatid abnormalities starting from dosage range of 41-100 mSv. In dosage range of 100-400 mSv the dose dependence has a plateau and the frequency of cytogenetic abnormalities is constant, but significance is increasing relatively the control group.

The performed study allowed identifying threshold doses of low-intensive radiation for induction of chromosome aberrations, and it gives an opportunity for further improvement of the existing radiation safety system.

P01.19
Repair of DNA Single- and Double-Strand Breaks in Peripheral Blood Lymphocytes of Chronically Exposed Individuals.

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DNA radiation induced breaks repair one of the first barrier before exposure effects realization as in cell as in organizme. Repair processes activity depend of presence DNA breaks and thus depend of fact ionizing radiation exposure.

Our purpose was investigation DNA single-strand breaks (SSB) and double-strand breaks (DSB) levels in peripheral blood lymphocytes exposed and non-exposed individuals and also evaluation DNA breaks dynamics after irradiation in vitro with 10 Gy.

Two groups of humans was formed: exposed (20 subjects) and non-exposed (21 subjects). Groups are similar by age, sexual and ethnic structure.

We used comet assay alkaline and neutral variants. In the capacity of DNA breaks level assessment test was used tail moment (TM).

In peripheral blood lymphocytes of exposed individuals we detect increase spontaneous SSB and DSB level in comparison with control: 1,2±0,1 vs 0,5±0,2 for SSB and 4,8±0,4 vs 1,6±0,3 for DSB.

For DNA breaks repair evaluation after irradiation in vitro with 10 Gy slide preparation made right after impact and also in 1, 2 and 4 h after impact. During analysis DSB repair increase TM in lymphocytes of exposed individuals in hour (12,5±1,5) in comparison with control group (9,8±1,4) was detected. Differences of DSB level in 2 h is statistically significant: 6,6±0,8 in lymphocytes of exposed individuals vs 3,5±0,9 in control.

Significant differences of SSB levels in lymphocytes of exposed and non-exposed individuals after irradiation in vitro in named intervals of time was not detected.

For DNA breaks repair efficiency evaluation tail moments in 1, 2 and 4 h after impact was assessed as percentage from TM right after irradiation in vitro. Differences of non-repaired DSB percent in 2 in lymphocytes of exposed and non-exposed individuals can be accept as statistically significant (45,9±8,1 vs 24,1±4,6).

Significant differences of SSB repair efficiency in lymphocytes of exposed and non-exposed individuals after irradiation in vitro was not detected.

Thus for peripheral blood lymphocytes of chronically exposed individuals increase DNA SSB and DSB level is character. Besides, in lymphocytes of exposed individuals DNA DSB repair delay was detected. Differences of DNA SSB dynamics was not detected.

Keywords: chronically exposed, peripheral blood lymphocytes, single-strand breaks, double-strand breaks, DNA repair, comet assay.

P01.20
Biological Material Bank Of The Seversk Biophysical Research Centre

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Seversk Biophysical Research Centre (SBRC) has been engaged in creating biological material bank (BBM) Siberian Group of Chemical Enterprises (SGCE) workers and residents of nearby territories (the town of Seversk) since 2002. Following the developed methodology, for each person this bank includes: DNA sample, RNA sample and 7 ml blood sample (spare sample). There is a bank of cytogenetic samples for estimate of frequency and spectrum of chromosome aberrations.

The BBM contains blood and DNA of 1 350 healthy workers of SGCE. The average age of the people 55.8 ± 0.32 years, 648 of them (48%) persons were exposed to only external radiation with an average dose of 133.8 ± 6.23 mSv, 64 (5%) persons were exposed only internal radiation to with an average content of ^{239}Pu 66.9 ± 13.7 nCi and 465 (34%) workers exposed to combined radiation. The middle age of 672 cancer patients is 62.6 ± 0.46 years, 150 (24%) exposed to external radiation with an average dose of 152.2 ± 16.68 mSv, 98 (16%) received only the internal radiation dose with an average content of 239Pu 346 ± 8,79 nCi and 69 (11%) person with combined radiation. The BBM also contains blood and DNA of 764 people who had the acute myocardial infarction with an average age of 61.8 ± 0.76, 170 (22%) patients were exposed to external radiation with an average dose of 137 ± 18 mSv. 24 (3%) patients exposed internal radiation and average content of ^{239}Pu 27.2 ± 5.62 nCi, group with combined radiation was 55 (7%) patients. In radiobiological tissue bank contains the 2 439 samples of autopsy and operational materials of cancer patients – SGCE workers and Seversk residents.

At present, this BBM includes 6 986 donors. For every donor there has been obtained an informed consent. There are such data in the database of Regional Medico-Dosimetric Register: age, doses of external and internal radiation, duration of occupational activity, data about important diseases, reasons of death and others.

Thus, SBRC biological material bank poses a unique and virtually inexhaustible supply of material for research aimed at revealing molecular basis, studying genetic aspects of pathogenesis of most significant human diseases (above all, cancers) under the influence of long term radiation in low dose range, as well as for other research into radiation and medical genetics.

P01.21 Allelic Imbalance of Genes in Spontaneus Tumor and in Tumor of Persons Expoing Long-Term Occupational Radiation

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The purpose. To compare the genotype distribution of polymorphic loci in tumor and normal tissues of cancer patients – Siberian Group of Chemical Enterprises (SGCE) workers professionally exposed to radiation and cancer patients – non-exposed residents of Seversk as well as non-exposed SGCE workers. Materials and methods. There has been studied DNA extracted from paraffin blocks. *XPD1* rs13181, *hOGG1* rs1052133, *TP53* rs1042522, *RB1CC1* rs2305427; *PTEN* rs701848; *CYP2C19* rs4244285; *ABCB1* rs1045642; *BAX* rs1805419, *MTHFR* rs1801133 SNP-markers genotyping was performed according to the real-time PCR method using.

Results. There has been shown the genetic difference between spontaneous and radiation carcinogenesis, as evidenced by the fact that the directions of mutations at the heterozygous loci are different between sporadic tumors and tumors on the background of radiation.

In sporadic tumor tissues there has been observed the mutation of heterozygous *Arg/Pro* TP53 rs1042522 genotype mainly into *Arg/0* (in 9.6% of cases) and *0/Pro* (in 8.9% of cases); in tumor tissues appeared on the background of irradiation there has been observed the mutation mainly into the Arg/0 genotype in 12.1% of cases.

In sporadic tumor tissues, there has been observed the mutation of *Lys/Gln* genotype of *XPD1* rs13181 into *Lys/0* and *0/Gln*, in tumors on the background of irradiation there has been observed *0/Gln* genotype in 56% of heterozygotes. There has been observed the loss of *Cys* allele at heterozygous *hOGG1* rs1052133 locus with the formation of only *Ser/0* genotype; and the *Ser* allele with the formation of only *0/Cys* genotype in sporadic tumors.

Studies have shown the phenomenon of the allelic imbalance in tumor tissues appeared on the background of low-level exposure and spontaneous tumors for the selected SNPs that indicates the universality of the mechanism inactivating heterozygous genotypes.

The directions of mutations at the heterozygous loci are different between sporadic tumors and tumors on the background of irradiation indicating that there are genetic differences between spontaneous and radiation carcinogenesis. The distinct direction of the vector of mutations at the heterozygous locus in tumor tissues coincides with the associative model of data and may indicate a pathogenetic significance of the gene. Evaluation of allelic imbalance in tumor tissues may be use as an additional criterion to evaluate either the risk significance of polymorphic loci or the verification criterion.

P01.22
Level of Lymphocytes in the Cell Cycle Delay in Individuals Exposed to Chronic Radiation Exposure.

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The system of checkpoints includes numerous proteins, among them protein Chk2. It is known that protein Chk2 is expressed in cells with predominantly double-strand DNA breaks. The accumulation of the activated form of this protein accounts for cell cycle delay at all checkpoints Chk2 of the cycle. Chronic exposure may induce a cell cycle delay at all checkpoints of the cell cycle. Also, chronic exposure can bring about single-strand and double-strand DNA breaks, including at late period.

In our study, we analyzed the frequency of lymphocytes expressing Chk2 protein in individuals who were exposed to chronic radiation from 1951 to 1956. The study group included 113 exposed residents of the riverside villages on the Techa River and 71 people living in uncontaminated areas (the control).The groups were comparable in terms of age (mean 70 years), gender and ethnicity. The mean dose to red bone marrow for all exposed individuals was 1.11 ± 0.06 Gy (0.06-4.46 Gy).

Analysis was performed on flow cytometer EPICS XL-MCL (argon laser 488 nm output of 15 mW).

It was revealed as a result of the study that there was a delay in cell cycle in 0.64% of peripheral blood lymphocytes of the exposed persons at late time after the onset of exposure (59-61 years later). Whereas in individuals unexposed to ionizing radiation, the level of such lymphocytes was significantly lower, amounting to 0.44% ($p = 0.02$). After incubation with mitogen (24 h), no differences were observed between groups of irradiated and non-irradiated individuals (2.70% vs 2.93%). However, after incubation (22 h) and ã-irradiation of the lymphocyte culture (1 Gy), a decrease in the frequency of cell cycle delays in the exposed individuals (2.14%) was noted compared with controls (3.14%), but the differences did not reach statistical significance.

The statistical analysis showed no dose dependence for the frequency of cells expressing the protein Chk2, both for the sample as a whole and for individual groups, divided by the dose ranges (less than 0.3 Gy, 0.3-0.6 Gy, and 0.6-1Gy more than 1 Gy).

In the course of the analysis of the frequency of mutations in gene Chk2 (PCR) 1100 delC mutation was detected in only one person which is not excessive. Thus, an increased number of cell cycle delay in lymphocytes of individuals exposed to chronic radiation is considered as a normal physiological response to an increase in the frequency of DNA breaks.

P01.23
Apoptosis and Mutations in the Gene of T-cell Receptor of Blood Lymphocytes in Persons Chronically Exposed to Radiation

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This study was focused on late effects of radiation exposure in members of the Techa River Cohort chronically exposed as a result of operations of the Mayak Production Association starting from 1949. The radiation exposure consisted of two components: external exposure to gamma radiation and internal exposure mainly to ^{90}Sr, the major dose-forming radionuclide.

Late effects registered among Techa River cohort members included an increased risk of oncopathology (leukemia), elevated levels of chromosome aberrations and somatic mutations. These observations allow for an assumption that chronic exposure resulted in genome instability, which is manifested, among other things, by an increased level of somatic mutations. The purpose of our research was to better understand the role played by apoptosis, the main defense-mechanisms of the cell (defense from the fixation of initial damage of genetic material in the form of mutations or/and aberrations).

The study group included 161 people. The mean age was 69 years; the majority of the group members were women. The maximum cumulative dose to red bone marrow amounted to 6.69 Gy, the maximum dose rate 2.03 Gy/year. The control group included 72 unexposed individuals who lived in similar socioeconomic conditions and had similar gender, age, and ethnicity characteristics.

Our research involved the use of the following methods of laboratory investigations: assessment of apoptosis of peripheral blood lymphocytes by the TUNEL methodology, Annexin and the method of CD-typing by antibodies to receptor CD95. Assessment of the frequency of cells with mutant T-cell receptor using fluorescence-labeled monoclonal antibodies to CD3 and CD4. All samples were analyzed using flow cytometry.

The number of apoptotic cells measured using TUNEL methodology in the group of exposed individuals is higher compared with the control group, but there was no statistical significance.

Another method for measuring apoptotic cells in exposed individuals using Annexin methodology provided a higher statistical significance as compared with the control group.

No statistically significant differences with regard to the frequency of cells that carry the membrane receptor CD95 were found between the chronically exposed individuals and the control group.

The assessment of somatic mutations in the study group identified a statistically significant increase in CD3-CD4+ cells in group of exposed people as compared to the control.

We have demonstrated that efficiency of apoptosis depends on radiation dose. In the range of doses up to 0.2 Gy, apoptosis compensates for the increase in genetic damages. At doses above 0.2 Gy, there are cases when cells overcome the apoptotic barrier and the organism starts accumulating cells with somatic mutations. At doses above 1.0 Gy, arrest of apoptosis and accumulation of structurally and functionally defective cells.

P01.24
Radiobiology Repository Of Nuclear Workers As Unique Source For Studies Of Radiation Effect

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The Radiobiological Human Tissue Repository (RHTR) was created and has functioned in Southern Urals Biophysics Institute of the Federal Medical Biological Agency (SUBI FMBA) for ten years with financial support from FMBA and the U.S. Department of Energy (DOE), USA. RHTR provides investigators in the field of biology and medicine with samples of biological material of individuals exposed to prolonged occupational internal α- and/or external γ-irradiation (Mayak PA workers and their offspring), to study radiation effect on human health. RHTR is a research source to study effects of prolonged combined radiation impact related to occupational exposure of nuclear facility workers. The uniqueness of the Mayak PA cohort is in the quality and reliability of the data on occupational history, individual dosimetry data, and detailed medical and demograph information available for all workers. The objective of RHTR is to receive, store, provide quality assurance and transfer biological material of exposed individuals, control individuals and their offspring to scientists to carry out research projects on different levels of organization of the organism, including molecular and cellular, using modern technology. Because of the quality of the dosimetry data, access to biomaterial will enable investigators in many countries to fill the gaps in knowledge on the effects of prolonged exposure to different doses of ionizing radiation

RHTR includes biological repositories of autopsy material (tumor and non-tumor tissue samples, 930 cases); surgical/biopsy tissues (750 cases) obtained during surgery; samples of blood and its components, including DNA, obtained from Mayak PA workers (4700 individuals) and their offspring; other tissues (samples of buccal epithelial cells, bone marrow cells, lymphoid, bone tissue, cells and supernatant of induced sputum, saliva). The biological material has been and continues to be used effectively to resolve different issues in radiation biology and medicine (Website: rhtr.subi.su).

P01.25
Development of ICRP-66 Respiratory Tract Model Based on a Study of Pu Microdistribution in Lung

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Development of an efficient biokinetic model of respiratory tract is an actual theoretical and practical issue. Recently SUBI has carried out a number of studies concerning quantitative micro-distribution of Pu in respiratory tract of human and laboratory animals (dogs) by autoradiography.

On the basis of studies it is demonstrated that in the long-term period after the inhalation of Pu significant fraction of nuclide is deposited in parenchymal and non parenchymal scars of lung tissue. The dynamics of formation of respiratory scars has been studied. Pu particles in scars are surrounded by the layer of a relatively radioresistant connective tissue and they do not produce an effect on radiosensitive alveoli type II and the Clara cells. Notion of “lost dose” has been introduced.

Some changes in ICRP-66 human respiratory tract model have been made.

P01.26
On the Question of Interpopulation Transfer of Risk Coefficients

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It is known that even under normal conditions in the cells there are numerous spontaneous DNA damages and that irradiation adds a certain amount of such damages. The vast majority of DNA lesions, spontaneous and radiation-induced, are eliminated by the cellular repair systems. However, a certain fraction may remain and can cause malignant transformation of irradiated cells or its descendants. Since the carcinogenic effect of radiation, how believed, arise due to radiation damages, which had not been eliminated, then under protracted exposure would be expected increase the rate of such injuries and to increase of the mortality rate from cancer by a constant factor. However in fact such an effect is observed after acute exposure, while this factor under protracted exposure increases with age approximately exponentially.

This contradiction can be explained by assuming that the effect of ionizing radiation is manifested to a greater degree in the suppression of the repair systems than in the formation of additional DNA damages which lead to malignant transformation of cell. Reducing the effectiveness of repair systems causes an increase in the number of spontaneous lesions, which pass into the category of potentially cancerous. The cumulative dose under protracted exposure increases with age, the efficiency of repair is reduced, resulting in rises of the transition probability the spontaneous damages in the potentially cancerous damage and, respectively, the mortality rate from cancer increases with age by a factor proportional to the cumulative dose.

Acute exposure causing a step-like reducing of repair systems efficiency, so the mortality rate at all ages after irradiation is different from the mortality rate prior to irradiation by a factor, which depended from dose but not from age. If account is taken additional damage, produced by radiation, then pattern is complicating, but not fundamentally changed.

The experiment that could verify the proposed hypothesis is to determine what impact will from radiation exposure on dependence of the probability of a mutation (or another cellular effect) from dose of any nonradiation carcinogen. Increase in the slope of such dependence would be evidence damage of repair systems. Proportionality of the slope to the radiation dose would be a direct confirmation of the hypothesis

Proposed mechanism of damage cell leading to cancer makes a logical widely practiced transfer risk coefficient for cancers of various localization between different population.

P01.27
Systems Biology of Cell Signaling: a Foundation of the Healthcare for People Exposed to Ionizing Radiation

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Stochastic nature of malignant tumor and leukemia formation upon ionizing radiation exposure causes lack of expert consensus on the existence of dose threshold for radiation-induced cancer (which has been tried to be derived from both research in radiation epidemiology and experimental radiobiology). Persisting uncertainty in this field of research attracts attention to the fundamental problems of molecular biology of mitogenesis that may be helpful in this difficult case, when classical methods of medical observation and animal experimentation show constant inability. Involvement of *in silico* analysis for signal propagation through the numerous pathways that provoke either mitosis or apoptosis/necrosis of the normal and malignant cells may be essentially helpful for radiobiology.

During the past decade, we have developed and put into the agreement with experimental data a set of complex network models for mitogenic and survival pathways that are initiated by numerous external agents, including epidermal growth factor (EGF), insulin, heregulin etc. This quantitative research was done according to the network-like approach that takes into account most complexes and reactions that may emerge during signal propagation.

Our current investigations are focused in systems-level study of multiple signaling pathways that are affected in cancer patients. By now, we have accumulated a database of more than 80 pro- and antimitotic pathways (where each pathway typically involves more than 100 protein molecule types). Using this database, we have analyzed the overall pattern of carcinogenic signaling for nine bladder cancer patients, whose transcriptome has been microarrayed and expression levels for thousands of oncogenes and tumor suppressor proteins obtained.

P01.28
Appearance of Heavy DNA Fragments in Circulating Immune Complexes Justifies Radiation Exposure In Vivo.

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In terms of radiation protection research, identification of novel sensitive biomarkers and biodosimeters of radiation exposure is of paramount importance. The present study was focused on search for irradiation-responsive alterations in composition of major constituents of blood serum. It was here found that pools of circulating immune complexes (CIC) precipitated by 2.5% polyethylenglycol (PEG) from samples of blood sera of healthy mice, rats and human donors often contain small amounts of low-molecular-mass (~2500-8000 base pairs) DNA fragments. Importantly, if the rodent or human organism was exposed to local or whole-body irradiation with gamma- or X-rays (0.5-6 Gy), other DNA fragments with the much greater molecular mass (18000-42000 base pairs) are always detected in the PEG-precipitated CIC. Isolation and analysis of DNA from serum pools of CIC were performed by routine methods including proteinase K treatment and electrophoresis in agarose gels. The extracellular heavy DNA fragments appear to be a result of nuclear DNA degradation in various cells killed by irradiation in vivo. Among major protein components of these DNA-containing CIC, we found such serum proteins as immunoglobulins (IgM + IgG), low density lipoproteins, fibronectin and vitronectin; in several cases, histone H1 was a minor component herein. Probably, these proteins are bound to DNA within CIC thereby protecting its strands from severing by serum nucleases; in fact, the heavy DNA fragments are stably detected in the PEG-precipitated CIC pools within 4-8 days following radiation exposure. In our tests with the in vivo irradiated rodents and clinical patients subjected to anticancer radiotherapy, the levels of CIC containing the heavy DNA fragments in samples of sera positively correlated with received doses of radiation. Thus, we suggest that the presence of such heavy DNA fragments in the serum (PEG-precipitated) CIC composition is to be considered as a biomarker justifying recent radiation exposure to the organism. We also hope that the PCR-based amplification technique will allow to detect much less amounts of the heavy DNA fragments which may appear in serum CIC pools following episodic or chronicle low-dose irradiation in vivo (e.g. medical or occupational exposure).

P01.29
Modulation of Radiation Induced Biochemical Changes in Brain of Swiss Albino Mice by Punica Granatum Fruit Rind Extract

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Irradiation of the skull causes hair loss, nausea, vomiting, lethargy, otitis media and severe cerebral edema. Some of these effects can be transient. Chronic effects are more serious and include atrophy, leukoencephalopathy, radiation necrosis, neurological deterioration and dementia. Mechanism of the late effects of radiation necrosis includes vascular damage, white matter injury and coagulation necrosis. Demyelination, inflammation and breakdown of the blood brain barrier are the main neurotoxic effects. Dysfunction in white matter structures including the corpus callosum can lead to deficits in sensory and neurocongnitive functions. Radiation exposure damages the nervous system depending on many factors including the total dose delivered the total volume of nervous system irradiated and the time. Early endothelial cell loss after irradiation results in acute blood brain barrier breakdown. Blood brain barrier serves to protect the central nervous system (CNS) from invasive agents such as inflammatory cells and bacteria as well as from chemical agents. At early times after irradiation, there is breakdown of the blood brain barrier with an associated increase in vascular permeability.

A number of chemical compounds have been tested and found to offer some protection against the damage associated with exposure to ionizing radiation, but their use in clinical field is limited due to their toxicity at protective dose level. Therefore, some commonly used medicinal plants may be good sources of non-toxic radioprotectors.

The present study is an attempt to find out efficacy of a well known medicinal plant *Punica Granatum* fruit rind extract in modulating the radiation induced biochemical alteration in the brain of *Swiss albino mice.*

For experimental studies healthy adult male *Swiss albino mice (mus musculus norvegicus)* weighing 25±2 g were selected from an inbred colony and divided into four groups. Group I was kept as such without any treatment (Normal). Group II was fed with Punica Granatum fruit rind extract (Acetone) at the rate of 10 mg/ kg body weight. Group III was irradiated with 8Gy CO^{60} gamma irradiation only (Control) and Group IV was given *Punica Granatum* fruit rind extract one hour before irradiation (Experimental). Mice were sacrificed at various post irradiation intervals and brain was removed weighed and analysed biochemically for estimation of its Reduced Glutathione content, Lipid peroxidation. Total Protein, DNA and RNA content. Brain weight of the control (group III) decreased till 3rd day post irradiation and in the experimental (group IV). It remained significantly higher then the control. Protein and RNA contents increased up till the 3rd post irradiation day and decreased till 28th day in control group. *Punica Granatum* fruit rind extract when given prior to irradiation maintains a higher level of protein and RNA content in comparison to control. GSH and DNA content decreased in control group and in experimental group they are found to be higher than the corresponding control group at all the post irradiation intervals.

Thus, results from the present study suggests that pretreatment of *Punica Granatum* fruit rind extract protect mouse brain against the radiation induced biochemical changes.

P01.30
Fenofibrate has Radioprotective Effect via PPARα-Mediated SOD Induction in HeLa cells

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The fibrates are ligands for peroxisome proliferator-activated receptor (PPAR) α and used clinically as hypolipidemic drugs. The fibrates are known to cause peroxisome proliferation, enhance superoxide dismutase (SOD) expression and catalase activity. The antioxidant actions of the fibrates may modify radiation sensitivity. Here, we investigated the change of the radiation sensitivity in two cervix cancer cell lines in combination with fenofibrate (FF). Activity and protein expression of SOD were measured according to the concentration of FF. mRNA expressions of SOD, PPARα and PPARγ were measured using real time RT-PCR. Combined cytotoxic effect of FF and radiation was measured using clonogenic assay. In HeLa cells total SOD activity was increased with increasing FF doses up to 30 μM. In the other hand, the catalase activity was little increased. As with activity the protein expression of SOD1 and SOD2 was increased with increasing doses of FF. The mRNAs of SOD1, SOD2, PPARα and PPARγ were increased with increasing doses of FF. The ROS produced by radiation was decreased by preincubation with FF. The surviving fractions (SF) by combining FF and radiation was higher than those of radiation alone. In Me180 cells SOD and catalase activity were not increased with FF. Also, the mRNAs of SOD1, SOD2 and PPARα were not increased with FF. However, the mRNA of PPARγ was increased with FF. In conclusion, FF can reduce radiation sensitivity by ROS scavenging via SOD induction in HeLa. SOD induction by FF is related with PPARα.

P01.31
Natural Radioactivity in the Soil Samples of Coastal Southern Nigeria.

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Studies on the gamma radiation level and the radionuclide distribution in the soils of the coastal region of Nigeria were carried out. The purpose of this study is to provide a baseline data on the radiation level and the distribution of some naturally occurring radionuclides in these coastal areas where a lot of oil exploration activities are taking place. The external gamma absorbed dose rates were measured using a high-resolution, low-background HPGe detector coupled to an EG & G ORTEC multi-channel analyzer. The activity of ^{40}K was found to vary between 7.049 and 586.69 KBq kg^{-1} with a mean value of 281.5 KBq kg^{-1}; that of ^{226}Ra varies between 4.103 and 91.293 KBq kg^{-1} with a mean value of 34.96 KBq kg^{-1}; while that of ^{232}Th was found to vary from 0.07 to 16.13 KBq kg^{-1} with a mean value of 9.16 KBq kg^{-1}. The contributions of ^{40}K, ^{226}Ra and ^{232}Th to the gamma absorbed dose rate were obtained to be 35.4%, 47.3% and 17.3% respectively. The mean values of the gamma absorbed dose rates obtained from the activity concentrations were compared with the literature values obtained for other coastal environments and also with the world average. In addition, the correlation between ^{40}K and ^{226}Ra, ^{40}K and ^{232}Th and ^{226}Ra and ^{232}Th were computed from results of the activity concentrations of these naturally occurring radionuclides. The correlation between these radionuclides varied from State to State with the strongest correlation occurring between ^{232}Th and ^{40}K in Akwa-Ibom State while the weakest correlation occurs between ^{232}Th and ^{226}Ra in Bayelsa State. The results are discussed in the paper.

Keywords: ^{40}K, ^{226}Ra, ^{232}Th, naturally occurring radionuclides, radioactivity, soil, environmental.

Poster sessions A-B: Area 1

P01.32
The Importance of Time in Low Dose Radiobiology Phenomena

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Time, the first and last dimension of biological effects of radiation, is a main factor in radiobiological studies. In addition to its importance in dose rate effect on biological systems, the role of time in biophysical, biochemical, and biological events after irradiation is very important. In low dose radiobiology phenomena, including adaptive response, bystander effect, genomic instability, low-dose hypersensitivity and hormesis, time is determinant factor. Speaking generally, time interval between adaptive and challenge doses, the time required for gene expression, cytokines, growth factors and proteins release by irradiated tissues and the activation time of repair and survivor mechanisms, time of other immunological mediators recruitment, the half-life of released materials in the cells, required time to stimulate other cells to produce a biologic response, time for occurrence of genomic instability, time of hermetic effect of low dose radiation and many important time dependent events after a biologic system exposed, demonstrate time is a vital factor in these phenomena. In the other hand, much time is required to see real effects of low dose radiation. In fact, most of low dose radiobiological studies are invitro and so, it is necessary to investigate long term studies invivo to understand real effects of low dose radiation. Keywords: time, low dose radiation, radiobiology phenomena

P01.33
Radiation Survival Curve for Pediatrics Rhabdomyosarcoma Cells

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We report on the survival curve of cultured pediatric rhabdomyosarcoma (RD) cells derived from children. X-ray radiation of variable doses (i.e. 4 Gy up to 20 Gy) was used for this purpose. Cell death resulted from chemical alterations in the genome. Both single-hit multi-target model and linear-quadratic model which base on the target theory allowed for the description of the survival curve, and for the calculations of characteristic parameters such as mean lethal dose (D0), quasi-threshold (Dq), extrapolation number (n), dose at which the contribution of linear and quadratic components of cell killing are equal (α/β) and the radiosensitivity of the cells (SF4 value). From the results obtained the survival curve was constructed, and it was found that D0 = 3.2 Gy, Dq= 9.2 Gy, n = 18, α/β = 9 Gy and SF4 = 0.79. Low radiosensitivity of cells under study was concluded.

Key Words: Cell Survival Curve/ Pediatric Rhabdomyosarcoma/ In Vitro Cell Culture/ Target Theory.

P01.34
Bcl-2/BAX Ratio Modified By Low Doses Of Gamma Radiation

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Mammalian cells have evolved complex molecular responses to physiological and environmental stresses, and many of these responses are mediated through alterations in gene expression. Several gene expression studies demonstrated an up-regulation of genes involved in the processes of signal transduction, cell cycle control, DNA repair and apoptosis after IR exposure in different mammalian cell types. The Bcl-2 family of genes play important roles in the regulation of apoptosis.

Whole blood samples were collected from four healthy donors. isolated Lymphocytes were irradiated in culture by gamma rays from a cobalt-60 source of 1.3789 cGy. Min^{-1}. For dose response analysis they were exposed to a different doses from 2 to 10 cGy. RNA was extracted 4 and 24 hours following to irradiation and cDNA was then synthesized. Two apoptotic genes BAX (pro-apoptotic) and Bcl-2 (anti-apoptotic) were examined for expression level. Gene expression level were measured and compared by relative quantitative Real-Time PCR. Comparisons of the expression levels for the irradiated samples and sham-irradiated (0 Gy) samples were performed by using beta 2 microglobulin as an internal control for normalization of the results.

from our results it is evident that down-regulation is induced for BAX gene and up-regulation for Bcl-2 gene when lymphocytes are irradiated by low doses(<10 cGy). A significantly decreased expression level of BAX genes was observed 4h after exposure to 10 cGy when compared with controls (p<0:05). A significantly increased Bcl-2/BAX ratio was observed 24h after exposure to 10 cGy and 4h after exposure to 2 and 10 (p<0:05).

Additionally, there was a great correlation between dose and relative expression of Bcl-2 gene 24 hours post-irradiation (at the 0.04 confidence level) and 4 hours post-irradiation (at the 0.11 confidence level). also, a significant correlation is observed between dose and Bcl-2/BAX ratio, 24 hours post-irradiation (at the 0.1 confidence level) and 4 hours post-irradiation (at the 0.09 confidence level).

Bcl-2/BAX ratio has been introduced as a predictive marker for therapeutic response to radiotherapy. Resistant cells are characterized by high Bcl-2/BAX ratio and sensitive cells are characterized by low Bcl-2/BAX ratio. The present study has showed that low doses of gamma radiation could increase Bcl-2/BAX ratio.

In other word although high doses of gamma radiation can cause apoptosis but the observed increase of Bcl-2/BAX ratio is an indication that low doses of gamma radiation cause an increase in lymphocyte radiation resistance. the molecular mechanisms underlying these findings have not yet been characterized.

P01.35
Effects of N-acetyl-L-cysteine in two Yeast Strains

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Superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CTA) were well conserved in all aerobic organisms that are exposed to reactive oxygen species (ROS) during aerobic respiration. Ionizing radiation generates ROS, which induce oxidative stress. N-acetyl-L-cysteine (NAC), a precursor of glutathione (GSH), is one of the antioxidants having a sulfidryl group. Two different strains of yeast were used to evaluate the effects of NAC on BY4741 as well as W303-1A which contained a mutant allele of YBP1, ybp1-1, that resulted in increased peroxide sensitivity. The yeast cells were pretreated with 0 mM to 20 mM concentration of NAC and/or irradiated with 0 Gy to 400 Gy gamma rays. The radiosensitivity was compared by the colony forming unit assay. And radioprotective effect of NAC was investigated through cell survival and gene expression of antioxidant enzymes including SOD, GPx, and CTA. The relative survival rate of yeast cells reduced with increasing doses of gamma rays in both strains. Higher concentrations of NAC reduced the cell division rates over 3 days of period in W303-1A. BY4741 strain was more resistant to gamma rays than W303-1A strain. The pretreatment of NAC (10 mM, 20 mM) did not improve gamma ray-induced cell death in W303-1A, while the pretreatment of NAC resulted in a slight amelioration of radiation-induced cell in BY4741. Gene expression of all antioxidant enzymes increased after irradiation (100 Gy) without pretreatment of NAC. The gene expression of antioxidant enzymes after irradiation (100) with pretreatment of NAC was lower than that of the control group without NAC pretreatment. These data suggest that, disruption of YBP1 gene leads to increased sensitivity to ionizing radiation. Even though NAC could not protect cells against gamma ray-induced cell death, it made a certain role in scavenging ROS generated by gamma rays in a radiosensitive strain. The effects of NAC are amenable to further study regarding cell rescues and ROS scavenging in vivo.

P01.36
Radiation Induced NF-KB Signaling Cascade Study In Mammalian Cells.

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NF-κB is one of the important transcription factors that respond to changes in the environment of a mammalian cell and plays a key role in many biological processes relevant to radiation response, such as apoptosis, inflammation and carcinogenesis. From medical and biological point of view it is important to understand radiation induced NF-κB signaling cascade. Cell based assays were found to be effective tools for studying signaling pathways precisely. One effective cell-based approach is the reporter gene assay for monitoring NF-κB signaling cascade in mammalian cells. It makes use of vector-driven fluorescent protein expression controlled by a promoter containing NF-κB binding sites as enhancer element. In our previous studies, green fluorescent proteins EGFP and d2EGFP were used for signaling pathway studies. In the current work the new red fluorescent protein tdTomato is used for comprehensive investigation of NF-κB activation after exposure of mammalian cells to ionizing radiation (X-rays, heavy ions). In this study an improved reporter system for the detection of NF-κB signaling activity is constructed, by maintaining both high sensitivity and low background level. This new reporter system is a very effective tool for in vitro imaging of NF-κB signaling pathway in mammalian cells.

P01.37
Radiological Implications of Electronic Waste Dump-Sites in the Most Populous City in Nigeria

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The developing countries of Africa have been the repository sites for electronic waste and the health hazards associated with these waste have been played down over the years. Electronic waste in the developing countries is causing various health and pollution problems. Apart from the hazards from the toxic metals which form the main components of these electronic devices, certain hidden components of these devices may contain radioactive substances that may alter and enhance natural background level of radionuclide at the dump-sites. This study examines the radionuclide concentration in four electronic dump-sites and other undisturbed sites as control in Lagos state, Nigeria using gamma spectroscopy. The radiological health detriment to the inhabitant of the area was estimated and appropriate recommendations needed to mitigate the health effects due to the indiscriminate dumping of electronic waste in Lagos state were proposed.

Keywords: electronic, waste, radionuclide, health detriment

P01.38
Development of Radioprotective Agent Using Smart Microorganism

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Ionizing radiation has inevitably become a health concern due to exposure from natural sources like space travel and from artificial sources like diagnostic and therapeutic medical usage. By definition, radioprotectors are chemical compounds that have the ability to reduce the biological effects of ionizing radiation on normal tissues, including lethality, mutagenicity and carcinogenicity. The radioprotective agents prevent or lessen the damage and lethal effects of acute radiation exposure. Isoflavones possess a variety of biological properties namely anti-oxidant, anti-cancer, anti-inflammatory, immuno-stimulative, anti-biotic and anti-fungal. Here, we review the state of the art production technology using microbial systems as an alternative for development of radioprotective agent. Thus, this system appears as attractive production alternatives for production of radioprotectors. This issue provides golden opportunities for the development of new methodologies and technologies in biosynthetic engineering that can be utilized in several other biosynthetic engineering projects related to high-value products. It might be great strategy for overproduction of isoflavones from biosynthetic engineering using combinatorial assembly. This artificial biosynthesis is a tool for the production of radioprotective agent in smart microorganism.

Keywords Ionizing radiation, Radioprotective agent, Microorganism, Biosynthetic engineering

P01.39
Experimental study of pharmacokinetics and radioimmunoimaging of 131I-labeled monoclonal antibody E-B5 against Pro-Gastrin-Releasing Peptide(31-98)

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Abstract. Purpose: To investigate the radiolabeling of E-B5, a monoclonal antibody against Pro-Gastrin-Releasing Peptide(31-98) by ^{131}Iodine and study the stability and immunoreactivity of ^{131}I-E-B5. To determine the in vivo biodistribution of ^{131}I-E-B5 in normal Kunming mouse and small cell lung cancer-bearing nude mouse models(SCLC mouse model) to study the pharmacokinetics of the ^{131}I-E-B5 in vivo. Characterize the radioimmunoimaging effect and the best imaging time of ^{131}I-E-B5 in different types of tumors. Methods: ^{131}I-E-B5 was labeled by chloramine¨CT method. The labeling efficiency and radiochemical purity were determined by thin-layer chromatography. The ^{131}I-E-B5 was incubated at 37 □water bath by itself or mixed with normal human serum, the radiochemical purity was then checked at different time points to determine its stability, and the immunoreactivity was determined by cell binding assays.^{131}I-E-B5 was injected into the tail veins of the normal Kunming mice which were sacrificed at different time points after injection, and the blood and representative tissues were collected immediately, and the %ID/g (percentage injected dose per gram of tissue) and pharmacokinetic parameters were calculated at various time points. Similarly, T/NT (tumor to non-tumor radioacticity ratio) at various time points were calculated after injection of ^{131}I-E-B5 into the SCLC model. Mouse models bearing small cell lung cancer, lung adenocarcinoma, colon cancer were utilized to study the radioimmunoimaging effect of ^{131}I-E-B5, and calculate the T/B ratio (tumor volume to the corresponding location at the other side). Results: ^{131}I-E-B5 labeling rate was 90.8%, radiochemical purity was 99.28%, and radioactivity was 2.69 MBq/ug. The radiochemical purity of ^{131}I-E-B5 was 90% after 6 hr at 37¡æ water bath, and remained at more than 70% after 24 hrs. The radiochemical purity was over 68.1% after 24 hrs mixing with normal human serum. The immunobinding rate of ^{131}I-E-B5 to NCI-H446 (SCLC cell lines) and A549 (lung adenocarcinoma cell lines) was 71.6%, and 33.2%, respectively. The pharmacokinetics of ^{131}I-E-B5 is consistent with a two-compartment model with first-order absorption. It was primarily metabolized via liver and kidney. The serum clearance rate is relatively fast. The %ID/g of ^{131}I-E-B5 in xenografts was dramatically increased to a level much higher than other tissues 48 hrs after injection, reached plateau at 72 hr, and the T/NT ratio was also gradually increased with time. Prominent uptake of ^{131}I-E-B5 in xenografts of SCLC in nude mice was observed after 24 hrs of injection. The radioactivity in the xenografts was gradually increased with time, and reached the peak at 72 and 96 hr. Xenografts of colon cancer showed similar results as that of SCLC although at a lower level. No observable accumulation was seen in the xenografts of lung adenocarcinoma. The T/B ratio in xenografts of SCLC was consistently higher than in colon cancer at all the time points, and both were significantly higher than that of lung adenocarcinoma which remained stable during the observation duration. Conclusion: The labeling rate and radiochemical purity of ^{131}I-E-B5 were high and stable both in vivo and vitro. The labeled E-B5 kept its immunologic activity. ^{131}I-E-B5 selectively accumulated at tumors expressing proGRP, and could effectively target SCLC, therefore is a promising radioimmunoimaging reagent for SCLC.

Keywords: Monoclonal antibody against pro-gastrin-releasing peptide$_{(31-98)}$ - ^{131}I-E-B5 -Small cell lung cancer - Radioimmunoimaging

P01.40
Granulocyte-colony stimulating factor (G-CSF) protects intestine injury and increases survival rate in irradiated mice

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Granulocyte colony stimulating factor (G-CSF) has been reported to protect from radiation-induced myelosuppression, however little is known about the influence on intestinal injury. We evaluated G-CSF for its capacity to decrease the severity of radiation induced mucositis in vitro and in vivo. For in vitro test, G-CSF was administered to IEC-6 intestinal epithelial cells prior to damage induced by radiation. G-CSF prevented the decrease in IEC-6 cell viability and cytotoxicity induced by radiation. Treatment with G-CSF after irradiation also decreased the increase of the cleaved caspase-3, p53 and p21 by irradiation. For in vivo test, this study examined the radioprotective effects of G-CSF in intestinal damage, and survival in subtotal gamma-irradiated BALB/c mice. G-CSF (100 µg/kg per body weight) was subcutaneously injected once daily for three days before radiation. Examination 12 h after radiation (5 Gy) revealed that the G-CSF treated mice were significantly protected from apoptosis of jejunal crypt, compared with radiation controls. Compared with radiation controls 3.5 days after radiation (10 Gy), G-CSF treatment attenuated intestinal morphological changes. Further, G-CSF markedly improved attenuation of mortality in lethally-irradiated (10 Gy) mice. The present study suggests that G-CSF as a potential drug for protection from radiation-induced intestinal damage.

P01.41
Ionising Radiation and Environmental Toxicants can Interact During Brain Development to Exacerbate Cognitive Defects in Mice

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There is lack of knowledge and increasing concern about low dose exposure to ionising radiation (IR) and induction of non-cancer effects. We are indirectly or directly exposed to persistent environmental toxicants and IR. It is therefore important to integrate different environmental agents, multiple stressors, which might act synergistically to exacerbate developmental toxic effects and thereby also change the dose-response curve. Foetuses and neonates are known to be high-risk groups for exposure to toxic agents. Epidemiological studies indicate that exposure to environmental toxicants, including IR, during early human development can have deleterious effects on cognitive development in childhood. By using the mouse as an animal model we can study the effect of a single toxic agent given directly to the neonatal animal during different stages of the rapid brain growth spurt, and also to study the combination of environmental agents in a controlled manner. In these studies we have observed that IR, and the environmental toxicants like MeHg, PCBs and PBDEs, can induce behavioural disturbances such as deranged spontaneous behaviour and habituation, learning and memory defects and reduced cognitive functions, together with altered function of the cholinergic system, when the exposure occurs during a critical phase of neonatal brain development (PND 10). In recent studies we have observed that the effects after co-exposure to IR (0.05 – 1.5 Gy) and environmental toxicants (e.g. MeHg 0.08 – 4.0 mg/kg bw, PBDE 99 0.8 mg/kg bw) on PND 10 significantly enhance the developmental neurotoxic effects at doses where neither compound nor the IR caused any developmental defects. Furthermore, the dose of IR is down to a single exposure of just 0.1 Gy. This indicates a change in the dose-response curve of IR that can have implications for risk-estimates of non-cancerous effects.

P01.42
Individual Radiosensitivity : A Key Issue in Radiation Protection

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Recent immunofluorescent techniques which permit the demonstration of nuclear targets specific of DNA lesions signalization and repair, e.g., γH2AX foci demonstrating DNA double strand breaks (DSB), have completely renewed the approach to individual radiosensitivity. It is a concern in radiation therapy where the hyper sensitivity to ionizing radiations is responsible for the development of adverse side-effects in normal tissues although there are no mistakes whatsoever in the delivery of the dose. Furthermore individual hyper radiosensitivity at low doses has been recently demonstrated in human mammary epithelium exposed ex vivo to ionizing radiations in the conditions of mammography. Four statistically significant effects have been observed: 1- a dose effect with an increase of the DNA DSB with the increasing dose, 2- a supra-additive dose effect with repeated doses i.e., more DNA DSB with 2+2 mGy than with 4 mGy in one single exposure, 3- a late effect of induction of DNA DSB between 10 min and 24h suggesting a DSB inducing process during repair, and 4- all the 3 previous effects are greater in high family risk patients than in low risk patients. Although these results on human mammary epithelium do not demonstrate directly the existence of mutagenesis they are in favor of a link between cancer proneness and hypersensitivity to ionizing radiations. Therefore individual hypersensitivity to radiations is a real concern in public health since 5-15% of the population could be concerned and individuals that are sensitive to radiations have higher cancer risk than the rest of the population when they are exposed to ionizing radiations. Thus individual radiosensitivity is a key issue to be addressed in future recommendations of the radiation protection system.

P01.43
Histamine and Its Ligands As Promising Radioprotectors Of Normal Tissues To Improve Radiotherapy

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Radiation side effects are inevitable, even with localized radiotherapy. Therefore, specific protection of normal tissues represents a promising approach to improve radiation therapy.

The aim of the present work was to determine whether histamine and JNJ7777120 compound (H4 histamine receptor antagonist) are able to protect bone marrow, small intestine and salivary glands against ionizing radiation damage.

For that purpose, male rats were divided into 8 groups (N=8 per group). Ligand treated and treated-irradiated groups received a daily subcutaneous injection (JNJ7777120 10 mg/kg; histamine 0.1 mg/kg) starting 24 h before irradiation. Irradiated groups received a single dose of 5 Gy on whole-body using Cesium-137 source and were sacrificed 3 or 30 days after irradiation. The number of medullar components, bone marrow trophism, oedema, vascular damage, number of intestinal crypts per circumference, and other histological characteristics were evaluated. Proliferation and apoptosis markers by immunohistochemistry and metacholine-induced salivary secretion of submandibular gland (SMG) were also determined.

Results indicate that JNJ7777120 and histamine treatments reduced the grade of aplasia, and substantially prevented bone marrow replacement by adipose tissue produced by ionizing radiation, preserving all medullar components. Furthermore, JNJ7777120 and histamine diminished mucosal atrophy, oedema and preserved villi and the number of crypts after radiation exposure (240 ± 8 in JNJ777120 treated and irradiated and 200 ± 7 in histamine treated and irradiated groups vs. 165 ± 10 in untreated and irradiated rats, $P<0.01$). Additionally, JNJ7777120 and histamine treatments completely reversed the reduced salivation induced by radiation, significantly conserved glandular mass with normal appearance, preserved structure organization of secretor granules and prevented the radiation-induced decrease in glandular cell proliferation. Radiation-induced toxicity in SMG and small intestine is prevented by histamine and JNJ7777120 essentially by suppressing apoptosis ($P < 0.001$).

We conclude that histamine and JNJ7777120 compound appear to be promising radioprotectors for cancer patients undergoing radiotherapy to attenuate the deleterious effects of the radiation on normal tissues.

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P01.44
Radioprotection of Sensitive Rat Tissues by Oligoelements Se, Zn, Mn plus Lachesis Muta Venom.

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The aim of this work is to study the radioprotective efficacy of the combination Se, Zn and Mn (4 µg/ml each) plus Lachesis muta venom (4 ng/ml) combination (O-Lm). For that purpose we first determined the survival of rats irradiated with different doses of gamma-rays. On the second part of the study we investigated the O-Lm ability to prevent ionizing radiation-induced damage on small intestine, bone marrow and submandibular glands.

For that purpose male Spague-Dawley weighing 200-230 g were randomly divide in 4 groups: group 1, non-irradiated, received daily s.c. saline; group 2, whole-body irradiated rats with a single dose ranging from 2 to 15 Gy; group 3, non-irradiated rats received 0,5 ml daily s.c. O-Lm treatment starting 30 days before irradiation; group 4, whole-body irradiated rats with a single dose ranging from 2 to 15 Gy receiving 0,5 ml daily s.c. O-Lm starting 30 days before irradiation.

A 137Cs source of 189 TBq (7 Gy/min) calibrated by Argentine National Commission of Atomic Energy with a TLD 700 dosimeter and validated by Argentine Nuclear Regulatory Authority was employed.

Small intestine, bone marrow and submandibular gland were examined by histopathological studies and immunohistochemical staining; salivary secretion was also determined.

Results show that all animals of untreated group 2 died after whole body irradiation with 8 and 10 Gy while 60 day-survival was more than 80% and 40% in O-Lm-treated animals, respectively. 30LD50 in O-Lm animals was significantly higher than non-treated rats.

Histopathological examinations revealed a high degree of small intestine and submandibular gland radioprotection 3 days post-irradiation. O-Lm inhibited histological damage on small intestine, restoring the radiation-induced reduction in villous height and crypt number. Also, O-Lm prevented radiation-induced loss of salivary gland function and morphological alterations. These effects were associated to a complete inhibition of radiation-induced apoptosis. Furthermore, studies performed 30 days post-irradiation revealed that O-Lm significantly improved bone marrow repopulation, increasing all medullar progenies to the extent of the non-irradiated animals, and completely prevented permanent submandibular gland alterations. We conclude that O-Lm is a non-toxic promising approach to achieve radioprotection for patients undergoing radiotherapy and also by individuals who may suffer environmental, occupational, or accidental exposure to ionizing radiation.

P01.45
Histamine Hinders Radiation-Induced Mesenchymal Transition In Epithelial Tumor Cells

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Epithelial-mesenchymal transition (EMT) is a physiologic process during which epithelial cells acquire mesenchymal features. Up to 90% of human neoplasias are carcinomas from epithelial tissues. During malignant progression the EMT process is necessary to the conversion of tumors to aggressive and highly invasive cancers. Due to complex interactions between cancer cells and their microenvironment, changes in cell adhesion, a positive regulation of metaloproteinases 2 and 9 (MMP2 and MMP9) and activation of cell motility are observed together with an increase in mesenchymal markers like N-cadherin, vimentin and smooth muscle alpha-actin. Intrinsic radiosensitivity of tumor cell is only one of the factors that affect effectiveness of radiotherapy existing evidence that proliferative, invasive and metastatic capacities can be increased in the surviving tumor cells of irradiated neoplasias.

In previous works on pancreatic adenocarcinoma (PANC-1) and breast cancer (MDA-MB-231) cell lines we demonstrated that histamine exerts an antiproliferative effect over 10 uM. The aim of this work was to study the effect of histamine on ionizing radiation-induced EMT.

Histamine treatment produced a concentration dependent effect on EMT in PANC-1 and MDA-MB-231 cells. At high concentrations (over 10 uM) a reduction in MMP2 and MMP9 activity (evaluated by zymography) and cell migration (evaluated by migration chambers) was observed in both cell lines. Moreover an enhancement of E-cadherin expression (epithelial marker) and a diminution of smooth muscle α-actin, vimentin and N-cadherin mesenchymal markers) were determined by immunocytochemistry or immunoblot.

When tumor cells were 2 gray gamma irradiated an increase in gelatinolytic activity, migration and expression of mesenchymal markers was detected in both cell lines evidencing some degree of mesenchymal transition. Notably, treatment with high concentrations of histamine before irradiation counteracted those effects.

The mechanisms that control the efficacy of radiotherapy have classically focused on the ability of ionizing radiation to kill cancer cells while sparing normal tissues. However, the identification of pharmacological agents that target oncogenic pathways which may regulate tumor cell proliferation and simultaneously control metastatic ability will help to delineate more effective strategies to improve overall and disease free-survival and health-related quality of life in patients undergoing radiotherapy.

P01.46
Sanguinarine Is a Novel Radioprotector for Acute Whole Body Irradiation

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Sanguinarine, a quaternary ammonium salt from the group of benzylisoquinoline alkaloids, provides powerful antioxidant activity. We for the first time found that sanguinarine at non-toxic doses significantly improved survival of mice exposed to acute total body irradiation at sublethal and lethal doses of X-rays. Pretreatment of animals with sanguinarine resulted in significantly increased bone marrow cell counts and spleen mass after irradiation and improved recovery of peripheral leukocytes and platelets. Furthermore, Sanguinarine significantly inhibited the incidence of micronuclei in irradiated mice. Taken together, supplementation with sanguinarine as a promising agent appears to be an effective approach for radioprotection of organs and tissues as well as improvement of animal survival after acute total body irradiation.

P01.47
Cancer Rates on the Area with Fuel-like Hot Particles Deposition – Unexpected Results

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Tiny particles of spent nuclear fuel („fuel-like hot particles”) were present in the Chernobyl fallout mostly at sites close to the damaged NPP. In northeastern Poland relatively massive precipitation of such particles was identified [1,2,3]. Fuel particles contained many radioisotopes of non-volatile elements (like: Ce, Eu, Ru, Nb, Zr, Sr, Pu, Am, U).

Our study we can divide on three steps. First we created geographic pattern of hot particles deposition in northeastern Poland. The Chernobyl plutonium deposition was found to be as high as 24 Bq/m^2 at the maximum [1,2]. This result suggests up to 2000 fuel particles of few micrometer diameter on a square meter deposited [1]. Next we measured plutonium isotopes activity in humans bones. Samples of bones were obtained from 25 persons during routine surgeries – the replacement if knee or hip joints by implants. Surgeries were conducted in a general Hospital in Bielsk Podlaski in Northeastern Poland. Minimum activity of $^{239+240}$Pu was equal to 5.4±1 mBq kg^{-1}, whereas the maximum activity reached 34.3±5.7 mBq kg^{-1}. In last part of our study we examined the cancer rates in the most exposed to the hot particles fallout counts (Polish name „powiat” – it is form of up to tens smaller units – the commons) for cancer of liver, bones, myeloid leukaemia, larynx and lungs with bronchus and trachea against their mean ratio in scale of whole Poland.

Radioactive contamination plutonium in human body is very low, moreover external dose from Chernobyl fallout during 1986 was estimated to be in average below 0.3 mSv reaching up to 1.5 mSv in the most contaminated areas of Poland [3]. The inhalation dose calculated in classical way gives even lower values [3] then the external doses. Thus one cannot expect any clear increase of cancer rates. However in case of myeloid leukaemia the increase can be observed, and this results is statistical significance for Poisson distribution. The results may suggests a need for serious reconsideration of dose-risk factors in case of incorporation into body radioactive particles.

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P01.48
Cancer And Non-Cancer Incidence Among Bulgarian Medical Radiogenic Workers

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Purpose: To contribute the cancer and non-cancer incidence estimate in relation to work history (years of first employment, duration of occupational exposure, radiation doses received for whole period) in a cohort of medical radiation workers.

Methods: A retrospective cohort study was carried out. The cancer incidence among 315 medical workers was compared with that of 320 other medical specialists who worked in hospitals on the territory in Sofia for period 1960-2000. Data concerning incident cancer and non-cancer occurrence was obtained from questionnaire. Data for individual doses were extracted from National System of Individual Dosimetric Control. Descriptive statistics, X^2, Fisher's exact test, ANOVA analyses were used.

Results: Cancer incidence was more frequently diagnosed among radiation workers compared to other medical specialists ($p=0.018$). When analyzing by cancer type the results were the same ($p=0.037$). No statistically significant difference in the non – cancer incidences between cases and controls has been observed. ($p=0.905$). No statistically significant relation was observed between cumulative radiation dose and cancer incidence ($p=0.121$), or non-cancer incidence ($p=0.109$). No statistical significance was found between the year of first employment and cancer development for cases and for controls ($p=0.854$ and $p=0.178$ for cases and controls, respectively) as well as and non-cancer incidence ($p=0.405$ and $p=0.552$ for cases and controls, respectively). It was not established statistical correlation between work duration in an ionizing radiation environment and appearance of cancer or non-cancer.

Conclusion: The present study shows that cumulative dose obtained and the duration of work in an ionizing radiation environment does not substantially influence the arising of cancer and non-cancer. Although we find higher degree of cancer occurrence among cases compared to controls, those two factors do not give us ground to confirm that work in an ionizing radiation sphere increases the cancer incidence. It is important to continue the monitoring the health status of medical radiation workers.

Key words: epidemiology, cancer incidence, non-cancer incidence, occupational radiation exposure.

P01.49
Individual Doses Estimation for the Semipalatinsk Historical Cohort

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The Semipalatinsk Nuclear Test Site (SNTS) was officially closed in 1991. Nevertheless assessment of the radiation effects on the residents lived near the SNTS due to the radioactive fallout is still important. It is worth noting that neither individual dosimetry at the time of the nuclear tests, no retrospective estimation of individual doses for these persons have been made (excepting several scientific researches concerning some settlements). Re-evaluation of radiation doses taking into account personal characteristics such as age, profession, place of residence, etc is necessary to study health effects of the nuclear tests on the residents. Furthermore dietary habits should be considered for assessment of internal doses. Neglecting these factors in some cases can result in systematic errors in dose estimation and distortion of general pattern of radiation consequences of the nuclear tests.

At present scientists from Russia, Japan and Kazakhstan take part in a collaborative international project related to assessment of individual external and internal doses for about 20 thousand persons included in the so-called Semipalatinsk historical cohort. These persons lived in 10 settlements located nearby the SNTS: Sarzhal, Karaul, Kainar, Kaskabulak, Kundyzdy, Cheremushki, Kanonerka, Mostik, Dolon and Znamenka. Data for calculations are derived from the register of the residents who lived on the territory of local radioactive fallout due to the nuclear tests on the SNTS. This register has been created by the scientists in both Kazakhstan and Japan.

P01.50
Mortality From Cardiovascular Diseases And Occupational Uranium Exposure: Cohort And Nested Case-Control Studies Of French Uranium Workers

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The risk of cardiovascular mortality (CVM) among French uranium workers after protracted low-dose exposure to different uranium compounds, was investigated among 2897 workers (79892 person-years) employed at the AREVA NC Pierrelatte uranium processing plant (1960-2006).

Cumulative exposure to different uranium compounds, classified by isotopic composition and solubility-type, was assessed using a plant-specific job-exposure-matrix. Hazard ratios and associated 95%-confidence intervals (HR [95%CI]) were estimated using Cox regression models accounting for sex, calendar period, initial socioeconomic status and associated exposure. A case-control study was nested into the cohort to address the role of individual biological and lifestyle parameters. At the end of follow-up, 111 CVM cases were observed. The CVM risk was increased only among workers exposed to insoluble compounds of reprocessed (HR=2.07[0.99-4.99], n=9) and natural uranium (HR=1.73[1.11-2.69], n=41), after adjustment for solvents and heat exposure.

The nested case-control study including all the CVM cases and 397 referents (matched by sex and 5-year age class) has been set up. Anthropometric (height, weight), biomedical (blood and urine biochemical analyses, diagnostic X-ray exposure), anamnesis and treatment, as well as smoking and alcohol consumption data were computerized on an annual basis using individual workers' occupational medicine records and analyses are ongoing.

Our cohort study is the first suggesting an increasing risk of CVM related to insoluble uranium exposure. The results highlight the importance of taking into account solubility. The nested case-control study will refine our exposure-response analysis and provide results adjusted for known CVM risk factors in order to draw an appropriate conclusion.

P01.51
Lessons of Chernobyl and Prognosis for Fukushima: Health Effects

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Results of studies of the Chernobyl accident, verification of ICRP prognostic models with an allowance for data on the Chernobyl accident, estimating potential health effects of the Fukushima nuclear accident are considered. The database of the Russian National Radiation Epidemiological Registry keeps medical and dosimetric data about more than 700 000 persons: 457 000 residents of contaminated areas , 8000 evacuees , 196 000 emergency workers, 39 000 children of emergency workers born after the accident.

Leukemia incidence in emergency workers increased 2.5-3-fold in 5-7 years after the accident and reduced to the baseline level in the last decade. No increase in solid cancers incidence in emergency workers with dose < 100 mGy was found.

993 thyroid cancer cases among 309 000 residents were detected. Significant risk was found in the cohort of 0-17 years of age at exposure; thyroid cancer incidence in adults increased 3.7 -fold, however the effect of ^{131}I was not detected. No statistically significant relative risk of thyroid cancer incidence was detected for doses < 100 mGy.

Possible health effects of the Fukushima nuclear disaster were estimated on the basis of available data with the use of ICRP models .We compared actual data of the National Registry on thyroid cancer incidence after the Chernobyl accident and modeled results. The both values are in close agreement with each other.

We found that in population with possible annual dose of 5-10 mSv 150 additional cancers could be developed, etiology fraction for radiation related solid cancers of 0.2% could be expected.

Main estimates of Chernobyl associated radiation risks are in close agreement with ICRP models. Prognostic estimates of health effects of the Fukushima nuclear disaster are preliminary. We think that determination of potential risk groups based on radiation epidemiological data will be rational.

Key words: Chernobyl accident, estimating radiation risk, ICRP models, prognostic estimates, health effects of Fukushima nuclear disaster.

P01.52
Infant Mortality Among Offsprings of Occupationally Exposed Fathers

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Issue of genetic effects of chronic radiation exposure becomes more topical with increased influence of nuclear technologies and is of great interest. Radiation genetic effects in the first generation of exposed parents include severe disorders in offsprings: embryonic death, birth defects, infant mortality.

The analysis estimates rates of infant mortality among offsprings of the first generation of males exposed due to occupational activity at the first Russian nuclear facility, Mayak production association.

The analysis is performed on children cohort born in 1949-2002, based on Child Register of Ozersk database. Fathers of 16 139 individuals were subject to preconception occupational exposure at Mayak PA. Average external gamma-dose accumulated by the time of conception was 29.25 cGy (0.01 – 632 cGy). Control group includes 26 782 individuals whose parents were not hired at nuclear facility. Infant mortality rates like dynamics, rate and structure were analyzed. Infant mortality dynamics in exposed fathers' offsprings tends to exceed that of the control group during the follow-up.

Infant mortality rate in occupational workers' children is higher than in the control group (16.9 and 14.5 per 1000 infants correspondingly). Large contribution in the mortality structure of the study and control groups was made by perinatal life diseases and fatal congenital anomalies.

Significant excess of infant mortality rate is registered in the group of children whose fathers have external preconception cumulative gamma-dose greater than 100 cGy.

P01.53 Cancer Mortality in Personnel of the Siberian Group of Chemical Enterprises and in Population of Nearby Territories

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The purpose. The study of cancer mortality among the workers of the Siberian Group of Chemical Enterprises (SGCE) and among the population of the closed administrative territorial formation Seversk, living in the SGCE influence zone (during the period from 01.01.1970 for 31.12.2005).

Materials and methods. The object of the study is the SGCE personnel (the workers of reactor plant (RP), radiochemical plant and plutonium plant (PP)) and the population of Seversk.

Results. The leading positions in a structure of cancer mortality of the Seversk population among men are occupied the following: malignant neoplasms of digestive organs (38%), respiratory organs (32.6%) and hemoblastosis (7.6%). The structure of cancer mortality among women was following: the first place was occupied the cancer of digestive organs (42.9%), the second place – the tumors of female genitals (15%) and the third place – the breast cancer (13.4%). In period of 2000-2005 the cancer mortality was 223.5 cases on 100 000 inhabitants (259.8 cases among men and 191,4 cases among women) that more than in 3 times surpasses value of a similar indicator for the interval 1970-1974. During the studied period the cancer mortality among men owing to a cancer of digestive organs has grown more than in 3 times (with 29.7 to 94 cases on 100 000 men), owing to malignant tumors of respiratory organs – more than in 5 times (with 17 to 86.6 cases) and owing to hemoblastoses about in 2 times (with 8 to 13.9 cases). It was established that level of cancer mortality among female increased more than in 3 times (with 9.3 to 30.3 cases on 100 000 women) account of the cancer of female genitals, more than in 5 times (with 5.7 to 28.9 cases) account of the breast cancer and more than in 2 times (with 6.2 to 13.1 cases) account of hemoblastosis.

When analyzing cancer mortality risk in the SGCE personnel, standardize relative risk (SRR) was higher than 1 among the workers of the PP for all solid cancers (SC), but the difference with the standard (RP personnel) was not significant. Cancer mortality risk (for all SC) among the PP personnel exposed external radiation showed to be higher than standard (1.37; 95% CI 1.12-1.73), but RR for separate SC localizations did not differ significantly from the standard.

P01.54
The Risk of Acute Myocardial Infarction Development in Siberian Group of Chemical Enterprises Personnel Exposing Long-Term Radiation

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The purpose. The evaluation of the risk acute myocardial infarction (AMI) development in Siberian Group of Chemical Enterprises (SGCE) personnel exposing long-term radiation.

Materials and methods. For study of standardize relative risk (SRR) of acute myocardial infarction (AMI) development among SGCE personnel the prospective cohort study of AMI morbidity in period 1998-2007 was conducted. Morbidity rate from AMI among Seversk adults (individuals older 20) was studied according to the World Health Organization programme “The Register of Acute Myocardial Infarction” that was amended by us with the results of life-time up-to-date methods of examining persons suffering from ischemic heart disease followed by observation. To calculate the indices of AMI morbidity only the cases of “determined” and “possible” AMI were taken into account.

The diagnosis was established for 943 patients. The median of cumulative dose of external radiation of SGCE workers – AMI patients (n = 360) was 44.8 mSv (interquartile interval: 14.3; 158.72 mSv).

Results. When evaluating the SRR AMI morbidity it was established that the index of SGCE male personnel exposed external radiation was statistically much bigger, compared to male personnel without radiation exposure with a comparable age structure and the level of examination (SRR = 1.16 (1.04; 1.29)). The risk of personnel without radiation exposure was equated to 1.

To study the dependence “dose-effect” we have performed a comparative analysis of SRR of AMI morbidity for subgroups personnel depending on the cumulative dose of radiation exposure. The risk for each dose interval was calculated concerning to “nought” group, i.e. for workers not exposed radiation (on the data of individual dosimetric control).

According to the analysis of AMI risk in subgroups of the personnel with different cumulative radiation doses, it has been established that the risk of AMI development with cumulative dose more than 300 mSv is significantly higher than the standard (SRR = 1.46 (1.09; 1.91)). The increase in risk of AMI development was not observed with increasing radiation dose up to 300 mSv.

It may happen automatically due to the peculiarities of the study cohort, in which about 90% have a dose up to 200 mSv.

Thus it was revealed statistically significant increase of AMI development risk in group of SGCE personnål exposed long-term radiation in a range of low doses. No excess AMI incidence risk when increasing radiation dose has been found.

P01.55
Cancer Effects in the Population Chronically Exposed to Radiation on the Techa River

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As a result of activities of the Mayak Production Association (Mayak PA), a facility for production of weapon-grade plutonium in the Southern Urals, the Techa River was contaminated with radioactive waste. Residents of the Techa riverside area were exposed to chronic internal and external irradiation. Maximum waste releases took place in 1950-1952. The major contribution to the radiation exposure was made by the radionuclides ^{90}Sr and ^{137}Cs. To render medical assistance to the population exposed in the Southern Urals, a health center was created which currently bears the name of the Urals Research Center for Radiation Medicine (URCRM). The URCRM researchers have identified the Techa River Cohort (TRC) which includes persons born before 1.1.1950 who were permanent residents of the Techa riverside villages during the period from 1.1.1950 through 31.12.1960. Individualized doses accumulated by TRC members were estimated by URCRM researchers and specialists based on the dosimetry system TRDS-2009. Median, mean and maximum doses accumulated by the end of the follow-up period in soft tissues of TRC members amounted to 11 mGy, 36 mGy and 960 mGy, respectively, and the doses accumulated in the red bone marrow reached 270 mGy, 430 mGy and 9000mGy, respectively.

The cohort of almost 30,000 people is an unselected population of men and women of all ages from two ethnic groups, who were resident in riverside villages through which the river flows. The period of follow-up of TRC members totals 55 years, from 1.1.1950 through 31.12.2005. The catchment area encompasses raions from which we can obtain vital status, cancer incidence and cause of death information systematically. Persons who have moved from the catchment area are considered as migrants, and they are included in the analysis for the time period from the date of initial exposure to the date of departure from the catchment area.

Analyses of cancer incidence risks confirmed our previous results obtained over a period by 3 years shorter than the current follow-up period using an earlier version of the dosimetry system, and showed a statistically significant linear dependence of cancer incidence on dose received.

P01.56
Radiation Risk of Lung Cancer Incidence with regard to Histological Tumor Type among the Mayak Nuclear Workers

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Radiation risk of incidence was estimated for malignant neoplasms of lung with regard to different histological types in the cohort of male nuclear workers from the Mayak Production Association.

The cohort included 16,685 male workers employed at the reactors, radiochemical and plutonium production facilities during 1948-1982. The follow-up period was until 31 December 2004. The information on accumulated doses from external gamma-rays and internal alpha-radiation, and incorporated plutonium was used from a dosimetry system of the Mayak nuclear workers, Mayak Doses 2008. By the end of follow-up, 414 cases with malignant neoplasms of lung as the primary disease were registered in the cohort under study, without regard to non-melanoma skin cancers. The histological verification was available for 77.5% cases.

There was a significant linear dose response in the excess relative risk (ERR) model both with regard to internal ($p<0.001$) and external doses ($p = 0.02$), without any evidence of non-linearity ($p>0.3$) for lung cancer in general. The highest radiation risk (ERR/Gy) was found for adenocarcinoma, which was 10-fold higher with regard to internal alpha-radiation than for squamous-cell cancer, 30.42 (95% CI: 15.43; 66.59) versus 2.95 (95% CI: 0.32; 7.84); and 5-fold higher than for other epithelial malignant neoplasms, 5.77 (95% CI: 1.78; 14.05). ERR was 7.64 (95% CI: 5.09; 11.13) for lung cancer in general with regard to internal alpha-radiation.

A statistically significant ERR/Gy was found for adenocarcinoma and a group of other epithelial malignant neoplasms, 1.08 (95% CI: 0.23; 3.38) and 0.50 (95% CI: 0.01, 1.54), correspondingly, with regard to external radiation.

For the purposes of this study, internal doses to lung from a dosimetry system of Doses-2008 were averaged for the whole lung, without accounting for non-uniformity of plutonium distribution in lung tissue. Plutonium was known to be rather non-uniformly distributed within lung, with the highest fractions of this radionuclide retained in the upper lobes and peripheral regions of lung. This could be explained by a worse clearance from these compartments due to slower blood and lymph circulation, rather than by a significant intake of the radionuclide. In this context, dose to the peripheral region of bronchioles and alveolar-interstitial compartment would be much higher than homogenous dose to the whole lung. Thus, ERR of adenocarcinoma, which is often located at the periphery, would be lower.

P01.58
The Acute Myocardial Infarction Morbidity Among Siberian Group Of Chemical Enterprises Personnel And Population Living In A Zone Of Its Located

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The purpose. To study the acute myocardial infarction (AMI) morbidity in Siberian Group of Chemical Enterprises (SGCE) personnel and population living in a zone of its located.

Materials and methods. The object of study is the population of closed administrative territorial formation Seversk. For research of AMI morbidity the AMI register as a structural constituent of the Regional Medico-Dosimetric Register of SGCE personnel and Seversk population was created. Morbidity rate from AMI and its dynamics among Seversk adults (individuals older 20) was studied during the period 1998-2008 according to the World Health Organization programme "The Register of Acute Myocardial Infarction" that was amended by us with the results of life-time up-to-date methods of examining persons suffering from ischemic heart disease followed by observation.

Results. It was established that AMI morbidity of studying population had tendency to growth (from 2.62 to 3.01 per 1 000 residents in 1998-2008, accordingly). It corresponds to tendency of AMI morbidity in Russia. AMI morbidity among SGCE personnel (5.7-6.06-6.02-6.06-5.38-7.01-7.35-4.7-4.46-5.77-4.62) during the period of observation was much bigger than such index among Seversk citizens (1.78-1.47-2.07-2.3-2.48-1.75-2.22-2.71-2.65-2.74-1.70; $p < 0.001$).

During the research period 57.65 ± 0.41% among Seversk's citizens were women, but 64.31 ± 0.63% among SGCE personnel were men. It was established that standardize indices of AMI morbidity among SGCE male personnel was statistically significant higher compared to analogical indices among Seversk's men in period 1998-2008 ($p<0,05$).

It was noted increase of AMI morbidity among SGCE support production personnel (which not exposed occupational radiation) and decrease that index among SGCE main production personnel. However it was established that AMI morbidity of SGCE main production personnel exposed long-term radiation was statistically significant higher ($p < 0,05$) compared to such index of SGCE support production personnel (8.49-7.9-8.05-8.24-6.15-10.6-5.2-5.49-7.23-5.28 and 3.13-4.36-4.52-4.23-4.72-4.57-4.29-4.1-3.41-5.45-3.88 in period 1998-2008 accordingly).

Thus, it was established that AMI morbidity of SGCE personnel statistically significant higher then among Seversk population (in groups with a comparable age and sex structure and the level of examination). Besides the highest levels of AMI morbidity were registered among the SGCE personnel exposed long-term radiation.

P01.59
Possible Source Of Uncertainty In Radon Epidemiological Studies At Low Radon Concentrations

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In the last decade, the epidemiological evidence of the carcinogenicity of *(danger of cancer related to*) radon exposure in dwellings was greatly enhanced by a number of studies that showed a significant relative risk (RR) for lung cancer even at relatively low radon concentrations that are commonly found in most countries. Moreover, some of these studies claimed that a threshold, if any, should be fixed at a concentration of the order of 100-150 Bq/m^3, corresponding to an effective dose of the order of a mSv per year.

Obviously, these results have had very important consequences. National and International regulation bodies have in fact encouraged a general decrease in the established limits and in the Action levels for radon. These limits, in some situations and countries, approach the values of the local natural background and thus could be very difficult to be respected .

It is therefore important to investigate in detail the credibility and reliability of these assertions. In this work we show that, starting from a simple model for radon concentration in dwellings and from some reasonable assumptions, the probability of a correlation between radon concentrations and that of the other domestic pollutants is much greater for the lower class radon concentration data than for the higher ones.

Therefore, while for those data relative to high enough radon concentrations the measurements or the evaluation of other pollutants (such as: passive smoking, household cleaners, paints and solvents, lawn and garden care, automotive products, pool chemicals, etc.) could be avoided without any particular problems, for those referring to lower radon concentrations a significant bias could occur.

Thus, for low class radon concentration data (for instance, of the order of 100 -150 Bq/m^3) a more detailed evaluation of all the possible domestic pollutants would be necessary.

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P01.60
Thyroid Cancer Incidence due to Technogenic Exposure in Childhood

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Ozersk and Kyshtym are the closest cities to Mayak PA - the first Russian nuclear facility. In the course of technology mastering the facility was not equipped with gas purification system, therefore the population in the vicinity of Mayak PA could be subject to production induced exposure due to unmonitored gas-aerosol discharges, with iodine-131 as the main dose-forming radionuclide. Thus the main objective of the analysis is to estimate risk of thyroid gland cancer incidence for people who lived in Ozersk and Kyshtym in childhood.

Epidemiological analysis was carried out by cohort and “case-control in cohort” methods and based on “Child Register” of Ozersk and Kyshtym residents. Selected subcohort contains 85 928 individuals born in 1934-1988 in the cities or moved there before they were 15 years old. 97 thyroid gland cancer cases were registered in the subcohort in 1948-2009. Information about the cases was obtained from archive and current medical documents. City residents of the Chelyabinsk regional center were considered the most suitable control population to calculate relative risk of thyroid cancer incidence due to the regional endemicity. Relative risk coefficients are estimated with 90% confidence interval by AMFIT and PECAN of Epicure.

In the cohort analysis relative risk of thyroid cancer incidence in Ozersk and Kyshtym, standardized by age, exceeds the standard rate by factor of 1.5. In Kyshtym cohort risk is higher than in Ozersk cohort, in males in particular. “Case-control” analysis for Ozersk residents demonstrated significant increase of incidence risk due to point of residence.

Obtained results suppose relation between thyroid gland cancer incidence and incorporated iodine exposure, whose main source is dairy products consumption. This assumption is supported by obvious correlation of incidence risk coefficients and place of residence of the studied cohort members when children.

P01.61
A Cohort Study on Low Dose Exposure and Mortality in Nuclear Power Workers in Germany

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Introduction: In a previous historic cohort study of German nuclear power workers including 4.844 employees having worked in 10 nuclear power plants between 1991 and 1997, no increase in cancer mortality was seen [1]. As the expected health risks of low doses of ionizing radiation are small, epidemiological studies require large sample sizes and long periods of follow up. Based on this former cohort study an extended cohort study started in October 2009, which included approximately 9.800 employees of 17 German nuclear power plants, followed up in the period January 1991 to December 2008. The aim of the study is to provide estimates of long term health risks in nuclear power workers in Germany after protracted low doses of ionising radiation.

Materials and Methods: The cohort includes exposed persons employed as category A radiation workers. For every individual, a mortality follow-up was carried out through compulsory population registries. Death certificates were obtained from the local health authority of the place of death. According to the data protection protocol, individual exposure data (annual doses of external photon radiation) will be provided by the operators of the nuclear power plants at the end of follow up.

Results: The mean follow-up time was 11,2 years. The mean age of the workers at the end of the follow-up was 49,2 years. In December 2008, 4.910 persons (50,2%) were still working as occupationally exposed persons. A mortality follow up was carried out for the former employees. The vital status was determined with a completeness of 99,8%. During the observation period 366 deaths occurred. The individual socioeconomic status could not be determined individually for the cohort members. Hence, the distribution of occupational groups among the nuclear power workers was assessed in one plant. A total of 26% of the employees were higher educated, non-manual employees, approximately 70% were skilled manual workers and 4% were trainees. Standardized mortality ratios for all causes of death, all cancers and cardiovascular diseases will be available in May 2012.

Discussion: Workers in the nuclear industry are relatively well paid and educated, which may be associated with a comparatively healthier lifestyle. A strong healthy worker effect was observed in the previous cohort (all-cause SMR = 0,54, 95% CI 0,42-0,67). This was in line with the IARC results of a retrospective cohort study in 15 countries [2]. However, the estimates of the extended cohort are necessary in order to verify (or falsify) former results and to conduct further joint analyses of international studies.

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P01.62
Socially-Psychophysiological Estimation of a State of Health Suffered from Heavy Acute Irradiation in Failure Of Chernobyl Accident

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The Average profile of multilateral research of the person (MMPI) and dynamics of indicators on years of supervision (1999-2011) are registered in borders of population statistical norm (<70> 30) on a scale of T-points and testify to efficiency of psychophysiological adaptation of G.O.I., which has transferred acute radiation sickness III severity levels and plural local radiation injuries I-II of degree (80 %). Dynamics of an emotional pressure and intensity of its mental adaptation (the test of Kettella) correspond to relative density of infringements of mental adaptation, characteristic for the period of stable adaptation. Tendency to hyperthymical type of the person, not falling outside the limits normal indicators, with characteristic optimism for this condition, sociability, high activity, vigor, ease to dialogue promote efficiency of psychophysiological adaptation. Rather high indicators of intelligence (factor B-8-7-6-5 of walls) and is figurative-logic thinking (there are complexities in analitiko-synthetic cogitative activity) - the test of Ravena remain. Operator abilities of G.O.I. are kept in full at level of indicators of operation personnel of the atomic power station and it can perform work of the operator without contact to radiation. Efficiency of psychophysiological adaptation depends not only on a dose of an irradiation and weight of the transferred disease, but in more to a measure, from premorbidal properties of the person of the victim and its sociolabor installation. Specific features of psychophysiological adaptation of G.O.I. its expressed personal lines, despite heavy acute radiation sickness and local radiation injuries, appreciably correspond to requirements of environment and have defined its behavior and recover.

P01.63
Lifetime Radiation Mortality Risk from Lung Cancer. Direct and Indirect Estimates of Nonlinear Dose Trend

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Analysis of lifetime specific risk rates LR(D) dose trend in cohorts with long follow-up is important for two reasons: 1) they make radiation harm normalization more adequate; 2) they better express stochastic and individual nature of health status damage compared to annual population risks. The latter are more connected with impact of risk competition and deterministic reduction of lifespan due to cancer onset, not just stochastic reasons of its development.

Mayak PA workers cohort (Russia) is a representative group of individuals subject to combined chronic radiation exposure at average doses more than 1Sv. LR trend was assessed by two different mathematical methods, direct (almost nonparametric) and indirect (parametric). The first was based on analysis of difference of cumulative distribution by dose for males died from lung cancer (667 cases) and males died from all cases (9106 cases and controls). The second method used "case-cohort" analysis and logistic regression (without distribution analysis). Three statistical criteria were used to assess quality of approximation.

The methods showed agreement of dose trends estimates within limits of random deviate. Logistic regression trend was significantly different from both strictly linear nonthreshold and log-linear models. No hormesis was observed by LR rate. LR(D) best performance curve could be treated as combination of two significantly different trends with "smooth sewing" region from 0.1 to 0.5Sv. Nonparametric method revealed a "plateau" region at 0.2–0.3Sv. Analysis of approximation residuals supposes relation of composed character of a curve with lack of homogeneity of the cohort. Radiosensitive part of the cohort studied groups is estimated in values up to 5–6% of particular patients. LR value in the region of trends "sewing" corresponded with population lifetime risk of lung cancer. However below the "sewing" region (by dose) dependency was quite attributive up to several mSv. For the cohort in general this leads to value of attributive risk at the level of 0.71 (CI 90%: 0.65…0.76), at average dose 1.67Sv for died exposed members, which is significantly higher than the previously found value (DL Preston, ME Sokolnikov, P Jacob, etc.). Above the "sewing" region average angle of the trend was ~40% per 1Sv to ~20% per 1 Sv tending to decrease with dose increase which is consistent with earlier estimates.

P01.64
Expert and Prognostic Assessments of the Public Health in the Vicinity of the NPP

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Burnasyan Federal Medical Biophysical Centre (FMBC) has a large experience in assessment of the public health within the radiation and hygienic monitoring performed in the areas of the NPP location. Such experience revealed the necessity to unify methods and approaches to assessment of health in the mentioned population groups.

Today, FMBC has developed the recommendations on procedures of the expert and prognostic health assessments of the population living in the areas of the NPP location.

The recommendations establish the single requirements for the selection of indexes and criteria for the health assessment, arrangement of the information database, and methods of treatment and presentation of the pooled data. The recommendations also include some proposals on procedures of prognostic assessment of changing basic health indexes.

The following things are recommended to use as the basic health indexes of the population: morbidity and mortality of adult and child population, reproductive and genetic health, health of critical (in terms of their sensitivity to unhealthy environmental factors) groups of the population (pregnant women, infants), conditions of the critical (according to their sensitivity to the radiation exposure) systems of the organism (hemopoietic, endocrine).

P01.65
Radiation Risk Assessment, Taking into Account the effect of Irradiation on all Causes of Death

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The values of radiation risk coefficients, which recommended ICRP, are based mainly upon data on deaths from cancer in LSS-cohort, as well as in several other cohorts (radiation workers, individual irradiated at radiation accidents, individual subjected to radiation treatment, living under high levels of radon, etc.). For data on additional non-cancer mortality by radiogenic reasons, they are actually existing only for the LSS-cohort, and with great difficulty (or rather, with a large error) can be determined for others of the above cohorts. However, there are many facts that suggest that radiation risk is associated not only with mortality from cancer. In this report, radiation risk is estimated by analyzing changes in the intensity of all-cause mortality and life expectancy after acute exposure, depending on sex, age at exposure (year of birth) and attained age. As input data have been used results of the observations for all-cause mortality in a cohort of LSS, published on site RERF www.rerf.jp. The method of analysis of the impact irradiation on the mortality rate is founded on the usual assumptions of model relative risk and on hypothesis about linear excess risk dependency from dose. Extrapolation of the observed survival functions in range older ages for estimates of life expectancy of younger age groups LSS cohort was performed under the assumption of applicability Gompertz law for the age dependence of the mortality rate from all causes. In the calculations as the main tool's used the maximum likelihood method.

*This report makes use of data obtained from the Radiation Effects Research Foundation (RERF), Hiroshima and Nagasaki, Japan. RERF is a private, non-profit foundation funded by the Japanese Ministry of Health, Labour and Welfare and the U.S. Department of Energy the latter through the National Academy of Sciences. The conclusions in this report are those of the authors and do not necessarily reflect the scientific judgment of RERF or its funding agencies.

P01.66
Radiation Risk Assessment, Taking into Account the Effect of Irradiation on all Causes of Death

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The values of radiation risk coefficients, which recommended ICRP, are based mainly upon data on deaths from cancer in LSS-cohort, as well as in several other cohorts (radiation workers, individual irradiated at radiation accidents, individual subjected to radiation treatment, living under high levels of radon, etc.). For data on additional non-cancer mortality by radiogenic reasons, they are actually existing only for the LSS-cohort, and with great difficulty (or rather, with a large error) can be determined for others of the above cohorts. However, there are many facts that suggest that radiation risk is associated not only with mortality from cancer. In this report, radiation risk is estimated by analyzing changes in the intensity of all-cause mortality and life expectancy after acute exposure, depending on sex, age at exposure (year of birth) and attained age. As input data have been used results of the observations for all-cause mortality in a cohort of LSS, published on site RERF www.rerf.jp. The method of analysis of the impact irradiation on the mortality rate is founded on the usual assumptions of model relative risk and on hypothesis about linear excess risk dependency from dose. Extrapolation of the observed survival functions in range older ages for estimates of life expectancy of younger age groups LSS cohort was performed under the assumption of applicability Gompertz law for the age dependence of the mortality rate from all causes. In the calculations as the main tool's used the maximum likelihood method.

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P01.67
TRACY : The French cohort of uranium cycle workers

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Objective: To set up a longitudinal cohort for investigating the risk of mortality from cancer and non cancer diseases in relation to uranium and other occupational exposures.

Methods: All workers involved in the French nuclear fuel cycle, employed by the AREVA group establishments and by the French Atomic Energy Commission (CEA), were potentially eligible. The cohort is limited to workers employed for at least 6 months between 1958 and 2006. Retrospective historical data on occupational exposure and individual measurements, such as urinalyses for internal doses assessment and external radiation exposure, are collected. Moreover, the gathering of individual risk factors data, such as tobacco consumption, blood pressure, and other biological data from workers personal medical files is under way. As a complementary approach, plant-specific job-exposure matrixes are developed to assure the completeness of data on associated exposures (chemical and physical hazards). Vital status and causes of death will be collected from the French National Mortality registers.

Results: Approval of the study protocol by French ethical authorities and workers representatives have been obtained and the data collection is ongoing. Identification and administrative information have been collected for workers employed at Comurhex (purification and conversion: n=1,600), Eurodif (uranium enrichment: n=2,016), AREVA NC (uranium enrichment, chemicals transformation of reprocessed and depleted uranium: n=2,864), Socatri (uranium recovery and cleansing: n=567), FBFC (manufacture of nuclear fuel: n=1,982), Melox (manufacture of Mox fuel: n=723) and CEA (research: n=2,837). For the period 1986 to 2004, urinalyses and other biological measurements data were computerized. Historical external dosimetry data were gathered for most of the companies. Job-exposure matrixes for the AREVA NC Pierrelatte and Eurodif plants have been constructed and validated.

Conclusion: Data collection for the 12,589 workers is well progressing. This cohort will be very informative for the investigation of uranium related risks, taking account of multiple exposure patterns of the workers involved in the nuclear fuel cycle. It will allow investigating cancer and non cancer effects, in particular cardiovascular risks. As a pilot study, an analysis of uranium exposure effects on cancer mortality was performed among a sub-cohort of the AREVA NC Pierrelatte plant workers, which provided promising results.

P01.68
Solid Cancer Mortality in Mayak Workers Cohort

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Mayak PA is Russia first nuclear cycle industrial complex started operation in 1948. In the early period of operation during development of technology for Pu production substantial number of workers was exposed to ionizing radiation from both external sources and incorporated Pu at levels exceeding those considered permissible.

This study analyses solid cancer mortality in cohort of Mayak workers. This (extended) cohort includes 25757 workers started their employment at Mayak in 1948-1982 at reactor, radiochemical, plutonium, mechanical repair and water treatment plants. Analyses include 812 deaths of lung cancer, 85 deaths from liver cancer, 38 deaths from cancers of bone and connective tissue, 1660 deaths from other solid cancers occurred in cohort members with duration of follow-up greater than 5 years. The number of person years included in analyses is 719000.

Analyses utilized data of improved dosimetry DS2008 and presented primarily in terms of effects of external exposure although effects of exposure to plutonium were accounted for. Excess relative risk for solid cancers other than lung, liver and bone/soft tissues was 0.09 (95% CI 0.006 – 0.19), total number of excess deaths was 109, 88 of them due to external exposure. We did not find indication of departure from linearity.

P01.69
Regional Medico-Dosimetric Register of Siberian Group of Chemical Enterprises Personnel

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[1]Seversk Biophysical Research Centre of the Russian Federal Medical and Biological Agency, Seversk, Russian Federation; [2]Siberian Group of Chemical Enterprises, State Atomic Energy Corporation, Seversk, Russian Federation; [3]Clinical Hospital ¹81 of the Russian Federal Medical and Biological Agency, Seversk, Russian Federation

Regional Medico-Dosimetric Register (RMDR) of Siberian Group of Chemical Enterprises (SGCE) personnel in Seversk Biophysical Research Centre was created in 2001. RMDR database contains individual medical and dosimetric information as well as data on occupational activity of SGCE main production workers (reactor, radiochemical and plutonium plants): year of first employment, occupational history and time contact with ionizing radiation sources or radioactive substances. RMDR database also contains information on exogenic and endogenic risk factors for the main diseases development (heredity, smoking, neurosis, etc.).

To evaluate the spectrum of stochastic ionizing radiation effects ("traditional" and hypothetical) there have been created a number of "thematic" registers such as oncologic diseases, congenital malformations and hereditary diseases, thyroid gland diseases and acute myocardial infarction registers as well as the register of osteoporosis. RMDR database contains information on almost 66 000 SGCE employees, who began to work from 01.01.1950 to 31.12.2008. SGCE personnel are 8 053 reactor production workers exposed to external γ-radiation, 6 135 radiochemical production workers exposed both to external and internal radiation and 9 441 plutonium production workers exposed to internal radiation due to ^{239}Pu. Vital status is determined for 82.8% reactor production workers, 83.8% radiochemical production workers and 86.9% plutonium production workers. Individual dosimetric control of the personnel is carried out since the moment of putting into operation the main technological processes in 1953. The total number of workers exposing individual dosimetric control of external radiation is about 20 000.

The great majority of SGCE main production workers were exposed to low dose radiation. Thus, about 88% of all SGCE employees who were monitored individually have overall cumulative external doses of 0.03-200 mSv, and about 9% employees - doses of 201-500 mSv.

RMDR is the basis for a wide range of research to assess the course of morbidity and mortality of SGCE different productions workers, to study the impact and place of radiation factor in the process of the main diseases (cancers, cardio vascular and endocrine diseases) and to identify the relationship between ionizing radiation and 'traditional' factors for the main diseases development; it is also the basis for external and internal doses reconstruction.

P01.70
Preconceptional Exposure and Cancer Risk Mortality in Children of PA «MAYAK» Workers

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Evaluation of relation of neoplastic diseases development in exposed fathers' offsprings to radiation effect is an important and by far not resolved issue of radiation epidemiology. Available literature data concerning fathers' preconceptial exposure effect on potential development of neoplasms in their offsprings are quite contradictory due to a variety of reasons, in particular insufficient amount of monitoring, incorrect exposure doses estimates, lack of individual exposure doses, and other causes. Therefore evaluation of neoplastic diseases risk for offsprings born in 1949-1068 whose fathers by the time of conceptions were subjected to occupational chronic exposure to wide range of doses during work at the first Russian nuclear enterprise PA Mayak is of great interest. Investigation of this issue is important for radiation protection, health protection and social security of exposed individuals' offsprings.

On the basis of Registry of Ozersk children which includes over 85,000 people (as of 31.12.2008) residing in Ozersk since childhood a cohort of live-birth children born in 1949-1968 whose fathers had been occupationally exposed to external gamma-radiation prior to conception. Average total dose accumulated by fathers by the time of conception was 53.6 cGy. Range of preconceptional doses varied widely from 0.01 to 877 cGy.

The children whose mothers never worked at PA Mayak were selected to exclude mothers' prenatal and antenatal exposure. Total amount of the selected cohort was 8191 individuals including 4180 men (51%) and 4011 women (49%) aged 40-59. Vital status was established for 97% of individuals in the cohort. 75 cases of death from cancer among offspings were analyzed.

The analysis results showed that total preconceptional doses and preconceptional doses received by fathers up to 1 year before conception had no significant effect on cancer mortality among offsprings. Cancer risk among offsprings significantly rose for the following fathers' preconception doses: 11 and more cGy received during 1 year prior to conception (RR=3.5; CI=1.8-6.9;) 5.5 and more cGy received during 6 months prior to conception (RR=3.4; CI=1.8 – 7.0); 2.7 and more cGy received during 3 months prior to conception (RR=2.8; CI=1.5-5.2). The last three preconception doses had high correlation relation: r from 0.75 to 0.92 ($p<0.001$). It is obvious that at the current stage of the study the preconception doses of 11 and more cGy received 1 year prior to conception, 5.5cGy 6 months prior to conception, and 2.7cGy 3 months prior to conception are to be considered "dangerous". Finalizing of the issue solution will require more advanced study. On the other side it should be noted that lack of corresponding preconception doses during a year prior to conception ensures absolute radiation protection in terms of preconception cancer effects in offsprings even if such exposure took place before this period.

P01.71
Epidemiological Study Of Health Status Of Population Around A Jadugoda Uranium Mines In India

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Introduction: There is a concern about increased risk of cancer & congenital anomalies in populations staying around Jadugoda Uranium Mines, Jharkhand, India due to uranium mining activities. A survey was carried to determine existing health conditions around Uranium Mines. There is also an increased awareness in the community regarding possible harmful effects of radiation.

Methodology: It was a cross-sectional quantitative study to assess the prevalence of morbidity and mortality status of the population in terms of carcinomas and congenital anomalies. The area of 5 km around Mining site was covered. The study consisted of 3 stages: 1) The household survey covered 6900 households (total population 34953). 2) From these, 2693 were called to the health camps for further screening. 3) From 1523 who attended the health camp, 220 cases were referred to tertiary health center for confirmation of diagnosis. Only 91 cases could complete most of the diagnostic tests.

Results: During household survey, presence of lump (1.8%) was the most common complaint followed by bleeding from any site (1.4%), persistent cough / change in voice / difficulty in swallowing during last 6 months (1.1%), change in color / size in wart / mole (0.4%), and excessive and sudden loss of weight (0.3%). Among females the most common complaint during last 6 months was leucorrhoea (3.4%). Past history of long standing chronic illness among family members was reported by 1.3% individuals. Mental retardation and physical deformity was reported in 0.3% and 0.7% individuals respectively. Out of 56 people referred to confirm cancer, only one case was confirmed, cancer was ruled out in 38, and 17 could not complete the investigation. From 35 people who were referred to confirm congenital anomaly, only 6 cases were confirmed and remaining could not be complete the investigations.

Conclusions: Most of the complaints are reported from a single block which may be because people here are more aware and conscious regarding their health and effects of radiation on health. This data can be considered as baseline data for any future studies in this area. Also findings can be used for comparison with either national or state data. Analytical studies like case control or cohort study can be carried out using data available with local hospital. A similar study in a control area geographically away from the mining site can enable us to compare the prevalence rates.

P01.72
Risk from Occupational and Environmental Radon and Role of Smoking

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Background and aims: Because of the predominant role of cigarette smoking as a cause of lung cancer, an understanding of the joint effect of smoking and radon exposure is needed for the appropriate assessment of the risk from radon.

Methods: The present study is based on two Czech cohorts of U miners (N=10 900) and on another cohort of people exposed to high levels of radon in houses (N=11 900). Results are based on recent data by 2010 which include 1190 and 275 cases of lung cancer in the occupational and residential studies, respectively. Individual smoking data were collected for most of subjects (68% and 75%, respectively). The relative risk is evaluated in dependence on cumulated exposure with effect modification by time since exposure and smoking.

Results: It is shown that the excess relative risk per unit exposure from earlier periods of exposure (20 years and more) is about 1/3 in comparison to recent exposures (5-19 years), whereas the relative effect from exposures before 35 years is only about 1/10. Smoking specific estimates of excess relative risk per unit exposure were 3-5 times higher among never smokers in both studies. In addition, the interaction of radon and smoking is evaluated by geometric mixture models and is found to be between additive and multiplicative model. When smoking specific equivalent doses to the lungs and modifying effect of time since exposure are used, the combined effect of radon and smoking is close to the additive model.

Conclusions: The study confirms the additive role of smoking and radon, particularly when temporal factors and smoking specific estimates of radiation doses are used in the model.
The work was conducted under project NS 10596 of the Czech Ministry of Health.

P01.73
Cancer Risk Estimate by Rate of Cancer Mortality for In-utero Exposed Individuals

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Elevated risks of cancer incidence and mortality have been reported following in utero exposure to acute gamma-neutron exposure from the atomic bombing in Japan (LSS cohort) as well as from in utero x-ray exposure. Estimates of cancer risk following protracted prenatal radiation exposure are also needed for radiation protection practice.

Women accounted for 25% of personnel at Mayak PA, the first Russian nuclear facility. A majority of these women were of reproductive age. The objective of this analysis was to estimate cancer risk among 8,000 offspring born in 1948-1988 to female members of the Mayak Worker cohort. The offspring cohort includes 3226 individuals exposed in utero to gamma radiation (range 0.003 to 891.5 mGy). Relative risks (RRs), excess RRs per Gy, and 95% confidence intervals (CIs) for cancer mortality risk were estimated using Poisson regression methods (Epicure, AMFIT module). Follow-up started from age of 1 and ended at the date of death, date of moving out of Ozersk, or December 31, 2008.

During follow-up, there were 698 deaths. There were 75 deaths from solid cancer (28 cases among in utero exposed) and 12 deaths from leukemia (6 cases among prenatally exposed). The average age of death from solid cancer was 43.9 years and 20.3 years from leukemia. The relative risk for solid cancer mortality was 0.94, 95% CI 0.58-1.49 and that for leukemia was 1.65, 95% CI 0.52-5.27. The excess relative risk per 1 Gy was -0.1, 95% CI <-0.1 – 4.1 for solid cancers and -0.8, 95% CI< -0.8 – 46.9 for leukemia.

Overall, no significant excess of solid cancer or leukemia was observed following in utero exposure. However, limited statistical power and the relatively young age of the cohort at the end of follow-up may have limited our ability to detect a significant association. Follow-up of this cohort will be continued and risks from both external gamma radiation and internal plutonium exposure will be estimated.

P01.75
Monitoring of Possible Health Effects in the Vicinity of Nuclear Sites in Belgium: Is There an Increased Incidence of Childhood Leukaemia?

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Introduction

This study has been carried out at the demand of the Belgian Minister of Social Affairs and Public Health to assess, by means of an epidemiological study at the national level, possible health effects of living in the vicinity of nuclear sites.

Objectives

To investigate (1) whether there is an excess in incidence of acute leukaemia in children aged 0-14 years within the 20km proximity area around the nuclear sites in Belgium as compared to what is expected in a reference area, and (2) whether there is evidence for an (increasing) leukaemia risk with increasing ‘surrogate’ exposure around the nuclear sites, i.e. (i) residential proximity to the site, (ii) prevailing winds, and (iii) radio-active discharge estimates from the plants based on mathematical modeling.

Methodology

Ecological study around the nuclear installations of Class 1 in Belgium, i.e. the nuclear power plants of Doel and Tihange, the nuclear sites of Mol and Fleurus, and the Belgian territory within the 20km proximity area around the nuclear power plant of Chooz (France). Cancer incidence data were retrieved from the Belgian Cancer Registry (BCR), a population-based registry at the national level. For this study, leukaemia data were available from 2002 till 2008 for Flanders and from 2004 till 2008 for Brussels and Wallonia. Age-and sex-specific population data for this period were collected from the Federal Public Service (FPS) Economy, S.M.E.s, Self-employed and Energy. Dat a on socio-economic status and urban-rural situation were included as covariates.

To study a possible excess of childhood leukaemia, age- and sex-standardized incidence ratios (SIRs) were calculated and Poisson regression was carried out. In a further step, we conducted a sensitivity analysis by varying the radius of the proximity area; SIRs and RRs were then recalculated for each of these areas of proximity with increasing radii.

The hypotheses of increasing childhood leukaemia incidence with increasing levels of ‘surrogate’ exposure were tested by means of focused hypothesis tests (conditional forms), i.e. Stone’s Likelihood ratio test and Bithell Linear Risk Score Test. To facilitate the interpretation of the results from the focused hypothesis tests, the ‘exposure’-response relations were estimated and visualized using varying coefficient models.

Results

Results of the study will be presented and discussed at the Congress.

P01.76
Knowledge of and attitude to nuclear power among residents around Tianwan Nuclear power plant in Jiangsu of China

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Aims The aims of this paper were to determine the level of knowledge of and attitude to nuclear power among residents around Tianwan Nuclear power plant in Jiangsu of China.

Design A descriptive, cross-sectional design was adopted.

Participants 1,616 eligible participants who lived around the Tianwan nuclear power plant within a radius of 30km and at least 18 years old were recruited into our study and accepted epidemiological survey.

Methods Data were collected through self-administered questionnaires consisting of a socio-demographic sheet. Inferential statistics, t-test and ANOVA test were used to compare the differences between each subgroup and correlation analysis was conducted to understand the relationship between different factors and dependent variables.

Results Our investigation found that the level of awareness and acceptance of nuclear power was generally not high. Respondents' gender, age, marital status, residence, educational level, family income and the distance away from the nuclear power plant are important effect factors to the knowledge of and attitude to nuclear power.

Conclusions The public concerns about nuclear energy's impact are widespread. The level of awareness and acceptance of nuclear power needs to be improved urgently.

P01.77
Modification of Innate Immunity in Individuals with Late Radiation-Induced Neutropenia Using Hemopoietic Cells of Fetal Liver

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The objective of the study was to assess the effect of hemopoietic cells of fetal liver (HC FL) on the key characteristics of innate immunity in persons who developed neutropenia at late time after a long-term chronic radiation exposure. The study group was composed of 12 residents of Techa riverside villages, including 10 women and 2 men aged 49-80 years, who were exposed to combined external gamma-raditaion and internal radiation, mostly due to ^{90}Sr. Mean radiation dose to red bone marrow amounted to 0.92±0.46 Gy. To alleviate late radiation-induced neutropenia, HC FL were administered in the ratio of 1.4•10^6 cells per kg of the patient's body weight. Immunological examinations were performed before the treatment was started, and then were repeated over the 18 months after the course of treatment (at month 6, 12 and 18).

The number of neutrophils was constantly increasing over the whole period of observation, and it reached statistically significant differences from the initial values after 2 months, or later. The most substantial changes in the immune status following treatment with HC FL were manifested by the innate immunity. Attention is attracted to the progressive, in dynamics, suppression of innate immunity factors (reduced number of NK cells, phagocytic activity and values of intracellular oxygen-dependent metabolism of neutrophils and monocytes) playing a leading role in the maintenance of anti-tumor immunity. Patients treated with HC FL were also noted to have increased levels of proinflammatory cytokines while the levels of antiinflammatory cytokines were diminished.

P01.78
Radiological Health Risk from Soil, Well Water and Borehole to the Inhabitants of Some Cities across Ondo and Ekiti States in Nigeria

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The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K have been determined in soil, well water and borehole from selected locations across Ondo and Ekiti States in Nigeria using N-type coaxial high-purity germanium detectors (HPGe). The activities of ^{226}Ra, ^{232}Th and ^{40}K in the soil across the two states ranged from 45.6 ± 3.0 Bq kg^{-1} to 210.4 ± 8.8 Bq kg^{-1} , 31.9 ± 1.8 Bq kg^{-1} to 227.5 ± 4.4 Bq kg^{-1} and 364. 9 ± 6.4 Bq kg^{-1} to 1348.9 ± 21.8 Bq kg-1, respectively. The activity of ^{226}Ra, ^{232}Th and ^{40}K in the well water and borehole in the two states ranged from 2.1 ± 0.5 Bq kg^{-1} to 78.4 ± 14.2 Bq kg^{-1} , 0.5 ± 0.2 Bq kg^{-1} to 33.2 ± 6.0 Bq kg^{-1} and 34.5 ± 2.9 Bq kg^{-1} to 556.9 ± 30.7 Bq kg^{-1}, respectively. The mean absorbed dose rate (± SD) due to the soil in both states is 140.9 ± 65.3 nGy h^{-1} and 173.3 ± 85.4 nGy h^{-1}. The effective dose due to the radionuclide in the states is 0.26 mSv y^{-1} and 0.32 mSv y^{-1}, respectively. The annual intake of radium and thorium from well water and borehole in the area ranged from 6.6 kBq to 13.4 kBq and from 1.9 kBq to 6.1 kBq, respectively. The committed effective dose due to the annual intake of uranium and thorium in the well water and borehole from both states is 4.1 mSv and 1.5 mSv, respectively. The implication of the result is that the committed effective dose is far higher than the reference limit of 0.1 mSv y^{-1} for drinking water.

P01.79
Excess Lethal Cancer For the Total Population of Sabzvar City in Iran Arising From Five Common Conventional X-ray Examinations

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Introduction: Recent reports published by national and international institution such as NCRP are evident that exposure to ionizing radiation from man- made sources (diagnostic applications in particular) has increased sharply over past 20 years. Undoubtedly general population dose and associated biological effects are increased proportionately.

Cancer in general and genetic mutations are two major ill health consequence of low doses. Cancer induction from low doses is a late effect and may be manifested many years following to the exposure. According to the definition presented in the BEIR7 report doses within the 0-100 mSv are classified as low doses which are a true representation of doses received from most conventional diagnostic X-ray examinations.

Material & Methods: This work was carried out in 8 radiology centers located in Sabzevar city of Khorasan Razavi country of Iran ,four hundred and eighty five patients who under took one of the five conventional X-ray examinations (eight views) including: chest (AP-PA), cervical spine (AP,Lat), lumber spine (AP, Lat), simple abdomen and Pelvis(AP), were studied.

To assess the total annual risk of cancer induction for total population in the region of interest exact knowledge of collective dose of the whole population is essential. Effective dose is an appropriate dosimetric quantity which based on the over all risks of exposure can be estimated.

Total population, average entrance surface dose per capita per examination and total number of examinations per year for Sabzevar were acquired. Patients information such as gender, weight, heightand age and technical parameters such as mAs,kVp and FFD applied per examinationm in conjunction with PCXMC software were used to estimate organ and effective dose .

Effective dose has been commonly adopted as a good representative of overall biological damage, it is also a major factor for cancer risk estimation .In this study collective dose of the Sabzevar population acquired from PCXMC and the algorithm recommended in the literature (based on LNT model} were utilized to estimate risk of lethal cancer from the radiological examinations of interest in this work.

Results: excess lethal cancer cases for the entire Sabzevar population per year arising from chest (AP&PA),abdomen AP, pelvis AP,lumbar spine (AP&Lat) and cervical spine (AP&Lat) radiographies are :0.229, 0.032, 0.0845, 0.0475 and 0.046 respectively. The total excess cancer from the studied examinations is equal to 0.44 cases per year.

Discussion: although the estimated cancer risk is not significant, but it only includes risks from low dose simple common radiographies. But if risks from high dose techniques such as CT scan and fluoroscopy procedures are added a much higher figure will be expected.

P01.80
The Offspring Of Liquidators Of Accident On Chernobyl Atomic Power Station: Effects Of Complex Confounding And Stress Non-Radiation Factors

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There is no data for hereditary effects at the irradiated people till now, recognized by International Organizations. Estimations for such effects for human carried out by extrapolation from frequency of mutagenesis in genes of irradiated mice (UNSCEAR 1993–2001; ICRP-99; BEIR-VII, etc.). The total risk of an increase of hereditary anomalies is low (an order of 0.5% from background) at an irradiation of parents even in a dose of 1 Gy.

Nevertheless, in Russia, Ukraine and Belarus disturbance and pathologies are found out in children of liquidators of accident on the Chernobyl atomic power station at all levels: from molecular, genetic and chromosomal to psychological and mental (Baleva L.S. et al., 2001–2007; Vorobtsova I.E. et al., 1995–2007; Suskov I.I. et al.) Authors of articles connect effects only with irradiation (the majority of liquidators received only low doses) though there were also other factors. So, for animals and people it is shown that the psychogenic stress leads to genomic and chromosomal damages and enhance the effects of mutagens. At offspring of the parents being in the state of psychoemotional stress there were registered the set of disorders and diseases. For liquidators probably there existed also an influence of a complex of other non-radiation factors with hereditary effects: heavy metals, gasoline, exhaust gases, organic, drugs, alcohol, smoking etc. (Il'yin L.A., Kryuchkov V. et al., 1996–2011)

Thus, we conclude that the effects in children of liquidators have mainly nonradiative nature. The influence of effects of other agents on fathers and stress in the families of liquidators could give birth to less healthy children. Higher level of genetic and cytogenetic damages at children is caused, most likely, by hypersensitivity to factors of the environment at the weakened organism.

P01.81
Stress-Test of the Two-Fold Increase of Radon Risk Factor in dwellings

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Purpose: WHO and ICRP recently lowered their reference levels for radon concentration in dwellings because of a doubling of the risk factor estimate by the last European meta-analysis. This correction is explained by the measurement uncertainty and the fact that more subjects are exposed to low than high doses. Several government bodies involved in the implementation of the new reference levels struggle to understand the rationale of this increase and would like to be confident in the soundness of the effect. Our paper describes how the measurement uncertainty could double the risk factor and ascertains the confidence we could have in this factor through the use of Monte Carlo simulation.

Method: We start by describing the details of the underlying Bayesian calculations performed by the European analysis, with special emphasis on the distributions of the prevalence of expositions and the measurement uncertainties. Then we artificially generate seven data sets compatible with the European observed data, simulated with relative measurement uncertainties ranging from 5% to 100%, and assuming a true risk factor of 0.0016 (Bq/m^3)^-1. On each of these populations, we estimate the risk factor either directly from the observed simulated data or with the Bayesian calculation. This last estimation was repeated for different estimated measurement uncertainties.

Results: For small measurement uncertainties, the estimation of the risk factor without Bayesian calculation is correct. For measurement uncertainties higher than 10%, the estimated risk decreases and becomes rapidly not compatible with the true risk factor. Conversely, when the Bayesian calculation is performed the estimated risk is correct.

Discussion: The large uncertainties associated to radon exposition measurements, have a distinct effect on the estimation of the risk factor. Our simulations show that the risk is correct if the measurement uncertainty is well estimated.

Conclusion: We confirm that the observed data of radon in dwellings have to be corrected for measurement uncertainties in order to estimate the risk. Our simulations show that the two-fold increase of the European risk is in the correct order of magnitude, but that the value of the uncertainty has a large influence. Unfortunately, we know that the uncertainties are large, but no thorough evaluation has been performed yet.

P01.82
The Social-Psycological Status Of The Population Residing In The Contaminated Territories Of The Urals Region

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The social-psychological status of the population residing in the territories contaminated with radionuclides (TCR) remains a major problem in the late period after the radiation accidents in the Southern Urals. Territories in Chelyabinsk, Kurgan and partially Sverdlovsk Oblasts were exposed to radioactive contamination in the result of radioactive waste release into the Techa River, and in the result of the 1957 accident at the Mayak PA. Over 20,000 people, mainly rural residents, were affected by this environmental disaster and the social-psychological status of the TCR residents has been affected. Our research indicates that high levels of anxiety are characteristic of 73.6% of the TCR residents; 53.6% of the respondents consider the social-psychological situation as tense.

According to the data of a face-to-face poll of TCR residents in Chelyabinsk Oblast, the major current problems for them are personal health (55.4%), radiation hazard (50%) and fear for the future of their children (39.3%). The respondents associated health problems with the exposure to high radiation levels (80.5%) and had fears associated with radiation (71.5%). Respondents also pointed out inadaptability to the changing conditions, lack of confidence in tomorrow, feeling that social problems were not attended to (64.2%). Against this background, TRC residents developed behavioral stereotypes that are characterized by social immaturity and unearned income orientation.

The information factor exerts a significant influence on the social psychological situation in the contaminated territories. Publications of unverified and controversial information create opportunities for manipulations of public opinion and growth of distrust to the Government. Individual and collective psychological trauma during radiation accidents is associated with the perception of radiation risk, which often is not based on the real extent of radiobiological threat, and has a complex structure of sources and psychological laws of formation, resulting in psychological problems which require a comprehensive system of measures for their correction.

This work is based on a survey of residents of radioactively-contaminated areas. The survey, which was conducted in the Techa riverside villages, involved residents inhabiting the localities of Upper Techa, Anchugovo, Lobanova, Kazantsev, and Kataysky raion of Kurgan oblast.

The program for psychological assessment of the exposed residents included a modified method of semantic differential (C. Osgood., Dzh. Syusi, L. Tannenbaum).

The study confirmed that the perception of radiation risk by residents of contaminated territories of the Ural region has a negative emotional color.

A complex of psychogenic, somatogenic, radiological and social factors creates a negative social-psychological background.

P01.83
Changes In Immunological Indicators In The Peripheral Bloods of Three Accidently-exposed Persons

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Objective: In order to identified as candidate biomarkers for early diagnosis or as therapeutic targets in late damages of ionizing radiation, Subgroups of Lymphocytes, Serum proteins and gene expression profile were analyzed in the peripheral blood of three 60Co γ-ray accidentally-exposed persons during the three years after irradiation.

Methods: Flowcytometry and serum protein electrophoresis were conducted to measure the subgroups of Lymphocytes and composition of serum proteins, respectively. Gene expression profiling was obtained using Gene expression Chip assay.

Results: Both the percentage of CD^{4+} T lymphocytes and ratio of Th to Ts were persistently declined compared with the normal control value during the three years after the accident. The percentage of Albumin was reduced whereas beta globulin was increased. There were 285 up-regulated and 446 down-regulated genes in irradiated samples compared with control samples. The raw data from microarray experiments were submitted to the Gene Expression Omnibus(http://www.ncbi.nlm.nih.gov/geo/accession©|GSE34131).The large majority of those differentially expressed genes encode proteins that are associated with immune response, inflammation, cell structure, oxidative stress, neuro-hormone regulation, reproduction, susceptibility of psychiatric disorders, and transcriptional regulators. The expressions of IL3, KDR, CEACAM8 and OSM were validated by real-time RT-PCR method.

Conclusions The findings of our study suggest that CD^{4+} lymphocytes, the ratio of Th/Ts and beta globulin may be biomarkers for prediction of the late damages of ionizing radiation. Furthermore, the results should help us understand the molecular mechanisms underlying the late effects of ionizing radiation and develop better diagnostic and therapeutic strategies for those damages.

[key words] accidental exposure; gene expression profile; ratio of Th/Ts; Albumin; radiation biomarkers

P01.84
Severe Injuries Induced By Occupational Exposure In Interventional Radiology

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In this paper we present the case of severe radiation injuries induced by occupational exposure of radiologist (55 yrs old) mostly in interventional, non-vascular radiology for 23 years. The injuries were developed during the regular working activity, without the excess of annual dose limits or severe accident in the workplace. Retrospective analysis showed that radiologist was exposed to higher doses early in his carrier due to failure of x-ray equipment in gastro-diagnostic. There was no data off this accidental situation.

We already presented some data about this case almost 10 years ago, when the skin changes were detected: severe onychodystrophy, with brittle, swelling, dark yellow to brown nails of thumb, forefinger and the middle finger of both hands, as well as hyperkeratosis of the skin of both hands. Suspicion of chronic radiation skin injury was made as well as hypertension and incipient bilateral cataract. Additional multi-detector measurements were performed and all the doses were bellow limits. At that time, he was treated and was not allowed to work in interventional radiology. He did not follow the rules and kept on working in spite of restrictions.

Three years later progression of the chronic radiodermatitis was noticed. Additional medical tests included general clinical assessment, complete blood count with differential white blood cells; routine biochemical analysis of blood and urine; slit-lamp examination of the eyes and dermatological examination with pathologic analysis; oxidative stress parameters and activity of anti-oxidative enzymes; cytogenetic tests (classical chromosomal aberration analysis, CB micronucleus test and the radio-sensitivity test).

Cytogenetic tests were positive: conventional chromosomal abberations test on 200 cells showed three aberrant cells-two of them with ring and acentric fragments, and one with acentric, biger then the bigist chromosome. Micronuclei score was 40/1000 binucleated cells, and radiosensitivity 201/1000 binucleated cells. Tests of oxidative stress expressed as superoxide anion and MDA production indicated highly elevated values of both parameters as well as the activity of anti-oxidative enzymes. Pathologic analysis confirmed skin planocellular cancer infiltration G-1.

Therefore the excision of the epithelioma of the left tumb was performed and a few months later partial amputation of the left forefinger.

P01.85
The Prevalence of Thyroid Nodules in Radiographers

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Purpose of the study: The thyroid gland is a potential target organ for radiation-related damage, as it receives a considerable radiation dose from scattered radiation. The study was aimed to assess any possible correlation between the prevalence of thyroid nodules among radiographers exposed to relatively low dose, constant or fractionated ionizing radiation.

Materials and method: A total of 103 volunteers' radiographers were participated in the survey. Each participant neck was scanned with a real-time thyroid ultrasonography using direct contact technique with 10 MHz linear array transducer. The size, position, symmetry, nodularity, texture and echogenicity of the thyroid gland was reported accordingly. A blood sample was withdrawn from the participants for a serum thyroid function test. The test had been analyzed by Radioimmunoassay RIA procedures.

Results: Thyroid nodules were detected in 38 (36.9%) of the total number of participants. Multinodular goiter was detected in 50% of the participants showed thyroid nodules. In young radiographers (≤ 25years) there was only one radiographer (2.6%) showing an incidence of thyroid nodule out of the 38 radiographers participating in the survey. In the middle age (26-35 years) group, 7(18.4%) participants had prevalence of thyroid nodules. The age group (36-45 years) showed the maximum prevalence of thyroid nodules 16(42.1%). The age group < 45 years also revealed high incidence 14 (36.8%) of developing thyroid nodules.

Conclusion: The survey concluded significant and important evidence suggesting that prolonged low-dose exposures to ionizing radiation (fractionated) may cause a small increase in the risk of thyroid nodules and age is an important risk factor in prevalence of thyroid nodules. Radiographers must perform safety aspect when using ionizing radiation in the diagnostic medical x-ray department including; their responsibilities as radiation protectors, dose and area monitoring, shielding, distance as well as proper equipment handling.

P01.86
Let Calculations for Low Energy Diagnostic X–Rays

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Radiobiological and microdosimetrics studies have investigated the RBE of low energy X-rays mammography, and related the RBE produced by a reference X-beams of 200 kVp. These studies have shown an expressive disagreement between their RBE values. Photons are in general considered to be of low LET radiation. There is a concern with the increase of their biological effectiveness due to ionization density increase of the secondary electrons released. The existing studies on mammography have also motivated risk-benefit investigations on diagnostic procedures such as in pediatrics radiology, using low energy X-rays. This study uses the Monte Carlo code to investigate realistic quality factors for low energy photons and to derive more appropriated values of RBE for the energy range typically used in pediatric radiology. This data is presently in need, in order to improve the existing radiation protection recommendations as well as the justifications for the use of diagnostic X rays procedures in pediatrics. Initially, the code was validated by obtaining the photons and secondary electrons spectrum of the ambient dose equivalent H*(10), and of the LET for a homogeneous medium. The code was then used to obtain the spectrum of the H*(10), the mean absorbed dose LET, $_{D,}$ and the mean frequency LET, $_{f}$. This work presents the LET for X ray energies used in pediatric exams obtained using the ICRU phantom at H* (10) and in a water solid phantom.

P01.87
The Late Consequences and Outcomes of Acute Radiation Syndrome

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During the average 20 years (19,7 ± 1,8) (separate follow-up – till 54 years) were observed 157 survivors of acute radiation syndrome (ARS) of various degree. Research is devoted studying of health status of patients and outcomes in the period of late consequences of ARS.

The obtained data testifies that the consequences of the radiation exposure defining quality of life in the late period are radiation cataracts (at 37 from 157 patients), and consequences of local radiation injuries (at 70 of 157 patients). In the period of late consequences of ARS were found individual not stable, moderate deviations of blood indices. The most typical deviation of peripheral blood indices throughout the next 10 years after an irradiation is the moderate thrombocytopenia.

The dose of radiation exposure on a thyroid gland is known only for participants of Chernobyl accident. For the majority of the patients it was less than threshold for this organ. For all years of supervision 4 cancers of a thyroid gland have been revealed.

32 patients among 157 ARS survivors had solid tumors (12 basaliomes, 20 malignancies of various localizations).

Among all somatic diseases which were found in the late consequencies period the first 3 places occupy diseases of cardiovascular, respiratory and gastroenteric systems.

By now we have information about death of 58 ARS survivors. Average life expectancy died patients - 59 ± 1,7 years. It not differ from expected life expectancy of Russian men in 2007 - 61,5 years. The main causes of death were cardiovascular diseases (45 %) and malignancies (32 %) with obviously increased share of blood malignansies.

P01.88
Radiological Assessments of the Public: The Challenge of Assessing Changes to the Critical Group at Sellafield

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Routine discharges of radioactive waste in the UK are made under authorisation or permit and dose assessments of the public are regularly published (e.g. RIFE 2010). In the vicinity of the Sellafield reprocessing plant in Cumbria, exposure pathways to the public have included radiological assessments to identify representative persons (formerly critical groups) including children. In ICRP terms, such people are considered to represent those potentially most exposed. Such assessments may include estimation of annual and life-time doses from the consumption of foodstuffs such as seafood. This work has been carried out since at least the early 1980s (Leonard & Hunt 1985). The purpose of this study is to attempt to follow some of those observations from 1981 to 2011. The challenge of identifying such people through personal contact, use of diary records and duplicate diet samples is summarised, together with an overview of how doses can be calculated. Additivity of doses from e.g. external exposure (Leonard and Hunt 1988) and multiple anthropogenic sources e.g. atom bomb fallout and the Chernobyl reactor accident are also briefly considered as well as exposure to enhanced levels of natural radioactivity e.g. Po-210. Conclusions are drawn from the findings of how the make-up of the Sellafield seafood critical group has changed over time. References

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Poster sessions A-B: Area 1

P01.89
Save Our Sievert!

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The protection quantity *effective dose* was devised by the International Commission on Radiological Protection (ICRP) as a measure of radiation detriment which takes into account the different sensitivities of different organs and tissues to the induction by radiation of stochastic effects. However, in the case of exposure to radon decay products, effective dose is used differently. Without being explicitly acknowledged, effective dose is used as a measure of detriment from the combined effects of two separate carcinogenic agents: radiation (from radon decay products) and tobacco smoke. With recent epidemiological studies now able to estimate the risk of lung cancer as a function of both exposure to radon decay products and exposure to tobacco smoke, it has become clear that the major contributor to this hybrid form of effective dose is tobacco smoke. In the absence of smoking, the dose conversion convention - from radon decay product exposure to effective dose - would be several times smaller than the value recommended by ICRP.

The conflation of risks from tobacco smoke and radon decay products into a protection quantity intended to be a measure of radiation detriment disguises the relative significance of each carcinogen. While this may have reflected a limitation of knowledge in the past, it should not be perpetuated as, among other drawbacks, it distorts perceptions of risk. Unfortunately, a view seems to have taken hold that continuing the obfuscation is necessary in order to implement the ICRP system of radiological protection. But this is not the case: it is quite possible to recognize the contributions to total detriment of the two carcinogens without putting the system of protection at risk, while also retaining the original definition of effective dose as a measure of radiation detriment. This paper discusses the undesirable consequences of failing to properly distinguish the effects of smoking and radiation on lung cancer risk, and proposes an approach to protection, within the ICRP system, that more clearly recognizes the origins of harm.

P01.90
Comparison of Methods of Estimation of Lifetime Cancer Risk Due to Chronic Exposure to Transuranics

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The cancer risk due to chronic transuranic intakes is properly calculated using an integration over multiple years of intake of the annual effective dose rates arising each year following an intake multiplied by age-dependent risk functions for the year during which the dose is actually received. Approximate computations of risk involving sums of the products of committed effective dose and the age-dependent risk functions for each year of intake indicate the appropriateness of the committed effective dose as a surrogate quantity for risk when applied to different circumstances. The assumptions that all dose is received at the time of intake with committed effective dose and that risk is uniform over a range of ages both lead to a misuse of the available age-dependent risk functions and thus contribute to a divergence from the true risk associated with an intake over multiple years. Comparison of the correctly integrated risk functions with the approximations gives insights into how the current committed effective dose models used for regulatory purposes are not necessarily indicative of the risk for chronic intakes of radionuclides with long biological and radiological half-lives. A summary and comparison of such computations for transuranic intakes was prepared for the ingestion of water and the inhalation of different particle sizes by both males and females. Risk results for committed effective dose consistently overestimated risks by approximately 100% for all transuranics for ingestion models and approximately 75% for all transuranics for Type M inhalation models considering age-dependent risk models. For constant risk as a function of age, the committed effective dose integration underestimated the actual risk situation by nearly 60% for ingestion and 50% for Type M inhalation during the first 20 y.

P01.91
Risk of Lens Opacification in the Exposed Techa River Population

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The objective of the study was to assess the risk of cataract development for the population chronically exposed to external and internal radiation as a result of releases of radioactive waste by the Mayak PA into the Techa River. The Techa River Cohort includes persons born before 01.01.1950 who lived in any of the 41 riverside villages on the Techa during the period from 1950 to1960. Important advantages of the Techa River Cohort include a long period of follow-up (over 50 years); large size of the cohort (29729 members); composition of the cohort which includes persons of both genders, different ethnicity and various ages; availability of a fairly reliable retrospective dosimetry information based on the latest Techa River dosimetry model (TRDS-2009). The minimal dose estimate in soft tissues calculated based on TRDS-2009 is 11 mGy, and the maximal estimate is 960 mGy. Over the period from 01.01.1950 to 31.12.2010, 1380 first-diagnosed cases of cataract were registered among cohort members. A peculiarity of the cohort consists in the fact that it only includes persons born before 1950, due to which the proportion of cohort members of younger ages is decreasing, i.e. it is an aging cohort. Over the past decade (up to 01.01.2011) 700 new cases of cataract were diagnosed. Before 01.01.2000, 680 cases were registered.

Our dose-effect analysis was based on a simple linear model for excess risk estimation taking into account all non-radiation factors that can modify the baseline rates of cataract incidence, viz., gender, ethnicity, attained age, birth year, presence of diseases prior to the diagnosis of cataract (retinal angiosclerosis, diabetes, cerebral atherosclerosis, hypertension, ischemic heart disease, obesity). The ERR for cataract development calculated per 1 Gy was 0.40 (95% CI: -0.43; 1.47). The assessment of the excess relative risk of cataract incidence did not reveal any significant effect of the use of cumulative dose calculated with allowing for differences in the latency periods (0, 2, 3, 5, 10 and 15 years).

The number of cataract cases caused by exposure to radiation in the Techa riverside villages amounts to 12.7 which corresponds to the attributive risk value equal to 1.9%. Although the contribution of radiation-induced cases of cataract seems rather insignificant, it should be noted that 15% of the total excess cases developed in persons with cumulative exposure dose of over 0.3 Gy. The risk of cataract development increased 1.7 times if cataract diagnosis was preceded by retinal angiosclerosis ($p < 0.001$), 1.3 times in case the patient suffered from concomitant diabetes ($p=0.04$), and 1.2 times in case the past history included hypertensive disease.

P01.92
Damaged Lymphocytes and Cancer Risk in Medical Nuclear Workers

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Aim: Cytogenetic anallysis of peripheral blood limphocytes is the most sensitive test for detecting a clinical biologic response to ionizing radiation. Damaged lymphocytes, contaning chromosomal aberrations, and cancer risk in medical nuclear workers doe to contamination with radioiodine may indicate a thyroid gland tumor while it was operable and curable may lead to immune disorder, a susceptibility to certain cancers, and/or other chronic disorders.

Method: Workers are periodically reviewed to check the contamination (by measuring the radioactivity in urine) and received doses, analysis of the frequency of chromosome aberrations. The 24 h urine samples were measured by gamma-spectrometry methods. Chromosomes were observed in peripheral blood lymphocytes. Moorhead's method and conventional cytogenetic technique were used for preparation of lymphocytes.

Results: Workers in nuclear medicine had a chromosomal abnormality. Significantly higher probability to occur chromosome aberrations, λ=0.62, have been found on periodical examination PE_3. Higher probability to occur chromosome lesions, have been found on each periodical examination, λ_1=0,12/λ_2=0,14/λ_3=0,31.

Conclusion: Consequently, the probability (λ) that a greater number of lymphocytes is damaged due to aberrations and lesions of chromosomes, significantly increases with exposure; *p=0.01*. Their sensitivity for measuring exposure to low dose and their role as early predictors of cancer risk have contributed to this success.

P01.93
Radioactive Decay Series in Drinking Water Sources Of Iran

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The Uranium (^{238}U) decay series provides the most important isotopes of elements Radium (^{226}Ra), Radon (^{222}Rn) and Polonium (^{210}Po) with half-lives of 1600 years, 3.8 days and 140 days, respectively. Although the chemical structure of radium is very similar to calcium, the fact that it produces a radioactive gas (Radon) complicates its handling in the laboratory and natural environment.

The average concentrations of naturally occurring radio nuclide ^{226}Ra in drinking water at different parts of Iran were used to estimate the annual effective dose equivalent. The results indicate that the average concentration of ^{226}Ra in drinking water is low compared to 100 mBq/l that is recommended by the World Health Organization (WHO).

P01.94
RBE of Radon: An In Vitro Study Using Chromosomal Aberrations As A Biomarker

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Introduction: Radon in homes and workplaces remain a major concern of radiological risk from ionizing radiation. Although ICRP has a designated a radiation-weighting factor of 20 for alpha particles, uncertainty exists on a realistic value of RBE of alpha radiation since risk estimates were derived from epidemiological studies masked by confounding lifestyle and other unknown factors. Although lung cancer is the primary health effect of radon exposure, cancer as a biomarker of risk estimate needs a consensus. Chromosome aberrations are now proven biomarkers of the early biological effects of carcinogen exposure and show better promise as a biomarker of risk. Moreover, *in vitro* studies have the advantage wherein confounding factors may be eliminated.

Aim: To estimate relative biological effectiveness values for radon with respect to gamma radiation by cytogenetic method by exposing blood lymphocytes *in vitro* to various doses of radon.

Materials and Methods: Peripheral blood samples were collected from healthy donors and exposed to different doses of gamma radiation and also to radon using a simple, portable radon irradiation assembly designed and tested at the Radiological Safety Division of IGCAR. Chromosome aberrations in giemsa stained first division metaphase preparations were scored and RBE estimated.

Result: The RBE value at low doses and dose rates are likely to be significantly greater than 20. Large variations in RBE values are indicative of inter-individual differences in DNA damage and repair.

P01.95
Use of Effective Dose for Pu Exposure Regulation Standards

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Effective dose is a quantity used currently for regulation of radiation exposure. Effective dose is not only an estimate of physical dose (energy absorbed by organ/tissue) but also a measure of contribution of different organs to total detriment resulting primarily from carcinogenic risk. The principal aim of using this quantity is development of flexible generalized estimate of radiogenic risk which might be used in any radiation exposure situation including non-uniform exposure from incorporated nuclides with affinity to specific limited number of organs such as Plutonium.

Such approach requires averaging and weighting of contributions to detriment by persons of different gender, age etc. In the same time regulatory measures for workers employed at potential contact with plutonium should take into account fact that 1)these workers are primarily males of age above 18-20 and 2) inhalation is dangerous route of Pu intake. Under these circumstances the total Pu induced radiogenic detriment is primarily due to radiogenic lung cancer since lung accumulates highest doses of alpha-particles after Pu inhalation. Lung cancer mortality among males of ages above 20 is much higher then average lung cancer mortality in all ages and is rapidly increasing with age and contribution of radiogenic lung cancer to total detriment is higher then it is assumed by current ICRP 103 publication (12%).

For limited group of workers employed at work with potential contact to Pu it is reasonable to use specific regulatory rules for exposure to Pu.

P01.96
Assessment Of a Priori Threshold Values For Acute And Chronic External Exposures

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The assessment of threshold values is an issue of relevance for radiation protection, which is also of applied relevance in radiation medicine and biology. The research objective was assessment of a priori dose and time thresholds for some effects of acute radiation syndrome (ARS) and chronic radiation sickness (CRS) based on the clinical data. The time to onset of vomiting and initiation of agranulocytosis is associated with absorbed external dose for ARS, with inverse power dependence. The latency period of ARS is associated with acute dose. There is an inverse power dependence of the forming period for CRS with dose rate rather than with total accumulated dose at the time of disease. Thus, is one knows the dose dependence for a specific effect, which is well described by Weibull distribution given the inverse power dependence, the time parameter distribution can be obtained. Using the inverse power dependence between time and dose or dose rate, one can calculate a threshold for the dose parameter. The a priori threshold values for the time and dose parameters were calculated using this method. For ARS, a threshold with regard to the time to onset of vomiting was 8.9 hrs with a dose threshold of 0.44 Gy for the Mayak workers; the threshold latency period for ARS was 36.6 days with the corresponding dose threshold of 1.5 Gy. For CRS, the maximum dose-forming period was 30.6 months, and the corresponding threshold with regard to dose rate was 0.021 Gy/month.

P01.97
Radiation Injury to the Scalp following Neuro-Intervention- A Case Report

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Radiation injuries are quite rare in radiology with the advent of new dose reduction technologies and clinician awareness nowadays. How ever there is under-reporting as well since most of the injuries are too trivial and usually at locations not directly visible to the patient. The predisposing factors may be related to the operator, equipment or the patient.

We describe below a patient who developed scalp epilation following neurointervention with pictorial follow up.

A 46 year old, previously healthy female patient presented to the emergency neurolgy unit with sudden of loss of conciousness in February 2011. Her CT on admission showed a subarachnoid hemorrhage with an anterior communicatng artery aneurysm. A digital subtraction angiogram confirmed the aneurysm and she underwent a stent assisted coil embolization for a anterior communicating artery aneurysm at the Interventional Radiology Unit in July 2011. GE Advantx single C-Arm LCA 2001 model digital subtraction Angiography unit was used.

The procedure and immediate post procedure was unevntful.

2 weeks later patient complained of loss of hair on the back of the head which gradually worsened in following 2 weeks. There was no pruritis,blistering or skin ulceration. It progressed to complete loss of hair in the involved region. The area of hairloss was rectangular shaped and corresponded to the shape of collimation of x-ray beam.

The affected region was treated with topical steroid cream. Regrowth of hair in the affected region was detected about 2 weeks later (6 weeks after the procedure) This unit did not have dosimetry displays and the procedure lasted 52 minutes of fluroscopy time with kv range of 80-120.

P01.98
Targeted And Non-Targeted Responses To Occupational Exposure Of Medical Personnel From Radio Therapy

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The study aimed to assess tissue and organ reactions in subjects at risk of occupational ionizing radiation exposure.

23 subjects (60.9% females) from a radiotherapy unit with 19 years exposure to gamma (^{60}Co) and other 3.6 years to X-rays radiation (linear accelerator) were investigated by physical examination, hematological tests, cytogenetic exams-micronuclei (MN) in both blood peripheral lymphocytes and oral mucosa exfoliated cells and non-specific cellular stress and oxidative processes markers (whole blood superoxide dismutase activity-SOD, serum lipoperoxides-Lpox).

Peripheral blood MN tests were assessed during 8 years, showing at first determinations numerical changes (13% of cases), while the latest tests in buccal epithelial cells revealed only nucleus damages (karyorrhexis, karyolysis, binuclear) in 73,9% of cases, possibly due to inhomogeneous radiation exposure.

The enhanced SOD activity and serum Lpox revealed the imbalance in antioxidant protection induced by chronic ionizing radiations exposure.

Specific tissues effects were detected in the eye lens (fine opacities) and skin (vitiligo, papillose, allergic dermatitis – 47.8% of subjects). Ocular damages appeared at one subject after 18 years exposure length, accompanied by a six years earlier detected thrombocytopenia.

For non targeted effects we account for arterial hypertension in 13% of subjects and irritative/allergic upper respiratory tract syndrome as well as renal lithiasis in 9% of cases.

Health workers from radiotherapy develop early and late cells and tissues reactions in different types of damage, some with high probability of stochastic effects. Meanwhile, their occupational exposure might induce other non targeted effects which could initiate invalidating co morbidities.

P01.99
Karyo Pathologic Change of the Thyrocytes in Chernobyl Affected Children

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Analysis of the epidemiologic evidence for children and adolescents affected by the Chernobyl accident showed a statistically significant augmentation of prevalence of thyroid cancer and other nodular disorders of the thyroid gland.

Estimation of the excess relative risk due to gender and age was within the limits:

for single-node goiter - from 0,19 (0,05÷0,33) to 0,68 (0,37÷0,98) per 1 Gy;

· for a multinodular goiter - from 1,07 (0,36÷1,77) to 2,37 (0,75÷3,99) per 1 Gy;

· for a thyroid adenoma - from 2,42 (1,11÷3,72) to 2,87 (0,94÷4,81) per 1 Gy.

Estimation of presence and rate of the known radiation markers in the form of chromosome bridge in patients with the mentioned above forms of thyroid pathology seems to be quite interesting.

The FNAB-obtained material was examined.

The patients with singlnodular and multinodular goiter living in Gomel Region of Belarus were included in the basic group as the patients with the same pathology living in Leningrad Region of Russian Federation were included in the reference group.

In patients with single-node goiter from the Leningrad region thyrocytes with internuclear bridges seen in 20% of cases. The maximum frequency of thyrocytes with bridges reached 4,0‰. The average frequency of thyrocytes with bridges in the control group was 1,12 ÷0,28 ‰. Patients from the Gomel region with internuclear bridges were identified in 80.0% of cases. The maximum frequency of thyrocytes with bridges in individual patient reaches 12,0 ‰. The average frequency of thyrocytes with bridges in the control group was 5,25±0,28 ‰, that statistically significantly higher than in the controls ($Z = 4{,}137$, $p < 0{,}001$).

In patients with multinodular goiter from the Leningrad region thyrocytes with internuclear bridges seen in 16.7% of cases. The maximum frequency of thyrocytes with bridges reached 4,0 ‰. Patients from the Gomel region thyrocytes with internuclear bridges were identified in 75.0% of cases. The maximum frequency of thyrocytes with bridges in individual patient reaches 10,0 ‰. The average frequency of thyrocytes with bridges in the control group was 4,17±0,95 ‰, that statistically significantly higher than in the controls ($Z = 4{,}137$, $p < 0{,}001$).

It should be noted that in the group of patients from the Gomel region extra-long bridges were identified in 35,0% of cases, while patients in the comparison group similar nuclear abnormalities were not observed at all.

Detected in irradiated patients with giant thyrocytes internuclear bridges, apparently, is a specific marker of radiation exposure.

P01.100
Immune Status Of the Occupationally Exposed MAYAK Workers

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The aim of the study was to study the effects of chronic exposure to external gamma-rays and internal alpha-particle radiation from incorporated ^{239}Pu on immune status of the Mayak workers.

The main group included 100 Mayak workers first employed at one of the main facilities during 1948-1972 and chronically exposed to external gamma-rays and internal alpha-particle radiation from incorporated ^{239}Pu. The control group included 50 individuals, who never worked at Mayak and were never occupationally exposed to radiation. The mean age of respondents was 78.5±0.44 years. The range of external gamma-doses was 0.47-2.99 Gy. The blood serum immunoglobulin was measured by enzyme immunoassay. Expression of the lymphocyte differentiation clusters was estimated by flow cytometry.

As compared with the control group the blood serum concentration of immunoglobulin G and the absolute number of T-lymphocytes were statistically significantly lower among individuals exposed only to external gamma-rays, but concentration of the immunoglobulin E and the relative content of natural killers were statistically significantly higher.

The blood serum concentrations of immunoglobulin M and A, TN-K cell count and the absolute content of natural killers were statistically significantly higher, and the relative content of T-lymphocytes was statistically significantly lower among Mayak workers exposed to both external gamma-rays and internal alpha-particle radiation from incorporated ^{239}Pu in comparison with the control group.

The study showed that chronic exposure to external gamma-rays and internal alpha-particle radiation from incorporated ^{239}Pu lead to changes in different components of immune system. These changes could play a significant role in pathogenesis of the late radiation effects and different somatic diseases. However, further studies to confirm these preliminary findings are required.

P01.101
Radiation Protection Aspects of New Full-Body Rtg Scanners

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The paper summarizes the recent situation regarding the design and construction of new full-body security rtg scanners which are being installed at some airports for passenger control. Special attention is paid to assess the exposure associated with this screening in terms of the effective dose resulting from one check up. Based on an estimated number of passengers and the data from manufacturers, a collective effective dose is estimated. Then, a total number of additional cancer cases (besides their spontaneous occurrences) is calculated and compared with the risk which can be avoided when this sophisticated equipment is used for the security screening of persons. Preliminary results have shown that this technique can be considered fully justified under the present situation where there is still a real potential threat of radiological terrorism. This conclusion relies on the data about the effective doses given by manufacturers which, however, may not be always accurate. Some more efforts have to be aimed at reliable testing and QC of new scanners in order to establish more precisely their radiation protection characteristics.

P01.102
A Study of Space Radiation Effects on Microgravity Bone Resorption

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Radiation has a potential to aggravate bone loss caused by microgravity exposure through increased osteoclastogenesis. The National Research Council identified microgravity and radiation as two major concerns for human space flight. The NASA Life Science research division aims to understand the effects of radiation and microgravity in space environment. Further investigations into the understanding of the major contributors of radiation induced bone loss are needed. Preliminary studies by Sundaresan et al. 2007 indicate that osteoblasts are suppressed and osteoclasts remain active for a long period in the microgravity analog environment. This study will discuss results from rodent/human 3D bone constructs cultured in the HARV vessel (modeled microgravity) and irradiated with low and high total exposure under photon radiation environment. Radiation is found to work synergistically with some organ systems especially inflammatory and immune response systems. Hence in our current study we focus on the effects of microgravity combined with radiation exposure in bone tissue and observe if similar synergy is present. The effects of dose and cell function assessments such as apoptosis, bystander effects and bone cell proliferation are also assessed to develop a preliminary numerical model of microgravity effects in osteoclastogenesis and the relative kinetics of osteoblast function.

P01.103
Taking Into Account Radiation Induced Circulatory Diseases At Low Doses: What Impact On The Radiation Protection System?

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The system of radiation protection is cautiously based on a linear relationship between the dose and the risk of death, also called detriment. Within the past, the detriment was used as a rational basis to set annual exposure limits for the workers and the public or for the calculations of tissue and organ weighting factors. The current system of radiation protection is no more risk-based, but risk-informed, optimisation of radiation protection being the key principle of the system for all kind of exposures. Nevertheless, quantification of the detriment still plays a key role.

Radiation induced circulatory diseases have been considered for a long time at high doses and dose rates. They were already mentioned in ICRP Publication 8 (1965). Recent epidemiological evidences show that doses as low as 0.5 Gy could lead to a statistically significant excess of such diseases, for chronic or acute exposures. In the absence of information on a convincing mechanistic model to support the possible link between circulatory diseases and exposure to low doses, ICRP has considered in its Publication 103 in 2007 not to take into account these effects in the calculation of the radiation health detriment. There is nevertheless a growing questioning in recent international meetings on the potential impacts of circulatory diseases on the radiation health detriment.

Beyond the need to further investigate the mechanistic model for radiation induced circulatory diseases, CEPN performed preliminary calculations to investigate the possible contribution of circulatory diseases to the detriment.

Calculations have been achieved on a various set of simple hypothesis Preliminary sensitivity analysis has been performed for the key parameters - excess of relative risk, population, etc. - so as to assess the potential implications of circulatory diseases on detriment quantification. On this basis, an increase by 20 to 50% of the detriment is estimated.

This paper presents and discusses the hypothesis and results of these calculations. It also addresses their potential impact on the radiation protection system.

P01.104
Effects of Low-Dose Ionizing Radiation Exposure on Chromosomal Damage and Immune Parameters in Interventional Cardiologists

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It is well known that occupational doses of radiation in interventional procedures guided by fluoroscopy are the highest doses registered among medical staff using X-rays. Radiation exposure is a significant concern for interventional cardiologists because workloads and the complexity and number of procedures have increased over the past few years. Ionizing radiation accounts for risk-dose-dependent stochastic effects (no threshold dose) and dose-dependent deterministic effects (threshold dose). Ionizing radiation can induce various forms of DNA damage, including the possibility of increasing the incidence of chromosomal aberrations and micronuclei that might be causally involve in early stages of carcinogenesis. Apart from cytogenetic, there is a growing body of evidence regarding immunological changes induced by low-dose radiation. The aim of the present study was to assess the effects of chronic low-dose X-ray radiation exposure on chromosomal damage and major immune responses of interventional cardiologists working in high volume cardiac catheterization laboratories in comparison with clinical physicians without any work-related exposure to ionizing radiation. Results showed that while cytogenetic results show higher chromosomal damage, however most humoral factors are not affected, some cellular responses are stimulated and cytokine production is immunomodulated in response to chronic low dose radiation exposure in interventional cardiologists. Moreover, it was revealed that cytogenetic effects, lymphocyte number and interleukin concentrations in sera of interventional cardiologists did not depend on the length of their employment and exposure. However, based on the evidence, radiation exposure leaves a genetic mark on somatic DNA of the interventional cardiologist. Since interventional cardiology is recognized as a high-radiation-risk practice and interventional cardiologists have the highest radiation exposure among health professionals, they should be aware of the ICRP's recommendations and international Basic Safety Standards requirement for radiation protection and evaluation and follow-up of occupational doses should be considered an important part of quality assurance programmes.

P01.105
Health Status Assessment Among The Exposed In Utero Offspring Of MAYAK Nuclear Workers

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Objective of the study was to assess health status of the in utero exposed offspring of workers of the first Russian nuclear facility, Mayak Production Association (PA).

The medical examination of 136 individuals (70.6% of whom were females) *in utero* exposed due to the occupational activity of their mothers and born in 1949-1956 was performed. Control group (136 individuals) included offspring from non-exposed families matched by gender and the year of birth (± 1 year).

Total occupational external gamma-ray doses of mothers of exposed offspring over a period of pregnancy ranged from 11.0 to 948.7 mGy (the mean dose was 197.8 ± 13.3 mGy). In addition, 86.8% of these mothers were exposed to ^{239}Pu aerosols before delivery of a child. 90.5% of mothers and 42.6% of fathers were exposed to irradiation before conception.

Medical examination included questionnaire survey, examinations by different medical doctors, and series of instrumental and laboratory tests aimed to assess the state of various body systems. The age of individuals varied from 50 to 59 years.

The medical examination findings indicated a wide prevalence of atherosclerosis and involutive changes as among *in utero* exposed offspring as among individuals from the control group. There were no statistically significant differences in the prevalence of hypertension, ischemic heart disease, cerebral atherosclerosis, visual organ diseases, respiratory diseases, genito-urinary diseases, and disorders of carbohydrate and fat metabolism in the studied groups. The mean concentration of the total cholesterol and LDL cholesterol was higher in the group of *in utero* exposed offspring as compared with control group, but further studies are needed. A statistically significant increase of the nodular goiter prevalence was found among *in utero* exposed offspring in comparison with the control group. Due to the fact that all of the individuals involved in the study could be exposed to radioiodine in their childhood as a result of non-controlled gas and aerosol emissions by the Mayak PA, causes of this increase need to be further analyzed.

A significant increase of the premature births and deliveries of a child with body mass less than 2500g was found among women exposed *in utero* in comparison with women from the control group. It is necessary to continue the study of reproductive function among exposed offspring accounting for non-radiation factors.

Immunoassay found dose-dependent decrease of C5 and dose-dependent increase of TNFα among *in utero* exposed offspring as compared with the control group, and increase of the prevalence of allergic and autoimmune syndromes. FISH study revealed significant increase of the stable chromosomal aberration yield (mainly of translocations and aneuploidies) among *in utero* exposed offspring of the Mayak workers against the literature data.

P01.106
The Gender Problem in Radiation Protection

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Gender is a range of characteristics used to distinguish between males and females, particularly in the cases of men and women and the masculine and feminine attributes assigned to them. While the social sciences sometimes approach gender as a social construct, and some gender studies particularly do, research in the natural and medical sciences investigates whether biological differences in males and females influence the development of gender in humans.

The health status of men versus women and boys versus girls can be significantly different by virtue of the differences in their gender. This is true regardless of any exposure to ionizing radiation.

Many studies have found that a number of major illnesses are influenced by gender. The same holds true for the potential risks associated with exposure to x-rays or ionizing radiation from radioactive materials or accelerators.

For example, female breasts are more sensitive to ionizing radiation than male breasts. While men can develop breast cancer, it is extremely rare.

The radiation protection policy as outlined by ICRP in its Recommendation 103 takes does not take care of the gender problem. The radiation legislation in the European Union follows the ICRP policy. The fetus will be well protected according to the ICRP policy. When more radiation risk data will be collected in the future for male and female, the present ICRP conclusion may eventually change.

Reference

ICRP Publication 103: The 2007 Recommendations of the International Commission on Radiological Protection. Annals of the ICRP; Volume 37; Nos. 2-4 2007.

P01.107
Radiation Exposure During Video-Urodynamics in Women

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Video-urodynamics (VUDS) is the most comprehensive method to assess lower urinary tract dysfunction. VUDS uses fluoroscopy in order to add high-resolution anatomical details to the urodynamic data. Since VUDS involves radiation, there is some concern over the risks to females who undergo this procedure. As such, an investigation into the dose received by women in typical examinations was performed. Consecutive VUDS, performed by five different operators, were reviewed which included 412 patients. Of these, 264 studies with complete data were included in the study and video playbacks of examinations were analysed in order to model a typical examination. The Monte Carlo programme PCXMC was utilised to calculate normalised entrance skin doses for radiosensitive organs. For each of the patients in the study the effective dose was calculated.

The procedure was found to be associated with a very low exposure and therefore low risk of deleterious effects. The mean effective dose of 0.34 mSv is comparable to that resulting from an abdominal X-ray and much lower than that reported in the literature (4.3 mSv) [1] for procedures involving a combination of fluoroscopy and abdominal X-rays. An analysis of covariance showed that patient's weight and fluoroscopy time were the only statistically significant factors ($p<0.05$).

P02.01
Validation of Linac Bunker Shielding Calculations

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A recommended method for determining shielding requirements for linear accelerator bunkers is to use the formulae described in NCRP 151. These straightforward formulae use published data (tenth value layers, scatter fractions and reflection coefficients) along with the user's bunker dimensions and linac output data to determine dose rates in the surrounding environment. The simple calculations can be done without a need for complex computer modelling.

The objective of this work was to validate design calculations by comparing the dose rates calculated using NCRP 151 methodology to actual measured values for a number of geometries.

Geometric data such as wall thicknesses and isocentre location were extracted from the plans for our new 6 and 10 MV linac bunker. Points of interest were selected at the maze entrance, directly behind the primary and secondary shield walls. Expected instantaneous dose rate (IDR) values were calculated using the NCRP 151 methodology. Measurements of actual IDR values were taken using an ion chamber (Victoreen 450P), with the geometry and linac settings chosen to match the calculation assumptions as far as possible.

The measured and calculated dose rates are presented and showed that actual dose rates beyond the primary shielding and maze entrance area were underestimated by calculation, whereas those beyond the secondary shielding were overestimated.

For our bunker, the design calculations have been successfully validated by dose rate measurements. Validation work is continuing using different bunkers and points of interest; this will give further confidence in the validity of the simple NCRP 151 calculations.

P02.02
Dose Enhancement in Thin Layers of Skin-Equivalent Material Caused by Photons and Electrons: A Monte-Carlo Study Using MCNP

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Foreign bodies penetrate not infrequently into the skin. If they are amicrobic, the can get stuck in the skin and do no harm in normal case. When irradiated with photons and/or electrons, however, they can lead to an enhanced absorbed dose. The dose-enhancement effect of graphite, lead and gold is investigated for particles having a kinetic energy up to a few MeV. Both the length and the radius of the foreign bodies reads 0.1 cm. It is found, among others, that a considerable dose enhancement is visible within hollow cylinders with a thickness of 0.002 cm at a depth of 0.007 cm which the basal-skin layer is referred to in particular. Furthermore, substantial dose-enhancement effects are found for an equally thin slab with a cross-section area of about 0.025 cm^2 for several depths. All dose-enhancement effects are almost not noticeable if the cross-section area of the slab is enlarged to 1 cm^2 which is usually taken into account in operational radiation protection. The small layer thickness of only 0.002 cm requires a careful application of MCNP.

P02.03
Radiometric Characterization of High Background Radiation Areas (HBRA): Some Results from Kenya

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Several studies around the world have reported a number of so-called high background radiation areas (HBRA), which are due to the local geology and geochemical effects that have highly enhanced levels of radiation. There are HBRAs in Kenya, which include among others Mrima Hills, Jombo Hills, Kerio Valley, and Homa and Gwasi Mountains. The enhanced levels of radioactivity in these HBRA is attributable to carbonatite rocks, which contain high levels of Th and U: levels of naturally occurring radioactive materials (NORM) at a place depend on the distribution of rocks and soils from which they originate and processes which concentrate them. Most of the available information on the HBRA is derived from geological and mineral exploration surveys. Radiometric studies in HBRA are important because HBRA need to be evaluated for radioactivity and radiation exposure impact on population and environment, and to provide baseline data for radiation protection regulatory frameworks. We present results of direct measurements of absorbed dose rates in air in the various HBRA (which indicate these values are within the range observed by other workers in different HBRA – sometimes higher); determined (using HPGe- and NaI(Tl)-based gamma-ray spectrometry and liquid scintillation counting) activity concentration of ^{238}U, ^{232}Th, ^{40}K and radon (^{222}Rn) in the various HBRA environmental compartment matrices; and estimated annual average external and effective dose rates. Annual external effective dose rates in Lambwe were found to be 12 times the global average, while in Mrima Hill was 50 times. We also report the results of quantification of the radiogenic fluxes and radiation exposure due to NORM in the extraction and processing of the columbite-tantalite (coltan) mineral in selected regions of artisanal mining of Rwanda where absorbed dose values were found to be 11 times higher than world average; and explored the multivariate relationships among the radiometric data and the regions using chemometrics. Chemometric analysis of the activities of radionuclides (^{238}U, ^{232}Th, ^{40}K) and concentrations of radioactive elements Sr, Rb, Pb was used to classify processed coltan according to their geographical origin. This classification was found to have potential in nuclear forensics of cross-border nuclear materials.

P02.04
QA/QC programme in use at UPSR/ITN

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The Individual Monitoring Service (IMS) of the Unidade de Protecção e Segurança Radiológica (UPSR) at the Instituto Tecnológico e Nuclear (ITN) in Portugal operates a thermoluminescence dosimetry system for individual and environmental monitoring.

The TLD system in use is based on two Harshaw 6600 automatic readers and on the Harshaw two detector cards of LiF:Mg,Ti (TLD-100) inserted in the 8814 and symmetrical holders for the evaluation of H*(10).

The main aspects of the QA/QC programme will be presented in this paper using fluxograms and schemes.

The main technical procedures will be presented in this paper and references will be made to a Quality Control database internally developed and designed for the storage of important QC parameters like the element correction coefficients, reader calibration factors, intercomparison results, electronic quality control data generated on a daily basis, and the study of their evolution with time.

P02.05
Environmental Monitoring at ITN with Passive Detectors: Comparison of the Symmetrical and Traditional TLD Holders

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Since December 2004 environmental measurements are performed on a quarterly basis at the ITN (Nuclear Technological Institute) campus in Sacavém and in several sites located around the country.

The main methodology in use for environmental measurements is based on the Harshaw 8814 card and holder containing LiF:Mg,Ti (TLD-100) detectors readout on semiautomatic Harshaw 6600 readers also used for individual monitoring. For environmental measurements the system is calibrated in terms of ambient dose equivalent and the irradiations are performed free in air on a 137Cs beam. Recently another dosemeter configuration was introduced based on the same detector elements but inserted in the Harshaw symmetrical holder, requiring half the number of dosemeters previously used. The aim of this work is to compare the results obtained using both methods

For the purpose of this work only the measurements performed at ITN campus were considered.

At each site and for each exposure period a set of twelve dosemeters arranged in three sets of four were always used. Two of the sets were irradiated to a reference dose either before or after the exposure period. The third set was not irradiated at all and was dedicated to the evaluation of the environmental dose. The dosemeters of all three sets were prepared, exposed, removed and readout at the same time. From the results of the two irradiated sets a correction factor was obtained to take into account the fading and sensitivity changes on the glow curves, induced by the temperatures endured during the integration period.

A similar method was used with the symmetrical holder detectors including pre and post irradiations for fading corrections. However, half the number of dosemeter cards were used. In each quarter, several integration periods were considered to analyse the evolution of the fading correction factors and of the ambient dose equivalent estimates.

The dosemetes used with both methods were prepared, exposed and readout at the same time so that the results are directly comparable.

Estimates of the ambient dose equivalent will be compared and the results discussed in terms of the fading, as well as other properties of the two dosemeter configurations.

KEYWORDS: Environmental monitoring; ambient dose equivalent.

P02.06
Detailed Dose Rate Measurements On Ruthenium-106 (Ru106) Eye Plaque Treatment Using An Anthropomorphic Rando Phantom

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Introduction: This work presents results of dose rate measurements performed using a Ru-106 eye plaque placed over the left eye of an anthropomorphic RANDO head phantom. This is in response to the proposed merger of an ophthalmic ward with a different speciality. The ward has side rooms and 4 central bays containing 5 beds , 2.6m apart bed centre to centre. Not all Ru-106 patients will be nursed in side rooms with up to 3 plaque patients being in a central bay.

Methods Beta-ray emitting Ru-106/Rh-106 ophthalmic applicators are an effective treatment for choroidal melanoma. For this work a 20 mm diameter model CCB plaque, activity 23.9 MBq was used. Measurements were taken over the 4 cardinal points from the phantom from a distance of 35cm to 2.5m and repeated with a double plastic eye shield in place .

Results The table below presents comparative dose rates at 35cm, 100cm and 250 cm with and without double plastic protective eye covers in place for dirs. North, facing the RANDO, West on the plaque side and East contralateral to the plaque <P<

	North	
Distance (cm)	Dose Rate(no eye guard) (uSv/hr)	Dose Rate(eye guard) (uSv/hr)
35	265	137
100	14.4	6.8
250	0.6	0.1
	West	
35	165	78
100	19	6.3
250	0.1	0.1
	East	
35	30.2	22
100	2.7	2
250	0.1	0.1

North Distance(cm) Dose Rate(no eye

Conclusions Dose rate measurements based on a realistic anthropomorphic phantom demonstrate that with eye shields a 1 m zone around a bed defines a controlled area. At 2.5 m the dose rate is minimal indicating that the risk to patients in adjacent beds is negligible.

P02.07
Resolving Ambiguity in Individual Dose Measurement with Dosemeters Calibrated in Terms of Different Quantities

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Operational quantity, Personal dose equivalent 'Hp(d)' has been recommended by ICRU for Individual monitoring of radiation workers. The implementation of Hp(d) for individual monitoring requires that the response of the dosemeter conforms to the requirement of the specified accuracy for different energy of the radiation and its angle of incidence. In India, three element TLD badge based on $CaSO_4$:Dy TL Phosphor is being used for Individual Monitoring which has been proved to conform to the response requirement of estimation of personal dose equivalent penetrating, Hp(10). However the operational quantities are yet to be implemented. Active dosemeters such as quartz fiber pocket dosemeter, Electronic pocket dosemetrs (EPD) etc. are used for day to day dose control. The current generation of EPDs is providing the individual dose in terms of the personal dose equivalent. The difference in quantities measured and process of calibration creates a sort of discrepancy in the individual dose. A study was carried out to understand the difference in measurements of TLD and EPD and their response to the phantom backscattering. The study was extended to measure the dose at 10mm depth in PMMA phantom with the use of TLD badge and TLD cards at 10mm depth by covering the dosemeter using specifically designed PMMA sheet of appropriate thickness. The result was correlated with the on phantom surface and in air measurement results. The response of EPD calibrated in terms Hp(d) to on phantom measurements and the error which may occur for free in air measurements has been estimated. The paper discusses the results of the measurements and its significance in resolving the ambiguity related to measurements with dosimeters calibrated in terms of different quantities.

Key words: Personal dose equivalent, TLD, EPD, Individual monitoring

P02.08
Investigation into the Variability of Dose Measurement using a Selection of Approved Dosimetry Services

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Aim: To assess the suitability of five different approved dosimetry services (ADS) for hospital dosimetry by exposing dosimeters from each service to known doses of gamma radiation covering the range normally expected for hospital workers

Methods: Each ADS provided fifty dosimeters for testing. Dosimeters tested were of two types. Thermoluminescent dosimeters (TLD) were supplied by four of the ADS' and Optically Stimulated Luminescence (OSL) dosimeters by one ADS. The lower limit of detection quoted for each dosimeter differed between service providers, ranging between 0.01 mSv - 0.1 mSv. An experimental setup was devised whereby batches of dosimeters were exposed to Hp(10) doses of 0.014 mSv, 0.054 mSv, 0.113 mSv, 0.216 mSv and 0.493 mSv. Exposures were made using 140keV gamma ray photons from a Tc-99m source, with the dosimeters attached to water filled containers to provide realistic backscatter. Seven dosimeters from each ADS were kept unexposed in order to monitor the reliability of the control reading.

Results: Differences between calculated and reported doses at each ADS' lower limit of detection were 7-100%. At doses greater than 0.1mSv the differences between calculated and reported doses were 3% – 43%. Coefficient of variation (CoV) measurements showed a high level of variability at the lower limit of detection for all the ADS' tested (40% - 50%). At doses greater than 0.1mSv CoV measurements were 2-11%.

Conclusion: Care should be taken when using a lower limit of detection less than 0.1 mSv as reported doses may be unreliable. Accuracy of reported doses varied between ADS' for all doses tested. The precision of reported doses at the ADS' lower limit of detection was poor. Precision improved for doses greater than 0.1 mSv and was consistent between service providers at this level.

P02.09
European Population Dose From Radiodiagnostic Procedures - Results Of DOSE DATAMED 2

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INTRODUCTION: In the end of 2010 the European Commission launched the DOSE DATAMED 2 (DDM2) project (www.ddmed.eu) with the objective to collect available data on the doses from radiodiagnostic (x-ray and nuclear medicine) procedures in the European Union and to facilitate the further implementation of the "Radiation Protection 154. European Guidance on Estimating Population Doses from Medical X-Ray Procedures". A database for population doses will be established for the purpose of systematic evaluation of results and to enable a continuous follow-up and up-date of population doses in Europe as well as trends in their development.

MATERIAL AND METHODS: The data collection will be carried out by electronic online questionnaires. Data of frequencies and effective doses for the Top 20 procedures, NM top 5 and for all radiodiagnostic procedures will be collected until November 2011. Particular attention will be paid on population dose determinations of the most challenging techniques: computed tomography and interventional radiology. Moreover, the existing diagnostic reference levels will be collected for all radiodiagnostic procedures.

RESULTS: The first survey was sent to 40 countries and 36 of them replied. Most of the countries have frequency and dose data available for estimation of population dose from x-ray procedures by Top 20 method according to the RP 154. Some of the countries have partial data which is either regional or consists of incomplete set of examinations. Data for Top 225 or more is available from 16 countries at least partially. Dose data concerning nuclear medicine examinations is available at least from five most common examinations from 17. Frequency data is available from 28 countries. Population dose for x-ray procedures has not been previously estimated (using effective dose) in one third of the countries. Three countries informed that estimation has been carried out partially.

DISCUSSION AND CONCLUSIONS: In the European Union Member States regulations or recommendations to estimate population dose originating from radiodiagnostic procedures exists two thirds of the countries. The DDM2 project will provide the first estimation of the population dose from radiodiagnostic procedures in the whole Europe. The results will be available in 2012.

The usefulness of the Top 20 method will be tested in the project and suggestions for improving the method will be given. For nuclear medicine similar guidelines will be developed.

Most comprehensive national data from some countries will be used as a baseline to which Top 20 method will be compared. Also new conversion factors from ICRP 103 (ICRP 2007) will be used and the influence of them on the population dose will be investigated.

DDM2 is a two years project financed by the European Commission. The project started in the beginning of 2011.

P02.10
An Evaluation of the Equivalent Dose due to Natural Radioactivity in the Soil Around the Consolidated Tin Mine in Bukuru-Jos, Nigeria.

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The equivalent dose in the human body due to the natural gamma-emitting radionucides (^{238}U, ^{232}Th and ^{40}K) in the surface soil surrounding the Consolidated Tin Mine site in Bukuru-Jos, Nigeria has been determined in this study. Measurements of the soil natural radioactivity were made using a multi-channel pulse-height analyzer (Canberra Series 10 plus) coupled to a 76 mm x 76 mm Nal (Tl) scintillation detector. A total of 20 surface soil samples of natural origin were collected from the 20 different locations at the same depth level of 0 to 6cm around the 20 km2 Tin Mine site. The mean concentrations obtained for each of the radionuclides are 35.4±17.6 Bq kg^{-1} for ^{40}K; 776.0±158.0Bgkg-1 for ^{238}U and 2.72±0.58 kBq kg $^{-1}$ for ^{232}Th. The mean absorbed dose rate due to natural radioactivity calculated at a height of 1.0 m above the ground is 2.16 µGy hr-1 which converts to an equivalent dose of 3.0 mSvyr^{-1}. The equivalent dose obtained in this study is far above the world average equivalent dose of 0.41 mSvy^{-1} but lower than the annual limit of 20 mSvyr^{-1} for radiation workers but still represents a health risk to workers on the site..

Keywords: Equivalent dose, natural radioactivity, gamma-ray,scintillation detector, soil, absorbed dose,

P02.11
Investigation of Life Dose of Workers at Different Occupational Groups in Planned Exposure Situations in Iran

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Workers of different activities will be retired in Iran after 30 year services. According to radiation protection act of Iran, at the time of retirement health surveillance and life dose report of worker shall be submitted to legal authority, Iran nuclear regulatory authority (INRA). Occupational dose of workers being registered in national dose registry system (NDRS) on a routine basis. And at the time of retirement a report on the life dose of worker will be generated for submission to INRA. In this article, life dose of workers in different occupational groups such as conventional radiology, angiography, radiotherapy, dentistry and nuclear medicine as well as industrial radiography are investigated. Statistical quantities such as median and quartiles and dose distribution at different intervals are presented. Median dose of monitored workers at different groups were compared. Analysis and discussion are made on the life dose of workers in planned exposure situation as criteria of radiation protection.

P02.12
A Passive Radiation Dosemeter for Environmental Photon and Beta Monitoring

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The Defence Science and Technology Laboratory (Dstl) provides a range of radiation dosimetry services to the United Kingdom Ministry of Defence (MoD). One of these services is the measurement of environmental photon and beta doses in the workplace. Until now, the Harshaw 8840 thermoluminescent dosemeter (TLD) has been used for this purpose. This dosemeter has filters on one side of the holder only, as it is intended for personal radiation monitoring. It is therefore not ideally suited to making free-in-air measurements of environmental doses where the radiation field is multi-directional.

Dstl is therefore commissioning the Harshaw 8855 TLD for use as an environmental dosemeter. The Harshaw 8855 TLD has two components: a TLD card and a dosemeter holder. The TLD card has four LiF:Mg,Cu,P (TLD-100H) chips, all of which are 0.38 mm thick. The dosemeter holder has various filters to discriminate against different types and energies of radiation. The holder design is symmetrical, that is, the filters are the same on both sides of the holder, to optimise the angular response of the dosemeter.

Dstl has type tested the Harshaw 8855 TLD against International Electrotechnical Commission (IEC) Standard IEC 62387-1. This poster presents the results of the type testing (examples of which are given in Figures 1 and 2), as well as results of workplace trials. It was found that the dosemeter would perform well in the MoD workplaces for which it is intended, although it may need to be protected with a plastic cover to prevent ingress of moisture in some environments. The lower limit of detection for the dosemeter is 20 microSv.

When the Harshaw 8855 TLD comes into service, dosemeter results will be recorded on the Dstl Approved Dosimetry Record Keeping System and maintained indefinitely. These results will help MoD meet its duty of care to its employees to keep radiation doses as low as reasonably practicable.

Figure 1. Angular response to 65 keV photons.

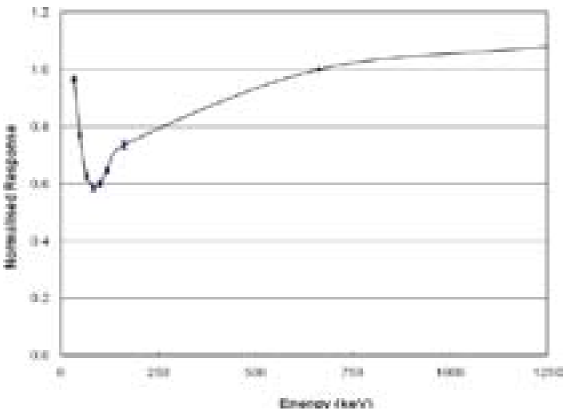
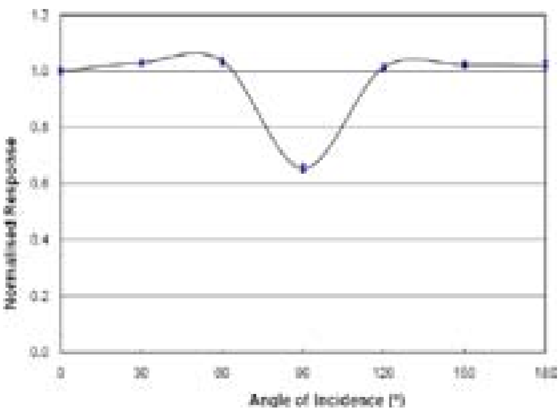


Figure 2. Photon energy response.



P02.13
TLD Doses Investigation around Container/Vehicle Inspection System

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Justification of mobile linear accelerators expanding [1] is based on possibility of cargo container dangerous content. More than billion travelers and pieces of baggage undergo scans each year; but, many millions of cargo containers cross borders with little screening at all [2].

Mobile low energy linacs have been licensed few months ago by SRPNA with conditional options of additional *on situ* measurements. First TLD results are presented in this paper.

A set of TL dosemeters (two crystals per card packed in standard filtered holders, [3]) has been placed around NUCTECH MT1213LH Mobile Container/Vehicle Inspection System at different distances to collect radiation during a month. At the same time, eight TL dosimeters which were exposed to three scans were read-out three hours later. Preliminary results enact unexpected results which are given in Table 1. Crystal (ii) has position below 1 cm tissue equivalent filter and crystal (iii) has position below skin equivalent filter.

Table 1: TLDs surrounding NUCTECH MT1213LH Mobile Container/Vehicle Inspection System

No.	TLD bar-code	Three scans (TLD in air) (ii) (nC)	Three scans (TLD in air) (iii) (nC)	Distance from spot (different angles)	Check crystals (*) (nC)	Check crystals (*) (nC)
1	11039	0.9709	1.75959	11 m right back	13.25	12.85
2	4232	1.0630	7.64617	19 m left front	13.52	13.86
3	2510	0.8061	1.60664	9 m left front	13.16	13.84
4	2985	1.0260	5.64319	9 m central back	13.60	12.85
5	4158	0.8874	7.79779	8 m right front	13.15	13.91
6	4033	1.9780	11.6002	13 m left back	14.12	14.07
7	4223	1.0360	1.33133	6 m central front (beam)	12.68	13.21
8	10244	1.1740	2.01362	25 m left front	12.37	12.74
9	5537	0.8372	2.60281	Not exposed (background)	13.35	12.40
10	4113	0.8786	1.24128	Not exposed (background)	13.74	13.54
	average	1.06572	4.324269		13.294	13.3286
	stdev	0.340241	3.628713		0.505573	0.592033

(*) Signal of TLD exposed to Sr-90, 10 s (after exposing in linac surroundings and after annealing)

Results indicate very high doses in scattered radiation field with extremely low level of energy, close to ultraviolet radiation (TLD (iii) No. 2, 4, 5 and 6). Complete results will be discussed in full paper.

Preliminary recommendation for truck drivers is to keep windows closed driving vehicle through scanner. Justification of truck drivers exposing has to be investigated again.

Occupational exposure due to mobile linacs has to be optimized regarding low level energy scattered radiation.

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P02.14
Reproducibility of 3DCRT Isodose Curves Evaluation Obtained Using Spherical Fricke Xylenol Gel Phantom

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For an effective quality control of complex radiation treatment techniques, such as three-dimensional conformal radiation therapy (3DCRT) and intensity modulated radiation therapy (IMRT), is necessary to perform the absorbed dose distribution verification, aiming to confirm that the target volume received the prescribed radiation dose and the healthy tissues surrounding were spared of the ionizing radiation effects. The planar representation of the dose distribution is offered by isodose curves which can be measured in water phantom directly, for example. Isodose curves are lines that join points of equal dose and are used to evaluate treatment plans along a single plane or over several planes in the patient. In this study, in order to evaluate the reproducibility of 3DCRT photon beam isodose curves determination using Fricke xylenol gel (FXG) dosimetry, the isodose curves were obtained from slices of images obtained employing magnetic resonance imaging (MRI) evaluation technique of different spherical FXG phantoms prepared using 270 Bloom gelatin from porcine skin (made in Brazil). The phantoms were obtained using a spherical glass balloon of 2000 mL (156 mm internal diameter and 2 mm wall thickness) which were maintained at room temperature and light protected before irradiation. The irradiations were performed using a VARIAN® Clinac 600C linear accelerator and the images were acquired 30 min after irradiation using a SIEMENS® MAGNETOM® Sonata Maestro Class 1.5 T MRI scanner both of the Sao Paulo Hospital (HSP) of Federal University of Sao Paulo (UNIFESP). The calibration curves were obtained by means of images of polymethylmethacrylate (PMMA) cuvettes (10 x 10 x 45 mm^3) filled with the FXG solutions positioned at source-surface distance (SSD) of 80 cm in a PMMA phantom and irradiated with different photon doses ranging from 2 to 40 Gy using a GENERAL ELECTRIC COMPANY® Alcyon II ^{60}Co gamma radiation (HSP/UNIFESP). The cuvettes were also evaluated by optical spectrophotometry technique to compare the obtained results. The percentage of the dose at each specific reference point of each MRI slice obtained was evaluated and the reproducibility of the FXG 3D evaluation method was obtained.

KEYWORDS: Spherical FXG phantom; 3DCRT; clinical photon beams; magnetic resonance imaging; isodose curves.

P02.15
Characterization of Optically Stimulated Luminescence Response of LiF:Mg,Ti and microLiF:Mg,Ti Dosimeters for Beta Radiation

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Optically Stimulated Luminescence (OSL) is the transient luminescence observed during illumination of crystalline insulators or semiconductors that were previously excited, typically by exposure to ionizing radiation. The phenomenon has been known for a long time and has been suggested for radiation detection first in the mid-twentieth century. OSL has emerged as a practically applicable dosimetry technique only in the past two decades. In vivo dosimetry is desired for cancer patients to ensure that the patient is not overexposed or that the exposure occurred in the desired region. In radiodiagnosis OSL has been used with great success in imaging systems. The high sensitivity means that the dosimeters can be very small, which gives them the property of high spatial resolution, meaning that they have the potential for measurement of dose in regions of severe dose gradients. This work aims to study the application of OSL technique using dosimeters of lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti and microLiF:Mg,Ti) produced by *Harshaw Chemical Company* for application in beta dosimetry. The dosimeters were previously selected according to their thermoluminescent responses for ^{60}Co gamma radiation with sensitivities better than ± 5%. The dose-response curves for doses ranging from 0,5 to 15 Gy, thermal fading to a storage period up to 50 h under environment free of light and the reproducibility of the OSL response of the dosimeters for beta radiation of an ^{90}Sr-^{90}Y source accommodated inside the OSL reader RisØ TL/OSL DA-20 were evaluated using a OSL reader RisØ TL/OSL DA-20. The obtained results indicates that these dosimeters can be used as an alternative dosimeter for beta radiation.

KEYWORDS: Optically Stimulated Luminescence, LiF:Mg,Ti, beta dosimetry

P02.16
Assessment of Dose and Optimization of Image Quality in the XVI Cone Beam CT System

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1. Introduction

The x-ray volumetric imaging system (XVI) consists of a kV x-ray source and opposing flat panel 2D detector of amorphous silicon allowing for volumetric imaging. It is mounted on retractable arms perpendicular to the gantry and facilitates IGRT by tracking interfractional motion. The XVI is capable of imaging in 2D (planar), 3D (cone beam CT, CBCT) and 2D plus time (fluoroscopic-mode). Recently, Elekta introduced new protocols, which are used regularly in the department, each with varying kV, mAs, field of view (FOV) and kV filters (bow-tie or no filter) contributing different doses and image quality. The FOV is varied by changing the width of the kV x-ray field from small (S), medium (M) and large (L).The S setting has a FOV of 27.67 cm and is centered in the middle of the patient. The panel is moved by 11.5 cm or 19 cm for the M and L setting respectively which results in partial scans and allows larger diameters to be scanned. A bow-tie filter is used in order to increase beam uniformity by shaping the energy distribution across the beam. Further to this, the filter "hardens" the beam; removing low energy x-rays that contribute to dose but do not significantly increase image quality.

1.1 Image Quality and Dose

The image quality required depends on the purpose of the image, for example, whether bony landmarks only (lower dose) or soft tissue (higher dose) is used to line up the image and the DRR for patient positioning. There are a number of ways of reducing dose, but these methods will lead to a decrease in image quality. However, the relationship between image quality and dose is not linear and there are a number of variables which contribute to this relationship. Dose can be reduced by reducing mAs. This in turn reduces the contrast to noise ratio and leads to an increase in the value low contrast visibility. Dose can also be reduced by decreasing the beam energy (tube potential kV), as dose is proportional to kV2. Reduced kV leads to increased contrast as there is less Compton scatter and more photoelectric interactions. A reduction in number of projections, leads to a faster scanning time, which can, in turn, reduce set-up errors due to reduced patient-on-couch time. A decrease in FOV leads to a reduced dose with less scatter.

1.2 Objectives

A general investigation of imaging quality for the most commonly used protocols will be carried out in order to reduce the dose to the patient while maintaining optimum image quality

P02.17
Cosmic Radiation Monitoring for RAF Aircrew

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Military Aviation Authority Regulation requires Aviation Duty Holders and Commanders to take appropriate measures to assess the exposure to cosmic radiation, when in flight, of those members of aircrew who are liable to be subject to cosmic radiation in excess of one milliSievert per annum.

Recent discussions between Dstl and the RAF have focused on the approach which the RAF will adopt to assess doses to aircrew. These discussions are based upon a trial conducted by Dstl in 2007 to study doses to RAF aircrew from cosmic radiation, which resulted in a review of the systems which could be implemented for dose assessment.

This poster reviews the progress of these discussions to date in implementing a dose assessment programme. Particular emphasis is given to the dose assessment methodology used to identify aircrew who are likely to receive a significant annual dose in excess of 1 milliSievert per annum

P02.18
Applicability of CaSO4:Eu,Ce Detectors in Personal Dosimetry

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$CaSO_4$:Eu,Ce detectors were recently developed at Nuclear and Energy Research Institute as an alternative to the long term applied $CaSO_4$:Dy detectors considered as a standard in this study. To assess $CaSO_4$:Eu,Ce applicability in personal dosimetry, a batch of 200 detectors was submitted to the tests demanded by the National Nuclear Energy Commission, CNEN - Brazil, to use a detector for personal dosimetry purposes in the routine of an external individual monitoring service and the results were compared to those of a batch of 200 new $CaSO_4$:Dy detectors. $CaSO_4$:Eu,Ce detectors fulfilled all criteria established for their use in personal dosimetry. The most expressive differences between the newly developed $CaSO_4$:Eu,Ce detectors and the standard $CaSO_4$:Dy detectors were the mean assessed values, respectively, 2.02 mGy and 2.10 mGy, the standard deviation, of 0.06 mGy and 0.16 mGy, and the maximum relative deviation, of 0.0110 ± 0.0003 and 0.165 ± 0.013, for an irradiation with 2.00 mGy in a 60Co gamma source, the lowest detectable dose by $CaSO_4$:Eu,Ce detectors, of 5.75 ± 0.25 µGy, and by $CaSO_4$:Dy detectors, of 32.8 ± 1.0 µGy, and the energy dependence, determined by the maximum relative deviation in the assessed values for the sets irradiated with 10 mGy of 60Co gamma radiation or of 20 to 25 keV, 30 to 40 keV or 80 to 100 keV X radiation, found to be of 0.0551 ± 0.0028 for $CaSO_4$:Eu,Ce detectors and of 0.82 ± 0.12 for $CaSO_4$:Dy detectors. Although the routine validating test period has not yet been observed, $CaSO_4$:Eu,Ce detectors can substitute standard $CaSO_4$:Dy detectors with advantages as far as personal dosimetry is concerned.

P02.19
Evaluation Of Patient Radiation Dose And Risk Estimation During Orthopedic Surgery

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Interventional radiology in orthopedic surgeries now is common and favorite practice. However patients exposed to significant radiation doses during these procedures due to the considerable number of image taken and long fluoroscopic time applied. All these procedure are justified by benefits against risk. This study aimed to (I) evaluate radiation dose to patients during two type of orthopedic procedures and (II) estimate patient organ dose and risk estimation. A total of 37 procedures(19 dynamic hip screw (DHS), fixation of proximal femur and 18 dynamic cannulated screw (DCS), fixation of distal femur) were performed in three centers in Khartoum state, Sudan. All procedures were performed by a single operating consultant orthopedist and different assistant staff in each center. C-arm machines were used in all centers. A calibrated thermo luminescent dosimeters (TLDs) (LiF:Mg,Cu,P type (GR200)) were used. TLDs were attached to patient skin at center of the radiation filed, where it situated inside envelope that contained three chips. Effective doses were assessed from the ESD value using the NRPB software .All C-arm machines subjected to excessive quality control tests and have passed these tests before any measurement. tests performed by Sudan Atomic Energy Commission (SAEC) . The mean fluoroscopic exposure factors for aforementioned procedures were 72.4 kVp ±13, 1.4 mA±0.6 and 0.79 ±0.1 mins. Patient's ages were ranged between 29-76 years. The mean entrance surface dose (ESD) for the patient per procedures was 7.9 ± 2 mGy and 6.9 ±0.9, for DHS and DCS procedures, respectively. The mean effective dose per procedures was 0.51±0. 2 mSv. The mean testicles equivalent dose was 2.1 mSv while the mean ovaries dose was 0.61 mSv. .During DHS patient dose was slightly higher compared to DCS procedure, this may attributed to the higher fluoroscopic factor encountered. Patient doses in this study were higher than previous published studies. The patient dose is far below the tissue reaction effect and cancer probability is low. Keyword: Patient radiation dose, TLD, orthopedic, Radiation Risks

P02.20
Experimental Determination of the 3-D Photon Dose Rate Field in the Airspace Above the Chernobyl New Safe Confinement Constructi

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The measurements of gamma dose rates in 3-D airspace above Arch Assembly Area (AAA) and Service Area (SA) of Chernobyl NPP site within the altitude range from 1 to 110 m above ground were taken in order to provide essential information needed to radiation safety management at time of construction and operation of the Chernobyl New Safe Confinement (NSC) – the arch which is being constructed now by the NOVARKA Joint Venture. Dose rate measurements were performed using MiniTrace S-100 dose rate meters equipped with radio transmitter and GPS module. The systems of delivery of the measurement equipment to the desired areas in 3-D space varied and included helium filled aerostat driven by three ground-based winches, motorized aerostat, hand navigated bunch of helium balloons, automatic octocopter and the kite. Exact coordinates of the measurement points were determined using precise geodesic GPS set or robotized tacheometer coupled with 360o reflection prism. Dose rate measurements were transmitted in real time by radio ShortLink and recorded in DataExpert database. Results of dose rate measurements and ticks of precise coordinates were linked to each-other by synchronizing the time scales of the two arrays. As a result, two sets of 4-D data (x,y,z, dose rate) containing 10,694 and 8,944 unique primary measurement results of the DR and the coordinates were received for the AAA and SA respectively. Further processing included declusterization of data, regularization along 1x1x1 m3 grid and interpolation in 3-D space by kriging (AAA) and by local interpolation using the method of inverse distances (SA). Selection of interpolation methods and assignment of their parameters was supported by extensive cross-validation exercises.

By this procedure dose rate values were estimated in 373 locations within the AAA and 89 within SA, which are aligned along regular grids in respective areas. The data on dose rates in those points will be presented in a talk.

The results obtained by this experiment constitute a solid basis for further radiation safety and design evaluations which depend on the knowledge of the dose fields characteristics in the three dimensional space over construction and operation sites of the NSC.

P02.21
The Process For The Approval Of UK Dosimetry Services

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In the UK the Ionising Radiations Regulations 1999 require certain dosimetry services to be approved by the Health and Safety Executive (HSE). These services may relate to dose assessment (internal or external) or to co-ordination and record keeping.

Dosimetry services submit requests for approval, or re-approval, to HSE along with supporting documentation. HSE assesses dosimetry services' submissions against requirements, which are available from HSE in a series of guidance documents, and undertakes a physical inspection of the service. This normally results in the need for clarification and / or resolution of some points either during the assessment or shortly thereafter. Once satisfied that the service meets the appropriate standards, HSE issues a certificate which clearly defines the scope of the approval to the Approved Dosimetry Service (ADS).

In this paper we will discuss our recent experience of this process with a view to helping ADSs to avoid pitfalls and learn from experience. We would welcome suggestions as to how the current approval process might be improved. Wider challenges facing approved dosimetry in the UK will also be discussed.

P02.22
Occupational Radiation Exposures in Medicine and Industry in Poland

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The Laboratory of Individual and Environmental Dosimetry (LADIS) at the Institute of Nuclear Physics (IFJ PAN) in Krakow applies MTS-N (LiF:Mg,Ti) and MCP-N (LiF:Mg,Cu,P) thermoluminescence (TL) detectors for individual dosimetry in terms of the personal dose equivalent $H_p(10)$ – for whole body and H_p (0.07) – for finger- for photon radiation fields, within the range from 0.1 mSv to 1 Sv. The TL detectors are readout in automatic DOSACUS or RE2000 (Rados Oy, Finland) readers. Dosimetric service is currently performed for ca. 4400 institutions and 37000 occupational personnel over the whole Poland. According to Polish Atomic Law exposure periods are on a quarterly basis. The laboratory participated with positive results in the international intercomparisons organized in 2007 and 2009 by the European Dosimetry Group EURADOS, in order to verify performance of different extremity dosemeters used in Europe.

For whole body doses four MTS-N (LiF:Mg,Ti) TL pellets (4.5 mm diameter and 0.9 mm thickness) are placed in the standard Rados Oy badge with three Al filters. For finger doses the plastic ring holder with adjustable finger size are applied. One MTS-N, (4.5 mm diameter, 0.7 mm thickness), is placed in a bar coded holder under a plastic cover, 0.4 mm thick. The dosemeters can undergo various sterilization processes, used at the clients' hospitals.

The paper presents the results of statistical evaluation of more than 470 000 quarterly or monthly effective dose measurements in oncology centres, hospitals, dentists, research institutes, food-, light-, fuel industry, state border officers, police, antiterrorist troops, prisons, museums and in many sites where X- or gamma-ray systems are used for inspection, performed by LADIS in years 2003-2011. The dose records are being divided in dependence of technical and medical institution and type of measurement performed (individual dosimetry or environmental dosimetry). Results show that more than 85 % of Hp(10) measurements are below 0,1 mSv /quarter and are on the level of natural radiation background. The rest 15% is above 0,1 mSv/quarter, with cases reaching even several hundreds of mSv/quarter. The highest readings of individual dosemeters, exceeding the dose limits, are almost exclusively due to the accidental exposure of dosemeters left in the vicinity of radiation sources.

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P02.23
OSL of Personal Belongings and In Vivo Materials and their Potential use in Accidental Dosimetry

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A radiological emergency situation will require dose assessment of potentially exposed people in order to rapidly carry out proper remedial actions and medical treatments and to inform people about their exposure situation. In cases where members of the public are involved, it is unlikely that they carry personal dosimeters. Therefore other ways of estimating the absorbed dose are needed.

To retrospectively determine the absorbed dose of an individual from materials in, or close to, the body would be very useful since this would provide an individual dose estimate, instead of relying on coarse estimates for the whole affected group of people.

The optically stimulated luminescence (OSL) technique uses light to stimulate the sample and a photomultiplier tube to detect the luminescence light, which originates from the recombination of radiation-induced charges trapped at metastable defects in the material. In this study we are investigating the OSL properties of two types of materials; i.) dental repair materials and ii.) components from mobile phones. So-called dental ceramics and composites are widely employed in dental prosthetics and repairs, and almost everyone owns a mobile phone today. Their abundance makes these materials attractive for retrospective dosimetry and making individual dose assessments.

The OSL responses of the two types of material to gamma radiation exposure are investigated using a ^{90}Sr/^{90}Y source with a low dose-rate (~0.9 mGy s^{-1}) and a Risø TL/OSL-15 reader. The results so far show that the examined dental repair materials exhibit desirable OSL properties in terms of linear dose-response and low minimum measurable dose (MMD). MMD values of 70 mGy have been obtained so far.

The fact that OSL uses harmless light opens up the possibility for measurements *in vivo*, on dental repair materials.

KEYWORDS: OSL, Dental repair materials, Mobile Phones, Accidental Dosimetry

P02.24
Retrospective Dose Estimation of Fetus from Radiological and Nuclear Medicine Examinations

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Human embryo and fetus are much more sensitive to radiation that the adult. Occasionally, it is necessary to perform radiological and nuclear medicine examinations on a woman who is known to be pregnant or an examination is performed on a woman who subsequently discovers that she was pregnant at that time. In such cases, counseling and comprehensive discussion about the risks of radiation exposure to the fetus based on accurate dose estimation of fetus should follow. In this paper, we describe retrospective estimations of the physical absorbed doses due to nuclear medicine and radiology examination during the pregnancy in 74 pregnant women accrued over the period of 3 years (2008-2010). Most of these women were not aware of pregnancy at the time of their examination. They were referred to a National Radiation Protection Department of Iran for estimation of fetal dose. Gestational age ranged between 1 and 15 weeks. Radiation absorb dose to the embryo/fetus was estimated from a knowledge of technique factors and examination details using dose estimation software's. Dose to the embryo/fetus varied between less than 0.01 µGy and 40 mGy, depending on procedure.

P02.25
ORAMED Recommendations to Reduce Medical Staff Exposure in Interventional Radiology and Cardiology

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Medical procedures using ionising radiation are the largest contribution to people's exposures by man-made sources. In particular, interventional radiology and cardiology (IR/IC) procedures are increasingly performed worldwide. However, these procedures often imply high radiation doses to patients, but also to the medical personnel, resulting in high extremity doses to hands and legs, as well as to the eye lens. ORAMED (www.oramed-fp7.eu), a European collaborative project, was set up in 2008 in order to develop methodologies to better assess and reduce exposures to medical staff. This paper summarises the main results and recommendations to reduce exposure in interventional procedures.

In order to obtain a set of standardized data on extremity and eye lens doses for staff in IR and IC more than 1000 measurements were performed in 34 hospitals in 6 European countries. Furthermore, simulations of the most representative workplaces in IR and IC were carried out to determine the main parameters that influence the extremity and eye lens doses. Special attention was also given to practical aspects of active dosimetry in order to obtain direct dose measurements during procedures and to guide manufacturers to improve the current status of this technology. In addition, a new dosemeter specially designed to monitor eye lens has been developed together with the corresponding specific calibration procedure to determine the operational quantity $H_p(3)$.

The analysis of the results led to the following main recommendations:

1. The equipment used for interventional cardiology and radiology should fulfill specific requirements in their design and maintenance.

2. Personal protective equipment should be used for all the personnel in the room (at least lead collar and aprons).

3. The ceiling suspended shield should be placed just above the patient. When ceiling shield is not available, protective lead glasses should be used.

4. Table shield should be always properly adjusted to protect both legs.

5. Mobile floor shield should be used for the assisting personnel.

6. The X-Ray tube should be placed below the operating table and, when possible, the femoral access of the catheter should be preferred to the radial one.

7. Operators should avoid direct exposure of hands to primary radiation.

8. Monitoring of the eyes and fingers (or wrists) should be performed on routine basis. Dosemeters should be worn on the side of the operator which is closest to the X-ray tube.

P02.26
Efficiency of Radon Remediation in Swedish Houses

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Landauer Nordic has measurement data from more than 1000 Swedish houses in which radon remediation has been done. These data are compared with measurement data before the remediation in order to evaluate how much the radon levels have been reduced. The influence of different building construction parameters on the efficiency of the radon remediation is also discussed.

P02.27
Nuclear Power Plant Data Analysis for InLight LDR Model 2 Dosimeter

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Landauer services approximately 75,000 nuclear power plant workers worldwide using the InLight Analytical System composed of InLight LDR Model 2 whole body dosimeter and InLight Reader. Servicing this many nuclear power plant (NPP) workers provides an excellent repository of occupational radiation worker and dosimeter response data for this industry.

The InLight LDR Model 2 dosimeter has become very popular in nuclear power industry by proving accurate dose results in challenging irradiation fields, enabling long wear periods due to its negligible fade and the ability of providing accurate dose results during the wear period without impacting the final dose. The dosimeter contains four discs of Al_2O_3:C placed under different filters for improved energy response and energy discrimination. InLight Reader uses Continuous Wave Optically Stimulated Luminescence (CW-OSL) to interrogate the dosimeter and provide an output signal directly proportional to the amount of ionizing radiation that interacted with the dosimeter.

Dose results from the Nuclear Power Plant industry segment were studied to determine opportunities to enhance dosimeter system performance, catalogue radiation fields and dosimeter response, determine trends, and document experiences with the NPP market segment. This paper will review the performance of the InLight analytical system acquired from United States Nuclear Power Plants serviced by Landauer. The data set include results from both pressurized water reactors (PWR) and boiling water reactors (BWR).

P02.28
Occupational Radiation Exposure Trends In Whole Body Dosimetry - Hp(10)

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Landauer Glenwood, Illinois facility services approximately 1.2 million participants in 76 different countries. Landauer provides whole body radiation dosimeters to monitor the uses of radiation in medical, academic and scientific applications, industrial, defense, and nuclear power applications. This repository of occupational radiation exposure information was studied to determine radiation monitoring trends for whole body doses.

The analysis of observed trends in *Hp(10)* dose data can reveal opportunities for optimization of occupational exposure, for dose reduction and for improving product offering in the market place. The analysis of the data falls into six key indicators which include number of monitored workers, number of individuals with minimal dose, number of individuals with measurable doses, collective dose, average dose, and dose distributions.

The trends presented in this paper are based on the *Hp(10)* dose as measured by the Luxel+ whole body dosimeter. The Luxel+ dosimeter uses aluminum oxide (Al_2O_3:C), an optically stimulated luminescent (OSL) dosimeter. The Luxel+ dosimeter is used to monitor beta and photon radiation. With the addition of CR-39 detector, the dosimeter is able to monitor neutron radiation in addition to beta and gamma radiation. When a neutron dose was present, the total *Hp(10)* included the summation of the *Hp(10)* photon and *Hp(10)*) neutron dose components.

P02.29
Clinical Application of GAFCHROMIC EBT Film for in Vivo Dose Measurements from Total Body Irradiation

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Purpose: To investigate the in vivo absorbed doses for total body irradiation (TBI) by GAFCHROMIC EBT film, post processing procedure including pixel-by-pixel values, film uniformity, and sensitometric curve were established to evaluate dose uniformity on the patient.

Method and Materials: The 10MV photon beam by Siemens Primus linac was used for TBI. The Rando phantom was set in the treatment position with bilateral opposing TBI technique with a source-to-axis distance of 455 cm and 2136 monitor-unit irradiation(per orientation). The distance from skin entrance to umbilicus was 14.5cm for 150cGy prescribed dose. Four thermoluminescent dosimeters (TLDs) and one EBT film with the size of 3cm x 3cm were placed together at the surface of 6 anatomical regions including umbilicus, genitals, both temples, and chest wall. Epson 1680 color transmission flatbed scanner was used as film scanning system, with only the red-color-channel response extracted from irradiated EBT films converted to the pixel-to-dose sensitometric fitting curve. Furthermore, EBT films were tested for the in vivo surface dose measurements on two patients undergoing TBI.

Results: The overall dose uncertainty determined in EBT film was 3% as compared to the farmer-type ion chamber. In phantom test, the average surface doses measured by TLDs and EBT films at 6 anatomical regions were 2.00 and 2.03Gy(left temple), 2.00 and 2.03Gy(right temple), 1.83 and 1.86Gy(left chest), 1.86 and 1.90Gy(right chest), 2.18 and 2.21Gy(umbilicus), and 1.54 and 1.57Gy(genitals), respectively. It showed the good agreement in phantom between EBT films and TLDs measurements with the average difference of 1.7±0.3%. The average doses measured by EBT films at the corresponding regions on two patients were 1.79Gy/1.78Gy, 1.71Gy/1.64Gy, 1.17Gy/1.21Gy, 1.15Gy/1.17Gy, 2.46Gy/2.32Gy, and 1.65Gy/1.79Gy, respectively.

Conclusions: The performance of EBT film for TBI dosimetry was satisfactory, with the dose difference of 1.7% between EBT film and TLD measurement. The use of EBT film for in vivo dose verification of TBI technique may be applicable and convenient.

P02.30
Retrospective Dose Assessment In A Radiation Mass Casualty By EPR And OSL In Mobile Phones

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In the retrospective dose assessment of individuals potentially exposed to ionizing radiation after an accident, dosimetry with inert materials can complement or be used as an alternative to biodosimetry assays. Dosimetry based on physical methods such as Electron Paramagnetic Resonance (EPR), Optically Stimulated Luminescence (OSL) provides measurements of absorbed dose in a variety of material through the measurement of the radiation damage therein induced. Materials contained in personal objects can therefore be collected and used almost as physical personal dosimeters. Portable electronic devices (PED), i.e. mobile phones, MP3 players, are very appropriate items because owned and carried by a large part of the population.

We propose a combined system of dose measurements in components of mobile phones, based on measurement by EPR and OSL of different components from the same device. Glass of the window displays and touch screen as well as electronic components (EC) with alumina rich substrates are both sensitive to radiation. This work is carried out in the framework of the EU funded project Multibiodose with the objective to develop and validate methods for dose assessment specifically in a mass-casualties scenario.

25 mobile phones of different brands and models were analyzed at each partner laboratory, leading to a total of 75 devices covering 61 different models. The EC and glass types were classified according to three criteria: a) availability in PED, b) presence of a radiation specific signal immediately after irradiation and c) presence of a remnant radiation induced signal 10 days after irradiation. All mobile phones contained EC presenting a radiation induced signal detectable by OSL and about 85% of mobile phones presented a detectable radiation induced EPR signal in glass. The detection limit of the OSL signal was lower than 1 Gy, although with some differences, depending on the type of component and on the size and number of components available. The radiation sensitivity was found to be lower for the EPR/glass than for the OSL/EC. For both glass and electronic components the signals were still clearly detectable 10 days after irradiation. In all electronic components a signal loss was observed and the mean value of remnant signal was 50% after 10 days, whereas in most glass samples the signal loss was not detectable or was within the measurement uncertainty. The complementarity of EPR and OSL supports our hypothesis about the advantages offered by using two independent measurement methods. A European intercomparison will be organized through the Eurados network in 2012 in laboratories owning OSL and EPR equipments. This exercise will be aimed at spreading the expertise on these techniques in a laboratory network to develop large-scale capacity of measurement.

P02.31
Development of a Double Dosimetry Algorithm for Assessment of Effective Doses to Staff in Interventional Radiology

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Medical staff involving interventional radiology(IR) procedures are significantly exposed to the scatter radiation because they stand in close proximity to the patient. Since modern IR techniques are often very complicated and require extended operation time, doses to IR workers tend to increase considerably. In general, the personal dose equivalent at 10mm depth, $H_p(10)$, read from one dosimeter worn on the trunk of a radiation worker is assumed to be a good estimate of the effective dose and compared to the dose limits for regulatory compliance. This assumption is based on the exposure conditions that the radiation field is broad and rather homogeneous. However, IR workers usually wear protective clothing like lead aprons and thyroid shield which allow part of the body being exposed to much higher doses. To solve this problem, i.e. to adequately estimate the effective doses of IR workers, use of double dosimeters, one under the apron and one over the apron where unshielded part of the body exposed, was recommended. Several algorithms on the interpretation of the two dosimeter readings have been proposed. However, the dosimeter weighting factors applied to the algorithm differ significantly, which quests a question on the reliability of the algorithm. Moreover, there are some changes in the process of calculating the effective dose in the 2007 recommendations of the International Commission on Radiological Protection(ICRP); changes in the radiation weighting factors, tissue weighting factors and the computational reference phantoms. Therefore, this study attempts to set a new algorithm for interpreting two dosimeter readings to provide a proper estimate of the effective dose for IR workers, incorporating those changes in definition of effective dose.

The effective doses were estimated using Monte Carlo simulations for various practical conditions based on the voxel reference phantom and the new tissue weighting factors. For the most common cases of under-couch beam projection, the proposed algorithm is given by $E=0.80(0.80)H_u+0.04(0.05)H_o$, where $E$is the effective dose, H_u the personal dose equivalent under the apron and Ho over the apron(on collar). The weighting factors in parenthesis are for the case of no thyroid shield. In overall including other projection conditions, the double dosimeter algorithms proposed in this study showed capacity of providing satisfactory estimates of the effective dose within a factor of 0.97 to 1.97.

P02.32
Patient Dose Research in Interventional Radiology Suites in Rio de Janeiro, Brazil

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Fluoroscopy-guided interventional procedures offer a large number of benefits. However, these procedures contribute significantly to patient exposure. In interventional procedures, patient dose is difficult to assess for several reasons. Examinations are dynamic, with many variable parameters: X-ray field size, angle of incidence of the beam, magnification, beam quality, focus-skin distance, irradiation time, etc. One method to perform patient dosimetry is to measure kerma-area product (P_{KA}). This quantity is related to the total amount of imparted energy to the patient. The objective of this study was to quantify the radiation exposure of the patient by measuring P_{KA} in interventional procedures performed in catheterization rooms in Rio de Janeiro.

Data were obtained in four hospitals from a sample of 318 patients undergoing interventional procedures, divided in 202 coronary angiography (CA), 80 percutaneous coronary angioplasties (PTCA), 14 (CA+PTCA) and 22 electrophysiological studies (EE). In our country, the measurement of P_{KA} is not mandatory and many X-ray equipment does not have incorporated P_{KA} meters. On some devices the geometry of the head of the X-ray tube does not allow the direct placement of an ionization chamber at the exit of the collimation system. For these reasons, it was necessary to design PMMA supports for each equipment in order to attach the P_{KA} ionization camera without hinder the movement of the C arm. This paper presents different supports as a solution to cases where the PKA meter is not incorporated to the equipment.

The following results were obtained (median, third quartile for P_{KA} and third quartile for total irradiation time):

For CA, 10941 cGy.cm^2, 5143 cGy.cm^2; 7.6min.

For PTCA, 7688.5 cGy.cm^2, 10779.5 cGy.cm^2; 17.1min.

For CA+PTCA, 10557 cGy.cm^2, 15706.5 cGy.cm^2; 15.4min.

For EE, 42575 cGy.cm^2, 62586.5 cGy.cm^2; 30.6min.

Results were compared with data from literature. The relationship of P_{KA} with number of images, fluoroscopy time, total irradiation time and patient's weight was also studied.

The obtained values are considered high. Consequently, optimization strategies for practices are proposed owing to improve the radiological protection of patients in interventional procedures. A project to involve the interventional cardiology societies and health agencies is being developed to enhance the effectiveness of the optimization process. We intend to continue the survey in a significant number of hospitals to establish diagnostic reference levels for interventional cardiology.

P02.33
Radiation Dose To The Eyes Of Readers At The Least Distance Of Distinct Vision For Normal Eye From Nigerian Newspapers

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This work reports the measurements of the radionuclide contents in some widely read daily newspapers published in Nigeria, using gamma spectrometry. The radionuclides detected in the newspapers measured consisted of the natural radionuclides belonging to the series headed by U-238 and Th-232 as well as the singly occurring radionuclide K-40. The mean activity concentrations obtained for ^{40}K, ^{226}Ra and ^{228}Ra respectively in the newspapers were 183.41, 9.06 and 6.11 Bqkg-1, 139.10, 7.58 and 5.29 $Bqkg^{-1}$ and 152.10, 9.62 and 5.76 $Bqkg^{-1}$ respectively. The doses to the eyes due to the measured activity concentrations in the newspaper samples were determined for a distance of 0.25 m (least distance of distinct vision for normal eye) from the eyes. The annual effective doses to the eye resulting from the activities of the radionuclides identified with observed regularity in all the newspaper samples, obtained in this study are 0.0116±0.0100, 0.0093±0.0090, 0.0091±0.0089 $\mu Sv\ y^{-1}$ respectively for the newspapers. These values are lower than the annual dose limit of 15 $mSv\ y^{-1}$ to the lens of the eye.

Key words: newspapers, least distance of distinct vision, effective dose, eyes.

P02.34
Study Of Different PADC Materials With Regard To Sensitivity And Background

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The major problem in routine application of solid state neutron track dosimetry with PADC material has been the batch-to-batch and even sheet-to-sheet variability in both sensitivity and background. Of particular importance has been the problem of occasional large variance of mean sheet background and other properties such as fading and aging. With the availability of a microscope based automatic scanning system (TASL scanning system) [1] the characterizing of tracks became more comprehensive and the analysis more stringent. By using several specific track characteristics such as size, shape and optical density and their distributions and by comparing them with the distributions of a reference set the discrimination of background tracks or noise can be improved. The influence of material inhomogeneities should no longer be a problem. The goal of the present study was two folded. On one side the performance of the TASL track analysis system regarding the latter described problem was tested using three different PADC materials. And on the other side the variability in both sensitivity and background was compared between three different PADC materials and between different sheets of the same material. The PADC used for the tests has been produced by Thermo Electron (USA), Track Analysis System Limited (UK) and Chiyoda Technol Corporation (J). For each manufacturer three sheets have been employed: all the detectors of one sheet and half of the detectors of a second sheet have been irradiated at 3 mSv Hp(10) with an ^{241}Am-Be source at PSI; the remaining half of the second sheet and all the detector of a third sheet haven't bee irradiated. For each sheet the value of the average background signal, the average neutron sensitivity and the minimum detectable dose equivalent have been determined. All detectors have been processed according to an identical etch procedure and have been analyzed with TASL scanning system.

[1] A high sensitivity neutron and radon dosimetry system. Radiat. Prot. Dosim. (2011)

P02.35
Comparison of Passive and Active Neutron Dosemeter Measurements around a Spent Fuel Cask

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Radiation protection around a spent fuel cask presents a metrological challenge due to the presence of an inhomogeneous mixed radiation field of neutrons and photons. In particular, the neutron spectra of such fields strongly depend on the measurement position with respect to the radioactive content and the shielding of the cask. The energy range of neutrons can vary from thermal to several MeV.

An intercomparison of the response of different neutron detectors was performed in several measurement positions around a spent fuel cask filled with 4 MOX and 8 UO_2 15x15 PWR fuel assemblies at the nuclear power plant Gösgen (KKG) in Switzerland. The instruments used in the study were active and passive neutron detectors calibrated either for ambient or personal dose equivalent.

The aims of the measurement campaign were to compare the responses of the radiation instruments and to study the ratio between the results of the measurements taken in contact with the cask and the personal doses, which persons would receive standing at a distance of 0.5 m.

It has been shown that the indications of the neutron detectors are dependent on the neutron spectra due to their different energy responses and the spectra seem to vary around the cask. However, it has been shown that the routinely used active detectors are reliable instruments and taking into account the measurement uncertainties they deliver conservative measurement results.

P02.36
Neutron dosimetry around GUINEVERE

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The GUINEVERE-project consists out of the nuclear research reactor VENUS, which is modified to a fast reactor configuration, coupled to the GENEPI-3C accelerator resulting in an ADS (Accelarator Driven System) configuration. This facility allows online reactivity monitoring and subcritical level determination in Accelerator Driven Systems. In nuclear reactors, similar to this one, there is a possibility of a non-negligible dose to employees originating from neutrons.

The aim of this study is to characterize the neutron fields around the VENUS reactor and the GENEPI-3C accelerator and achieve a reference value for the neutron dose in different locations around the GUINEVERE facility.

A major concern with neutron dosimetry is the energy dependency. Since the neutron dose is strongly dependent on the neutron energy, a change in the energy spectrum will result in a fluctuation of the neutron dose. Neutron dosemeters are constructed to have an energy response similar to the energy dependency of the neutron dose. This approach however is never perfect which can result in an over- or underestimation of the neutron dose, depending on the neutron field where the measurement has taken place. Through characterisation of the neutron field, the measured values can be corrected, taking into account the specifications of the neutron field and the energy dependency of the detector.

Next to the energy dependency, neutron doses also depend on the angular distribution of the neutron field. In order to measure the angular distribution, personal monitors are placed in different orientations on a slab phantom. To take into account the angular response of the dosemeters, characterization of these dosemeters is performed in a well-defined ^{252}Cf field. Previous studies have already achieved reliable results for the angular response up till 75° with steps of 15°, this will now be extended for 90° and 180°. This characterization will lead to a better dose estimation, since dosemeters will be placed on the front, back, left, right, top and bottom of the slab phantom to estimate the angular distribution. The measurements around the GUINEVERE facility will allow to define field specific correction factors for the electronic personal dosimeters, making it possible to perform routine dosimetry around the facility.

P02.37
Analysis of Photon Energy Distribution at the Working Places in Nuclear Power Plants and Application to Lead Vest Shielding

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Radiation field information in nuclear power plants should be provided for optimal job planning and worker's dose management. It can be categorized with radiation type, incident direction, energy distribution and dose rate for external exposures. Survey meters and multiple personal dosimeters are used to obtain the information but the energy distribution analysis is not generally carried out. Photon energy distribution information can be used to design proper shielding for high dose jobs or to reconstruct worker's organ specific doses.

Working places for photon energy distribution measurements were selected by high collective dose jobs in PWRs during refueling outage periods. A portable NaI scintillation counter was used with Monte Carlo calculation based in-situ calibration methods. The measured photon energies were applied to dose reduction effect of various types of workers lead vests using a mathematical phantom with Monte Carlo calculations.

Results showed that mean photon energies were about 0.2 to 0.6 MeV. For all working places, the mean photon energy was lower than the standard photon energy for personal dosimeter calibration. Also, the radiation doses to the worker with lead vest were much lower than estimated doses by a normal standard mono energy photon.

Measured photon energy distribution information will be applied to radiation protection optimization and organ dose reconstructions for radiation induced cancers of workers in nuclear power plants.

P02.38
Personal Dosimetry Management A Nuclear Industry Good Practice Guide

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Have you ever wondered how dosimetry aspects should be managed at a typical UK Nuclear Licensed Site?

In 2008 the Nuclear Industry Safety Directors Forum (SDF) requested that the Industry Radiological Protection Co-ordination Group (IRPCG) review the Dosimetry arrangements within the UK Nuclear Industry. The IRPCG established that although there was generally acceptable practice it was not consistent and it was not clear what constituted industry good practice.

As a direct result, the IRPCG set up a sub-group consisting of relevant experts from member organisations with the objective to *'Develop and make available to the Nuclear Industry a Dosimetry Management Good Practice Guide (GPG)'*. The GPG aims to describe the provision of dosimetry services and management from the perspective of the nuclear industry radiation employers responsibilities with regards to establishing, meeting and providing the employers dosimetry arrangements. It is directly applicable to the design, development and implementation of nuclear site and radiation employer dosimetry management and provision and will be of use to employer's duty holders such as Radiation Protection Advisers, Health Physicists and Dosimetry Staff

The GPG details the principles and practices that are considered to be nuclear industry good practice with regards to personal dosimetry management and dosimetry provision to the employer. It describes the various aspects of good practice including systems, processes and arrangements.

Ultimately the guide provides answers to the question 'how dosimetry should be managed at a typical UK Nuclear Licensed Site?'

P02.39
Preliminary Study of Dose Estimation Using Fingernail/EPR and OSL Method

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EPR (electron paramagnetic resonance) and OSL (optically stimulated luminescence) are well known dosimetry method using a part of human body and personal belongings like nails, teeth, business card and mobile phone. In emergency situation related radiation, interested exposure dose is at least 1 Gy that is clinically meaningful dose level for medical purpose. For the purpose, fingernail is regarded as good object for dosimetry, because of its easiness for collection and high yield rate of radical when exposed to ionising radiation. EPR dosimetry using fingernail was tested for dose range at relatively low dose range. Several sample clippings was chosen to be used simultaneously by EPR and OSL dosimetry method. Using blue LED (470 nm) optical stimulation, several properties of fingernail were investigated for using fingernail as dosimetric sample. Initial native signal was not exist and sensitivity on radiation dose was good to be detected by OSL system. Minimum measurable dose ranged from 0.1 Gy in case of OSL dosimetry. Dose-response curve was linear for doses until 10 Gy. Fading of fingernail /OSL signal was different for the situation and samples, but at most fading time can be estimated as 2 hours after irradiation at room temperature and humidity. EPR dosimetry was only meaningful at dose range from 3 Gy to 10 Gy. Because noise signal from cutting process interfere radiation induced signal at all time, exact estimation of radiation induced intensity of signal is almost impossible at relatively low dose range. Also, the difference of individual fingernail sample, moisture level or integrity of structure, caused much big variability for estimation. Using these two dosimetry methods at the same time maybe allow us to approach accurate absorbed dose in the future. Complement by another method using same sample can be helpful to estimate dose quantity.

KEYWORDS: EPR; OSL; fingernail; dosimetry; radiation; emergency dosimetry

P02.40
Dose Conversion Coefficients for Pediatric CT Body Procedures based on Specific Sizes: Optimizing Radiation Protection of Saudi Children

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Pediatric CT procedures in Kingdom of Saudi Arabia constitute about 20 to 30% of the total procedures. Each CT facility follows specific protocols based on weight and other parameters which may differ from center to center. The aim of this study is to determine normalized dose conversion coefficients for pediatric CT procedures of Saudi children based on the recommendations in AAPM report 204. It also aims to develop a CT dose calculator to estimate pediatric doses. Radiation doses to 340 pediatric patients for chest, abdomen and pelvis CT procedures were investigated in three (3) large medical centres. The pediatric patients were grouped into age groups 0, 1, 5 and 10. The mean effective dose for each age group was evaluted using the Impact dose calculator and the $CTDI_{vol}$, DLP and exposure parameters (peak kilovoltage, mA, rotation time, slice thickness, pitch and total scan time). The equivalent cylindrical diameter (ECD) was determined to estimate the standard patient diameter for each age group using the height and weigth data of about 1,040 patients. The normalized conversion coeffcients for effective doses for each machine brand per cylindrical diameter were deteminded and plotted for curve fitting (r = 0.96). The mean effective doses can vary from 15 to 44 % from center to center. Data shows that normalized dose conversion coeffcients for chest vary from about 10 to 25% for different effective cylindrical diameters. A CT dose calculator for effective dose estimation when the weight, height or BMI data is available will provide information help in optimization of protection.

P02.41
Risk of Radiation Exposure of the Lens of the Eye for Members of the Public

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In its statement on tissue reactions approved on April 21, 2011, the International Commission on Radiological Protection (ICRP) has reviewed its recommendation about the equivalent dose limit for the lens of the eye. The new recommendation is then: "For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv". ICRP Statement does not contain any explicit recommendation regarding the organ dose limit for the lens of the eye for public exposure which is interpreted as no change being proposed.

In the general ICRP approach, the current equivalent dose limit for the public is ten times lower than for occupational exposure. Thus, no reduction of the limit for the public may question the coherence of the overall approach. In this context, additional data on potential scenarii for public exposure of the lens of the eye is needed. In particular, potential situations where planned exposure situations can lead to exposures exceeding 1 mSv/year for the lens of the eye should be explored.

This paper, based on a bibliographic study aims at providing, as far as possible, an exhaustive list of the situations in which members of the public are exposed to potential dose to the lens of the eye. Once these situations have been defined (in terms of nuclides, activities, occurrence, etc.), a summary of existing studies giving estimates of doses to the lens of the eye is presented, completed by IRSN calculations. The situations for workers or patients are not in the scope of this study.

This bibliography study did not reveal any current situations where members of the public would be able to receive significant radiation dose to the lens of the eye. The very few existing situations for which the dose to the lens of the eye might reach about 1 mSv are exotic ones.

P02.42
Retrospective Dose Reconstruction Using Household Salt

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In the event of large scale radiation accidents or malevolent acts with radioactive materials, non-invasive and sufficiently accurate retrospective dosimetry methods are necessary for fast triage and quantitative dose estimate of the stricken individuals. NaCl in form of household salt is a cheap and widely available material. This study investigated the potential of household salt for purposes of retrospective and accident dosimetry using optically stimulated luminescence (OSL). Attention was concentrated on sensitivity and background signal, minimum detectable dose, dose and energy dependence of the OSL signal, fading, optimisation of the OSL read-out procedure and application of analytical protocols which do not require a specific calibration. A potential of NaCl as a neutron activation dosemeter was considered also. The behaviour of the OSL signal observed was found to be favourable for dosimetry.

P02.43
Application of in-situ gamma-ray spectrometry to assess the concentrations of 40K, 238U and 232Th and mean annual effective dose rate levels in the several United Arab Emirates cities.

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A rapid *in-situ* gamma-ray spectroscopy method was employed for assessing radiation activity and detecting changes in environmental radioactivity in 35 locations in various United Arab Emirates (UAE) cities. These values were then used to calculate the natural gamma radiation dose levels in these cities. A 76 mm x76 mm NaI(Tl) detector, with a resolution of 8% at the 0662 MeV line of Cs 137, was placed 1 m above the ground and the tested locations were selected so that they cover the different geology of the UAE terrain.

The collected spectra then analyzed and the results show a noticeable variations in the total counts per second for the selected sites, with sites near the coastal cities showed lower cps rates. The total air absorbed dose rate was then calculated using standard models, which take into account the contribution due to activity concentrations of ^{40}K, ^{238}U and ^{232}Th in Bq kg^{-1}. The results indicate that the values of terrestrial gamma radiation dose rate measured ranged between 11 and 325 nGy h^{-1}. The corresponding dose equivalent was also calculated. These results, which are the first in the UAE, are comparable to values reported in the literature for Saudi cities.

P02.44
Assessment of Occupational Dose Records in a Radiopharmaceutical Facility

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Routine monitoring of occupational radiation exposure is associated with the continuing operations and is intended to demonstrate that the working conditions remain satisfactory and in compliance with dose limits. Statistical analysis of past and present dose records provides a useful tool in the management of institutional radiation safety programs. In this context, the aim of this paper is to carry out a retrospective study of occupational doses from radiopharmaceutical production facility. The trends are analyzed and presented over the 20 years period from 1991 to 2010. A total of 2455 annual individual dose records were evaluated and the characteristics of dose distribution were estimated on the basis of the average annual effective dose, the annual collective effective, measurable dose and the number of monitored workers for each dose interval. Several doses ranges (mSv), were considered taking into account some flexibility, such as: 0-2.4; >2.4–5; >5–10; >10–15; >15–20; >20 mSv, in order to get information that best conveys the impact of the practices undertaken in a Brazilian Radiopharmaceutical Production Facility. The average annual effective dose of all monitored workers during the period studied ranged from 2.58 to 7.38 mSv. The results showed that there is a wide variation in the average annual effective dose among the workforce. The fraction of the workers monitored with annual effective dose greater than 2.4 mSv corresponding about 34% although it was observed a significant impact on the total collective dose and its contribution was accounted for over 50%. However, the levels of individual dose remained satisfactory and are in compliance with national regulatory requirements.

P02.45
Trends in Occupational Exposure at Different Practices in a Nuclear Facility

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The Nuclear and Energy Research Institute State of São Paulo, Brazil, IPEN is recognized as a national leader institution in research and development in the areas of radiopharmaceuticals, industrial applications of radiation, basic nuclear research, nuclear reactor operation and nuclear applications, and others sources. IPEN has a rigorous program of radiological control and nuclear safety for the activities related to nuclear and radiological aspects. This program comprises personal and environmental monitoring and radiological emergency assistance. The goal of the occupational safety and health programs is to foster a safe work environment, and also a protection of the public who may be impacted by the workplace environment. For this purpose, the aim of this study was to provide information about the level of occupational exposure arising in different practices in the institution. The trends are analyzed and presented, over 10 years period from 2001 to 2010. The data analysis was based on the records of the radioprotection service and analysis of trends of annual effective dose, numbers of monitored workers and percentage of measurably exposed workers. Most of the dose comes from external exposures and the greatest contribution to the occupational exposure comes from radiopharmaceutical and cyclotron facility. The average annual effective dose for workers involved in these practices was 3.3 mSv over time. In addition, the direct environmental gamma radiation levels near the nuclear and radioactive IPEN facilities, assessed with thermoluminescent dosimeters during the last ten years, presented a mean value of 1.5 $mSv.y^{-1}$. In summary, the monitoring practice is such that more workers are individually monitored than is strictly necessary to meet regulatory requirements, with the consequence that only a fraction of 4% those monitored received measurable doses.

P02.46
Estimation of Whole Body Effective Dose in the Cardiac Catheter Laboratory: An Intercomparison of Currently Recommended Monitoring Strategies

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The use of ionising radiation in Cardiology for diagnostic and interventional studies provides some of the highest occupational risks encountered in diagnostic radiology. An important dose quantity that must be measured within a personal monitoring programme is that of effective dose.

In the UK the most widely adopted approach for the assessment of occupational effective dose is through the provision of a single whole body badge worn on the trunk underneath a suitable lead apron. However in ICRP report 85 (Avoidance of Radiation Injuries from Medical Interventional Procedures) and in a current draft ICRP report (Patients and Staff Radiology Protection in Cardiology), ICRP recommends that two personal dosimeters should be provided for occupational dosimetry in Interventional and Cardiac fluoroscopy procedures.

In this study several Cardiologists working in local catheter laboratories were provided with double monitoring in accordance with ICRP recommendations. The monitoring devices provided included traditional passive monitors in the form of conventional film dosimeters, TLDs and state of the art active monitoring devices. In total 6 devices were provided to each wearer over a 4 month monitoring period. In this paper the following comparisons and analyses have been made:

• Comparison of effective doses derived from double dose monitoring and the single dosimeter approach.

• Comparison of double dose monitoring effective doses and the effective dose derived from a single collar badge employing the following equation employed in NCRP report 122.

$E = H_n/21$

• Intercomparison of derived effective doses provided by different types of measurement device.

• Estimates of the annual effective dose and associated risks for the exposed group employing double dose monitoring.

P02.47
Study of Radon Exhalation Rate from Soil and Rock Samples and Gamma Exposure rate in Chamaraja Nagar District, India

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Terrestrial radiation is due to radioactive nuclides present in varying amounts in soil, building materials, water, rocks and atmosphere. The most commonly encountered radio nuclides inside earth are ^{238}U, ^{232}Th, their decay products and ^{40}K. Radon isotopes are decay products of radium isotopes in the uranium and thorium decay series. As an inert gas, radon can diffuse through the soil and enter the atmosphere. ^{222}Rn exhaled from soil into the atmospheric air depends on radium content in the soil and other environmental parameters viz. soil moisture, pore spaces, temperature, relative humidity and atmospheric pressure. The correlation between the radon exhalation rate from soil samples measured in the laboratory and from the ground surface is not fully understood. The assessment of gamma radiation dose and the study of radon exhalation rate from natural sources are of particular interest as natural radiation is the largest contributor to external dose of the population.

The Study area Chamaraja Nagar District, Karnataka State, India. Geologically it is covered by the rocks of Archean age i.e., granite, gneiss and schistose rock. They comprise essentially gray to pink granite gneisses. Measurements of natural radiation were made in few schools, temples and hill stations of Chamaraja Nagar District by using Environmental Dosimeter. Radon exhalation rate and radium concentration from the soil and rock samples collected from different villages of Chamaraja Nagara district were estimated employing “Can Technique” using solid state nuclear track detectors (LR-115 type II).

The absorbed dose rate due to background radiations in indoor varies from 69.6 to 301.02 $nGyh^{-1}$ with a median of 138.7 $nGyh^{-1}$ and in outdoor it varies from 78.3 to 244.5 $nGyh^{-1}$ with a median of 120.1$nGyh^{-1}$. The mass exhalation rate of radon in soil samples has been found to vary from 0.002 to 3.28 $mBqkg^{-1}h^{-1}$ with an average value of 0.38 (± 0.19) $mBqkg^{-1}h-1$.The surface exhalation rate of radon 0.003 to 1.65 $mBqm^{-2}h^{-1}$ with an average value of 0.26 (± 0.16) $mBqm^{-2}h^{-1}$. Radium concentration in soil and rock samples has been found to vary from 0.15 to 28.13 $mBqkg^{-1}h^{-1}$ with an average value of 8.10 $mBqkg^{-1}h^{-1}$.

P02.48
Population Doses from Medical Diagnostic X-ray Exposure in Belgium

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Introduction An analysis was made by the Federal Agency for Nuclear Control of the annual population dose from medical diagnostic X-ray applications in Belgium. Monitoring the exposure of the population per caput and on a collective scale allows identifying trends and comparison to other sources of exposure to ionizing radiation. Materials & Methods: The analysis was based on data frequencies from the National Institute for Health and Disability Insurance for 2008. Because of the limitative nature of the data on frequencies, the evaluation did not include an estimation of the population dose to examinations in nuclear medicine and radiotherapy. The effective doses per type of examination were derived from different sources, such as the UNSCEAR reports, with representative estimates from studies in patient dosimetry carried out by the Federal Agency for Nuclear Control.

Results: The annual per caput effective dose for Belgium was estimated 2,3 mSv, accounting for more than 22 000 manSv. CT accounts for 12 % of the diagnostic procedures, representing 66% of the population dose from medical diagnostic X-ray applications. Dental X-ray procedures accounts for 23 % of the diagnostic procedures, with more than 3,5 M procedures each year, and merely represents less than 1 % of the population dose.

Discussion & Conclusion: The Belgian population dose from medical exposure is high in comparison with neighboring countries. The total number of x-ray examinations per 1000 caput is at the high end in comparison with other European countries, but in line with some neighboring countries. Although the individual doses to the patient are generally ALARA, the annual per caput effective dose is rather high and consistent with the existing fact that Belgium is a high consumer of medical imaging procedures. These trends cannot be ignored an urge the medical sector to invest in qualitative care with guarantees to the justification and optimization of the doses to the patient.

Limitations of the study: Although the data on frequencies assume to cover 100 % of the medical examinations, a number of examinations are not included into the health care reimbursement system in Belgium (e.g. medico-legal examinations). The national codes for health care reimbursement do not always allow a specific estimation of effective dose per examination. The use of effective dose and collective brings a lot of uncertainties and assumptions into the estimation. The exposure to ionizing radiation from medical applications is only on a limited profile within the general population, with specific anatomic regions being exposed. Risk analysis and radiation management of medical exposure should be adapted to these considerations.

P02.49
A Discussion on the Number of Age-specific Phantoms Practically Needed for External Exposure to Gamma rays

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The cohort of the atomic bomb survivors of Hiroshima and Nagasaki comprises the major basis for investigations of health effects induced by ionizing radiation in humans. To estimate the risk due to radiation exposure, organ and tissue doses must be determined. It is well known that organ doses are dependent on the energy spectrum and angular distribution of the incident radiation and the orientation of the body in the radiation field. The organ doses are also dependent on the characteristics of the human body that subject to considerable variations between individuals depending on sex, age, body weight and height. Since organ doses cannot be measured directly, determination of organ doses is a complex problem that can be approximately resolved by computational approaches involving human phantoms and the Monte-Carlo method.

Three age-specific phantoms (infant, child and adult) are used in the current Dosimetry System 2002 (DS02) in organ dose calculations for atomic bomb survivors. The need of more age-specific phantoms was identified at a RERF workshop in 2011. The DS02 calculates doses for fifteen organs. With age-specific fluence-to-organ dose conversion coefficients derived from voxel phantoms, organ doses are calculated from the total gamma-ray free-in-air fluences at 1 m above ground for individuals of different ages at 500m, 1500m and 2500m from the hypocenter in Hiroshima. Based on the percentage changes in organ doses with age, a discussion is given for the number of age-specific phantoms practically needed for external exposure to gamma rays in DS02.

P02.50
CT Patient Dose Monitoring Using Radiochromic Dosimeters

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With the increased concern of radiation exposure received by patients undergoing medical exams, especially computerized tomography (CT), methods to quickly and economically estimate the dose received by the patient have become a critical issue. Radiochromic film requires no chemical processing and can be read in visible light. Improvements in the stability and dynamic range of radiochromic film have led to its use in a wide variety of medical physics quality assurance applications and in estimating skin doses from various procedures.

A new radiochromic film dosimeter, RADView™ CT, developed by International Specialty Products, was used to measure exposure from commonly ordered CT scans at our facility. The dosimeter is a flexible card with five circular windows through which the active element is viewed. Printed color patches surrounding each window provide a reference for estimating the exposure. The color patches are printed to match doses of approximately 0.5, 1, 2, 5 and 10 rad. After exposure, the color of the active element in the window is visually compared to the reference colors and the dose is estimated by interpolation.

The CT studies chosen for this evaluation were of the head, abdomen, brain, pelvis, liver (4 phase), and excretory urograph (exu). Five dosimeters were used for each type of study. To validate the dose observed on the RADView™ CT card, two LiF100 TLD chipstrate dosimeters were placed on each side of the card.

After each CT procedure, the dosimeters were independently read by four medical physicists at our facility. In addition to visual dose estimation, the darkening on the RADView™ CT dosimeters was measured with an EPSON 10000XL photo scanner calibrated to reference dose film strips.

The visual assessment of dose for the five dosimeters used in each CT procedure ranged from -15% (under estimate) to 28% (over estimate) when compared to the calibrated scanner results for a head CT, -16% to 5% for an abdominal CT, 11% to 32% for a pelvic CT, 4% to 23% for a liver (4 phase) CT, and, -17% to 4% for an exu CT. Results could not be obtained for the brain perfusion CT since they exceeded the upper dose range of the dosimeter film used in this study. When calibrated scanner results were compared with raw TLD data, good agreement, within 15%, was obtained for all dosimeters within the dose range of the radiochromic film.

In conclusion, the radiochromic film dosimeters used in this study provided a good first approximation of skin dose to patients undergoing high volume CT procedures at our institution. The doses recorded by the exposed dosimeters were quickly estimated with good accuracy compared to quantitative measurements. It would be helpful to extend the sensitivity range of the tested dosimeter to include higher doses typical for CT perfusion studies.

P02.51
Patient Dose Assessments in Diagnostic Radiology Employing Electronic Examination Records

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In 1956 a study group of ICRP and ICRU established by UNSCEAR rejected the universal recording of doses from diagnostic radiology for the entire population due to:

- Excessive cost
- Difficulty in obtaining dose values
- Assessment and management of resulting data

Given the technical advances that have taken place in the intervening period the time is now ripe to re-evaluate the feasibility of undertaking patient dose assessments for the whole patient population as a routine aspect of an x-ray examination protocol This paper will describe methods for undertaking patient dose assessments for every x-ray examination by employing information available from electronic patient examination records. The system that has been developed employs electronic examination records either from a hospital's Radiology Information System (RIS) or from PACs by means of DICOM header examination details included within the digital image data set. This information can be combined with x-ray tube and generator calibration data already collected as part of Type A quality assurance measurements in order to calculate the Entrance Surface Dose (ESD) for radiography. For Direct Digital Imaging (DDI) the DICOM header includes the appropriate DAP value and for CT the examination DLP.

Results of large scale patient dose assessment programmes will be presented for different hospital sites and x-ray examinations, including CT, over an extended period of time by means of both methods. Results from each approach will be compared and their potential role in the optimisation process, including the establishment of Local Dose Reference Levels (LDRLs) will be discussed. Mechanisms for centralised data processing and analysis of this type of data will be presented.

P02.52
Occupational Dosimetry During Intra-Procedure Placement And Removal Of Ru106 Brachytherapy Sources For The Treatment Of Choroidal Melanoma

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Background: Serving local, regional and national populations, typically 123 patients per annum are treated for choroidal melanoma using Ru106 brachytherapy sources in our trust.

Dose rates in excess of 100mGy/min in close proximity (0.6mm) from the centre of the treatment surface are quoted by the source manufacturer and supported by independent calibration at the National Physical Laboratory (Teddington, UK). To minimise operator dose, a non-radioactive sterile plastic plaque is used for alignment purposed prior to introduction of the brachytherapy source.

Methods: Occupational dosimetry is recorded using a combination of Thermo Luminescent and Film Badge dosimeters for specific operators and specific roles where staff rotation is utilised. In addition to regular staff monitoring, radiation dose surveys were carried out intra-procedure as part of a risk assessment review.

Results: Results from the Approved Dosimetry Service recorded 2011 annual equivalent doses of 1.15mSv(left) and 2.20mSv(right) to the surgeons' upper extremities and whole body effective doses of 0.0 mSv. Occupational doses to nursing, anaesthetist and support staff are also monitored.

The dose survey estimated a cumulative extremity equivalent dose of 57 µSv for insertion (7µSv) and removal (50µSv) of a 22.7MBq 20mm diameter Ru106 plaque.

A small less radioactive (4.8MBq) 15mm diameter plaque is estimated to deliver an extremity equivalent dose of 23µSv for insertion and removal.

Conclusion: Summated doses for the surgeon sub-group exceeded the Local Investigation Level of 2mSv/year defined in the Local Rules and therefore underlines the necessity to involve multiple operators to reduce the dose of ionising radiation to any one employee.

Our results show that a large throughput of patients can be treated for choroidal melanomas whilst maintaining a Local Investigation Levels of 50mSv (extremities) and 2mSv (whole body) for any one individual employee.

P02.53
Type Testing Of A Harshaw™ Ext-Rad Extremity Dosemeter With PTFE Filter For Measuring Dose To The Lens Of The Eye In Terms Of Hp(3)

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Introduction: This paper describes the Type testing of a headband eye dosemeter that measures $H_p(3)$ using LiF:Mg,Cu,P and a tissue equivalent filter.

The UK Health Protection Agency uses Harshaw™ whole-body and extremity TLDs, all of which use Harshaw™ high-sensitivity lithium fluoride, LiF:Mg,Cu,P (the neutron-insensitive variety, known as TLD-700H), together with Harshaw 8800™ automated readers. This material has a higher sensitivity and improved tissue-equivalence over LiF:Mg,Ti. The extremity finger stall is of a design developed by UK dosimetry services in collaboration with Thermo Electron (now ThermoFisher Scientific) and TLD Sachets UK. The finger stall uses the Harshaw™ EXTRAD TLD element covered by aluminised polyester at 3.2mg cm−2. HPA has now developed an eye dosemeter based on similar principles.

Due to evidence that cataracts can be induced by ionising radiation at dose levels lower than previously thought, protection measures have to be optimised and dose limits for the lens of the eye are expected to be lowered to 20 mSv in the future. It is therefore envisaged that more people will need an approved eye lens dosemeter.

HPA has approval to use its body TLD as an eye dosemeter for photons only. The TLD is worn on the collar. It does not measure $H_p(3)$ directly but uses an average of the H_p (0.07) and $H_p(10)$ readings. Simple headbands that measure $H_p(0.07)$ are used by some of HPA's customers, for category B (unclassified) workers, but these have no filtration and over-respond in terms of $H_p(3)$ for betas. They are not an approved dosemeter.

The new design of eye dosemeter is based on modified headband, using the Harshaw™ EXTRAD TLD element with a PTFE filter of a tissue equivalent thickness of 3mm, so enabling the measurement of $H_p(3)$.

The tests were based on the ISO 12794[7] standard and included energy and angular dependence of response for photons and betas. All were done on the proposed ORAMED cylindrical head phantom.

Results: The results show that this eye lens dosemeter fulfils all the criteria needed to pass the type test and subsequent approval for use.

Conclusion: This headband using the Harshaw™ EXTRAD TLD element with a PTFE filter of a tissue equivalent of 3mm would be suitable to use in the HPA's approved dosimetry service.

P02.54
Patient Organ Dose From CT Scan Examinations In Elven State Owned Hospitals Of Khorasan Province-Iran

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CT is a high dose technique; it involves higher patient doses than most conventional X-ray examinations. It is very important that CT exposure parameters are optimized and ALARA principle is observed, however high image quality is maintained. A complementary approach to the in-air or in phantom measurements is to measure ESD by TL dosimeters. In this study we have investigated radiation exposure of 370 patients at 11 hospitals. Organ and effective doses were estimated for all patients who underwent CT examination of brain by ImPACT software. ESD of same patients were measured by TLD-100. Brain examinations were performed with fixed kV, mA and T for all scanners. Patients who were scanned by Toshiba Xvision/EX, received maximum organ dose (brain) equal to 47 mGy, minimum organ dose of 12.7 mGy was delivered to patients who were scanned by GE HiLight. Our average effective dose (0.85 ± 0.23 mSv) is smaller than the corresponding value (1.81 ± 0.24 mSv) reported by NRPB. Scanning by Toshiba XVID gave rise to maximum ESD (29.8 mGy). On the other hand minimum ESD (5.65 mGy) was achieved when patients were scanned by CE HiLight machine. The dosimetric quantities presented in this study provide a valuable tool for the optimization of Head CT protocols in the region. The radiation dose to a particular organ from any given CT test depends on: number of scans, mAs, patient's size, axial scan range, scan pitch, kVp, and scanner design. Many of these factors are controllable.

Key Words: Patient Exposure, ImPACT Calculator, Dose Reduction

P02.55
Enhanced Local Radiation Injury from Encapsulated Sources

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Contact with encapsulated gamma emitting sources can yield significant damage to tissue due to secondary electron emission from the encapsulation. Contact dose rates are important to understand for radiation therapy applications, and also for inadvertent exposure analysis which would require forensic (retrospective) dosimetry estimates. There have been numerous instances over the years where people have been severely injured by handling encapsulated radiation sources. Rapid dose assessment can help guide treatment in the early stages and determine the extent of required resources. Despite the need, there are relatively few published contact dose conversion factors for these sources. Most of the work in this area was performed in the early days of radium therapy, and as such there is a reasonably significant amount of data on encapsulated Ra-226 sources and associated filters. NCRP-40, published in 1972, list contact dose rates for Ra-226, Ir-192, Cs-137 and Co-60 encapsulated sources. The rate for the Ra-226 source was determined from experiment, whereas the others were estimated using theoretical enhancement factors. Coupled photon-electron Monte Carlo calculations were performed to explore the secondary electron contribution from a Ra-226 source using various cladding material, and validation against original work performed by Sievert, Benner and other early researchers in the field. Good agreement was found with the estimated secondary electron production for Ra-226, and similar Monte Carlo simulations were performed for Ir-192, Cs-137 and Co-60. Lower dose conversion factors were found in Monte Carlo simulation versus experimental data, with the greatest implication being that dose estimates based upon historical tabulated values will underestimate risk when related to biological indicators. An expanded catalog of contact dose rate conversion factors for encapsulated sources is presented.

P02.56
Criticality Accident Dosimetry: Harwell experiences with a Criticality Accident Dosimetry User Group

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A criticality accident may lead to an acute (potentially fatal) exposure to radiation. Special dosemeters may be used to assess neutron doses from such an accident. These contain gold, sulphur and indium components which are activated by neutrons and then measured to assess the dose. Additionally, diodes, whose internal properties are affected by fast neutrons, can also be used as a dosemeter. Calculations of dose are complex, so supporting software is essential. In the 1980s the Criticality Accident Dosimetry User Group (CADUG) was established by staff at Harwell, where much of the research and development in this dosimetry was carried out. Group members co-operated by pooling resources and funding development work and intercomparisons. The Approved Dosimetry Service at Harwell has now ceased to provide a criticality dosimetry service. In addition, other parties are now looking after CADUG's interests. It is thus appropriate to review some key accomplishments and consider the future of this dosimetry.

The paper provides a brief overview of criticality accident dosimetry and some of the work carried out by Harwell and CADUG. For example, the developments of dose assessment tools, a dosimetry manual and supporting CRISIS software are described. The paper also shows how a number of (UK and international) intercomparisons and intercalibrations were used to compare the performance of dose assessment techniques. This includes the irradiation of (i) dosemeter components and (ii) a man-sized phantom in a reactor to simulate the exposure of a person during a criticality accident. In the latter, handheld monitors were positioned against the phantom to assess the levels of induced radiation emitted by a person following exposure to a high dose of neutrons. As well as addressing dosimetry issues, the paper discusses some key issues which operational staff may have to address at the scene of an accident such as dealing with activated dosemeters and injured staff.

Finally, the paper provides an overview of issues which need to be considered for the future. For example, can new dosemeters be developed which would avoid the use of activated elements?

P02.57
In situ Measurement of Outdoor Gamma Radiation Level in Redemption Camp, Ogun State, Nigeria

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The knowledge of the level of ionising radiation that the general public is exposed to at any point in time is very important. This knowledge will help in estimating the annual effective dose the general public is exposed to and advising the general public at that area whether to relocate from the area in case of high background radiation level especially, if the area is just growing or to exercise caution in their activities in order not to enhance the radioactivity concentration of the environment. Redemption camp is a growing city hosting the redeemer's university and some small plants like the gas turbine. This present work deals with the outdoor gamma radiation dose in the redemption camp, Ogun state, Nigeria. In situ dose rates were measured at forty-eight (48) locations within the camp using RDS-30 radiation survey meter. The effective dose rates obtained varied between 0.09 to 0.12 μSvh-1 with the annual outdoor effective dose ranging between 0.61 to 0.21mSv. This is below the worldwide annual outdoor effective dose calculated by UNSCEAR (0.41 mSv).

P02.58
Dose Measurements of a Dental CBCT in Comparison with a 4 row MSCT and a Panoramic Device.

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In dental radiology an Alderson-Rando-phantom was used to compare the dose equivalent of a dental CBCT with that of a 4 row MSCT and a panoramic device (PAN).

Several radiosensitive organs were chosen to determine the dose equivalent by means of tissue equivalent LiBO thermoluminescent dosimeters. The phantom was loaded with several TLDs in the head, which were exposed to the radiation beam, as well as with other TLDs, in areas which received stray radiation, i.e. scattered radiation from the phantom itself as well as leakage radiation from the x-ray tube assembly. The irradiated volumes were almost identical in all cases. Further measurements were made using a protective apron to determine the effectiveness of shielding patients.

The dose received by the radiation beam of the CBCT device is about 30% of that received by the MSCT; the dose received by the radiation beam of the panoramic device (PAN) is about 10% of that received by the CBCT. In the areas of stray radiation, i.e. scattered and leakage radiation, the dose received using a panoramic device (PAN) is almost negligible, but this is not the case when using MSCT or CBCT.

The sense of using protective aprons for exposures with a panoramic device (PAN) in dental radiology can be questioned. Nevertheless the psychological effect of safety achieved by shielding a patient should be seen as the highest priority. For exposures with MSCT or CBCT the use of protective aprons is effective and therefore advisable.

P02.59
Exposure Measurements on Portable X-Ray Fluorescence Spectrometers

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Portable X-ray fluorescence (XRF) spectrometers are more and more used for the verification of alloy in metallic materials, heavy metals in plastics and other applications. Documents on portable XRF-spectrometers which have been available up until now show high dose rates at the exit window of the spectrometers. However, these values are often not traceable. There is lack of information in regard to how the values were measured or inadequate electronic measurement equipment was used.
To verify this values the authors measured five portable XRF spectrometers with thermoluminescent dose meters in combination with an Alderson phantom. At operating parameters of 40 kV and 50 µA, for example, an extremely high dose rate of 76 Sv/h in the primary beam had been determined. In recent years, hazards have been underestimated so far. The measurements, the results and the consequences for protection measures will be presented and discussed in the presentation.

P02.60
Dose Estimation of the Radiation Workers in the Cyclotron and PET/CT Center

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Objectives: To measure and evaluate the personal radiation dose for medical stuff working in the Cyclotron and PET/CT center, in order to offer the reference data for clinical radiation protection.

Methods: We monitored the radiation dose level in the workplace and performed radiation dose meter to measure dose rate on 10 medical staff members during each procedures in Cyclotron center and PET/CT department. In this study the actions of each radiation worker were observed and recorded. The assuming annual dose of each member at different working sites were calculated depends on the dose rate, worktime and workload.

Results: The annual dose per procedure per person were: hands 35.0 mSv and whole body 2.5 μSv for dispensation; hands 2.4 μSv and whole body 2.0 μSv for carrying the compound; whole body 0.3 mSv for injection and whole body 0.1 mSv for set the patients for imaging operation.

Conclusions: Under the normal operational conditions, the dose received by staff members do not exceed the annual limit for professional workers that has published as GuoBiao safe standard (GBSS).

Key words: cyclotron; PET; radiation protection; dose estimation

P02.61
Establishment of National Dose Reference Levels (DRLs) for Dental Radiology Practices at the UAE

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1- Background and Objective: To optimize patient radiation safety, international and national organizations endorse the establishment of Diagnostic Reference Levels (DRLs). This study is aiming to evaluate patients' doses incurred during dental radiology examinations in order to introduce UAE dental DRLs.

2- Method: This dental dose survey covered 109 Intra Oral (I.O.) systems (24 Conventional Film Based and 85 Digital units) and 16 Panoramic (OPG) machines. Radiation exposures from I.O. units were measured using UNFORS ThinX Intra and Multi-O-Meter electronic dosimeters. The dose survey for most of the OPG machines was performed using CT Cylindrical Ionization Chamber. The exposures for the I.O. were measured in air at the end of the spacer cone; this estimated as the Patient Entrance Dose (PED) while the exposure for the OPG was measured as the dose at the surface of the image receptor. Exposure parameters implemented in this work were reflecting those used in the clinical situations.

3- Results: The UAE DRLs in this study were based on the third quartile dose values. The results showed that the pediatric PEDs for all views for film based and digital intraoral systems were 2.5 mGy and 0.642 mGy, respectively while those for adults were 3.85 mGy and 0.8 mGy, respectively. PEDs were also evaluated for the common image views in the dental radiology. The OPG 3rd quartile doses were 4.9 mGy and 6.335 mGy for pediatric and adult, respectively. The dental dose ranges for both pediatric and adults showed a significant variation which reflects the variation between different vendors and the diversity in imaging parameters, mainly the exposure time, that are followed at the UAE hospitals.

4- Conclusions: Recent developments in dental digital image receptors have contributed significantly in patient dose reduction. Patient doses incurred in the dental radiology practices at UAE are comparable to the accepted dose level stated by the International Atomic Energy Agency and the European Commission.

P02.62
Estimating the Doses for the Workers of a PET Radiopharmaceutical Production Facility

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In this work an estimate of the doses for the workers of a PET radiopharmaceutical production facility was done. The facility studied was the Section of Research and Production of Radiopharmaceuticals (SECPRA) of the Development Centre of Nuclear Technology (CDTN/CNEN) in Belo Horizonte, Brazil. The doses for the workers were estimated not only for routinely activities of production as for maintenance of the systems / equipments utilized in the production. For the dose assessment during the routine production of 2-[18F] fluor-2 deoxy-D-glucose (FDG), a run in a maximum condition was performed and the dose rates in several points around the installation were measured in each stage of the production process: from the cyclotron irradiation until the shipment of the PET radiopharmaceutical doses to the hospitals. The maintenance activities considered in the doses estimates were: (a) exchange of the targets of the cyclotron, (b) preventive maintenance of the cyclotron, (c) exchange of the irradiated water transfer lines and, exhaust filters and, (d) maintenance of the equipments of the production and quality control laboratories. The doses values estimated in the production performed in a maximum condition were, respectively, 27 μSv, 25 μSv and 24 μSv, for the technician responsible for the physical-chemical quality control tests, the responsible for the micro-biological tests and the radioprotection workers responsible for the package and shipment of the FDG. In maintenance activities the maximum doses estimated were 100 μSv for the cyclotron operation staff. The accumulated doses in one year for all the workers, considering 180 productions in the maximum condition were less than 5 mSv. The methodology utilized for estimating the doses for the workers can be used for the establishing of the dose constraints of a PET radiopharmaceutical facility.

P02.63
Estimation of Finger Doses Resulting from Laboratory Use of Beta Emitting Radionuclides

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We have developed an online tool for the estimation of finger doses resulting from laboratory procedures using beta emitting radionuclides. The tool forms an integral part of the prior risk assessment for all new experimental procedures with the University of Aberdeen.

Ensuring that suitable prior risk assessments are carried out across an organisation which uses a variety of radionuclides at various sites can be challenging; as such, it is useful to utilise a method which may be carried out by staff with only basic radiation protection knowledge.

The online tool utilises a calculation methodology requiring the input of simple information about the experiment such as the radionuclide, handling times and dispensing methods. This allows straightforward completion by laboratory staff, whilst producing a useful estimate of finger doses.

Details will be shown of the calculation methodology, along with the implementation in an online system. Results will be shown comparing calculated dose estimations with results from a personal dosimetry program.

P02.64
Estimating the Effective Dose Equivalent During Transport Radioactive Material Using the Two Dosimeter Approach

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The two-dosimeter approach was used in this work to calculate the effective dose equivalent (EDE) that the drivers may be exposed to during transporting radioactive materials. An external radiation source (Cs-137) was loaded into the back side of a vehicle, and a water phantom was used in the cabinet of the vehicle. The phantom is covered by a 3x3 matrix of TLD detectors on the front side of the body for the first irradiated experiment, and another matrix was placed on its backside for the next irradiation. The scenario was simulated using MCNP5 Monte Carlo code to estimate the conversion factors for the different angular distribution of the Cs-137 source at 175 cm from the back side of the body. The results as a function of the angle were tabulated for the entrance dose which corresponds to the detector matrix in the front of the phantom and for the exit dose that corresponds to the detector cells at the front of the matrix. The absorbed fractions that represent (entrance-exit)/entrance against the angle were calculated from which the absorption of the beam by the phantom was obtained.

P02.65
Evaluation of Photoneutron Activation and Radiological Impact Induced from a Medical Linear Accelerator

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Radiotherapy uses X-ray generated by a medical linear accelerator with the voltage range of 4-25 MV. When energy of X-ray becomes greater than 10 MV, a photoneutron based on photonuclear reaction is produced from a linear accelerator, and the head of a linear accelerator, a radiotherapy room and shielding facilities can be activated by the photoneutron activation. Therefore, assessment of the photoneutron activation effects is required in terms of radiological safety.

In order to assess the photoneutron activation effects, design concepts for simulation firstly was determined and total photoneutron flux and energy fluence were then calculated via Monte Carlo simulation. Based on the Monte Carlo simulation results, the photoneutron activation effects to each target material were analyzed via Isotope Generation and Depletion simulation. Further, time dependence radiation effects to workers were estimated.

This study aimed at analyzing source terms from a medical linear accelerator, evaluating the total stock of neutron activation radioactivity, and assessing the radiological impacts. The results will be used as an assessment methodology for radiological safety of a medical linear accelerator and shielding facilities. Further, it will be also applied to the medical radioactive waste disposal criteria as a fundamental basis, suitable to local conditions in South Korea.

P02.66
Estimation of Effective and Equivalent Dose Rates for Submersion in a Semi-Infinite Radioactive Cloud based on ICRP 107 and 110

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In the International Commission on Radiological Protection(ICRP) 2007 recommendations, ICRP adopted reference male and female computational phantoms(ICRP 110) for forthcoming updates of organ dose coefficients of both internal and external radiation sources. The objectives of this article are to calculate the effective dose rates and equivalent dose rates of radioactive noble gases with the nuclear decay data(ICRP 107) and the adult reference phantoms. The effective dose rate and equivalent dose rates for each mono-energetic photon were computed at the maximum exposed distances(MEDs). The MEDs of 24 mono-energetic photon energies from 0.01 to 10 MeV were estimated using a Monte Carlo code(MCNPX 2.7.0), for a tissue equivalent 1 meter diameter sphere target at 1 meter above the ground level. The exposure model considered was semi-infinite homogeneous volume sources in the air. The external dose conversion factors in the semi-infinite radioactive noble gas cloud were calculated by the Monte Carlo code. The results of the computed equivalent dose rates of gamma-ray energy from 0.1MeV to 10 MeV at each MEDs were corrected by the equivalent dose ratio method (EDRM) of a target organ to reference organ(MUSCLE). Effective dose rates for most of noble gases in this study are 94.92 % to 134 % difference for IAEA BSS 115 data except a few nuclides.

Key words: Effective dose, Equivalent dose, Noble gas, ICRP 103, ICRP 107, ICRP 110

P02.67
A Dosimetric Reconstruction Simulation Code Based On Geant4 and Voxel Phantom for Radiological External Photon Exposure Accident

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Dosimetric reconstruction is one important issue to evaluate biological consequence after radiological accident. The physical dosimetry approach for dose reconstruction is based on either real physical phantom experiments or numerical simulation techniques. Monte Carlo simulation together with human voxel phantom, being the-state-of-art technique, provides a more powerful capability to assess the organ dose to victim since its faithful and flexibility simulation. This paper presents a new Monte Carlo simulation code, called VDOSE, dedicated to dosimetric reconstruction purpose for external photon radiological accident based on Geant4 and human voxel phantom. VDOSE can calculate not only the organ dose but also the dose distribution of the victim, so it could be a kind of technical support for surgery treatment. To validate this code, some calculations with a voxelized Alderson RANDO phantom were made to compare the real experiments which were carried out using the same physical Alderson RANDO phantom with thermoluminescence dosimeters (TLDs) for gamma source irradiation. The preliminary results show good agreement between the calculations and measurements, most of the relative deviations are within ±15%.

P02.68
A Study on the Annual Doses Received by the Workers of some Medical Practices

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This paper describes occupational radiation doses of workers some medical practices during the year 2007. The annual doses received by the workers of a public hospital are presented in this report. The Department is facilitated with HARSHAW Reader model 6600 and assigned the rule of personal monitoring to contribute in controlling and reducing the doses received by radiation workers. TLD cards with two TLD chips type LiF:Mg,Ti (TLD-100) were calibrated to measure the personal dose equivalent Hp (10). Around 150 medical radiation workers were monitored throughout the year. Each worker received a single TLD card worn on the chest above lead apron and returned for laboratory reading every two month.

The average annual doses received by the workers of radiotherapy, nuclear medicine and diagnostic radiology were evaluated. The annual doses for individual radiation workers ranged: from 0.55 to 4.42 mSv, 0.48 – 1.86 mSv , 0.48 – 0.91 mSv for the workers of radiotherapy, nuclear medicine and diagnostic radiology; respectively. The mean dose per worker was 1.29±1, 1.03±0.4, and 0.69±0.2 mSv; respectively. The results showed compliance with the International dose limits. Our results reconfirm the importance of personal dosimetry service in assuring the radiation protection of medical staff in developing countries.

P02.69
A Bayesian Analysis of Uncertainties on Lung Doses Resulting from Occupational Exposures to Uranium

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In a recent epidemiological study, Bayesian uncertainties on lung doses have been calculated in order to determine lung cancer risk from occupational exposures to uranium. These calculations used a revised version of the human respiratory tract model (HRTM) published by the ICRP. In addition to the Bayesian analyses, which give probability distributions of doses, point estimates of doses were also provided for that study using the existing HRTM as it is described in ICRP Publication 66; these are to be used in a preliminary analysis of risk. In order to explain the differences between the point estimates and Bayesian uncertainty analyses, the methodology was applied to former UK nuclear workers, who constituted a subset of the study cohort. The resulting probability distributions of lung doses calculated using the Bayesian methodology were compared with the point estimates obtained for each worker. It is shown that mean posterior lung doses are on average 8 fold higher than point estimates and that uncertainties on doses vary over a wide range, greater than two orders of magnitude for some lung tissues. It is shown that it is uncertainties on the parameter values, rather than the model structure, which are largely responsible for these effects. Of these it is the parameters describing absorption from the lungs to blood that have the greatest impact on estimates of lung doses from urine bioassay. It is concluded that accurate determination of the chemical form of inhaled uranium, and the absorption parameter values for these materials, is important for obtaining reliable estimates of lung doses and hence risk from occupational exposures to uranium.

P02.70
Study of Dose Variation in Bladder and Rectum due to Positional Variation of Applicator in HDR Intracavitory Brachytherapy.

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Introduction: Carcinoma Cervix is common most cancer in Nepalese women. Most of the Ca cervix patients are found to be present with advanced stage disease and require radiation Therapy.

The Fletcher-suit-delclos applicator is used. The prescribed dose 7Gy per fraction is given to the Point 'A' with minimum possible dose to the rectum and bladder. 50Gy dose is delivered to the entire pelvis from external radiotherapy and 3 applications of ICR 7Gy per fraction in 3 week using Varisource Brachytherapy machine and Brachyvision planning system.

Materials and Methods: This is retro-prospective hospital based study. Variation in dose may arise due to various factors. The plans of two successive ICR are analyzed, Variation of dose in bladder and rectum in these two plans and contributing factors are also assessed.

Result and Discussion: Plans of 100 patients who received treatment in 2009 and 2010, were analyzed .The dose variation between two application in bladder and rectum is found to be as high as 40 %(2.8Gy) and 27.43 %(1.92Gy) of 7Gy respectively. In case of Bladder 8 (8%) patient got more than 20%.26 (26%) patient got (10- 20) % and 18 (18%) patient got dose variation of (5 -10) %.Remaining patients have dose variation less than 5%. In rectum 12 (12%) patient got more than 20%, 24 (24%) patient got between (10- 20) % and 32 (32%) patient got (5 -10) % dose variation. Remaining patients got dose variation less than 5%. Regarding contributors to dose variation 40 (40%) are due to application variation, 35(40%) digitization of ovoid and 25 (25%) are due to both application and digitization.

Conclusion: Positioning of applicator, digitization of ovoid and planning are found to be most important factors contributing to dose variation.Careful positioning,digitization and planning reduce the errors.

P02.71
Radioactivity of Bottled Drinking Water and Consequent Dose Exposure to Consumers in Ondo State. Nigeria.

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The existence of naturally occurring radioactive materials in many groundwater systems worldwide has raised concern because of the connection between radiation exposure and human health. In this work, the activity concentrations of ^{40}K, ^{214}Bi, ^{214}Pb, ^{224}Ra, ^{226}Ra, ^{228}Ac and ^{232}Th have been measured in 32 brands of bottled drinking water samples produced and consumed in Nigeria. The measurement was done using a high-resolution co-axial high purity germanium (HPGe) detector coupled to a Multichannel Analyzer. Measured activity concentration in the drinking water samples ranged from 40.23±2.38 to 144.17±6.48 Bq l^{-1}; 0.56±0.18 to 9.41±0.90 Bq l^{-1}; 0.41±0.18 to 7.20±0.64 Bq l^{-1} 0.10±0.01 to 3.38±0.51 Bq l^{-1}; 5.08±1.25 to 30.76±3.38 Bq l^{-1}; 1.15±0.41 to 47.75±0.71 Bq l^{-1} and 1.05±0.31 to 5.39±0.90 Bq l^{-1} for ^{40}K, ^{214}Bi, ^{214}Pb, ^{224}Ra, ^{226}Ra, ^{228}Ac and ^{232}Th respectively. The activity concentrations and the ingested dose conversion factors of the radionuclides were used to calculate the total annual effective dose rates due to the ingestion of the waters by the six International Commission on Radiological Protection (ICRP) age groups 0-1y, 1-2y, 2-7y, 7-12y, 12-17y and > 17y. Estimated annual effective dose rates ranged from 6.76 to 37.50 mSv y^{-1}; 1.97 to 10.50 mSv y^{-1}; 1.40 to 7.55 mSv y^{-1}; 1.82 to 10.10 mSv y^{-1}; 5.18 to 29.60 mSv y^{-1} and 1.48 to 8.01 mSv y^{-1} respectively. The total annual effective dose rates from the water samples exceeded the ICRP limit of 1.0 mSv y^{-1}.

P02.72
Practical Recommendations to Occupational Health Services of Nuclear Facilities for Monitoring of Internal Exposure to Radionuclides

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In France, 64000 workers of basic nuclear facilities (INB) are occupationally exposed to a risk of internal contamination with radioactive material. Their follow-up is ensured by approximately 450 occupational health practitioners.

A working group composed of occupational health practitioners, biological pharmacists and experts in internal dosimetry was set in 2004, on the initiative of occupational health practitioners of various INB, to discuss and to list the difficulties in dose assessment for cases of internal contamination, in order to harmonize the related practices. In 2008, the group started to draft a guide of recommendations, promoted by the French society of occupational medicine (SFMT) and approved in 2011 by the national authority for health (HAS, agency under supervision of the ministry of health)*, which could be used as a reference by professionals concerned with this risk.

The guide makes recommendations or requirements based on regulation and international standards, scientific knowledge and practical experience of professionals in this field. Each item is presented as an argued answer to a practical question, with the aim of supporting the occupational health services:

1. Setting up monitoring programs consistent with the level of exposure risk In routine, for primary prevention, or following an event, for primary and secondary prevention, the occupational health services collect information and assess the risk of exposure at workplaces, prescribe individual monitoring consistent with the level of risk, and periodically evaluate the global monitoring program.

2. Interpreting monitoring data Decision making is supported by early gradation criteria for the potential significance of the contamination, operational criteria for interpretation of bioassay results, methods for assessment and validation of the committed effective dose, and criteria for requesting support from expert bodies.

3. Answering workers concern about the individual risk The guide provides the occupational health practitioners with elements for estimation of the health risk depending on the assessed dose. It includes consistent information to convey to the worker.

The guide can also help emergency physicians with the management of nuclear or CBRN incidents. The authors will present the editorial work method and the content of the guide.

*To be available for download on http://www.chu-rouen.fr/sfmt/pages/Recommandations.php

P02.73
Measurements of Uranium Radionuclides in Urine Samples and Internal Dose Assessments for the Personnel of Uranium-Mining Industry in Ukraine

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The State Owned "Eastern Mining And Processing Complex" (SkhidGZK) was established in 1951. Now it is the largest uranium mining enterprise in Europe. SkhidGZK is the only enterprise in Ukraine engaged in the mining of uranium ore and the production of a uranium oxide concentrate. Several thousand workers of SkhidGZK have a risk of incorporation of uranium radionuclides.

Pilot project for measurements of uranium radionuclides in urine samples and internal dose assessments for the SkhidGZK personnel was started in 2008. It was a first attempt to determine content of uranium radionuclides in urine of SkhidGZK personnel. 108 daily urine samples from 7 workers were collected during 2008 – 2009. Measurements of ^{234}U and ^{238}U contents in samples were performed.

As expected, measurements demonstrate a steady correlation between contents of uranium radionuclides in urine. Average ratio ^{238}U:^{234}U is 0.996. All results were in range from 3.6 to 766 mBq per sample. It was revealed that contents of both radionuclides in urine are lognormally distributed. Geometric means are 50.5 and 50.3 °mBq per sample for ^{234}U and ^{238}U respectively. σg is 2.54 for both radionuclides.

Additionally, for purposes of internal dose assessments, activities of alpha emitting radionuclides in air at workplace airs of the specified personnel were measured. Total alpha activities in air were in the range from 0.09 to 0.31° Bq/m^3.

Internal doses were calculated on the base of measurement results. Committed annual doses from inhalation intakes of uranium and thorium radionuclides (and 'accompanied' progenies in air) were assessed in the range from 12 to 20 °mSv.

P02.74
Application of Radiotherapeutic Fixation Tools to Achieve Patient Setup Reproducibility during in vivo Gamma Spectrometry Investigation

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During the past two decades, significant efforts were made to introduce the individual voxel phantoms and radiation transport calculations for the calibration of *in vivo* gamma spectrometers, which are used to assess the radionuclide content in patients' organs and tissues. According to this approach, the counting rate of gamma spectrometers is recalculated in terms of radionuclide content using the in silico simulation of gamma ray transfer from inside the body of a patient into the sensitive volume of a detector, which is typically placed near the patient.

However, by the current the voxel phantom calibration of in vivo gamma spectrometers was not free of numerous uncertain factors. Among these factors, there was unsatisfactory reproducibility of the patient setup from the CT scanner table (where the data for individual voxel phantom creation are obtained) to the table of the *in vivo* gamma spectrometer. On the other hand, radiotherapy has accumulated much experience in obtaining patient's setup reproducibility. To achieve these goals, several fixation devices, such as thermoplastic masks are used. These masks are typically shaped to fit the patient's face and (optionally) shoulders at the moment of diagnostic CT scans.

We suggest the use of these masks to reduce uncertainties in the patient setup for in vivo gamma spectrometry. Calculated results for our patients show that such devices can eliminate the bias of the radioactive actinide assessment in bones by tens of percents.

P02.75
A Bayesian Method for Identifying Occupational Intakes for Uranium Workers

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Bayesian methods are becoming increasingly important for estimating uncertainties on internal doses for epidemiology and risk assessment. Another important application of the Bayesian approach occurs in occupational radiation protection where it is important to identify real intakes from bioassay measurements to ensure that worker exposures comply with acceptable dose limits. In routine monitoring programmes for uranium workers, for instance, a problem is to determine whether a measurement of uranium in urine is actually an intake or simply represents a background level of natural uranium. This project develops Bayesian hypothesis testing methodology that addresses this problem. In this approach different exposure scenarios are represented by discrete modelling hypotheses. However, parameter uncertainties within each hypothesis are represented as continuous distributions which may also affect the outcome of the test. The methodology is applied to typical uranium measurements, and the results of the Bayesian test are compared with those determined using a classical decision level. It is shown that identification of a real intake is particularly sensitive to the assumed solubility of the inhaled material. This has implications for the design of monitoring programmes. Beyond this application however, the described methodology provides a general method for model selection, given a set of data, and may therefore prove useful in biokinetic modelling.

P02.76
Dose Assessment Due to Inhalation of Plutonium Nanoparticles

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The International Commission on Radiological Protection (ICRP) has published reports on all aspects of radiological protection. Since 1928, ICRP has produced International Systems of Radiological Protection used world-wide as the common basis for radiological protection standards, legislation, guidelines, programs, and practice. In 1994 ICRP released its publication number 66 (ICRP-66), which proposes a very comprehensive model for the respiratory tract. The model describes deposition of radioactive aerosols and the subsequent processes of mechanical removal and blood absorption into systemic organs associated with the deposited particles.

Recently a proposed update to the model has been suggested, more specifically, a reduced number of sub-compartments of the alveolar-interstitial region (AI) has been proposed. The proposed model replaces the compartments AI_1-AI_3 with two compartments, one representing the alveolar region (ALV) and one the interstitium (INT). However neither the ICRP-66 nor the new proposed model have addressed the very particular aspects of inhalation, deposition and further distribution of radioactive nanoparticles in the human body.

Experience has shown that inhaled plutonium nanoparticles clear from the lungs at a much faster rate than micron-sized particles. In this paper, the specific absorption parameters for inhalation of plutonium nanoparticles have been derived. The calculated dose coefficients and the impacts on interpretation of bioassay measurements associated with the inhalation of plutonium nanoparticles are compared against the corresponding results for micron-sized particles.

KEYWORDS: nanoparticles, plutonium, lung model, dose assessment, blood absorption parameters, dose coefficients

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P02.77
Dosimetry Of Natural Uranium Exposure By Integrating Alimentary Uranium Contribution To Bioassay Measurements

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During the preparation of nuclear fuel, workers may inhale uranium aerosols. The monitoring for intakes is usually based on measurement of urine and/or faeces samples. However, uranium is naturally present in food and drinking water. Consequently, detectable amounts of natural uranium can be measured by modern techniques even in the absence of occupational exposure. For radiation protection at the workplace, it is important to distinguish the contribution of alimentary and professional intakes to the in vitro measurement of uranium.

This study proposes a method to build a decision threshold which ensures that an occupational contamination occurred with 5 % (alpha) risk of error if the measurement result is higher than this threshold. The determination of the threshold is based on the natural background of uranium in excreta measured in a population of workers not occupationally exposed to uranium on the nuclear centre of Cadarache (France).

The results of measurement of ^{234}U, ^{235}U and ^{238}U by alpha-spectrometry in urine and faeces for the unexposed population were compiled into empirical distributions. The decision thresholds for the different isotopes are then defined as the 95th percentile of the empirical distributions of the unexposed population.

The measurement results reported as below the detection limit were integrated in the empirical distributions by a Kaplan-Meier method in order to model the empirical distributions by lognormal probability distributions using a maximum likelihood estimation. In a Bayesian approach to the calculation of intakes and effective doses, these probability distributions can be used to represent the uncertainty introduced by the presence of alimentary uranium in samples. Therefore, probabilistic methods are developed to calculate the individual dose and its associated uncertainty from a routine measurement result.

However, an individual dosimetry can be difficult to be performed if individual monitoring is not sensitive enough; a collective dosimetry may be more appropriate. Firstly, to determine if an exposed group of worker is subject to occupational contamination, a variance analysis is carried out to determine if the bioassay measurements of the exposed population is statistically different from the unexposed population. From this statement, a collective dosimetry could be developed along with the use of the decision threshold to improve the radiation protection of workers exposed to uranium.

P02.78
A Comparison of True Alpha Activities in Air Filter Samples with Values Obtained from Radioactivity-in-air Monitors

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A fundamental problem with measurements of alpha activity on air filters from the nuclear workplace is that the calibration sources used with radioactivity-in-air monitors are not in the same physical form as actual samples. The samples suffer from alpha absorption due to effects such as self-attenuation within the radioactive particle, entrapment of the particle within the filter, and the accumulation of dust layers on the filter. This can lead to underestimation of alpha activity in air and therefore underestimation over time of intake and hence committed internal dose.

To obtain a first indication of the magnitude of the problem, NPL obtained a set of nineteen contaminated air filters from three UK nuclear sites and measured them using a number of typical workplace monitors. The same filters were then subjected to radiochemical analysis to measure the activities of Am, Pu and U nuclides. The ratio of true to monitored activities was typically in the range 1 – 5, but in a few cases was of the order of 20. The results are compared with 'correction factors' used at UK nuclear sites and from the literature. The study points to the possibility of significant underestimation of airborne alpha activity in some circumstances and that plant-by-plant determination of ratios may be required to ensure that workplace monitoring of alpha particulate in air is accurate.

P02.79
Estimated Thyroid Doses for Cohort Members of Epidemiological Study of Thyroid Cancer among Belarusian Children Exposed after the Chernobyl Accident

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The U.S. National Cancer Institute in collaboration with the Belarusian Ministry of Health is conducting a study of thyroid cancer and other thyroid diseases in a cohort of 11,733 persons who were exposed to fallout from the Chernobyl accident in 1986. The study subjects were less than 18 years old at the time of exposure and resided in the most contaminated regions of Belarus as well as in the city of Minsk. All cohort members were subjected to at least one measurement of exposure rate against their neck (called “direct thyroid measurement”) made in April-June 1986. Those measurements were used to estimate Iodine-131 (^{131}I) activity in the thyroid. Individual data on residential history, consumption rates and intake of stable iodine for thyroid blockade were collected for all cohort members through personal interviews conducted between 1996 and 2007. Based on direct thyroid measurements and questionnaire data, individual thyroid doses from intakes of ^{131}I were reconstructed for all cohort members. In addition, radiation doses to the thyroid due to exposure from the following minor pathways were estimated: (a) intake of short-lived ^{132}I, ^{133}I and ^{132}Te via inhalation and ingestion; (b) external irradiation from radionuclides deposited on the ground; and (c) ingestion of ^{134}Cs and ^{137}Cs. The mean thyroid dose from all pathways of exposures over all study subjects was estimated to be 0.61 Gy, while the median was 0.25 Gy. Iodine-131 intake, primarily with milk, was the major pathway for thyroid exposure; its mean contribution to the thyroid dose was found to be 92%. Uncertainties associated with the reconstructed doses arise from (1) errors in the ^{131}I activity in thyroids that were derived from the direct thyroid measurements; (2) variabilities in the thyroid mass and metabolic parameters between individuals; (3) uncertainties attached to the personal information from questionnaires; and (4) uncertainties attached to the ecological model.

P02.80
Thyroid Doses due to Iodine-131 Intakes among Chernobyl Clean-up Workers

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Between 1986 and 1990, several hundred thousand workers, called “liquidators” or “clean-up workers”, took part in decontamination and recovery activities within the 30-km zone around the Chernobyl nuclear power plant (NPP) in Ukraine, where a major accident occurred in April 1986. The Chernobyl liquidators were mainly exposed to external irradiation. However, those who were involved in clean-up activities during the first two weeks after the accident were also exposed to doses from internal irradiation resulting essentially from the inhalation of ^{131}I contaminated air. The model that was developed to calculate the thyroid doses from ^{131}I takes several factors into account, including the ground-level outdoor air concentrations of ^{131}I at the work locations of the liquidator; the time spent outdoors; the breathing rate, which depends on the type of physical activity; and, in some cases, the intake of KI pills for iodine prophylaxis. The validity of the model to reconstruct thyroid doses to liquidators was evaluated on the basis of measurements of dose-rate near the neck taken in 30 April - 5 May 1986 in a group of 624 early liquidators. Information on the whereabouts and intake of KI pills was also available for those individuals. The ^{131}I activities in the thyroids that were calculated using the model were compared with those derived from the direct thyroid measurements. The mean of the ratios of measured-to-calculated activities was found to be 0.8, while the median of those ratios was 0.5. The model is being used to estimate thyroid doses due to ^{131}I intakes in the pilot study of thyroid cancer risk among Chernobyl clean-up workers in Ukraine.

P02.81
Biokinetic Models for Pregnant and Lactating Woman: Adaptation of ICRP Models for Epidemiological Studies of Exposed Southern Urals Populations.

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A unique database of measurements of ^{90}Sr in humans, compiled at the Urals Research Center for Radiation Medicine (URCRM) from long-term monitoring of the Techa River population, allows models developed by the International Commission on Radiological Protection (ICRP) to be adapted specifically for the studied population. Development of population-specific models is an important prerequisite for reliably assessing internal doses for epidemiological studies of radiation risk. This paper presents the results of adapting ICRP biokinetic models for calcium and strontium in pregnant and lactating women. The maternal models were based on biokinetic models for calcium and strontium for an adult female that were developed recently for the Techa River population. Using ICRP methodology the models were adjusted to include foetal compartments for the period of pregnancy and to allow for increases in maternal gastrointestinal absorption, urinary excretion and bone turnover rates. Parameters of the foetal model specific to the Techa River population were estimated using ICRP approaches which account for calcium content in the maternal diet and in the blood and skeletal compartments of mother and foetus. For the period of lactation, the ICRP methodology was extended to consider a longer breastfeeding period in the rural Techa villages that includes exclusive and partial breastfeeding and corresponding changes in maternal mineral metabolism. Calcium and strontium transfer to breast milk is determined on the basis of calcium content in maternal diet, skeleton and breast milk specific for the studied population. The models for pregnant and lactating women were validated using measurements of ^{90}Sr in foetuses and their mothers and measurements of ^{90}Sr-body burdens in pregnant and lactating women resident in the Techa River villages (see Tolstykh *et al;* these proceedings). The models were used to compute *in utero* doses from maternal ingestion of strontium radionuclides at the Techa River (see Shagina et al; these proceedings) and to calculate intakes of strontium radionuclides with breast milk by infants born in the Techa River villages. This will allow more reliable estimates of the internal doses received in early life to be used in epidemiological studies of the Techa River cohorts. This work has been funded by the European Commission Contract No. FP7-249675 “Epidemiological Studies of Exposed Southern Urals Populations” (SOLO).

P02.82
Validation of the Monte Carlo Simulation of HPGe Detector Using Point Like Source and the Homemade Emma Phantom

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Routine monitoring of workers in nuclear and medical installations consists of an assessment of the radiation dose from external and internal radiation. The Whole Body Counter (WBC) is a set-up for in vivo measurement of the radiation (X-rays or gamma rays) emitted from the body. For a WBC germanium (Ge) or NaI(Tl) detectors are typically used. A good assessment of radioactive body burden requires equipment and techniques to identify and quantify the contamination and it also requires a very good calibration of the system. However, due to the large subject-specific variations in the measurement conditions, the calibration set-up can, in principle, differ from the reality to a great extent. Since the 1960s, the radiological science community has developed and applied several computational models of the human body, called "phantoms", for ionizing radiation dosimetry studies. Nowadays, with Monte Carlo methods it is possible to simulate complex radiation interactions and energy depositions in human bodies of different sizes precisely. This can improve the reliability of the calibration of a counting facility, particularly for non-standard measurements (obese people, children, etc.). This poster presents the simulation of the HPGe photo-peak detector efficiency used in Whole Body Counting (WBC) laboratory from Belgium Nuclear Power Plant (KCDoel). Various geometrical set-ups and standard samples (point-like γ-ray sources) are measured with the aim at validating the virtual WBC set-ups. The calibration measurement was performed with a homemade phantom EMMA (A. L. Lebacq, 2011). The efficiency values obtained from simulations with the computational EMMA phantom (EMMA_COMP) were compared with the measured calibration data, and the results are around ±9% for energies above 121.80 keV and up to 1.408 keV.

P02.83
Uranium & Dosimetry in Aquatic Organisms: Which Isotopes & Descendants to Consider?

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Radionuclide toxicity toward organisms in environment can be assessed via total dose rate, in µGy per time unit, sum of internal dose rate (exposure after intake) and external one (irradiation by the media). The external dose rate is calculated with all the radionuclides (parent & progeny) present in the media whereas the internal dose rate is calculated in the organisms from data of bioaccumulation (measurement or calculation) of each radionuclide (parent & progeny) (Beaugelin & Garnier-Laplace, 2006). In both cases hypotheses of work have to be done according to the data available for the total dose rate calculation.

Uranium is a good candidate for this problematic of dose rate calculation and set-up of hypotheses. Indeed, it is a naturally occurring radionuclide, its concentration may increase in several environmental media because of anthropogenic activities and the isotopes 235 and 238 are parents of two radioactive chains.

Thus, to assess a dose rate toward one organism due to uranium presence, one of very conservative hypothesis, is to consider that both parents ^{235}U and ^{238}U and their progeny are at the secular equilibrium in the media and in the organisms. Concentrations in the organisms are then calculated from transfer factors either direct (water/organism) or trophic (food/organism) for each descendant.

However, chemical properties of uranium and its descendants being different, their geo- and bio-chemical behaviour should be totally different. Then, an alternative to this conservative hypothesis relies on taking into account concentrations of parents and progeny in biotic and abiotic compartments. This second approach enables (i) to accurately know the dose rate found for a specific media/organism couple, (ii) to compare dose rates obtained with several hypotheses et (iii) to refine descendants contribution in the observed effects.

This latter approach was performed in a simple way (use of depleted uranium, exposure media = contaminated water) for a model organism, crayfish Procambarus clarkii exposed to waterborne depleted uranium (10 µg/L) during 30 days. Bioaccumulation of ^{238}U, ^{235}U, ^{234}U, ^{234}Th and ^{234m}Pa was measured in gills and digestive gland. Internal dose rate was then calculated with EDEN software (Beaugelin et al., 2004).

Results showed that the measurement of such uranium descendants, i.e. ^{234}Th and ^{234m}Pa, is feasible after exposure with such concentration close to environmental one. However, the data emphasize the question of the real uptake of these descendants by organisms and therefore their real contribution in the internal dose rate calculation.

Finally, these preliminary results underline the need to accurately characterize (i) the transfer factor for each descendant (with no limitation to the first two that are not the major dose contributors) and (ii) the biodistribution of each descendant in both exposure media and model organisms to refine dose/effect relationship.

P02.84
Dose Estimation Method of the Public after the Reactor Severe Accidents in Fukushima

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In case of reactor severe accidents, some radionuclides are emitted, spread to the environment and finally the public are exposed through several pathways, for example, inhalation or intake of foods. Because intake radionuclides remain in their body and expose their organs for several days or weeks, the internal dose estimation draws particular attention as well as the past severe accidents in Chernobyl and Fukushima. In general, the dose of internal exposures is calculated by the following equations;

where, is the committed equivalent dose, is the committed equivalent dose per unit intake, is the effective dose, is the effective dose per unit intake, is the measured whole body activity or thyroid activity and is the retention function. The conventional retention function is usually defined for acute inhalation intended for radiation workers. The internal exposure of the public is, however, occurred by both acute inhalation and prolonged ingestion. It may causes degradation of the accuracy of internal dose estimation. The dose estimation method considering the intake situations of the public is proposed and the method is applied to rebuild the dose of internal exposure caused by the Fukushima nuclear power plant accidents as a case-study.

The proposed method consists of three steps; first, the intake situations of inhalation and ingestion are separately estimated. Secondly, the retention function is calculated by the biokinetics analysis, based on the general biokinetics models corresponding to the intake situation. The dose of internal exposure is finally provided by using the calculated likely retention function and the measured whole body radioactivity.

The intake situations at Iitate village in Fukushima, one of the highest dose regions outside the forbidden area, are estimated mainly based on the published environmental sampling data. The highest contributions to dose in the village, as a result, seem the iodine-131 intake by inhalation and that by ingestion of drinking water. The thyroid retention function is calculated for corresponding to above intake situations and internal dose is provided. The estimation, assumed an acute inhalation on March 12nd, might have been overestimated and the proposed dose estimation method taking in to account for intake situations is effective for public internal exposure after severe accidents.

P02.85
GuiAR: A New Tool for Implementation IDEAS Guidelines

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The IDEAS Guidelines provide a method to harmonize dose evaluations using criteria and flow chart procedures to be followed step by step. A Matlab-based computational tool, named GuiAR, was developed to help in IDEAS Guidelines implementation. This tool uses a graphical user interface comprising three basic modules: routine monitoring, special monitoring and effective AMAD. This software determines the presence of possible outlayers and other intakes. It works with different bioassay data: urine, faeces and whole body burden simultaneously. It calculates intake fitting measurements data with the maximum likelihood method and determines p-values. In the case that time of intake is not known, the code allows its determination. On the other hand, if early lung burden and faeces data are available, it is possible to estimate effective AMAD. The aim of this paper is to describe the capabilities and the verification of GuiAR, along with some application examples.

P02.86
Inhalation, Intravenous and Wound Exposure to Am-241: A Comparison of Unperturbed Biokinetics

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Animal models of the unperturbed biokinetics of radionuclides are being developed for use in evaluating the efficacy of new decorporating agents. Models of internal exposure by nose-only inhalation, wounds, and IV injection of ^{241}Am are described here. Animals were administered Am and placed in metabolism cages for the duration of each study before being euthanized at predetermined time points of 1, 4, 24 hr, 2, 4, 8, 16, or 28 days post exposure. Animals underwent a full necropsy and all tissues and collected excreta were analyzed by gamma pulse height analysis. All data for each animal are normalized to percentage of recovered dose. Urinary elimination profiles displayed a general two-component decay from a maximum concentration at 4 hours for the inhalation study (0.25 %RD), 1 day post exposure for the IV study (8%), and 1 day post exposure for the wound study (0.9 %RD). Fecal elimination profiles are similar for the wound and IV studies were the amount excreted increased to a maximum (2%RD at day 12 for wound; 3%RD at day 8 for IV) before slowly decreasing through 28 days. However, on the inhalation study, concentrations in the feces were at a maximum at 1 day post exposure (40% RD) before decaying through the rest of the study. Liver content for the wound and inhalation studies slowly rose to a maximum at 4 days (20% RD for wound and 5% RD for inhalation) before decreasing for the duration of the study; in comparison, in the IV study, liver content decreased monotonically with time from a maximum (60% RD) at 1 hour post exposure. As anticipated, the elimination profiles are different for the three models evaluated, however, this is the first time data sets this comprehensive have been assembled and compared. With this information in hand, studies of chelating agents are now being conducted and compared to models of unperturbed biokinetics to assess decorporation efficacy and effects on organ doses.

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P02.87
Determination of Actinides in Excreta by Alpha Spectrometry: Method Validation and Uncertainty Estimation

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Two essential technical requirements of ISO/IEC 17025:2005 guide for accreditation of testing and calibration laboratories are the validation of the method and the estimation of all sources of uncertainty that may affect the obtained analytical result.

The Bioelimination Laboratory from the Radiation Dosimetry Service of CIEMAT (Spain) uses the Alpha Spectrometry technique to quantify alpha emitters (Pu, Am, Th and Cm isotopes) in urine and faecal samples from workers exposed to internal radiation. Therefore and as a previous step prior achieving the ISO 17025 accreditation, the laboratory has performed some studies based on the obtained results in the last few years (calibrations, quality control and sample measurements, participation in international intercomparison exercises, etc), and has prepared a validation report and an uncertainty estimation procedure, which are resumed in the work we are presenting.

The alpha spectrometry measurements were done using two Alpha Analyst (Canberra) systems equipped with 24 chambers using Passivated Implanted Planar Silicon (PIPS) semiconductor detectors. The obtained spectrum can be analysed using Genie-2000 alpha analysis software.

The method validation was performed taking into account the following aspects:

- Use of certified reference materials in both energy and efficiency calibrations of the detectors, as well as in the radiochemical separation processes (tracers).

- Study of the energy and efficiency calibration curves for every chamber in the last 4-5 years, in order to establish a conformity and acceptance criteria for future calibrations.

- Study of the obtained chemical recovery in the last few years after the performance of the analytical procedure, regarding its direct relation with the Minimum Detectable Activity (MDA) applied to dosimetric surveillance programs.

- Participation of the laboratory in international intercomparison exercises.

Uncertainty estimation of the method requires the analysis of all factors influencing the measurement, the quantification of the uncertainties connected to each factor and finally, the estimation of the overall uncertainty of the measurement.

There were identified the following uncertainty sources: net peak area, detector efficiency, measuring time, environmental conditions, sample volume/weight and chemical recovery. All these sources were analysed and quantified, and the combined standard uncertainty was calculated.

P02.88
Measurement of Urine Radioactivites for the Internal Exposure of the Workers in the Hospitals

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Urine radioactivity measurement is a useful tool to assess to an individual internal dose of the radiation workers treating with a nuclear medicine in the hospitals. Depending on the biokinetics model, urine samples for 24 hours were measured to obtain a reliable internal dose. The samples were counted as both excreted with minimal sample preparation of the gamma spectrometry and prepared radiochemically before analysis. These samples were analyzed using either a high purity germanium detector or a NaI well detector. From the I-131 activity results of the urine samples of the workers, the individual internal dose was roughly assessed using the intake retention fraction in ICRP78. The results of the radio activities and the associated individual internal doses will be presented.

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P02.89
Air Sampling Measurement of a Working Condition for the Internal Exposure of the Workers in the Hospitals

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Air sampling in radiation facilities of the hospitals has been performed for the intake estimation based on the workplace of the workers. Static air monitoring was chosen in the determination of the intake scenario and physical or chemical properties. More than 10% of annual limit of intakes estimated by air sampling made additional enhances to reduce internal exposure in the facilities. Internal exposure, assessing with treating radioisotopes, was calculated by considering with instruments and processes in the workplace. Radioactivity of iodine-131 of the sampler was measured with a high purity germanium detector. Sampling time was around 1 hour not to interfere the workers for a long time. Detailed results of the measured activities of the sampler will be presented.

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P02.90
Estimated Average Annual Exposure to Background Radiation inside the Hospital and Health Centers of Erbil city and its impact

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Objective of the study was the survey of back ground radiation inside hospitals and health center in the city of Erbil (Capital of Iraqi Kurdistan). As well as, annual rate of radiation exposure (mSv per year) and its impact on health of workers and patient has evaluated.

In the present study around 30 hospitals and health centers are were selected, and short-term measurements used to measure radiation exposure rate (μSv per hr).The measurements included hospital's level, unit of diagnostic , patient halls, worker rooms (physicians and nursery), waiting halls and security rooms.

The results indicate that the average annual exposure dose ranged from 1.028±0.343 mSv to 3.456±0.212 mSv . The highest and lowest values of rate exposure found inside old hospital and new hospital, respectively. The values in each hospital were variable with the position type, more exposure was in the unit of diagnostic. On the other hand, type of building materials and ventilation rate were two important parameters, due to natural radioactive gases

P02.91
Predictive Model of Aerosol Transport and Deposition. Application and Validation to the PWR Reactor Building

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Accurate assessment of airborne particles amounts, which can be inhaled by an operator, is one concern in the radiation protection field, especially in industrials facilities such as nuclear power plants.

Efficient prediction of contaminant transfer inside a ventilated room can help to optimize the location and setting of radiation protection devices, and is essential for risk management and for the choice of collective protection equipments. For that purpose, a research programme was initiated 6 years ago by EDF R&D and IRSN in order to develop a multidimensional model of aerosol transport and deposition phenomenon in ventilated areas of various scales. A 3D model was developed from an aerosol transport equation coupled with a model of wall boundary conditions. This numerical model has been implemented in the Code_Saturne software, a free CFD (Computational Fluid Dynamics) code, developed by EDF R&D. It has been validated on multiple geometries, from very simple ones (horizontal and vertical duct, bend,...) to ventilated rooms with variable volumes (from 1 m^3 to 1500 m^3).

The present work aims at validating the aerosol model in more complex geometries and, particularly, in a PWR reactor building (75,000 m^3). First, in order to expand the model and make it more general, improvements have been made. Polydispersion of particles and additional mechanisms of aerosol deposition, such as thermophoresis and electrophoresis, have been implemented in the model and validated on small scale experiments.

Finally, a validation of the model in a PWR reactor building based on tracing-experiment data is performed. The measurements allow estimating the gas and airborne particle transfer coefficients in various sampling points spread over different levels in the building. The transfer coefficients estimated numerically almost agree with the experiment results. The difference between numerical calculations and experimental results is about 35% for the gas transfer coefficients and it reaches 50% for the particle transfer coefficients. Due to the complexity of the geometry, this result can be regarded as a very satisfactory result.

This model could be an important research tool for the simulation of various contamination cases. It might allow assessing the amount of contaminant that can be inhaled by an operator in case of contamination.

This predictive aerosol transport model is very relevant and allows a satisfactory prediction of aerosol deposition in very complex geometries such as a PWR reactor building.

P02.92
Radiation Dose Assessment of Consumer Products Containing Tritium

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Gaseous tritium light source (GTLS) is a sealed glass tube internally coated with a phosphor and filled with tritium gas. The GTLS as a source of illumination have been incorporated in consumer products such as timepiece, compasses, weapon sights, etc. These products are handled by members of the public and workers, who lack knowledge in radiation protection. The assessment of radiological consequences was conducted by estimating radiation dose during storage and transport of the products or GTLSs. The dose assessment was made for potential incident scenarios, including breakage and fire during storage and accident during transport. The incident scenarios were categorized into public use, industrial use, and military use. For each incident scenario, intake of tritium was estimated and radiation dose was calculated based on ICRP human respiratory tract model. For the public use, radiation doses for all the scenarios were below 1 mSv in spite of conservative dose estimation. Therefore, it is considered that radiological consequences of breakage or fire of a single product is not significant. However, the radiation dose would be higher if many products were stored and damaged together. For the industrial and military use, large number of products or GTLSs might be stored or transported together.

In addition, radiation dose depends on storage volume. Such data were collected by site visit. For many scenarios, radiation dose exceeded annual dose limit of the public of 1 mSv. For the scenarios of breakage of the GTLSs and accident during transport, radiation dose to industrial workers might be more than 100 mSv. Workers or servicepersons in the military might also receive more than 10s mSv for the fire in storage and breakage of discarded products stored in a warehouse. This study showed that radiological consequences from any incident scenarios of a consumer product containing tritium below exemption level were not significant. If plenty of products or GTLSs are involved, the radiological consequences might be significant. Therefore, it is necessary to establish safety control standards of consumer products containing radioactive substances such as limits of total storage activity, standards for storage volume and ventilation, limits of total transport activity, use of transport container, standards for transport vehicles, etc.

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P02.93
Evaluation of Internal Exposure of Nuclear Medicine Staff Working with Radioiodine and Technetium

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The increasing use of radionuclides for medical purposes creates a demand for feasible methodologies to perform occupational control of internal contamination. Currently in Poland there are about 100 nuclear medicine unites in operation but individual monitoring is still restricted to the control of external exposure.

A group of workers from about 20 Departments of Nuclear Medicine were monitored with available in CLOR mobile detection system for „in vivo" measurements of radioiodine and technetium, which which is consist with scintillation detector NaI(Tl) - battery-powered, portable tube base Multichannel Analyzer Canberra UniSPEC, paired with the notebook computer and Genie-2000 Basic Spectroscopy Software.

The detection system was calibrated with a neck-thyroid phantom developed in RSD. The MDA for mobile unit ranges from 10 – 70 Bq at the time measurement of 300 seconds. The measurements were performed in selected as low as possible background places at nuclear units .

All workers actively working with iodine and technetium show measurable amounts of this isotopes in their thyroids. The average measured activity in the thyroid of the nuclear medicine staff was found to be equal at average 550 Bq within the range from 50 Bq to 50 kBq. The average and range of I-131 activity measured in thyroids for all medical units were: 1400 Bq, (100 Bq – 70 kBq Bq), 400 Bq, (30 Bq - 3000 Bq), 140 Bq, (50 Bq - 1000 Bq) for technical staff, nuclear medicine staff and hospital services staff respectively. The technical and nuclear medicine staff show higher I-131 thyroid level comparing to hospital services staff.

Base on results of measurements, the Effective Dose Equivalent for particular person due to inhalation of I-131 and Tc-99m was calculated .

Calculated average Effective Dose Equivalent for particular exposed person is below 45 per cent of 20 mSv/year.

P02.94
Radionuclides Incorporated by Inhabitants of Surrounding Brazilian Uranium Mines

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Brazil has the 6th largest global geological reserve of uranium, with the main reserve in Santa Quitéria - CE still not under exploration. Currently, uranium mining and processing in Brazil only occur near to the city of Caetité - BA. Several Non-Governmental Organizations claim that uranium mining in this region is polluting and may jeopardize the human health and safety and the environment. However, those in charge of the complex extraction and production of "yellow cake" for generating fuel to the nuclear power plants reject these allegations. ^{238}U may be deposited in the skeleton by replacing the calcium, thus it is possible to estimate its incorporation by determining its concentration in the teeth. This study aimed to identify potential problems caused by mining to the population of Caetité, analyzing ^{238}U contained in samples of teeth extracted for orthodontic reasons from Caetité residents. The concentration of thorium and potassium incorporated were also determined by ICP-MS, as well the cumulative dose of radiation received by this population was estimated. For comparison sake, the same analysis was performed in samples from Santa Quitéria and Aracaju – SE (used as a control area). The doses estimated were compared to doses obtained with EPR spectra of the same samples. The accumulated amount of radioisotopes in the teeth of the population of Caetité is probably due to natural origin, thus it is not possible to state that the mining process in Caetité increases pollution or radiation exposure in a meaningful way.

P02.95
The Assessment of Internal Doses for the Korean Nuclear Medicine Workers based on the Thyroid Bioassay Measurement of I-131

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Internal doses for nuclear medicine workers in Korea have been assessed on the basis of thyroid bioassay measurements of ^{131}I. The total number of analysed thyroid bioassay measurements was 649 for 81 workers in 5 nuclear medicine departments in hospitals during 2007. Thyroid activity was detected in 10% of the total measurements from a NaI scintillation detector. The committed effective doses by inhalation of 131I during one month were assessed. For 10 workers who exceeded 0.1 mSv, the doses were in the range of 0.11 to 0.58 mSv, and 0.25 mSv on average. The committed effective doses through an annual intake of ^{131}I for 6 workers have been expected to exceed 2 mSv.

P02.96
Effect of Change of Biokinetic Models on Interpretation of Bioassay Data

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Since ICRP publication 78 (Individual Monitoring for Internal Exposure of Workers) was published, biokinetic models including respiratory, alimentary, and systemic model have been changed or revised. Human Respiratory Tract Model (HRTM) developed in ICRP publication 66 has been revised and the Publication 30 model of the gastrointestinal tract has been replaced by the Human Alimentary Tract Model (HATM) described in Publication 100. In addition, systemic models have been changed into more realistic models. For these reasons, retention fraction in tissues and organs, and excretion via urine and faeces after intake of radionuclides should be changed, which influences interpretation of bioassay data, i.e. prediction of intake. Thus, in this study, Intake Retention Functions (IRF) and excretion functions were calculated with changed biokinetic models when a subject inhales or ingests ^{60}Co. Using these functions calculated, intake of radionuclide was predicted for some example of bioassay data and effect of change of biokinetic models was assessed on bioassay data interpretation. While some cases were little influenced by the change, some cases were significantly affected by the change. In conclusion, biokinetic models changed which are more realistic than former models should be applied into interpretation of bioassay data because predicted intake can significantly vary with the models.

P02.97
Study of the Influence of Radionuclide Biokinetics Distribution in Human Body on the Efficiency Response of Lung Counters

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Reliable efficiency calibration of measuring systems is one of the most crucial tasks in *in-vivo* monitoring. The traditional calibration method is based on physical phantoms, such as the Livermore torso phantom for efficiency calibration purpose for lung counters. However, besides the shape of physical phantom does not represent realistic human anatomy faithfully, it is difficult for physical phantoms to simulate the non-uniformly source distribution in human body. Numerical calibration technique being the state-of-art provides a tool to investigate the above issue. In this paper, numerical calibration method is developed based on the Chinese Reference Adult Male (CRAM) voxel model, MCNP code, and the radionuclide biokinetics distribution data predicted by ICRP biokinetics model, then, it is applied to study the influence of radionuclide biokinetics distribution in body on the detection efficiency of lung counter configured with four HPGe detectors. The preliminary results reveal that the radionuclide activity could be overestimated up to 50% (AMAD=1μm), 150% (AMAD=5μm) for ^{241}Am inhalation in the early period (<3d) after intake; and a relative flat response exists for the period from 3d to 100d, in which the overestimation are 10%-40% for 1μm, and 20%-60% for 5μm respectively; however, the overestimation would become worse along with the time extended, e.g., 160% and 230% for 1μm and 5μm respectively at 300d.

Key words:Monte Carlo; efficiency calibration; in-vivo monitoring; voxel phantom; Biokinetics

P02.98
Element Transfer from Intake to Excretion in Human Body of Chinese adult men

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Purpose: to complete the element transfer disciplines from the soil to human body of Chinese adult men which based on the ideas of compartment--- “intake (including ingestion and inhalation) - Blood (the middle compartment) - organs and tissues (the whole body) - excretion (including urine and feces) “.

Materials and methods: 120 adult men’samples of food ,blood, Feces and urine were collected in 3 continuous day in 4 areas with different dietary types in China,the inhalable particles samples in air also collected in the same time.The concentrations of 46 elements in these samples were analyzed by ICP-MS,ICP-AES after pretreatment.

Results: The representative values of the elemental daily ingestion and inhalation,the element content in blood and the elemental daily excretion in urine and feces have been calculated by the median of results.

Conclusions:The research provide exploratory evidence for developing reference values of Chinese Reference Men and some important biokinetic parameters(eg. F_1,f_2 and T_e).It also provide the important national information for the amendment of international reference men ,UNSCEA reports and other related fields.

Keywords: element transfer ; Chinese adult men; human body;representative values

P02.99
Eurados Network on Internal Dosimetry

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EURADOS (European Radiation Dosimetry Group) is a self-supported European organization of laboratories and institutions involved in the field of the Dosimetry of Ionizing Radiation. The working group on Internal Dosimetry operates inside EURADOS as a network of scientists, services, regulators and laboratories collaborating for the coordination of research and the dissemination of knowledge in the complex world of the assessment of doses due to intakes of radionuclides.

EURADOS Internal Dosimetry Network started as a work package of the CONRAD Project (2005-2008), a Coordinated Action supported by European Commission (EC VI FP, EURATOM). The priority now is to maintain the collaboration with EC and IAEA and to guarantee that the work generated by this EURADOS group is in coherence with last ICRP developments and ISO standards on internal dosimetry, providing state-of-the-art tools and publications of great importance for internal dosimetry community.

EURADOS Network on Internal Dosimetry consists of 28 institutes from 17 countries, started as an European group but now has established formal agreements for collaboration with other institutions from America like USTUR (United States Transuranium and Uranium Registries), the Human Monitoring Laboratory (Health Canada), LRRI (Centre for Countermeasures Against Radiation, USA) and ARN (Autoridad Regulatoria Nuclear Argentina). Members of these American organizations participate actively with European colleagues in the current work program of the EURADOS internal dosimetry group. Tasks under development consider the elaboration of reference documents like the Update of IDEAS Guidelines for the harmonization of internal dose assessments, the research on new biokinetic models like the EURADOS/CONRAD DTPA Therapy Model, the application and quality control of new biokinetic and dosimetric models of ICRP and NCRP, training actions (like the EURADOS/IAEA Advanced Training Course organized in Prague in 2009) and Intercomparison exercises (like the two USTUR/EURADOS Intercomparisons for In-vivo monitoring of radionuclides and Monte Carlo calculations using USTUR phantoms).

The EURADOS Internal Dosimetry Group also established joint actions with other workings groups of EURADOS (e.g., action on "Computational Dosimetry" for the application of Monte Carlo Methods and Voxel Phantoms to internal dosimetry, jointly with WG6), and with CEA (Commissariat de la Energie Atomique) for the validation and development of the MADOR code: a new tool related with the administration of DTPA after intake of actinides.

The main aim of the Internal Dosimetry group inside EURADOS is to reach the harmonization on the assessment of internal doses and the coordination of research, using the Network for the dissemination of the scientific knowledge.

P02.100
Quantitative Plutonium Microdistribution In Liver Of MAYAK Radiochemical Plant Workers

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Hepatic tissue samples were taken for the study from 11 former Mayak workers, having liver cancers, with Pu liver and body burden (0.02 – 20.3) and (0.03 – 108.0), respectively. Histoautoradiagrams of hepatic tissue were obtained using method of classical photographic histoautoradiography (30 days' exposure). Quantitative analysis of Pu microdistribution was carried out.

Tracks in autoradigrams were distributed nonuniform. Maximum track number was registered in lobules of liver (cytoplasm of hepatocytes) – from 44% to 71%, fewer number was registered in structures of portal tracts (2% – 4%). More rarely tracks were registered in Kupffer cells (0.5% – 3%).

The quantitative estimation of Pu microdistribution in man's liver is obtained for the first time. According to the obtained data during the inhalation nuclide intake into the organism Pu deposition in liver is very nonuniform and it coincides with the qualitative analysis data of Pu microdistribution in liver of radiochemical production workers (A.P. Nifatov, unpublished data). The character of radionuclide distribution in liver, registered by us, does not agree with the experimental data, obtained during rats, rabbits and dogs studies with intravenous and intraperitoneal introductions. In the experiment Pu is mainly accumulated in reticuloendothelial elements of liver. In our opinion such difference is stipulated by different types and forms of compounds intake, ways of radionuclide intake and also life span after intake. The obtained data may be used in epidemiologic researches while studying peculiarities of liver carcinogenesis. After data volume enlarge, the work results may be taken into consideration in the models, used for estimation of Pu alpha-radiation doses, accumulated in liver during inhalation intake.

P02.101
Uranium Concentrations in Natural Water Around Mysore City, India

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Uranium concentration in water depends on lithology, geomorphology and other ecological conditions of the region. Natural uranium is a mixture of mainly three isotopes ^{238}U (99.285%), ^{235}U (0.71%) and ^{234}U (0.0054%). Uranium-238 is found in an average concentration of 0.0003% (3mg/kg) in the earth crust and it decays by alpha particle emission. This element enters the human body through ingestion of water and diet components. Since alpha emitters are the most dangerous studies of water for human consumption are very important. The aim of this study is to determine regional variations of concentrations of ^{238}U and to estimate radiation exposures caused by drinking water.

The study area is Mysore district, Karnataka State, India lies between 12°13" to 12°25"N latitude and 76°27" to 76°45"E longitude. Uranium-238 was measured in water samples collected from about 75 places from private and public bore wells, open wells, lakes, tap and rivers using Laser Flourimeter. The measurements are based on fluorescence of Uranyl salts. The Uranium concentration varies from 0.3 to 235.4 µg/L in different types of water samples with a geometric mean of 4.87 µg/L. In river it varies from 1.2 to 13.1 with a median of 2.2 µg/L, in tap water it varies from 1.2 to 10.6 with a median of 3.5 µg/L, in lake water it varies from 1.7 to 55 with a median of 2.5 µg/L and in bore well it varies from 1 to 235.4 µg/L with a median of 5.5 µg/L. The Effective dose due to the presence of ^{238}U in drinking water varies from 0.4 to 95.55 µSv/y and the annual effective dose (assuming 2 litres per day of water consumption) is 4.42 µSv/y which is lower than the maximum dose level (100µSv/y) recommended by the WHO.

Poster sessions A-B: Area 2

P02.102
Content of Uranium in Urine of Uranium Miners in Relation to Personal Dosimetry of Long Lived Alpha Radionuclides.

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Three exposure pathways are important for the miners of uranium mines: external gamma exposure, inhalation of radon and its short lived progenies and inhalation of long lived alpha radionuclides (LLRN). Exposure from radon and its short lived progenies has been widely studied in the connection with occurrence of lung cancers, external exposure has also been taken into account in epidemiological studies. In connection with leukaemia occurrence among uranium miners, exposure from inhalation of uranium dust becomes the subject of interest too.

In the Czech Republic, three component personal dosimeters ALGADE are used for monitoring of all three exposure pathways. The dosimeter consists from measuring head equipped with a membrane filter on which aerosol particles are collected, a track detector for short lived radon daughter products and thermoluminiscent detector for measurement of external dose.

The doses from LLRN contribute on average more than by 50% to overall doses in the Rožná mine, Czech Republic. The derived limit for annual intake of long lived alpha radionuclides by miners in uranium mines is, according to the Czech Decree on Radiation Protection, 1850Bq corresponding to 20 mSv (0.011mSv/Bq). This approach seems to be rather conservative, therefore, a programme was launched with the aim to check this approach for evaluation of doses from LLRN. The programme included experimental study of inhaled aerosol parameters (AMAD, fraction of radon retained in it, class of solubility in lungs) and determination of excreted uranium in urine by High Resolution ICP MS method for a group of more than forty selected uranium miners from uranium mine Rožná I. Results of this experimental study of the aerosol served for model calculations of retention and excretion of uranium using the biokinetic ICRP models and data from personal dosimeters of individual miners as input data. For model calculations, input data assuming AMAD of inhaled aerosol 6µm, rapid fraction $F_r = 0.14$, rapid dissolution rate $\lambda_r = 0.49d^{-1}$ and slow dissolution rate $\lambda_s = 0.004d^{-1}$ for dissolution in lungs were used. The results of model calculation of uranium content in the urine were compared with the experimental findings, the range of ratios was quite wide with log–normal distribution with median 0.58 and GSD 1.8 when results of 18 hewers were used and median 0.44 and GSD 2.0 when results of 40 miners were used. It was found that values of uranium excreted through urine, modelled using experimentally found parameters were higher nearly for all individuals than the measured ones; i.e. the current practice is conservative enough and suitable for further use.

Evaluation of conversion factor between measured gross alpha activity on filters from personal dosimeters and dose was also performed and, based on the experimental findings this value is less than half of the value used up to now.

P02.103
Assessment, using Monte Carlo and Biokinetic Models, of the Absorbed Dose in the Thyroid, as a Critical Organ, in Scintigraphies with I-123 and Tc-99m

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Objective: With the introduction of 123I in clinical practice, improvements in the dosimetry of patients were clear, when compared with procedures performed using ^{131}I. The thyroid blocking, as a critical organ, in scintigraphies performed using these isotopes is essentially equal. However, as the isotopes are physically different, it is important to assess existing thyroid blocking procedures for ^{123}I in terms of radiological protection, in order to realise if it could be optimized. Therefore, the ICRP biokinetic models, and state-of-the-art voxel phantoms based computation methodologies were used, aiming at: - The assessment of the absorbed dose in thyroid in studies with ^{123}I and in studies involving $Na^{99m}TcO_4$-, since its free form is also incorporated by this gland and it's blocking is not usually performed.

Methods: Four types of procedures were included in the study: DaTscan, mIBG, Meckel's Diverticulum, and Equilibrium Radionuclide Angiography. The first two use ^{123}I and the last two use $Na^{99m}TcO_{4-}$. The ICRP biokinetic models were applied and the activity versus time curves corresponding to incorporation of the isotopes in the thyroid were generated and information about the cumulative activity in was obtained. Afterwards, using the PENELOPE Monte Carlo simulation program and the GSF voxel phantoms Golem and Laura, the estimation of the dose per particle in thyroid for all the procedures was performed. With these information, the absorbed doses in the thyroid due to the incorporation of the isotopes were calculated. The obtained data was then validated with in vivo measurements of isotopes incorporated in the patients´ thyroid, using a NaI(Tl)-based detection system.

Results: The absorbed dose in thyroid due to incorporation of ^{123}I was assessed and then compared with the ICRP estimations; preliminary results indicate lower doses than the ICRP estimations, meaning that the optimization of blocking protocols must be considered. Furthermore, preliminary results indicate doses in the thyroid using $Na^{99m}TcO_4$- much lower than 50 mGy, the Administration of Radioactive Substances Advisory Committee´s (ARSAC) threshold for the adoption of thyroid blocking. Comparative results between ^{123}I blocked and unblocked procedures (in patients who denied the pre-treatment with the blocking agent) will also be reported.

Conclusion: The accurate assessment of the absorbed dose in the thyroid gland will pave the way to the review and optimization of radiological protection protocols in order to achieve the lowest absorbed dose in the thyroid with the least discomfort to the patient.

In this study, evidence is provided about the powerful predictive power that can be attained combining the utilization of Monte Carlo simulation methods with the predictions obtained using biokinetic models, for dose assessment in Nuclear Medicine examinations.

P02.104
Controlling Radiological and Chemical Intakes of Uranium in the Workplace: Applications of Biokinetic Modeling and Occupational Monitoring Data

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We reevaluated the most recent published case reports and used ICRP biokinetic models to update approaches for uranium bioassays. These models link the timing and concentration of tissue exposures to the concentrations excreted in the urine and feces. We calculated the biokinetics of uranium intakes with various characteristics in the human respiratory system, the alimentary tract, blood, and kidneys. The characteristics include: solubility, chemical form, activity median aerodynamic diameter, and enrichment. We calculated the biokinetics of both acute and chronic exposures and the superimposed combination of acute and chronic exposures. We produced graphs of investigation levels and immediate action levels that show the cross-over of chemical toxicity to radio-toxicity as functions of air concentrations of uranium, solubility, and percent enrichment. We predicted optimum times for collecting bioassay specimens or measurements.

P02.105
WBC IRSN 2011 Intercomparison: Participation Of The ISPRA Joint Research Centre WBC Laboratory

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The Joint Research Centre of Ispra is a research site belonging to the European Commission, Directorate General JRC. It was created in the late '50s, in order to steer European research on nuclear industry. The Whole Body Count (WBC) Laboratory belongs to the Radiation Protection Sector, Nuclear Decommissioning Unit and is dedicated to the direct monitoring of workers.

Intercomparison exercises provide an excellent opportunity to check quality controls applied in routine WBC measurements: in this context, WBC facilities can compare measurements' accuracy and reproducibility with those obtained by other laboratories, judging their own performance and verifying if their quality assurance programme is performing as expected.

Moreover, regular participation to intercomparisons exercises is becoming a significant requirement for any laboratory wishing to maintain its accreditation, as stated in ISO/IEC 17025:2005.

The IRSN organized the first of a series of internal dosimetry measurements' intercomparisons in 2011: a thyroid geometry measurement was then proposed.

The JRC-ISPRA WBC Laboratory participated to the IRSN Thyroid intercomparison exercise, together with some other 20 laboratories, providing measurements with both an NaI(Tl) scintillation detector and two HPGe semiconductor detectors, both for low and high energies (I-129 and Ba-133 sources).

Uncertainty calculations were also performed, taking into account many factors including: peak area, geometry (uncertainty due to phantom repositioning), radiation branching, efficiency and nuclide decay.

The object of this poster is to present the methodology followed for the participation to the intercomparison, and its results, for the JRC-ISPRA WBC Laboratory.

P02.106
Implementation of an Intercomparison Exercice according to ISO/IEC 28218 in the Internal Dosimetry Services of Spanish Nuclear Power Plants

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The Whole Body Counting laboratory (WBC) of CIEMAT Radiation Dosimetry Service (SDR) and the Spanish Nuclear Safety Council (CSN) have organised an intercomparison exercise aimed to Internal Dosimetry Services of spanish nuclear power plants and nuclear emergency mobile units for the In Vivo measurements of gamma-emitting radionuclides in total body and radioiodine in thyroid. The main aim of this exercise is to check the quality of the measurements realized in the whole body counters of the participant services in order to ensure the proper surveillance of workers occupational exposed on internal contamination. To achieve this goal, the design of the intercomparison exercise has to check and validate the calibration methodology of the detection systems, measurements procedures and the gamma spectrometry tools of the participant internal dosimetry services. To fulfill this purpose, an intercomparison protocol was sent them in order to explain the steps to be followed at the exercise. To carry out the intercomparison measurements a BOMAB (BOttle Manikin Absorption Phantom) were fabricated simulating ICRP 89 reference man according to ANSI/HPS N13.35 requirements in the CIEMAT SDR laboratories. The manikin consists of ten pieces of tissue equivalent plastic filled with distilled water and gamma emitters radionuclides solution homogeneously distributed in the different containers. The radionuclides were chosen with varied values of activity and complex energy spectrum in order to check the reliability of the calibration methodology and the capability of the spectrometry software to resolve energy lines very close to each. In case of thyroid measurements, the ANSI standard thyroid uptake neck phantom with 20 ml. vial simulating thyroid gland was used. Eight internal dosimetry services have participated in the intercomparison exercise developped during the first semester of 2010. The analysis of the results was realized according to “Relative Bias” and “Repeatability” parameters performance criteria defined in ISO/IEC 28218. Technical recommendations were proposed by SDR CIEMAT and CSN based on final results in order to promote improvements to ensure the quality of the measurements in the participant services.

P02.107
Results of Internal Monitoring for Nuclear Medicine Workers in the City of Medellin, Colombia

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In late 2010 the Health Office of Antioquia (DSSA) and the National University of Colombia campus Medellin conducted a monitoring program to estimate the committed effective dose due from the intake of 131I in 24 occupationally exposed workers in all services nuclear medicine of the city of Medellin, Colombia. We assume the calculation method proposed by ICRP 78, with a monitoring frequency of 15 days. The urine and thyroid measures were performed in a gamma spectrometry system with a NaI detector of 2x2". The system was char-acterized with a detection limit of 1.06 Bq for urine and for thyroid of 27 Bq. The results show that 2 workers intake are above the detection limit and the other 22 were below this limit. The effective doses of these 2 workers are below the levels of research. These results show that during this period of study, procedures per-formed in these centers are appropriate but also show the need for constant internal monitoring programs.

Keywords:

Internal Dosimetry, Intake, Nuclear Medicine.

P02.108
New Dose Factors for Ingestion of 131I

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The ^{131}I is a radionuclide widely used in nuclear medicine and is also a radioactive waste of great importance in the production of nuclear energy, due to its presence and its use in these areas, it is possible that this can be in-take into the human body. The effective dose of the intake is calculated based in the activity intake and the committed effective dose factor. These factors are published in ICRP 78 and used the human respiratory tract model of ICRP 66, the gastrointestinal tract model of ICRP 30 and the values of specific absorbed fractions calculated with stylized phantoms. In this work we have found the new dose factors derived from the intake by ingestion of 131I, using the human alimentary tract model of ICRP publication 100 and SAF values calculated with the computational phantom ICRP reference male 110. The values of committed equivalent dose and effec-tive dose changes are present, mainly due to differences in the values of masses of organs and differences in the SAF data obtained with the voxel phantom.

Keywords: Internal Dosimetry, ingestion of ^{131}I, Biokinetic and dosimetric models.

P02.109
Dose Coefficients For Incorporation Of Lead, Bismuth And Polonium

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Publications 67 and 69 of the ICRP proposed systemic models for radionuclides $_{210}$Pb, $_{210}$Bi, $_{210}$Po. Publication 71 reported dose coefficients for incorporation by inhalation and ingestion of these radionuclides for members of the public and ICRP 68 reports coefficients for the worker. These publications make use of the respiratory tract model proposed in the publication 66 and the gastrointestinal tract model of Publication 30 of ICRP and the methodology of Publication 60 ICRP. In this work we report the calculation of committed equivalent dose coefficients and effective dose for the incorporation of these three radionuclides inhaled or ingested independently, and the coefficients resulting from the incorporation of 210 Pb and the other two radionuclides as its daughters, using the models proposed by the ICRP in its publication 66, 100 and the calculation methodology of the publication 103.

P02.110
Human Hair as Biomonitor of Chronic Intake of Uranium: Studies at a Nuclear Fuel Fabrication Plant.

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Handling of U in the various processes of nuclear fuel fabrication may expose the workers to significant amounts of U by inhalation of airborne dust. The Westinghouse Electric plant in Sweden has a comprehensive program to quantify U levels in the workers environment and to assess the internal contamination, the latter involving e.g. personal mobile air sampling and analysis, analysis of U excretion in urine, whole-body HPGe gamma spectroscopy, and dose assessment using established dose models. Recent studies have revealed that the chronic exposure situation is under control but need continued follow-up.

The aim with this study is to investigate the potential of using human hair as a bio-indicator of intake of U as an alternative of studying excretion in urine as a base for U body burden assessment and subsequent dose assessment. The hypothesis is that endogenic U uptake in hair is less dependent on daily variations in U intake, regardless of the mode of intake (GI or inhalation), i.e. a robust indicator of chronic exposure. It also provide for chronologic evaluation of past exposure along the hair length. The idea of using human hair as a bio-indicator of chronic intake of heavy metals has been explored in many studies. However, quantitative correlation between intake and levels in hair remains to be shown.

The study has enrolled volunteers from different exposure categories; low, average and high levels, based on their U exposure history, <0.2 µg/l, about 0.5 µg/l and >1 µg/l U in 24 h urine samples, in order to establish dose-response relationships. Recruitment from both the U conversion work-shops and the U pellet work-shops were made to study differences in U excretion as a result of intake of low and high solubility U compounds; AUC /ADU and UO_2/U_3O_8 respectively. Also new employees have been enrolled in order to study the chronological build-up of U in the body, reflected in the U content in the hair. For the assessment of the cumulated inhalation of U aerosols participants have carried personal air samplers for subsequent radiochemical analysis of the air-filters. Hair samples were taken at three occasions including at the start and at the end of a working periods. By simultaneous urine sampling and analysis the relation between U levels in hair and in urine has been established.

An important aspect of hair analysis is to avoid exogenic U contamination of the hair. This has been studied by successive U analysis of repeated hair washes, using established washing protocols.

The U radiochemical analysis of air-filters and organic samples involve acid digestion and TBP solvent extraction followed by (i) electrodeposition and α-spectrometric analysis, and (ii) analysis by ICP-QMS. Quantification of the U isotopes (^{238}U, ^{235}U and ^{234}U) and their atomic ratios has yielded the occupational and the natural contributions of U to the total U load in the hair, also reflecting the source contributions.

P02.111
Determination of urine biological exposure index for the monitoring of uranium chemical toxicity

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Radiological versus chemical toxicity limits for varying uranium enrichments are used for evaluating when either radiological or chemical toxicity is of concern. A review of literature has shown that these limits are usually determined and defined in terms of airborne concentration levels. Most radiological individual monitoring programs for the monitoring of uranium intake is based on bioassay measurement (the mass of uranium in urine per day). This is since bioassay measurements, rather than airborne measurements, are more representative of the actual intake. An individual monitoring program, monitoring both the radiological and chemical exposure, will thus be based on airborne concentration monitoring and bioassay monitoring. The aim of this study is to determine a biological exposure index for chemical exposures. Thus, the individual monitoring program will only be based on bioassay monitoring. Chemical toxicity air concentration limits as stated by various occupational safety authorities are 0.2 $mg.m^{-3}$ and 0.05 $mg.m^{-3}$ depending on the type of solubility of the uranium. These limit values are converted to an intake value based on a chronic exposure over 30 days and typical breathing rates. The corresponding uranium concentration in urine is determined using a radiological dose assessment software (IMBA). The chemical toxicity biological exposure indexes were calculated as 1.7×10^{-2} mg/day and 1.2×10^{-4} mg/day. These chemical toxicity limits can then be compared to the radiological toxicity limits for varying enrichments.

P02.112
Simulation of Auger Electron Emission Spectra for 99mTc and 123I by Validated Monte Carlo Codes

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Radionuclides decaying by electron capture (EC) and/or by internal conversion (IC) are of special interest in radiobiology (^{111}In, ^{123}I, ^{125}I) and nuclear medicine (^{99m}Tc). Incorporated into the DNA structure, they can cause severe molecular and cellular damage. These findings open an unique possibility for an application of these nuclides in tumour therapy. Therefore, to utilise them effectively, the understanding of their radiation action mechanism is essential, which requires first of all a precise knowledge of the nuclides' electron emission spectra.

Due to a lack of experimental data for the particular nuclides of interest, computer simulations have become necessary. A decay by EC and/or IC induces an inner electron shell vacancy, the starting point of a complex cascade of photon (radiative) and Auger (non-radiative) transitions within the atomic energy levels. Because of the stochastic nature of these transitions, Monte Carlo technique is an appropriate tool for the study and simulation of these processes and for providing emission spectra. Those spectra are needed, e.g., as input for track structure calculations.

Auger cascades induced by photoionisation in noble gas atoms and by IC in 131mXe were simulated by a Monte Carlo computer code. For these cases many available experimental data allow a comparison of the results and a validation of the simulation code. In view of quite rough assumptions used here, a remarkable good agreement was obtained, e.g., with the experimentally found distributions of charges left on the atoms after the Auger cascades have finished. On this reasonable basis, the computer code was used to calculate electron energy spectra for ^{99m}Tc and ^{123}I.

In addition, also implications following from a molecular bounding of Auger electron emitting radionuclides will be discussed. Ion fragment distribution from small iodine-labelled molecules in the gaseous phase has been explained by a Coulomb explosion model. The possibility of such a damage mechanism also for an iodine-labelled DNA base could be confirmed here.

P02.113
Internal Dose Assessment of 177Lu-DOTA-SP for Quantification of Arginine Renal Protection Effect

Puerta, N*[1]; Rojo, A[1]; Crudo, JL[2]; Zapata, A[2]; Nevares, N[2]; López Bularte, A[2]; Pérez, J[2]; Zaretzky, A[2]

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^{177}Lu-DOTA-Substance P (SP) is presently investigated worldwide, in Argentina the trial is coordinated in the frame of an IAEA Contract Research Project (2011-2014).This radiopharmaceutical is proposed as potential alternative in the therapy of malignant glioblastoma.

With the aim to complete the preclinical animal studies, the biodistribution studies were carried out in normal NIH mice, for two conditions, with and without prior administration of arginine as a potential renal protective agent. These results include, in the two cases, the ^{177}Lu-DOTA-SP biodistribution analysis, the absorbed dose calculated in organs of interest and the extrapolation of the results to humans. Absorbed dose estimated in humans allowed the organs radiological toxicity assessment associated with this procedure.

The comparison of absorbed dose results between organs showed that kidney has the highest absorbed dose. Then, it is the healthy organ with the highest radiological risk, following the radiopharmaceutical intravenously administration. Based on these extrapolations, it was found that the administration of arginine prior to injection of ^{177}Lu-DOTA-SP optimize the treatment, showing a rapid clearance from the body and less retention in kidney with respect to the situation in which the amino acid is not administered.

Finally, again on the basis of extrapolations, the treatment with ^{177}Lu-DOTA-SP with pre-administration of arginine is likely to be safe in people if injected activities do not exceed the values reported in this work.

P02.114
Internal Dose Assessment of 177Lu-DOTA-SP for Quantification of Arginine Renal Protection Effect

Puerta, N*[1]; Rojo, A[1]; Crudo, J[2]; Zapata, A[2]; Nevares, N[2]; Lopez Bularte, A[2]; Perez, J[2]; Zaretzky, A[2]

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^{177}Lu-DOTA-Sustancia P (SP) is been widely investigated in the world, including Argentina where is coordinated in the frame of an IAEA Research contract ARG-16671 (2011-2014).This radiopharmaceutical is proposed as potential alternative in the therapy of malignant glioblastoma.

With the aim to complete preclinical studies, the biodistribution were carried out in normal NIH mice, for two conditions, with and without prior administration of arginina as a potential renal protective agent.

This paper included, in the two cases, the ^{177}Lu-DOTA-SP biodistribution analysis, the absorbed dose calculated in organs of interest and the extrapolation of the results to humans. Absorbed dose estimated in humans allowed the risk assessment associated with this procedure.

The comparison of absorbed dose results between organs showed that kidney has the highest absorbed dose. So that, it is the healthy organ with the highest radiological risk, when the radiopharmaceutical is intravenously administered.

It is found that the administration of arginine prior to injection of ^{177}Lu-DOTA-SP optimize the treatment, showing a rapid clearance from the body and less retention in kidney with respect to the situation in which the peptide is not administered.

Finally, the treatment with ^{177}Lu-DOTA-SP with pre-administration of arginine is likely to be safe in people if injected activities do not exceed the values found in this work.

P02.115
Ingestion dose coefficient update and uncertainty assessment in biokinetic and dosimetric models of α-, β-, αγ- and βγ-emitter

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The objective of the present study is to update the ingestion dose coefficients of some α-, β-, α γ- and βγ-emitters and to assess the corresponding ingestion dose coefficient uncertainty. In some cases new biokinetic models and various ICRP publications were recently published requiring the update of ingestion dose coefficients of radionuclides of interest. Moreover there is no clear analytical uncertainty assessment established for biokinetic and dosimetric models of α-, β-, α γ- and βγ-emitters.

Because ICRP dose coefficients are calculated as reference values, applying to reference persons, they are not regarded as subject to uncertainty. It is recognized, however, that there are uncertainties associated with all aspects of the estimation of doses and risks at low doses. Dose coefficients for the ingestion of radionuclides by members of the public and workers have been calculated by the ICRP. The parameter values used are representative of ranges because individuals exhibit metabolic variation, which can influence the intake, distribution and retention of radionuclides, and they also vary in size and shape, which influences dosimetric quantities. In addition, there is uncertainty associated with each of the parameter values used according to the quality and reliability of the data on which they are based.

New values of ingestion dose coefficients of ^{210}Po, ^{210}Pb and ^{238}U were calculated and compared to values given in ICRP 67. Clear uncertainty budget and well established mathematical relation were carried out for α-, β-, α γ- and βγ-emitters. Correlations between Specific Absorbed Fractions of each source and corresponding targets were also taken into account.

P02.116
Characteristics of a Thyroid Spectrometer Based on a LaBr3(Ce) Detector

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The Whole Body Monitoring Laboratory from IFIN-HH, Magurele, Romania, performs, regularly, *in vivo* measurements of the I-131 retention in thyroid using a gamma spectrometer. These measurements are required, strictly, from radiation protection reasons, for people involved in nuclear activities from hospitals and from radiopharmaceuticals production centers.

The aim of the thyroid monitoring is to determine the amount of I-131 activity incorporated and to estimate the equivalent and effective doses. Reliable results suppose accurate measurements which depend on the correct calibration of the monitoring system.

The energy spectrum associated to the I-131 decay contains gamma lines from tens of keV (80.2 keV) to hundreds of keV (284.3keV, 364.5keV, 637keV and 723keV).

The present thyroid spectrometer is based on a 2"x 2" NaI(Tl) scintillation detector that is traditionally used in gamma spectrometry for the detection of photons with energies higher than 50 keV. It makes possible to quantify the retained activity in thyroid by processing the peak spectra of the main I-131 line of 364.5 keV. Despite its poor resolution (6-8% at Cs-137 energy line of 661.5 keV), the NaI(Tl) detector was considered suitable for the detection of I-131 in thyroid because of its high detection efficiency and its operation mode, being a room temperature detector.

A new type nuclear detector, based on inorganic scintillation material, cerium-doped lanthanum bromide, is manufactured by Saint-Gobain Crystals, offering, for gamma spectrometry applications, promising properties: very good energy resolution, high gamma detection efficiency, very fast light output decay, high temperature and operation at room temperature. Taking into account these properties, the $LaBr_3$(Ce) detector became attractive to be tested and evaluated for *in vivo* assessments, particularly for thyroid measurements, because of detector small sizes.

A 1.5" x 1.5" $LaBr_3$(Ce) detector was available to replace the NaI(Tl) detector of the thyroid gamma spectrometer, being possible to preserve the measurement geometry. Background and radionuclide spectra were acquired in order to be evaluated its main features for a qualitative and quantitative analysis. It was performed the energy and the efficiency calibration using standard etalon point sources (Am-241, Ba-133, Cs-137, Co-60, Eu-152) and thyroid phantom with I-131, as volume source.

It was determined the Minimum Detectable Activity for the I-131 energy line of 364.5 keV , an important quantity for low level activity measurements. All the results were compared with those of the NaI(Tl) detector performed in the same measurement geometry. Discussion of the results and conclusions on the peculiar aspects of the $LaBr_3$(Ce) detector are treated, in detail.

P02.117
A Model of Plutonium Metabolism for Reconstruction of Doses for the Mayak Workers Based on the Autopsy Data

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The results of autopsy measurements for 507 nuclear workers of the Mayak PA, in addition to bioassay measurements in urine, are available at the SUBI. The analysis has revealed that the distribution of plutonium between organs using the current version of Mayak workers internal dosimetry system, MWDS-2008, based on bioassay measurements in urine, was not quite consistent with results of autopsy measurements for most of these workers. A ratio of the autopsy- to urine-based estimates of plutonium organ burdens was 0.47x/1.80 (geometric mean x/ geometric standard deviation) for liver; 0.83x/1.8 for lung; and 1.02x/1.4 for skeleton. A potential cause of such differences could be associated with the fact that the plutonium biokinetic model used in MWDS-2008 was designed to describe the radionuclide behavior in healthy workers. In the study group, many workers died at senile age and had severe chronic diseases. Some diseases altering a pattern of plutonium metabolism in impaired organs could affect the radionuclide re-distribution, for instance, between liver and skeleton. The MWDS-2008 model was modified to account for the health status of workers. A new model, MWDS-2008A, implied additional introduction of three modifying coefficients, *Lung, Skeleton, Liver,* to be applied simultaneously to groups of the MWDS-2008 model parameters. A coefficient, *Lung*, was applied to three parameters of the pulmonary part of MWDS-2008 model, i.e. the fraction of plutonium fast absorbed into blood, f'_r=$_r$(MWDS-2008)xLung; the fraction of plutonium constantly fixed in lung, f_b=a x (fr)^b; and the rate of plutonium slowly absorbed into blood, s_s=c x (f'_r)$_d$. Coefficients of power dependence, *a...d*, were calculated using the least squares method based on the Mayak worker data. A coefficient, *Skeleton*, was used for rates of plutonium transfer from blood onto the surface and into the cortical and trabecular bones from the time of started occupational exposure. A coefficient, *Liver*, was used for rates of plutonium transfer in liver and from liver into blood from the time of clinical diagnosing of severe liver disease. If a liver disease was diagnosed at the post-mortem examination, this coefficient was applied 7 years prior to the worker's death. If there were no data on liver diseases, the coefficient was applied from the time of started occupational exposure. These three coefficients were calculated individually for each worker using a deforming polyhedron method, with minimizing a functional dependent on the autopsy measured plutonium skeleton, liver, lung, and body burdens. The calculations of coefficients implied some limitations such as f'_r element of [0.1], $f_b$element of [0.1], s_s >0. A comparison of absorbed doses accumulated by the time of death demonstrated that the ratio of autopsy- (MWDS-2008A) and bioassay-based (MWDS-2008) dose estimates was 1.14 x/1.9 for liver; 1.10 x/1.9 for lung; and 0.87 x/1.5 for skeleton.

P02.118
Carbon-14 Dosimetry and the Latest Evidence for the Biological Half Life of Carbon-14 Radiolabelled Compounds

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Quotient Bioresearch Limited has instigated a reassurance dosimetry service to comply with the IRR99 requirements to demonstrate that non-classified radiation workers are not exceeding effective dose in excess of 6 mSv/y. This also ensures that the exposures assigned to employees are reliably estimated, without being unreasonably optimistic or prohibitive. Several issues had to be considered. To ensure that the best use was made of resources the analysis was carried out by liquid scintillation counting of urine samples. The choice of liquid scintillation counter, sampling frequency, sample counting time, biological half life and form of the exposure was carefully considered.

Quotient's open source work involves the radiolabelling of short and long chain organic carbon-14 compounds, often using simple precursors such as barium carbonate as starting material. This variation in use makes calculation of the effective doses that result from carbon-14 intakes difficult, due to uncertainties in biological half lives. A significant urine bioassay database has been built up by Quotient which shows that the biological half life of organic 14C compounds inadvertently taken by inhalation and absorption is dominated by a short half-life component which is very often less than 1 day and in most cases less than 2 days. To date no biological half lives have been measured that agree with the standard ICRP biological half life for Carbon-14 of 40 days (ICRP 56). The available data is not able to determine definitively whether or not there may be a small component of the retained 14C compounds with longer biological half-life: a range of bio-kinetic modelling studies have been undertaken to assess the significance of this uncertainty.

Collaboration between Quotient, Peak RPA and Nuvia has established a robust reassurance dosimetry service. This quantifies the exposures received within the context of the established site-specific dosimetry strategy, and provides reassurance that exposures are effectively controlled. This assessment is made by use of a spreadsheet to record and interpret the results of the twice weekly routine sampling programme. An investigation limit is defined which triggers special monitoring involving daily/ sub daily analysis of voided samples, case-specific modelling of the biological half life and a dose assessment for that individual by use of approved dosimetry methods. Examples of routine and special monitoring results are presented.

P02.119
Biokmod Application for the Evaluation of Different Types of Bioassays

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Biokmod application is a software that has been developed for the assessment of the internal contamination. This software has been developed using Mathematica but it is based on web application (http://www3.enusa.es/webMathematica/Public/biokmod.html) and therefore it is not needed any special piece of software else than the navigator. The biokmod application has different modules for use on radiological protection analysis.

One of the latest modules that have been recently upgraded is the Bioassay data evaluation. This tool, gives the estimated intake (acute or other kind of intake can be assumed) using the bioassay data determinations from different types of bioassay (urine and faecal excretions and lung retention for inhalation) for all types of isotopes . Acute, constant -chronic, continuous (variable in the time) and multi-inputs, even random intakes can be used. You can accept the default parameters or introduce specific values. Non-linear techniques are applied to estimate the intakes using bioassay data. The user doesn't need to make many assumptions about the intake (for instance: the AMAD is automatically fitted)

The program can be used for bioassay evaluations and for research and education purposes.

In this work the method applied (based on best fit approach) is explained and some examples where the software can be used are shown.

P02.120
Therapeutic Intervention Decision for Tritium Uptake within Limit

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Principle of radiation protection, justification, optimization and dose limits is applicable for normal and potential exposure keeping in mind economic and social factors. During normal operation, social factors are being considered whereas the impact of the potential exposure to the society is unpredictable. The external exposure by X, γ or neutron is such that once person has received can't be minimized whereas internal exposure by ^{3}H is possibly reduced. In the tritium handling facilities, occupational workers are exposed by nominal range of tritium. The idea encourages tritium uptake reduction from the body by accelerating the individual biological half-life through increase in water intake or therapeutic intervention. Now question is that when a person has to be recommended for therapeutic intervention to minimize the radiation risk due to tritium uptake? The decision for application of ALARA principle within limit is a gray area where social impact may be unfavorable for management of large number of tritium exposed victims. The biological half-life (BHL) of tritium is a variable factor for person-to-person as well as seasonal dependable which is useful for decision of therapeutic intervention. The persons with higher BHL of tritium shall be preferred compared to low BHL. The persons having tritium uptake equivalent to stipulated dose limit (monthly/quarterly/annually/five year) shall not be recommended for tritium reduction by therapeutic intervention. The criteria would be very useful for tritium handling facilities mainly nuclear fission/fusion reactors and other establishments. In absence of written guidelines inappropriate decision may create panic situations in the society.

P02.121
The Experimental Basis for Revising Particle Clearance from the Extra-Thoracic and Bronchial Regions in the Revised ICRP Human Respiratory Tract Model

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The ICRP Human Respiratory Tract Model (HRTM) Task Group in ICRP publication 66 notes where experimental information was lacking so that the model had to be based on the best interpretation of limited available data. Two such areas were clearance of inhaled particles from the nasal passage, for which there were few data and none for times after inhalation greater than ten hours; and slow clearance from the bronchial and bronchiolar airways, where there were limited experimental data and a lack of scientific consensus on their interpretation. Taking account of all new data available since its publication in 1994, the HRTM has now been revised for publication in a forthcoming ICRP document "Occupational Intakes of Radionuclides".

Results from two volunteer studies conducted at what is now the Health Protection Agency (HPA) Centre for Radiation, Chemical and Environmental Hazards (CRCE) have contributed to the model's revision. One study compared the retention of radio-labelled gold and polystyrene particles in the conducting airways of the lung. A slow cleared fraction was seen and its magnitude found to vary with the inhaled particles' aerodynamic diameter, not their physical diameter, indicating that slow clearance depends on the site of particle deposition rather than particle properties. This has been used with information from other studies in revising the HRTM model of slow clearance in the conducting airways. A second study followed the retention in and clearance of inhaled insoluble particles from the human nose for several days after intake, providing information on magnitudes and clearance rates of the different observed clearance fractions. Significant inter- and intra- subject variation was seen. On average, it was found that about 20% of the initial extra-thoracic deposition (IETD) was cleared by nose blowing and 45% IETD was cleared to the alimentary tract, both with half-times of 8 hours. The remaining approximately one-third of IETD cleared rapidly to the alimentary tract with half-times of tens of minutes, and showed consistency with previous measurements of nasal mucociliary clearance. These results show that more material clears from the nose to the alimentary tract, having stayed in the nose for longer, than predicted by the original HRTM. These data were used in determining a revised clearance model.

P02.122
The Effect of Radiological Protection Policies and Work Programme on Radiological Measurements at the Dounreay Site.

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Over the past ten years a number of radiological control developments have been introduced at Dounreay, including improved electronic dosimetry, modular containments systems, and contamination control. During the same time period the site has continued its move from being an operational site to a decommissioning site.

Throughout this time period the results of a number of radiological measurements have been collected and demonstrate good dose limitation and optimisation of exposure. This paper looks at the trends in radiological measurements and considers what changes in the Dounreay site work practices can be correlated with the measurement trends.

P02.123
Pregnancy and Lactation as a Factor of Increased Accumulation of Bone-seeking Radionuclides in Maternal Body

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A unique situation on contamination of the Techa River (Southern Urals, Russia) in 1950s by long-lived ^{90}Sr allows investigation of the features of bone-seeking elements (such as Y, Pb, Ba) accumulation in humans. This study is based on information compiled at the Urals Research Center for Radiation Medicine (URCRM, Chelyabinsk, Russia) over a long-term period, that includes the results of more than 38,000 *in vivo* measurements of ^{90}Sr-body burden obtained for 20,000 persons obtained with a whole body counter SICH-9.1; data on personal medical examinations and residence and family histories.
The effect of pregnancy and lactation on accumulation of the radionuclides in maternal body is not sufficiently known since the main attention in different studies was paid to accumulation of radionuclides in fetus and infant. Significant changes occur in maternal mineral turnover during pregnancy and lactation due to fetus/infant requirements in minerals. For example, such changes during pregnancy result in increase of Ca and Sr absorption from gastrointestinal tract; Ca and Sr urinary excretion and bone remodeling rate. Our study of about 100 women from the Techa riverside villages shows an increase in accumulation of ^{90}Sr in maternal skeleton during pregnancy and lactation by a factor of 1.5-2 in comparison with non-pregnant, non-lactating (NPNL) women. Such increase is resulted from increased consumption of water and foodstuffs during pregnancy and lactation, as well as, changes in the rates of bone mineral turnover in the mother. Water and foodstuffs consumption by women mostly increases at lactation (by 25%) than at pregnancy (by 5-10%). Another possible reason of additional radionuclide accumulation is a rapid restoration of maternal bone mineral loss during pregnancy and lactation coincided with ^{90}Sr intake. Our study indicates an increase in accumulation of toxic elements in pregnant/lactating women compared to NPNL women that lead to increased radiation/toxic doses and risk for women health. . This work has been funded by the European Commission Contract No. FP7-249675 “Epidemiological Studies of Exposed Southern Urals Populations” (SOLO) and the Russian Foundation for Basic Research Grant 10-04-96082.

P02.124
Estimates Of Effective Doses Among Czech Uranium Miners

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Czech uranium mining started on industrial base in the 1890s. It is estimated that the total production has been 110 000 t of uranium and the uranium industry has employed nearly 100 000 underground workers. Radiation doses in uranium mines include contribution form inhalation of radon and uranium dust and from external gamma radiation.

The Czech uranium mine at Rozna is still operated. The presentation includes an estimation of radiation doses, which is based on measurements of physical and chemical characteristics of the mining aerosol conducted recently in the mine. The main parameters were: size, chemical solubility in lung fluid, and amount of Rn gas emanating from uranium particles. The mean size of particles in terms of AMAD was in the range 5-9 ìm. Study of kinetics of dissolution of uranium collected on filters from personal dosemeters ALGADE estimated rapidly dissolved fraction of 0.142 and 0.177 for U-238 and U-234, respectively. Fraction of Rn gas emanating from uranium particles was estimated by measuring activity ratios of radon progeny and Ra-226. This fraction, which determines how the gross long lived alpha activity is distributed into radionuclides of the uranium series, were in the range 32% - 63% with the mean of 44%.

Based on these parameters, committed effective doses from long lived radionuclides in uranium dust were calculated using the IMBA software. In conditions at mine Rozna in 2000-2009, mean annual effective doses are 1.9 mSv from long lived radionuclides, 4.1 mSv from radon and its progeny (using conversion 1WLM=10mSv) and 2.2 mSv from external gamma radiation. This work was supported by the Czech State Office for Nuclear Safety, R&D project VZ 60022490.

P02.125
Effect of Respiratory Motion on Counting Efficiency Using a 4D NURBS-Based Cardiac-Torso (NCAT) Phantom

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For the last fifteen years the Human Monitoring Laboratory (HML), which is a part of the Canadian National Calibration Reference Centre for Bioassay and In Vivo Monitoring has looked at a variety of parameters (lung volume, lung deposition patterns, variability in the chest wall thickness profile. etc) that can affect the counting efficiency of its lung counting system. The calibration of the system is performed using the Lawrence Livermore National Laboratory (LLNL) torso phantom and the Japanese Atomic Energy Research Institute (JAERI) realistic torso phantom. However, the effect of respiratory motion cannot be accounted for using these phantoms. When measuring an internal deposition in the lungs of a subject, respiration causes a change in the volume of the lungs and the thoracic cavity and introduces a variable distance between the lungs and the detectors. These changes may have an impact on the counting efficiency and may need to be considered during a measurement. In this study, the HML has simulated the respiration motion using a 4D non-uniform rational b-spline (NURBS)-based Cardiac-Torso (NCAT) phantom and determined the impact of that motion on the counting efficiency of their lung counting system during measurement. The respiratory motion was simulated by a 16 time frame cycled 4D NURBS-based Cardiac-Torso (NCAT) phantom developed at the Department of Biomedical Engineering and Department of Radiology, University of North Carolina . The counting efficiency and its relative standard deviation for the four germanium detectors comprising the HML lung counting system was obtained using MCNPX version 2.6E for photon energies between 17 and 1000keV.

The amount of uncertainty due to the breathing motion was estimated by looking at the efficiency bias of the detectors comprising the HML lung counting system. The efficiency bias values were highest at low photon energies as expected due to attenuation and geometry effects. Also, to reduce the influence of the detectors positioning on the efficiency, an array was calculated by simply averaging the individual detector tallies for a given energy and time frame. For photon energies of 40keV and higher, the efficiency bias for the array of four 85-mm-diameter detectors used in the HML lung counting system showed an underestimation of about 5% in the activity estimate. If compared to other parameters already studied by the HML, this value demonstrates the insignificant impact of the breathing motion on the counting efficiency. This indicates that the use of this type of phantom to simulate the respiratory motion is unnecessary when calibrating the lung counting system.

P02.127
Natural Radiation Exposure from Indoor Radon and Thoron in China

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The exposure people received from nature radiation has changed greatly for two decades in China. Annual effective dose to the public varies from 2.3mSv/a in 1990s to 3.1mSv/a in the present, in which the most contributor is the indoor radiation level enhanced. Many buildings have been made of materials containing waste or slag from such as coal-fired power plants, iron and steel industry, phosphate industry and so on. Nature nuclide in waste or slag is enriched after materials burning or processing. The concentration of radon and thoron in rooms may rise significantly when the waste or slag is used to make building materials. Baotou iron and steel plant produces about $9x10^6$ t of iron and steel, yielding $3.55x10^6$ t of ferrous slag every year. About 1450,000 t/a of ferrous slag has been used to make cement, bricks and other building products. The ^{232}Th activity concentration of ferrous slag is about 0.5-$1.6x10^3$Bq/kg, which is above the exemption level of 1Bq/g. In order to comply with radiological regulations, the usual way to produce construction materials from slag is mixing blast furnace slag and the low radioactive material such as fly ash together under certain ratio to reduce the activity concentration of the materials, which are converted into qualified construction materials for the radiological requirement. For example, a formula from a manufacturer is as follows: steel slag- 60 - 70%; blast furnace water slag- 10 - 15%; fly ash- about 10%; cement- 12 - 17%. The products meet the requirements of radioactive level for construction materials. The indoor radon monitoring has been carried out for two season in Baotou, Annual effective dose people received from indoor radiation is 5.46 mSv/a in the buildings made of slag bricks, but about 1.86 mSv/a in the normal buildings without containing slag.

P02.128
Dose Coefficients For Beta Decay, By Incorporation By Ingestion Using The "Human Alimentary Tract Model",According To ICRP 100.

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In 2007, the ICRP proposed in its publication number 100, the human alimentary tract model (HATM), which contains a detailed morphological model describing the absorption, retention and secretion of incorporation by ingested and inhaled radionuclides. This model includes transfer coefficient values for different regions, ages and genders.

The HATM provides a methodology for calculating doses for different organs in the alimentary tract, replacing the gastrointestinal model used by the same organization in its publication number 30 in 1979. The model from the ICRP 30 was used in the ICRP publication 78 and describes the doses coefficients due to the absorption for incorporation by ingestion or inhalation, for the individual monitoring of the internal exposure of workers.

Due to the changes introduced by the HATM with regards to the transfer compartments as well as the retention fractions and the absorption types, is required to evaluate the doses coefficients due to absorption of radioactive material, specially the radiation emissions which do not penetrate (ã), taking into consideration the tissue weighting factors proposed by the ICRP in the publication 103.

P02.129
NATO Biodosimetry Exercise - Inter-Assay Comparison -

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Aim: Determine the suitability of the well established dicentric chromosome assay [DCA] and cytokinesis-block micronucleus assay [CBMN] and the emerging γ-H2AX foci and gene expression assays for biodosimetry and radiation injury assessment.

Materials and Methods: Lithium-heparinized whole blood from one healthy donor was irradiated (240 kVp, 13 mA, X-ray, 1 Gy/min, at ~37°C). 10 blind (and calibration) samples irradiated with single doses between 0.25-6.4 Gy and sent to participants to run their assays. Provided dose estimates were analyzed using a linear model, logistic regression analysis and report time was documented.

Results: Report time for dose estimates was 8-13 times earlier for molecular biology assays compared to cytogenetic assays. However, inter-laboratory variance of dose estimates was smallest for DCA (about 2.3-5.6 times relative to all other assays) and increased in an assay-dependent manner as DCA < CBMN < gene expression < foci. Binary categories of dose estimates could be discriminated with equal efficiency for all assays, but at doses ≥ 1.5 Gy a 10% decrease in efficiency was observed for the foci assay.

Conclusion: Dose estimates based on foci and gene expression assays are reported 8-13 times earlier compared to the DCA and CBMN assays, but estimates are 2.3-5.6 times more precise when running the DCA assay. This advantage in precision becomes negligible when discriminating dose estimates merged in binary categories of clinical relevance. All assays show an upper limit of applicability below 6 Gy. Scoring 50 instead of 20 cells did not lead to improved dose estimates using the DCA or the foci assay.

P02.130
Developing Biological Dosimetry Laboratory for the Assessment of Radiation Overexposure in Saudi Arabia

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In cases of individual radiation overexposure or radiological accidents, it is important to provide suitable dose assessment, medical triage, diagnoses and treatment to victims. Cytogenetic bio-dosimetry, based on scoring of dicentric chromosomal aberrations, is a proven, ISO and IAEA standardized biotechnology technique for calculating medically relevant radiation doses. The aim of this project is to set up a national biodosimetry laboratory and establish a national standard dose-response calibration curve, pre-required to estimate doses received in case of accidental radiation overexposure. Peripheral blood lymphocytes were collected from healthy Saudi volunteers and irradiated with different doses (0, 0.5, 1, 3 and 5 Gy) of 250 KeV X-Rays. Then, stained cytogenetic slides were prepared from cultivated lymphocytes according to the IAEA protocol. The Metafer system (MetaSystem, Germany) was used for automatic metaphase finding and assisted scoring of dicentric chromosomes. Results were fit to the linear-quadratic dose-effect model. The preliminary dose-response calibration curve for the induction of dicentric chromosomal aberrations in Saudi Arabia was comparable to those described in other population (Wilkins et al. Radiation Research 169, 2008).

Currently, more volunteers and experiments are being conducted, gamma rays and neutrons will be used for irradiation. The laboratory will also seek accreditation from IAEA and WHO, and cooperation with international biodosimetry network. It is expected that the various activities of the biological dosimetry laboratory will add depth to information for decision-makers and public health officials who assess the magnitude of public, medical, occupational and accidental radiation exposures in addition to providing a platform for advanced education, research and development in Kingdom of Saudi Arabia and neighbouring countries

P02.131
The Uptake Kinetics Of Ba-133 And Heavy Metals (Co, Cr, Cd And Pb) In The Gibraltar Strait Marine Waters

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Studies on radionuclide and heavy metal behaviour in natural waters are of interest because of their high particle-affinity, their complex chemical behaviour in natural systems, and their effect on human and environment health in relation to accidental spillage and planned release.

Interest in the uptake kinetics of radionuclides and heavy metals in natural aqueous suspensions has recently increased in order to understand and reliably model the dispersion of wastes in aquatic environments. The approaches based on the uptake kinetics are more appropriate than those based on the distribution coefficients, *kd*.

The study of the uptake kinetics of radionuclides and heavy metals by suspended loads in natural aquatic systems is pointing out the importance of a very fast component. This is shown from our laboratory tracing experiments to study the uptake of ^{133}Ba, Cd, Co, Cr, and Pb in natural aqueous suspensions (unfiltered waters and sediment suspensions) from aquatic systems in Morocco.

The amount, nature and dynamics of the suspended loads highly influence the behaviour of particle-reactive radionuclides and heavy metals. The kinetics of this process has a very fast component. Changes in pH, temperature and in the electrical conductivity are influencing the uptake kinetics and the final partitioning of the radioactivity.

We developed a numerical model able to reproduce the observed kinetic uptake in all the studied cases. Then this model was adapted and incorporated into a kinetic reactive transport model for aquatic systems. The kinetic coefficients (and the factors which affect their variability) can be experimentally determined for each natural system of interest. This model represents then a powerful tool to study basic processes in natural systems when it is coupled to the dynamic of suspended load concentrations.

KEYWORDS: uptake kinetics, Radionuclides, numerical model, distribution coefficients *kd*, Gibraltar strait, heavy metals

P02.133
Strategy for Validation of External Doses for Techa Riverside Residents

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Throughout much of the 1950s radioactive waste from the Mayak Production Association (MPA) was released into the Techa River, with the largest releases during the first few years of the decade. As a result, a large number of individuals living in the riverside communities were exposed to internal and external radiation. The strategic goal for the study of the Techa River cohorts is to derive credible, quantitative estimates of long-term risks of adverse health effects from protracted internal and external exposure of members of an unselected general population. The goal for the dose-reconstruction activities is to provide individual doses, with an expression of uncertainty, for members of the cohorts. The dose-reconstruction process is based primarily on a large number of measurements of long-lived radionuclides in the human body and the environment, as well as on measurements of exposure rates performed in places where people lived. The traditional approach of analyzing environmental pathways of exposure is only used as a backup when other approaches were exhausted, in particular for reconstruction of doses from short- and intermediate-lived radionuclides released in 1950-1951. Radioactive releases from the MPA were maximum in these two years and substantially determined the levels of external exposure. Thus, uncertainties associated with the source-term data required special studies aimed at validation of the estimates of external dose. Three methods are used for validation: luminescence measurements of quartz extracted from bricks; electron paramagnetic resonance (EPR) measurements on human teeth; and fluorescent in situ hybridization (FISH) measurements on human lymphocytes. Each method has its own advantages and limitations. The main issue in the application of the EPR and FISH methods for validation of external dose for residents on the Techa River is ^{90}Sr in teeth and bones as a source of confounding exposure. An important methodological aspect of the study is careful selection of exposed donors in order to minimise the contribution of ^{90}Sr. The major goal of the validation study is to provide individual estimates of external dose derived from EPR and FISH measurements for comparison with individual estimates of dose calculated for the exposed donors. Basically, the agreement between the estimates has confirmed the validity of estimates of external dose for the Techa Riverside residents.

P02.134
Biomedical Evaluation of a Radiological Incident - A Bayesian Approach for Presenting Uncertainty on Biological Dose Estimates

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The Biological Dosimetry laboratory of the Argentinean Nuclear Regulatory Authority (ARN) takes part of the WHO-Global BioDose Network. In this frame, the laboratory was selected to perform the biomedical evaluation of a radiological incident occurred in the Latin-American region, in the period October 2008 to February 2009.

The objective of the present paper is to describe the biomedical evaluation of a nuclear medicine female worker that presented values of her physical dosimeter register indicatives of overexposure (Effective dose: 596,33 mSv; Equivalent dose: 743.06 mSv) Blood samples arrived in bad conditions (nonconformity). Thus, during a meeting between the Ministry of Health of the country that requested the assistance and WHO-PAHO representatives evaluated the convenience of sending directly the worker to Argentina to perform the biomedical analysis. Taking into account the interdisciplinary capacities of Argentina as a Liaison Centre Institution of the REMPAN, the parties agreed to send/receive the worker.

The clinical exam, at the time of the evaluation, did not show signs of localized irradiation or compatible with ARS. A Bayesian approach was applied to present the uncertainty on the estimated biological dose. At present, classical statistics allows to produce a confidence interval to report such dose, with a lower limit that could not detach from zero. In this situation it becomes difficult to make decisions as they could impact on the labor activities of the worker if an exposure exceeding the occupational dose limits is inferred. The worker presented a probability of 5% of not have been exposed to IR (zero dose) and a probability of 95% of receiving a dose lower than the upper limit of the confidence interval (CI) [0.35 Gy]. Additionally, the 78% of the probability of have been exposed was restricted to the CI [0.02; 0.20] Gy.

Conclusions: We found that the requirements that should be fulfill to guarantee an appropriate biomedical assistance are: to perform a careful preparation of the samples for shipping them to a collaborative laboratory for dose assessment, to hire an appropriate Courier Service, specialized in biological sample transport, and to follow guidelines and standards (previously agreed) for shipment / analysis.

The usefulness of a multidisciplinary evaluation coordinated by biomedical networks under the Convention on Assistance was confirmed. We also suggest that the Bayesian approach proposed could be a useful tool to contribute to take the appropriate radiation protection measures when incidents occurred in occupational exposure scenarios.

P02.135
Biological Dosimetry for Occupational Overexposure: Some changes in Operation Concept

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The most of radiation accidents take place in occupational fields. Cytogenetic biodosimetry is a powerful tool and therefore is required both for monitoring occupational groups in everyday practice and for management of real or suspected events. From the other hand radiation accidents are quite rare and for economic reasons it is not always possible to keep running biodosimetry laboratories in radiation protection institutions.

We suggested and applied the additions to the concept of biodosimetry service that becomes possible with modern technology and world tendency of networking. The idea was to bring together the international expertise of radiation protection institution and cytogenetic laboratories and other experts in order to facilitate the biodosimetry in cases of suspected occupationally caused overexposure.

For the pilot study we have selected the group of 5 male volunteers who were occupationally exposed persons of category A in German Nuclear Power Plants with accumulated dose in 10 to 50 mSv range. The blood samples were taken by a medical office and then delivered to the laboratory at University of Duisburg-Essen for cultivating and processing. The metaphase images were captured at IfS with a metaphase-finder system. The coded images and microscope slides were brought and analyzed for chromosome aberrations to IMR.

The other group comprised 5 uranium miners from Ukraine (dose range from 34 to 620 mSv). The blood samples were taken and processed in IMR and then brought to IfS for image capturing. Both images and microscope slides were analyzed in IMR. The images and microscope analysis data were compared. The comparison showed a good agreement between microscope and image analyses for both groups. It was shown that image analyses run 3-5 times faster than microscope analyses. However, for image analyses better metaphase spread quality was required. Peculiarities of image analyses were discussed.

The data protection, the further directions of our work, the advantages and the problems in suggested way of cooperation resulted in “virtual” biodosimetry service were discussed.

P02.136
New Concepts for Modelling Pu/Am Decorporation by DTPA

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Because the low residence time of DTPA in blood and its fast urinary excretion, actinide (An) chelation is assumed to occur rapidly in extracellular fluids involving transferrin (Tf) complexes. Thus, the slow component of DTPA-An excretion was explained by its extracellular retention within an unidentified compartment. Using these hypotheses it was not possible to fit human data obtained after repeated delayed treatments. Recently, new rat experiments have been performed to identify compartments where DTPA-An complexes are formed. One hour after iv of Pu-citrate, when half of the actinide is still in blood, speciation of Pu in plasma is poorly modified after Ca-DTPA iv (most Pu remained as Pu-Tf). This demonstrates that, for early treatment, Pu-Tf is a minor source of Pu decorporation and that transient ligands before Pu deposit in bone and soft tissues could be involved. Moreover, after Pu-DTPA iv, significant activity can be measured in liver which slowly decreases with time. Thus, small amounts of DTPA can enter within intracellular compartments and once Pu-DTPA are formed, the complexes remain stable until excretion. This phenomenon refereed to as immediate chelation explains decorporation of intracellular actinide after delayed treatments..An unexpected result was that when DTPA was administered one or several days before contamination. In such experimental conditions, the amount of DTPA in extracellular compartments is too low to allow Actinide chelation. Thus, the significant decorporation observed visualizes chelation of new intracellular deposits (delayed chelation). Others studies were performed after pulmonary contamination. Actinide chelation is observed both in extracellular compartments, mostly in epithelial lining fluid and within cells. Local retention of monoatomic forms of actinides which might correspond to the fraction fb of the ICRP66 dissolution model might be involved. From these results, a simple model to describe actinide decorporation was developed which considers chelation only at the site of contamination and in the liver. With this model good fits of urinary and faecal excretion can be obtained for more than 10 human contamination cases (inhalation and wound) and default parameters can be proposed for Pu and Am which are suitable for both early and delayed repeated treatments. This simple approach which leads to the development of MADOR tools will consider other sites of retention after new animal experiments.

P02.137
MADORTools For Managment Of Internan Contamination By Actinides And DTPA Therapy

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Operational tools are been developed for early management of actinide contamination of workers or population and optimization of chelating agent therapy in terms of dose reduction. Different versions will be available which are dedicated both to physicians and dosimetric expertise. Version 1 provides help for early medical decision according to the French regulation (MEDOR recommendations) and for management of biological data for further dosimetric estimate. Version 2 is a tutorial which provides biokinetics and doses after contamination by 20 isotopes of U, Np, Pu, Am or Cm according to regulation but also after application of other models such as Pu systemic model of Leggett, transport model of Gregoratto, WT of ICRP103, and simplified model to describe decorporation of Pu/Am by DTPA. Different treatment schedules can be simulated for a first estimate of dose reduction associated with chelating agent therapy. At this time only IV, ingestion and inhalation are implemented and wound will be included using NCRP model. In the case of inhalation, only type F, M and S are considered but different parameters describing physical characteristics of aerosol and morphology and physiology of individuals can be applied. The number of deposited particles is also calculated to provide information on heterogeneity of alpha dose distribution within the lungs. MADOR v3 is dedicated to expertise and allows variation of all the model parameters. This tool has been used for analysis of more than 20 inhalation cases treated or not by chelating agents which are reported in EURADOS or USTUR data bases. Several solutions can be recorded and are used as examples in MADOR v2. Such examples illustrate that similar biokinetics and doses can be obtained using quite different parameter values. Moreover, in most cases with follow up for several years, only Gregoratto model fits the data, increasing effective doses by a factor 3-4. Depending on DTPA treatment schedule, for type M, doses can be reduced by a factor more than twice whereas a significant diminution can be obtained for type S. Development of a didactic tool, MADOR v2.1, is in progress so that the user could gradually reach a level near expertise.
In collaboration with MEDOR and WP7 EURADOS, more complete tool could be available in French and English comparing different modelling approaches to describe decorporation and including the most encountered fission and activation products.

P02.138
Conceptual Structure of Java-oriented Environment for Modeling Biokinetics of Incorporated Radionuclides and Internal Dose Calculations

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An ongoing revision of major ICRP publications affects models of biokinetics of chemical elements in human body, which along with clarification of weighting coefficients values for tissues and organs, decay schemes and radionuclides emission energies, switch to using of voxel-phantoms etc., should lead to changing the dose coefficient values pertained to internal exposure. It follows from the above mentioned the necessity to have a software tool, which allows performing biokinetic calculations rapidly and calculating the dose coefficient values accordingly to various scenarios. So, a development of a software tool which allows performing biokinetic calculations is an important practical stage.

Software complex, which is being developed by our team, is designed as a desktop application using NetBeans platform, which is a generic framework for Swing applications. Open-source PostgreSQL DBMS, one of the most reliable and high-productive data storage systems, is selected to store data in this system.

A set of various cross-platform software libraries is used to perform numerical calculations in developed system:

1) Mathematical library jblas is an open-source linear algebra Java library. Jblas is based on LAPACK and BLAS, which are industry standards for matrix computations for many years. Jblas is a lightweight wrapper around LAPACK and BLAS libraries.

2) Scilab is a cross-platform free numerical package, providing high-performance environment for engineering and scientific computations. JavaSci programming package is specially designed to integrate Scilab scripts with java code, which simplifies using these two platforms together.

3) Open source numerical java package ode2java, which offers developers a list of programming interfaces for solving systems of differential equations with various implementations of Runge-Kutta methods.

The carried out biokinetic calculations have shown that results necessary for internal radiation dosimetry, which are estimations of the accumulated activity values and the radionuclides contents in tissues and organs of the basic deposition, can be obtained with necessary performance and precision.

P02.139
Microdosimetric Assessment of the Cellular Responses to Low-Dose Exposure

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The difficulty in clarifying the cellular response to low-dose exposure results from diverse elements including (1) a minimal chance of radiation hit on the cell, (2) significant variations in cellular dose among target cells, (3) insignificant biological expressions of hit cells at low dose exposure and (4) the lack of traceability for radiation-hit cells against hit-free cells. The chance of radiation hit on a cellular target is expressed as the "hit probability." The variation of cellular dose is informed in terms of a probability function f(z) of a specific dose z in conventional microdosimetry studies. Microbeam irradiation systems in late 1990's and early 2000's, represented by those at Columbia University in USA and at Gray Cancer Institute in UK, played significant roles in differentiating the radiation-hit cells and hit-free cells and discovering the "bystander effect." The low-dose hit of a cellular target could be better recognized if one found the biological endpoint that expresses itself in more sensitive at radiation exposure.

In this study, we have established a microdosimetric scheme of assessing the cellular response in vitro at low-dose exposure by combining the micron-scaled beam delivery, radiochromic film dosimetry and radiation-hit cell tracing for its biological response. The X-ray beam is generated from the YXLON model 450-D08 system. The 30 mm-thick lead sheets make the primary collimator. The beam dimension is finalized by the secondary collimator made of 2 mm-thick tungsten sheets. The tungsten collimator makes a perfect shield of 200 kVp X-rays while delivering a microbeam of down to 100 µm at FWHM. A sequential beam delivery is made by moving the cell dish under the beam collimator. The movement is controllable in 100 µm per step. Dose profile of the cells is measured by employing Gafchromic EBT2 films, which inform radiation exposure levels in a micron-scaled resolution. DNA double strand breaks and clonogenic cell survivals are counted at dose levels ranging from 0.01 to 3 Gy. The scheme was demonstrated with mouse endothelial cells (ATCC, CRL-2161), which show relatively high sensitivity to radiation exposure.

P02.140 Time-dependent Gene Expression Analysis in Human Peripheral Blood Lymphocytes for Biodosimetric Applications after Low and High Dose Gamma-Irradiation

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In case of a large-scale radiation accident with involvement of individuals without physical dosimeters it is important to identify individuals who have received a moderate to high radiation dose to ensure proper medical care. As current methods are time-consuming, a fast and reliable method based on gene expression alterations is developed.

Human blood of 3 male and 3 female healthy donors, belonging to 3 different age classes, was irradiated *ex vivo* with 0, 0.02, 0.1, 0.5, 1, 2 and 4 Gy (γ rays, Cs-137). Peripheral blood lymphocytes (PBL) were isolated and cultured for 6, 24 and 48 h in the medium- and high dose range (0.5 -C 4 Gy) and for 24 and 48 h after low dose irradiation (0.02 and 0.1 Gy). Subsequently RNA and proteins were isolated and RNA was applied for processing whole human genome microarrays (Agilent) to analyze gene expression profiles. In the medium- and high dose range the most robust altered genes were selected for further qRT-PCR and protein expression analysis. To examine the radiation-specificity of the candidate genes, PBL were exposed to the DNA-damaging agents Paracetamol (25 and 200 µg/ml) and Mitomycin C (0.1 and 0.4 µg/ml) for 6, 24 and 48 h and gene expression was accordingly analyzed.

By a p-value and fold-change driven gene selection 9 genes were identified in the low dose range and 16 genes in the medium- and high dose range allowing a radiation dose prediction accuracy of 96% independently on the time-point post irradiation up to 48 h. For 6 predictive genes in the medium- and high dose range and for two genes in the low dose range the observed radiation-induced gene expression profiles were confirmed and validated by qRT-PCR measurements in pooled and non-pooled samples. Additionally, qRT-PCR analysis revealed that the radiation dose predictive genes are highly radiation-specific when compared to exposure with Paracetamol or Mitomycin C. Protein expression analysis showed only for two genes a weak correlation between gene and protein expression after irradiation.

In vitro gene expression analysis in human PBL based on whole human DNA-microarray data allowed identifying a rather small set of radiation dose predictive and radiation-specific genes with a high potential for biodosimetric applications *in vivo* after low-, medium and high dose exposure.

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P02.141
RENEB – Realizing The European Network In Biological Dosimetry

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Creating a sustainable network in biological and retrospective dosimetry that involves a large number of experienced laboratories throughout the European Union (EU) will significantly improve the accident and emergency response capabilities in case of a large-scale radiological emergency. A well organised cooperative action involving EU laboratories will offer the only chance for a fast and trustworthy dose assessment urgently needed in an emergency situation. In this regard the European Commission supports the establishment of an European network in biological dosimetry (RENEB) The goal of RENEB is to establish a sustainable European network mainly based on biological dosimetry laboratories involving 23 organisations from 16 countries identified by the TENEB survey that will guarantee the highest efficiency in the processing and scoring of biological samples for fast, reliable results implemented in the EU emergency management. RENEB also implements recent developments in retrospective dosimetry. This goal will be achieved through 5 tasks:

1) To create an operational basis of the network based on coordination of the existing reliable and proven methods in biological and retrospective dosimetry

. 2) To expand and improve the network implementing appropriate new methods and integrating new partners.

3) To assure high quality standards by education and training activities. Here, special focus will be placed on quality assurance and management regarding the performed assays and involved laboratories.

4) To develop an operational structure of the network including contacts to national first responders, a well organised transnational infrastructure to facilitate cross-border transport of samples, a long term funding strategy and to prepare an agenda to transform RENEB into a legal organisation.

5) To guarantee dissemination of knowledge by providing access to internal and external communication platforms and databases and close cooperation with national and global emergency preparedness systems and organisations.

P02.142
Approaches of the Cytigenetical Dose Evaluation of the Irradiation Nonuniformity

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The radiation exposure nonuniformity is typical for large number of accidental irradiation cases. A detection of acute external irradiation nonuniformity as soon as possible is very important for a prognosis of acute radiation disease course. Following approaches can be used for a detection of a fact of irradiation nonuniformity and an execution of dose evaluations. Firstly it is well-known classic Dolphin's method when overdispersion of lymphocyte distribution by the number of dicentrics (dicentrics distribution) in comparison with theoretical Poisson's distribution indicate sufficient nonuniformity of radiation exposure of victim body mass. It is purely qualitative method. Secondly there is the group of approaches for an evaluation of partial body dose and exposed fraction body value. This group includes advanced Dolphin's method and Qdr method. These methods are expounded in the IAEA manual. Also we suggested method of evaluation of partial irradiation parameters by dose relationship curves of frequencies of dicentrics per a cell with dicentrics and a percentage of cells with dicentrics. Thirdly in our Center Dr. Filushkin proposed the computer program which permits to represent any non-Poisson distribution as sum of several Poisson distributions. It permits to recover lymphocyte distribution by dose from dicentric distribution by lymphocytes. Apparently the dose distribution by lymphocytes reflects dose distribution by the body mass. In addition our experiments with cultures of irradiated lymphocytes and mixed cultures of non-irradiated and irradiated lymphocytes after in vitro gamma-irradiation of blood of healthy donors (1 to 8 Gy) permitted to determine quantitatively influence of interphase death and mitotic delay on dicentric yields for nonuniform irradiation. This approach can be used for any type of dose distribution on body. A comparison of real curves of postirradiated dynamic of blood neutrophils number with analogous curves reconstructed from estimations of dose distributions on body mass on basis of this computer analysis was realized for several of patients exposed by acute external nonuniform gamma-irradiation. As a whole satisfactory results were received. The fourth approach consists in the evaluation of dose distribution on hemopoietic tissue by cytogenetical investigation results of bone marrow punctates taken from regions available for a puncture: sternum, anterior and posterior iliac spines at each side, thoracic vertebrae spines.

P02.143
Monitoring Of Capillaries In Occupational Exposure As Biological Indicator In Radiation Protection

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As capillaries are notoriously sensitive to ionizing radiation, workers exposed in the university undergo a capillaroscopy examination during their periodic check-ups for medical surveillance.

In the last five years medical surveillance using in vivo biomicroscopic biological monitoring of capillaries was carried out in 247 workers of Naples University Federico II. These workers had been exposed to radiation sources constituted by a particle accelerator, RX Diffractometer, electronic microscope and radionuclides of low energy (^{32}P, ^{35}S, ^{7}Be, ^{3}H, ^{125}I, ^{32}P, ^{14}P, ^{14}C, ^{33}Y, ^{241}Am, ^{55}Fe, ^{109}Cd, ^{57}Co, ^{88}Y, ^{226}Rn, ^{133}Ba, ^{137}Cs, ^{60}Co, ^{210}Pb, ^{109}Cd, ^{22}Na). An operational protocol was adopted. According to this protocol workers exposed to radiation undergo in vivo an examination of the microvessels of the skin using a 'Videocap' (DS-Medica, Milan) video-capillaroscope with optical probes of 50x, 100x, 200x with reference to the characteristics of capillaries as to

- number (normal, reduced, increased);
- morphology (normal, thinned, twisted, ectasia);
- distribution (normal, irregular);
- microcirculation (normal, granular, sludge, stasis);
- subpapillary network (visible, not visible, accentuated);
- particular aspects (megacapillaries, microaneurisms, haemorrhages).

The analytical capillaroscopy has shown that radiological risk was well tolerated and has also allowed us to indirectly evaluate a worker's state of health by checking the capillaries as well as the tissues fed by those capillaries and refer their condition to the well-being standard.

For biological monitoring of the body zones in the subjects exposed to ionizing radiation, the authors propose the use of this microvascular quantitative analysis together with dosimetric monitoring. The application of new informatics technologies to capillaroscopy using biometric system for purpose of biological dosimetry enable us to increase the sensitivity of the microvascular and hemoreological investigation and to give markers of tissues perfusions useful for evaluating the health conditions of the exposed subjects. The algorithms developed include ad hoc techniques for image registration and segmentation. A set of algorithms has been implemented for working on video sequences for exploiting the all visual information that would be lost in a single snapshot. A second set of algorithms aim to remove possible artefacts and highlight the capillaries for the next feature extraction step.

P02.144
Nanohybrids composed of quantum dots and enzyme as photocatalysts induced by gamma rays

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Semiconductor nanomaterials, such as quantum dots (QDs), quantum rods (QRs), and nanotubes, have potentials in a wide variety of fields ranging from nanoelectronics and nanophotonics to the broad area of nanosensing and bioimaging. Currently, nanotechnology and biotechnology are being joined to develop novel materials and devices, leading to the establishment of the new field of nanobiotechnology. In this study, we elucidate on the photoactivated organic transformation catalyzed by hybrid devices composed of semiconductor nanoparticles and the enzyme cytochrome P450. Cytochrome P450 belongs to the broad class of monooxygenase enzymes which are well known to catalyze a range of stereospecific and regioselective oxygen-insertion reactions into organic compounds.

In general, the gamma rays-induced triggering of enzyme activity confers explicit advantages over chemical initiation with respect to the control of enzymatic reactions. Moreover, the P450/CdS nanohybrids should also enable convenient recycling of the catalyst in organic transformations. In addition to the investigation of other semiconductor QDs for improving the catalytic activity of such nanohybrids, which is currently under way, we are also aiming towards applications as photocatalysts in synthetic organic chemistry and as photosensitizers for intracellular reactions.

Keywords Nanostrucutures, Photochemistry, Quantum dots, Radicals, Gamma ray

P02.145
Performance of the automated dicentric and cytokinesis block micronucleus assays in a recent NATO exercise of established biodosimetry methods

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Accidents involving human exposure to radiation can cause severe health effects which may require extensive medical resources. Particularly in mass-casualty events, the rapid identification and classification of potentially overexposed individuals into medical treatment groups is of prime importance. For this purpose, clinical signs and symptoms (blood cell counts/acute radiation syndrome degree; clinical dosimetry) and biological dosimetry methods are the two main approaches for assessing radiation exposure in situations where no dosimetry badge was worn.

The dicentric chromosome assay is considered the “gold standard” method for biological dosimetry after an acute radiation exposure. However, it is time consuming and needs highly trained scorers. In contrast, the scoring of binucleated cells for the cytokinesis block micronucleus assay requires significantly less training, yet is still time consuming. Several new improvements in the automation of these cytogenetic assays promise reliable and fast results with little human interaction.

This comprehensive study was organized under the umbrella of the NATO Research Task Group RTG-033 “Radiation Bioeffects and Countermeasures” in order to compare the performance of the most validated biological dosimetry techniques. In a first step, blood samples exposed to known X-ray doses were provided for establishing calibration curves at each laboratory and for each assay. In a second step, ten coded blood samples irradiated with different X-ray doses were distributed and analysed with the automated cytokinesis block micronucleus assay in 5 institutions for triage-mode biodosimetry. Furthermore the automated dicentric assay was performed in 2 institutions.

This presentation focuses particularly on whether these improved automated systems are able to distinguish between different doses in a reliable manner. The new methods may allow faster results and have a higher throughput than the well established conventional assays to analyse dicentric and micronucleus manually and could thus become valuable dosimetric tools in the future.

P02.147
The Probability of Radiation-induced Damage of Macromolecules with Complex Spatial Structure

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A theoretical approach to radiation damage of macromolecules with complex spatial structure is developed. It takes into account the random excitation of a molecule and ability of excitation to migrate. It was established experimentally that the excitation can move through the molecule. Damage of the molecule is determined by mainly its "weak points". Ionizing radiation excites the electronic subsystem of molecule. If the magnitude of excitation is high enough, it leads to the disintegration of the molecule. So the probability of the complex molecule disintegration depends on localization of excitation and on excitation migration. We calculate the probability of radiation-induced damage of a complex molecule (linear, cyclic, such as a regular polyhedron, a fullerene and more complex) as a function of its spatial structure, patterns of migration and attenuation of the excitation.

P02.148
Establishment Of A Dose-Response Curve Of 60Co Gamma-Ray Irradiation By Dicentric Chromosome Analysis

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Ionizing radiation exposure causes DNA strand breaks that lead to chromosome aberrations. Among radiation-induced chromosome aberrations, multicentric chromosomes, as represented by dicentric chromosomes, are considered to be sensitive and specific biomarkers for assessing the radiation dose. For more than three decades, dicentric chromosome analysis (DCA) has been the 'Gold Standard' of biodosimetry. In DCA, a dicentric yield per cell of a radiation-exposed patient is applied to a calibration curve (dose-response curve). Many dose-response curves have been proposed thus far, but most of them have been generated respectively from one healthy donor by one in vitro experiment. According to the result of international collaborative works on inter-laboratory comparisons, it has been reported that in DCA, the significant variation of dose estimation is partly attributed to different experimental protocols including the scoring criteria of chromosome aberrations among institutions / investigators. Thus, it is necessary for a biodosimetry laboratory to have and use its own dose-response curve under its own experimental conditions.

In the present study, in order to evaluate the dose estimation of patients for better medical preparedness, a dose-response curve was established by analyzing 13 occupationally non-exposed healthy volunteers by DCA using peripheral blood samples irradiated *in vitro* with ^{60}Co gamma-rays at seven different doses (0, 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 Gy). The result of the first-division metaphase scoring followed a linear-quadratic equation, $Y=A+aD+bD^2$ (Y: the yield of dicentrics, D: the dose, A: the background frequency, a: the linear coefficient, b: the dose squared coefficient; IAEA Technical Reports Series No. 405 "Cytogenetic Analysis for Radiation Dose Assessment," Vienna, 2001), with the coefficients $A = 0.00027 \pm 0.00001$, $a = 0.018 \pm 0.002$, $b = 0.048 \pm 0.001$.

Then, we established a practical biodosimetry protocol for radiation emergency medicine, tentatively called the "NIRS DCA System" (including sample collection, cell culture, chromosome preparation, automated metaphase image-capturing, chromosome aberration scoring in triage- and full estimation-modes, and a diagnostic report format), for conducting dose estimation within several days of receiving blood samples. The NIRS DCA System is now being used for actual radiation exposure accidents in Japan.

P02.149
Validation Method of Biological Dosimetry in an Accreditation Process

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In the case of accidental exposure to ionizing radiations, it is important to assess as soon and as precisely as possible the dose received by the irradiated victims. Dicentric assay is considered as the most sensitive and specific biological dosimeter in case of recent exposure. The biological dose estimation includes the following steps: 1) blood withdrawal; 2) lymphocyte culture and arrest; 3) spreading onto slides; 4) scoring, either manually or using image analysis systems; 5) converting yield of dicentrics to dose using dose effect calibration curves. Comparison of experimental procedures applied in each laboratory performing biological dosimetry reveals that each laboratory proceeds the samples a different way. Therefore, two specific ISO standards 19238:2004 on dose assessment and 21248:2008 on population triage, were developed to address the homogeneity and confidence aspects of the dicentric assay use as a biodosimeter. To be qualified/accredited according these ISO standards, the biological dosimetry laboratory must establish the technical validation of the dicentrics assay. First it had to precisely describe the dose assessment process: relationship with customer, confidentiality of information, capability of laboratory staff, QA&QC program... Second, in order to test the influence of some deviation of the initial protocol, mitotic index and dicentrics yields should be measured according to the reagents variations and culturing laboratory specificities under different experimental conditions. An inventory of potentially influent factors must be carried out. By example, for testing the validity conditions of the biological dosimetry practice of the IRSN laboratory, seven parameters effect on the mitotic index and on the yield of dicentrics was measured: BUdr, PHA and colcemid concentrations, blood and medium volumes, culture duration and incubation temperature. The mitotic index is influenced by the concentration of BrdU, medium and blood, the culture duration and the temperature. By contrast, none of the factors has a significant impact on the yield of dicentrics. In addition, no operator effect is noted on mitotic and dicentrics yield. These results could be used by relevant laboratories as element of the quality of their dose assessment and their procedures robustness in any event requiring such demonstration.

P02.150
ESR dosimetry study of workers from Stepnogorsk uranium processing plant, Kazakhstan

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The method of human tooth enamel electron spin resonance (ESR) dosimetry was used to obtain individual absorbed doses of residents of settlements in the vicinity of the uranium mine and uranium processing plants in Stepnogorsk city, Akmola oblast, Kazakhstan. Measured teeth samples were extracted according to medical indications. In total, 60 tooth enamel samples were analyzed from the residents of Stepnogorsk city (180 km from Astana city, Kazakhstan). Some results of dose estimation of residents staying in Stepnogorsk city and workers of uranium enterprises were included. About 15 tooth samples have been collected from the workers of uranium plant. Results of tooth enamel dose estimation shows us small influence of working conditions to workers, the maximum excess dose is less then 100 mGy. This is pilot study of ESR dose estimation, for a final conclusion additional sample is required.

P03.01
Research On The Radiological Safety Conditions At Different Hospitals In Nepal.

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Nepal has a long history of medical radiology; but we still do not have any radiation protection infrastructure to control the use of ionizing radiations in the various fields. Recently Nepal is part of the IAEA and this will certainly support and speed up the creation of appropriate conditions

The aim of this study was an assessment of the radiation protection in medical field.

In this study, measurements were performed to assess the status of radiation protection barriers and general conditions in the same radiological centers. Questionnaire for radiation workers were used; radiation dose levels were measured and made an inventory of equipment. Another aim of the study was to create awareness in the workers aware on possible radiation health hazard and risk. It was also important to gain an inside of the level of understanding of the personnel in order to initiate steps towards the establishment of code of radiological practice.

Altogether, 33 radiological and radiotherapy facilities at different hospitals/institutions were monitored. The professionals who completed the questionnaire represent more than 65% working in this field in Nepal. Almost all diagnostic radiology working areas are safe. Radiation dose level around radiotherapy centers shows are within safe limit and are built according to protection criteria. Around 65% of the radiation workers are not monitored for radiation. There is neither quality program except radiotherapy nor training program in radiation protection. The basic radiation protection principles of Justification and Optimization should be taken into consideration in this period of rapid increase of investigation following the availability of new equipment.

P03.02
Development of the Standard System for Integrated Radiation Management

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Contents

Analysis of the safety hazard for the complex radiation facilities and Design of the standard system for radiation protection

· Analysis of the radiation safety system for the single or complex radiation facilities

· Analysis of the safety hazard, of the state for protection countermeasure and of the requirement for a complex radiation facilities

· Design of standardized and integrated management software for complex radiation facilities

- Study on the skill of the pending bill and a design of the standardized and integrated management hardware for complex radiation facilities

· Development of radiation safety and protection procedure for a complex radiation facilities

- Study on the efficient method of radiation safety management for the facilities by fewer manpower

· Design of a standardized and integrated management hardware for complex radiation facilities

Expected Contribution

· Development of a standardized and integrated management system to improve safety of radiation safety management and efficiency of operation for radiation facilities. Therefore it is obtainable to operate an optimized facility by less manpower.

· Development of this management system is available to apply for a single radiation facility easily.

· Analysis of the safety hazard and Development of the state for protection countermeasure secure safety and confidence from local residence. Therefore it is available to vital to operate facility safely.

· This system can defragment “Korean an integrated radiation management network system”. Therefore it is essential to keep watch and to build early warning systems for medical industries and research facilities in real time.

· This effort can provide the way of radiation safety control.

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P03.03
Changing of a Radiological Protection Management System – Impact at the Workface.-

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Chapelcross Nuclear Power Station is currently in the de-fuelling and decommissioning stage of its life cycle. Currently three reactors are available for de-fuelling and the final one being made ready. The Site recently joined the Magnox Limited fleet and went through the process of implementing the Magnox radiological safety management system, having previously worked to a management system based on that used at Sellafield.

Significant workforce engagement was conducted prior to the implementation to explain the required changes to the radiological protection aspects of work to be undertaken. Throughout this engagement there were levels of doubt, cynicism, fear of cost and time impact and some level of confusion expressed and these had to be addressed.

The de-fuelling process had previously been re-designed to minimise operator intervention. Shortly, after the implementation of the management system, faults developed within specific equipment crucial to de-fuelling operations that would require significant operator intervention. This had the potential to result in operator exposure to pieces of irradiated components, Magnox swarf and graphite dust. This gave rise to the ‘opportunity’ for practical implementation of the changes. This paper explores the challenges of implementing change, dealing with the reaction to change and the practical application of the changes required. It also reviews the practical aspects, the processes used, workforce reaction and the overall impact of the introduction of the change to the Site. Finally, it concludes that sometimes change is not as significant as first perceived.

Poster sessions A-B: Area 3

P03.04
Radiation Protection Management in Malaysia

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Malaysian Nuclear Agency (Nuclear Malaysia) is a leading agency in introducing and promoting the application of nuclear science technology for Malaysia development. The agency provides several major nuclear facilities purposely for research and commercialisation such as reactor, irradiation plants and radioisotope production laboratory. In order to ensure a safety of the workers, public and environment, a Health Physic Group under Radiation Safety Division was set up in 1980. The group is responsible in development, promotion, execution and enforcement of law and rules as well as in managing of radiation safety standard and system in Nuclear Malaysia. Beside that, the group also assists an authority body, Atomic Energy Licensing Board (AELB) for instance in Fukushima accident. This paper will discuss the group roles including an interconnected internal and external health, safety and security related departments. As summary, the radiation protection aspects are in line with the requirement of the Atomic Energy Licensing Act 1984 (Act 304).

P03.05
Managing The Workload And Workflow Of A Radiation Protection Advisor In Medicine

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In the United Kingdom anyone practising as a Radiation Protection Adviser (RPA) after 31 December 2004 must hold a valid certificate of competence from an Assessing Body recognised by the Health and Safety Executive (HSE).

Of the specialist fields where radiation protection advisers operate, the medical sector and the NHS in particular provides a high degree of diversity for the RPA with tasks often overlapping with other areas of expertise such as Medical Physics Expert (MPE). Indeed many RPAs within the NHS also act as MPEs and the boundaries between the two can often become blurred. As an example in one 3 month period from November 2010 to January 2011 some 30 individually identifiable task groups were carried out by RPAs at IRS Ltd. spanning both traditional RPA work and advice provided as an MPE. These tasks lead to a variety of outcomes from providing customer reports to liasing with legislators and contributing to legal proceedings. The ability to produce and manage these outputs also impacts on the business management capability of the organization for which the RPA works.

Interaction with appropriate management systems is essential in ensuring that the RPA can effectively plan his workload. The management system must also be capable of workflow analysis on the types and frequencies of various tasks and must accommodate trend analysis to define focus areas for particular activities. In addition the RPA management system must be able to integrate with other IT functionality within the organization such as customer relationship management systems in order to facilitate business planning and management of new and existing work within the context of the organization as a whole.

This paper describes the implementation of such a management system that enables appropriate, effective management of the RPA's time and tasks and integrates with other business management systems. The system utilises readily available IT applications but is tailored to enable categorisation of tasks not only to provide business management and development input but also to support an RPA training programme that will underpin the requirements for certification of new RPAs and provide a recertification facility for existing RPAs. In addition the RPA information management system described here crucially provides a management tool for business development within the radiation protection industry.

P03.06
Safety and Security of Radiation Sources in North Africa and Middle East

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Peaceful uses of atomic energy in North Africa and Middle East led to better life .The role of international organizations can not forgotten in general and International Atomic Energy Agency (IAEA) and World Health organization (WHO) in particular.

The unforeseen events such as Wars and revolutions in North Africa and Middle East may led to uncontrolled situations of radiation sources and contamination of large areas .

For better control of radiation sources in use in north Africa and middle east , the system of registry of radiation sources was introduced by IAEA through technical assistance programs as well as AFRA programs. In Egypt , Safety and security of radiation sources is also implemented through the competent authorities .

These are the Egyptian Ministry of Health and the Atomic Energy Authority .Furthermore , through the Egyptian –US cooperation , the IMPRES project was implemented and it is now in its second stage .

The aim of the present study is to remind the comptant authorities of the North Africa and Middle East counties to Keep the registry of radiation sources in safe place and to inform health physicists and radiation protection experts what to do in case of war or revolution.

IRPA-Egypt President

P03.07
Radiation Safety Management System At Your Finger Tips With Excel

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The development and management of a Radiation Safety Program is often challenged by the lack of resources provided to it. The complexity of regulations, the availability of qualified individuals and the general turnover of staff overseeing the program further jeopardize it. The governance of the Radiation Safety Program is undermined when the key elements of the program and their relationships are not documented to ensure appropriate management systems are in place.

Yet the corporation must have a management system that ensures compliance, due diligence, record management, business continuity and retention of corporate memory. This poster will demonstrate how these requirements are met using the Radiation Safety Management Information System developed on a Microsoft Excel platform, which is affordable, flexible and universally available.

The RMIS is one component of a comprehensive Radiation Safety Management System designed to integrate corporate and operational needs into a governance structure that provides confidence that strategic goals and compliance are being met. The RMIS is designed to provide the structural support which can accommodate the variable and evolving needs of the institution.

This system translates the operational functions into the corporate framework of governance; incorporating business continuity processes, performance indicators, record retention and tracking capacity. This makes the RMIS an asset in the event of an audit. Since the data is generated at an operational level and the framework at a corporate level, the RMIS has been designed to integrate both of these sectors needs. This promotes its use, maintenance and development by both sectors.

The five key structural elements addressed are:

1. Accountability/Responsibility Framework
2. Communication/Education
3. Compliance & Monitoring Activities
4. Documentation and Data Management
5. Security

These elements are incorporated into the RMIS system using a variety of Microsoft Excel worksheets, which address:

1. Program Overview
2. Acts and Regulations
3. Compliance
4. Data Management
5. Strategic Planning
6. Policies and Procedures
7. Central Records
8. Archival Records

Note: As new needs are identified, new worksheets are developed

P03.08
U.S Radiation Protection Best Practices

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Recognizing the various processes, methods or criteria used to implement the U.S. Nuclear Regulatory Commission's radiation protection regulations, nuclear power plant Radiation Protection Managers (RPMs) formed a steering committee to determine industry best practices. This steering committee, comprised of industry RPMs, prioritizes issues and practices to be evaluated, reviews existing industry radiation protection procedures that provide guidance to the radiation protection staff, and drafts the current industry best practice(s) for that issue of concern. These best practices are then discussed at a weekly conference call with additional RPMs for concurrence prior to finalization and publication. Radiation Protection Industry Best Practices are posted on the Institute for Nuclear Power Operations' (INPO) website for use by all U.S. nuclear power plant Radiation Protection personnel.

Examples of published Industry Best Practices include:

- Identification and Controls for Work with Radiological Risk
- Stop Work Authority
- Alpha Monitoring
- Control of Radioactive Material Outside (the plant)
- Station ALARA Committees

P03.09
Investigation of Radiation Protection Observation Data at a Nuclear Facility

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Programmatic operations at the Los Alamos National Laboratory (LANL) involve working with various amounts of plutonium and other highly toxic, alpha-emitting materials. The spread of radiological contamination on surfaces, airborne contamination, and excursions of contaminants into the operator's breathing zone are controlled through the Radiological Protection Program. A key element of the program is in-field monitoring of radiological conditions, observations, and incidents reports using the LANL Radiation Protection Observation (RPO) System. Employing Lean Manufacturing and Six Sigma business practices, statistically significant variations (trends) have been identified in RPO reports. An output metrics has been developed that measures LANL management progress towards meeting its Radiation Protection objectives and goals. Using a Pareto Chart, the primary radiological conditions, observations, and incidents have been determined. With a failure modes and effects analysis (FMEA), decisions have been made over which radiological conditions, observations, and incidents require management support. This paper focuses on the collection of RPO data; incorporation of this information into a visual format that LANL management uses to make decisions; and some of the decisions LANL management has made to improved operations. The research results presented in this paper are pivotal to the ultimate focus of the Radiological Protection Program, which is to maintain radiation exposures well below regulatory limits, minimize the number of contamination, and prevent uncontrolled releases.

P03.10
The New Food and Drug Administration of the Republic of the Philippines and Its Role in Radiation Protection

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The new Food and Drug Administration of the Department of Health of the Republic of the Philippines, created by law, in 2009 has the mandate to regulate the manufacture, import, export, distribution, promotion, sale, and use and testing (where appropriate) of health products. Under this law, health products now include radiation devices. Radiation devices are defined as electrical or electronic apparatus emitting ionizing or non-ionizing radiation, or sound waves. The law created the Center for Device Regulation, Radiation Health, and Research which was formed from what used to be a separate agency created in 1974. Its original function of regulating radiation devices and the facilities using these devices was retained. Provisions in the new law such as the creation of regional FDA offices with its own enforcement units and quasi-judicial power have strengthened the radiation protection mandate. The paper discusses in detail these and other relevant provisions.

P03.11
Radon Adsorbed in Activated Charcoal as a Tool for Teaching Radioactivity

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Some procedures for teaching the concepts of radiation and radioactivity are described in a simple way. They are based on the properties of radon, which is a ubiquitous naturally occurring source radiation. Radon gas from ambient air in the laboratory was adsorbed into about 70 grams of activated charcoal inside metallic canisters. A NaI gamma-ray detector, and its accessories, was used to monitor the build-up and decay of radon in the canisters. Data analysis was used to demonstrate the radioactive law and determine the half-life for radon. The procedures do not contravene the requirements of the Legislations on storage and use of radioactive materials, and they do not present any radiological concern for both students and teachers.

P03.12
Measurements of Ambient Gamma Radiation Levels as Practical Teaching for Physics Students

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The ambient gamma-ray level was measured at different locations to demonstrate that the natural background radiation varies from one location to another. The effect of shielding on the gamma radiation field was also demonstrated to explain the importance of shielding as a radiation protection tool to school and college students. The measurements were carried out with simple radiation detectors/measuring systems that can be found in most teaching laboratories, i.e. a NaI detector for spectrometry and a GM counter for dosimetery. The latter is used to provide the dose rate values as an overall quantity of radiation exposure. The measurements were carried out in various locations; outdoors, indoors, on different floors of a building, and on a boat at sea.

P03.13
Training of Radiation Protection Experts – 'Nuclear Training Centre' Experience

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Romanian regulation system requires level 3 training for radiation protection experts prior to the recognition by the nuclear regulatory body.

As response of Romanian training needs, 'Nuclear Training Centre' is carrying out training programmes for radiation protection experts (level 3). The course is organized once every 1-2 years and the syllabus is based on European and international recommendations (EC, IAEA and ICRP).

The Romanian legislation provides that the RPE license is granted depending both source and practice, therefore the training course was designed on a modular structure with one common module containing basic knowledge in nuclear physics and radiation protection and more specific modules depending on radiation source: X ray generators, sealed sources, unsealed sources. There are also sub-modules depending on practice: diagnostic radiology, interventional radiology, radiotherapy, nuclear medicine, well-logging, stereotactic radiosurgery, industrial radiography.

Each participant has to prepare a dissertation project to complete the training course, which is presented to the others participants and examination commission. It consists in offering expertise on a concrete example for each participant's practice.

The small number of participants in contrast with large number of practices could be a real concern for designing such type of course. From training provider point of view this has been also a challenge.

P03.14
A Novel Swedish Master's Degree Programme for Applied Radiation Protection

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Since the beginning of the 1960s Sweden has had a university programme for Medical Radiation Physics. This programme was expanded to a MSc level, when it was redesigned (mid-2000s) to generate a professional license as a clinical medical physicist, warranted by the Swedish National Board of Health and Welfare. The main end-users for this programme have been i.) hospitals and clinics, and ii.) research departments. Nuclear industries and authorities associated with radiation protection and emergency preparedness did not always recruit students from this particular programme as it was focused on topics related to the hospital environment. In the beginning of the 2000s it was identified that Sweden, as many other countries, needed an additional and supplementary skill in radiation protection, to meet a new threat from nuclear and radiological events, also including malovent use of radioactvity. A new cadre of experts had to be formed with competence within radiation protection for non-hospital issues in the next generation. In accordance with this need for a new profession, here referred to as applied radiation protection, the Medical Physics departments at Lund University (ass. prof. C. L. Rääf) and Göteborg University (prof. M. Isaksson) were commissioned by the Swedish Radiation Protection Authority in 2008 to elaborate an educational programme on a Master's level. This programme, *Applied radition protection*, has recently been accepted by the Sahlgrenska Academy board of basic education at Göteborg University and is presented here. The programme is 2 years, ending with a Master thesis (30 ECTS), containing six principal courses;

i.) Basic radiation protection – an introductory course to fundamental radiation protection.

ii.) Emergency preparedness and management in radiological or nuclear emergencies – focusing on the role of various authorities and stakeholders in the society.

iii.) Detectors and measurement methods in applied radiation protection – introducing the most common types of detectors used in stationary and mobile radiometry systems, including also search strategies for localising lost radiation sources.

iv.) On-site management of radiological and nuclerar events – consisting of practical field exercises performed together with rescue workers and first responders.

v.) Management of patients subjected to radiation exposure in emergency situations – focusing on the medical treatment of patients, from damage site to special medicine, including practical exercises.

vi.) Nuclear energy fuel cycle – an overview of the topic with special attention to radiation protection issues, including also nuclear weapons.

This Master programme is planned to be launched in autumn 2012 and is open also for applications from foreign students. For those students that graduate and wish to deepen their skills and expertise in this field, several PhD projects will be offered.

P03.15
Survey of Health Physics Research and Education in the Netherlands

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The Dutch Health Council expressed the concern that health physics research is declining, which might impair future radiation protection in the Netherlands. Commissioned by the Ministry of Economic Affairs, Agriculture and Innovation and supported by the Society for Radiation Protection, the National Institute for Public Health and the Environment in the Netherlands (RIVM) has therefore conducted a survey of health physics research and education in the Netherlands.

First, a search was conducted to identify researchers and organisations in the field of health physics. This included databases of scientific literature, members, participants and partners of societies, conferences and EU projects. Second, a questionnaire was sent out for the number of personnel involved in research, the specific research/educational area of interest, which research areas should be further explored, the number of students and courses involved, and the (expected) trends in these numbers for the last and next 5 years.

The questionnaire was sent to 90 persons, 50% of whom responded. However, these respondents produced about 75% of all scientific papers. The results show that some 90 FTE personnel is involved in research. This number has increased slightly over the last 5 years, but it is expected to decline over the next 5 years. Most researchers are active in the fields of dosimetry, radiobiology and radiology/radiotherapy and they feel more research should be conducted in risk modelling and risk perception and communication. Health physics education appeared to be diverse but often medically oriented. The numbers of students and courses in health physics are rising. A need is felt for more courses in risk perception and communication, risk modelling and analysis and general radiation protection.

Several social issues require health physics expertise. In the Netherlands these issues include increasing medical exposures, renewal and possible extension of nuclear facilities, radioactive waste management, indoor radon exposure, and the need for fundamental (radiobiological) research output. Medical education is on the rise, but nuclear education is not. Respondents ignored waste management and radon expertise is declining. Fundamental research is also decreasing. It can be concluded that a shortage in several health physics expertises, as already suggested by the Dutch Health Council, can be expected in the Netherlands in the near future unless actions are taken to prevent this.

P03.16
Bilateral Comparison Of Low Level RP Training And Education Courses – A Tool For Facilitating The Mobility Of RPOS And Radiation Workers

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The EUropean Training and Education in Radiation Protection (EUTERP) foundation has as its main objectives the harmonization of criteria for, and mutual recognition of education & training (E&T) in radiation protection (RP) within the member states of the European Union (EU). In achieving this aim it is believed that the mobility of RP professionals within the EU will be facilitated. For various reasons the focus of the EUTERP activities has been directed to high level RP professionals like RP experts. It should be recognized that the vast majority of people involved in radiation protection that cross borders are only part-time RP officers or Radiation Workers with a moderate or even low level of RP E&T. We thus concluded that there is a great need for tools to judge whether these workers, when originating from another EU member state, fulfill the requirements with respect to RP E&T set by either the national authorities or the employer.

A straightforward tool is the comparison of contents of RP E&T courses in the various member states. On the European scale this would be a huge task. In this contribution we report on a pilot initiative to compare the contents of low level RP E&T courses in The Netherlands and Germany. We will focus at first instance on the description of the project that has been carried out as part of an apprenticeship of the Dutch course for RP Experts. The results of the comparison itself will be presented separately. Secondly we will discuss the lessons learned during this pilot. We will pay attention to differences in national systems of RP E&T and also address the aspect of national legislation. We will finally give an idea of a possible roadmap to 'mutual recognition' of low level RP E&T courses between Germany and The Netherlands and, more in general, throughout Europe.

P03.17
Lessons Learnt from Specific Education and Training in Radiation Protection to the Security Forces and Armed Forces in Argentina.

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As part of its strategy towards competence building in radiation protection, nuclear safety and security, the Nuclear Regulatory Authority of Argentina (ARN) has been training for decades the Army and the Security forces in the various aspects of these subjects.

The experience gained by ARN in providing specific training to these institutions has shown that to develop and maintain in a sustainable way an effective training program for these cadres and thus, to enhance the level of safety, it is important to focus the activities on continuously improving their ability in performing their role and functions in relation to nuclear energy and ionizing radiation, whether in preparedness and emergency response, transport of radioactive material, or the security of nuclear facilities.

In the process to accomplish the goal of having well-trained army and security forces in relevant areas related to safety, the ARN has also learned that is more effective to develop training programs designed for the specific roles of the Army and the Security forces with practical exercises and role playing, without neglecting the learning of general concepts of radiation protection, nuclear safety and security, rather than only through a theoretical teaching modality. Another lesson learnt is the benefit to the training's goal of organizing the training activities on the premises of the cadres, that is, training on the premises, grounds and facilities in which these institutions perform their duties prove to be also more productive. Finally, in ARN´s view there is a byproduct of the training activities consisting in strengthening the links between the regulatory body and the Army and the Security Forces that can be appreciated to the fullest when a cooperation agreement is in place, allowing a more efficient organization of the medium and long term planning of the training program and the 'train the trainers' in a more systematic manner. This paper describes the lessons learned from years of continuous work with the people of these institutions. It is expected that this work contributes to the safety culture and to the exchange of lessons learned and experiences of others in the approach to training.

P03.18
Comprehensive Radiation Safety Training, a Systems Approach for Human Capacity Development

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A partnership between a US small business (Trinitek Services Inc.) and an internationally recognized education institution (New Mexico Tech, NMT) has led to effective and comprehensive radiation safety training courses. Trinitek provides experienced educators with extensive operational, regulatory and international experience to complement the University's training facilities and unique hands-on testing environment. The focus of the training is to provide training geared to student needs, with an emphasis on practical exercises using a systems approach to create a more confident and skilled workforce.

Traditional radiation safety training focuses on the radiation hazard and overlooks the associated hazards which can complicate activities such as source recovery. We use a systems approach to include nuclear quality assurance, multiple hazard analysis, and integrated safety management. We start with basics of radiation effects, radiation monitoring (personnel and environment), radiation physics, regulations, compliance audits, leading to operations, radioactive waste management and emergency conditions. Human factors, fitness for duty, management roles, teams, preparation of procedures, and operator aides are included to provide effective training usable in work applications.

In the USA, regulations pertaining to radiation safety are under the jurisdiction of various state and federal entities including US NRC, FDA, USDOE, NRC Agreement States, EPA, DHS, DOT and others depending on radiation sources and usage. Internationally, various agencies issue recommended guidance, standards and best practices which are adapted by individual countries. Our international training includes the basic elements of radiation protection, yet is geared to host country needs and regulations while including best practices and recommendations available elsewhere.

Senior radiation protection staff and regulators often have a thorough understanding of principals but limited operational or hands-on experience. In our training we emphasize theory, along with the application giving students confidence in responding to emergency incidents. A six-week source recovery course taught to Egyptian Atomic Energy Authority staff (2010) in New Mexico, using our approach, was well received. Comments included:"We are grateful to get the training. These are topics we had not been taught before". "The course addressed weakness we had in our program... made workers more confident in doing their job".

P03.19
The TRASNUSAFE project: development of training schemes on nuclear safety culture for managers

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TRASNUSAFE is a project supported by the European Commission (FP7 - 249674), aiming at designing, developing and validating two training schemes on nuclear safety culture for professionals operating at a high level of managerial responsibilities in nuclear installations. One of the training schemes is related to the nuclear industry, while the other is related to the other installations making use of ionizing radiation based technologies, mainly the medical sector. Both training schemes will have a common basis reflecting the challenging approach to risk management, followed by sector-specific specialised modules. The final product will consist in a package of five training modules for managers of both industrial and medical sectors, ready for use after validation through pilot sessions.

This poster presentation gives a general description of the project (running since end 2010), including its objectives, structure and methodology.

The main outcome of the analysis of the training needs, made by means of a questionnaire and a set of five regional workshops, is presented.

In addition, the project organised two reflection groups, one within the "European ALARA Network" (EAN) and the other one within the "European Training and Education in Radiation Protection Foundation" (EUTERP). While the first aimed to clarify the links between the ALARA principle currently used in the radiation protection community and the safety culture of the nuclear industry, the second focussed on the different meanings of 'justification' of the radiological risk in societal and occupational context respectively, and on the implications of these findings for nuclear safety culture. The conclusions from these reflection groups will be explained.

P03.20
Training schemes for Radiation Protection Expert and Officers, and accompanying tools, developed within the ENETRAP II project

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ENETRAP II is a coordination action within 7FP (project number 232620). ENETRAP II's overall objective is to develop European high-quality "reference standards" and good practices for education and training (E&T) in radiation protection, specifically with respect to the Radiation Protection Expert (RPE) and the Radiation Protection Officer (RPO). These "standards" aim to reflect the needs of the RPE and the RPO in all sectors where ionizing radiation is applied (nuclear industry, medical sector, research, non-nuclear industry). The introduction of a radiation protection "training passport" as a mean to facilitate efficient and transparent European mutual recognition, and mobility, is another ultimate deliverable of this project.

ENETRAP II is in its final phase; project will terminate by the end of 2012. This poster gives an overview of the results achieved with regard to the specific tasks. The project also developed its results in the framework of the ECVET principles and determined learning outcomes in terms of knowledge, skills and attitudes necessary to build competent RPEs and RPOs.

This poster presentation presents the specific results obtained in the following domains: - development of the European reference standards for RPE and RPO training and, based on that, develop European training schemes (ERPTS), with specific attention to non-technical and soft skills required to build competent RPEs and RPOs, on the job training, works experience, …;

- development and application of a mechanism for the evaluation of training material;

- establishing a recognized and sustainable "quality label" for training events;

- creation of a database of training events and training providers;

- development of some course material examples (including e-learning);

- Organization of pilot sessions of specific modules of the ERPTS and monitoring of the effectiveness according to a developed system;

- development of a European passport for continuous professional development in radiation protection;

- bringing together national initiatives to attract early-stage radiation protection researchers on a European level.

P03.21
SCK•CEN's Academy for Nuclear Science and Technology: Contributing to Education and Training in Radiation Protection

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Preserving and extending nuclear knowledge on fundamental and peaceful applications of ionising radiation to serve society, is one of the key elements in SCK•CEN's research policy. Thanks to its thorough experience in the field of nuclear science and technology, its innovative research and the availability of large nuclear installations, SCK•CEN is an important partner for education and training (E&T) projects in Belgium as well as at international level.

Beginning 2012, SCK•CEN launched its "Academy for Nuclear Science and Technology" (http://academy.sckcen.be). The Academy supervises all E&T activities in nuclear topics that are subject to our research; that is nuclear technology, nuclear materials issues, and topics that concern environment, health and safety. These activities include:

1. Guidance for young researchers in the preparation of their thesis:

Specifically towards young scientific researchers, SCK•CEN experts are available to supervise Bachelor, Master and PhD students, as well as some post-doc researchers. Specifically in radiation protection related topics, we currently have about 35 PhD's and 3 post-docs contributing to our R&D priorities in this field. This is rather more than half of the total pool of PhD and post-doc researchers that are presently working on a 4 or 2 year project in SCK•CEN's laboratories.

In addition, initiatives are taken towards high school pupils (guided thematic visits to for example our radio- and microbiology laboratories) and teachers (update on nuclear topics and provision of certain illustrations).

2. Academic courses and training for professionals

SCK•CEN collaborates with several Belgian and foreign universities and contributes to academic learning. In addition, we also foresee training in topics like radiation protection, emergency planning, decommissioning, waste and disposal issues, radiation biology, -ecology, -chemistry, etc., tailored to the needs of the trainees in terms of programme, duration, level, language (Dutch, French or English) and venue.

Among the lecturers are physicists, biologists, medical doctors, engineers, technicians and social scientists who all bring insights and ideas from their specific background into the course programmes. 3. Policy support

The implementation of a coherent approach to education and training in nuclear science and technology becomes crucial in a world of dynamic markets and increasing workers' mobility. Through networking and participation in international programmes, the SCK•CEN Academy contributes to a better harmonisation of education, training practice and skills recognition on a national and international level. Amongst others, we are coordinating 7FP ENETRAP II and are an active Board Member of the EUTERP Foundation.

4. Research on transdisciplinary aspects of education and training

Understanding the benefits and risks of radioactivity requires technical insight and training, but also notice of the context and a sense for the social and philosophical aspects of the situation. In coordination with the academic sector, the research of the SCK•CEN Academy concentrates on how to integrate this transdisciplinary approach in E&T programmes.

P03.22
Radiation Dose Training- Awareness Among our Doctors Adequate to make Justifiable Referrals to Radiology Department?

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AIM: The aim of this study was to assess awareness among our doctors from all the clinical departments expect radiology, of a tertiary cancer care hospital about radiation dose and its associated risk to the exposed individual.

MATERIAL AND METHODS: This was a descriptive study in which a one-time survey was used. A multiple-choice format questionnaire with a total of 10 questions was distributed amongst doctors in all the clinical departments of the hospital except for radiology department. Participants were asked questions that broadly concerned three parameters of radiology i.e. the radio-sensitivity issue, technical awareness of radiological modalities and the principles of clinical indiactiona dn justification of every radiological exam referrals that they make. Only 40 doctors (53.3%) out of 75 completed the questionnaires and returned which tested their knowledge of medical radiation exposures made at radiology department.

RESULTS: Average response in the parameter that judged their knowledge of radio-sensitivity was 62% correct and 38% incorrect. In the parameter of technical awareness about the radiological modalities, 44% respondents gave correct answers while the remaining 57% gave incorrect answers. Quiet surprisingly, only 21% of the respondents knew principles of clinical indication and justification while 55% didn't know the key criteria for ordering a radiological exam. Overall response to the survey was 55% correct, 40% incorrect and 5% of the respondents gave doubtful answers.

CONCLUSION: The current study demonstrated an urgent need to improve knowledge amongst doctors in clinical practice regarding radiation and associated risks with medical ionizing radiation.

P03.23
e-IRMER - An e-Learning Package for Radiation Protection Training of Health Staff

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In the UK, the Ionising Radiation (Medical Exposures) Regulations 2000 provide a framework for ensuring that medical exposures are conducted safely. These regulations require the provision of training to any health professional who is involved in the justification or practical aspects of medical exposures. Also any registered health professional is allowed to act as a referrer who may request medical exposures for diagnosis. Formerly this was the prerogative of medical doctors, but in recent years the right to request specific x-ray examinations has been devolved to other staff groups, particularly nurses. For example, nurses in Accident and Emergency Departments can be approved to request ankle x-rays, following examination of the patient according to a strict protocol.

Good governance requires these referrers to be educated in the radiation risks and benefits associated with diagnostic examinations. This education has traditionally been led by Medical Physicists in the form of half-day or full-day lectures. Pressure of work has resulted in such courses being poorly attended, and modern technology gives the possibility of using computer technology to provide e-learning, so that staff can study at their own convenience, and if necessary, in short sessions.

This paper describes the Institute of Physics and Engineering in Medicine (IPEM) initiative to develop such a course, and gives some examples of the material produced.

P03.24
The EUTERP Foundation: Towards a European Approach for Harmonisation in Education and Training for Radiation Protection Professionals

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EUTERP, Petten, Netherlands

Started as an initiative of the European Commission the European Platform on Training and Education in Radiation Protection (EUTERP) has been transformed into a legal entity under Dutch law. The EUTERP Foundation facilitates a permanent dialogue between all involved parties by the use of its website (www.euterp.eu), by issuing newsletters and by organising workshops. From the workshops several recommendations based on common agreement among the participants - were given to the EC, IAEA, IRPA and national authorities including proposals for definitions of the RPE and the RPO. Currently, the possible consequences for national legislation and E&T activities and guidance needed in relation to this proposed definitions of radiation protection experts (RPEs) and radiation protection officers (RPOs) that will be implemented in the Euratom BSS are the main focus of EUTERP. The role of EUTERP concentrates on the objectives to strengthen and harmonise education and training, and to facilitate the development of mechanisms of mutual recognition, based on a common approach. EUTERP will be provided with input from the ENETRAP II project. EUTERP aims for being a European body on harmonisation of criteria and qualifications for and mutual recognition of RP professionals.

P03.25
How To Build A Regulator

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What makes a good regulator for radiation protection? In South Australia, radiation protection in uranium mining is regulated by the Environment Protection Authority. The EPA protects the South Australian community from unacceptable levels of radiation through the implementation of state based legislation and national and international codes and standards. This is the job of the EPA regulator and it's far more interesting than it sounds. The skills and knowledge a regulator needs to operate effectively in radiation protection range from health physics to hydrogeology, from policy to uranium production and from stakeholder engagement to compliance and enforcement. The ideas and approaches to radiation protection are dynamic and, at times, contentious. Therefore regulation is not a job for the single-minded, but the open-minded, a person prepared to adapt to change as well as to instigate change.

As global demand for nuclear power increases and uranium exploration in Australia continues to expand, so to will the need for regulatory resources. But there is no one-stop-shop to pick up a fresh regulator, nor is there a single training package that addresses the myriad requirements. So the question is: how do you build a regulator?

This poster aims to provide a set of instructions to build your own regulator based on the experiences of the South Australian EPA and colleagues in government and the mining and radiation protection industries.

P03.26
Radiation Protection Training Activities

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The aim of the present study is to review training experience gained in the field of radiation protection locally, regionally and internationally. Locally, several training centers are offering basic radiation protection programs. Following Egyptian Ministry of Health guidelines , the course duration is one month and it cover several topics such as basic physics, radiation dosimetry, radiation biology , radiation protection measures, radiation and nuclear safety, transport of radioactive materials , waste management as well as nuclear and radiation emergencies. The Egyptian Atomic Energy Training Center (EAETC) is the leading training center locally. Furthermore, EAETC offers other radiation protection training courses not only as basic courses but also as advanced courses. Each course lasts one to two weeks it depend upon the practical part of the course. Regionally, training courses in the field of radiation protection was initiated through Arab Atomic Energy Agency. International radiation protection training courses was initiated by International Atomic Energy Agency.

P03.27
Comparison of the Lowest Level Radiation Protection Courses in Germany and The Netherlands

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Introduction: There exists a considerable variation in the approaches of European countries to the radiation protection (RP) education and vocational training arrangements for radiation protection. This diversity creates an obstruction to the mobility of radiation protection professionals in the EU. Therefore, the EUropean Foundation on Training and Education in RP (EUTERP) has been established. The main objective of the foundation is to support harmonization in the field of education and training systems for RP experts, officers and radiation workers. Therefore, as a first initiative, this study aimed to make a comparison between the lowest level RP courses in both countries.

Methods: As a reference for the German technical RP course, one course given by the Institut für Radioökologie und Strahlenschutz (IRS) of the Gottfried Wilhelm Leibniz Universität in Hannover was used. As a reference for the German medical RP course, the course given by the Landesanstalt für Personendosimetrie und Strahlenschutzausbildung (LPS) in Berlin was used. Both courses were compared to the Dutch level 5A/B courses by comparison of the course content and the course hours.

Results: The Dutch courses teach on average the minimum required subjects compared to the German expertise levels. Also the time used to teach these subjects meets the German requirements. However, because of the modular nature of the German system, each German expertise level cannot be considered equivalent to the Dutch level 5A/B. Although the German and Dutch courses both lecture national legislation to the same extent, the coverage of national legislation cannot be considered identical. Further the German system not only comprises of training, but also requires relevant practical experience which needs to be gained independent whether a German or Dutch certificate is used. Also the German system, unlike the Dutch, has a system of refreshing courses. In order for Dutch certificates to be recognised, these refreshing courses should be met too.

Discussion: A comparison between the lowest level of technical and medical RP courses in The Netherlands and Germany shows that, apart from some relatively small differences and accents in the covered items, the main difference is the covering of national legislation and the German requirement of practical experience. Therefore, in order for technical and medical RP officers and radiation workers from Germany to be recognized in The Netherlands and vice versa, these differences have to be addressed in an additional course and/or additional practical experience.

When these additional requirements are met, technical and medical RP officers can benefit from a mutual recognition of education and training programs on radiation protection. This study might therefore provide a suitable basis for harmonization of the lowest level of RP courses in The Netherlands and Germany resulting in mutual recognition.

P03.28
Undergraduate Radiation Protection Training - A Stakeholder Engagement Approach

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The University of Cumbria is located in England's North West – the Lake District. Being co-located with a large part of the UK nuclear industry (Sellafield, other Fuel Cycle sites, NPPs) the university is well placed to collaborate with industry in the provision of education and training. Staff at the University identified a gap in the Radiation Protection 'market' and put together a multi-professional project team to develop an academic programme aimed at enabling technical staff working in a Radiation Protection environment to extend their potential towards becoming and RPA along with professional registration with SRP. The University started its first cohort of part-time undergraduate students in October 2011. This is the first and only undergraduate degree in Radiation Protection in the UK. Although the first students are all from the nuclear industry, the university expects to make the course available to students from other sectors in the future. This paper describes how a highly collaborative approach has been developed, by close involvement of representatives of the profession, industry, academia and regulators. It outlines the progress of the cohort to date (i.e. to May 2012), examines some of the challenges which have faced the team and considers the potential for associated academic developments.

Poster sessions A-B: Area 3

P03.29
Radiation Education for High School Students Using Potassium Radiation Sources

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Many high school students came to view our research facilities, the national institute for fusion science, every year and some of them had radiation courses, in which they learned natural radiation and naturally existing radioisotopes. Recently radiation measurement practice was also started using natural radiation sources in the radiation courses. The natural radiation sources were those fabricated from natural materials containing naturally occurring radioisotopes, ^{40}K, ^{232}Th, ^{238}U and so forth. Typical materials containing 40K are potassium chloride chemicals, potassic chemical fertilizers and kelps, and then those containing ^{232}Th and ^{238}U are earth medium and sinter (hot spring deposits). Of these materials, potassium chloride chemicals were used as raw materials of natural radiation sources in this study. The radiation sources fabricated from potassium chloride chemicals are referred to as potassium radiation sources. The potassium radiation sources contain ^{40}K, which emits a 1.33-MeV beta particle as a result of beta decay (89%) and a 1.46-MeV gamma radiation due to electron capture (11%). Using the sources, four measurements were carried out with a GM survey meter in the radiation measurement practice. The first measurement was evaluation of background radiation. Other three were conducted to understand the dependences of radiation intensity (radiation counts or count rates) on time, on distance, and on shielding thickness. The measurements on three dependences were relating to principles underlying protection from radiation. The radiation course was held four times and 37 high school students took the radiation measurement practice using potassium radiation sources. To investigate the educational effect of the radiation measurement practice, measurement data obtained by 37 students and their free descriptions in questionnaire surveys were examined.

As a result, students could easily understand the existence of natural radiation, feel naturally occurring radioisotopes and better understand the radiation protection principles of time, distance and shielding. The potassium radiation sources could be handled safely and easily in radiation courses and the radiation measurement practice was favorably received by many students. It is expected that potassium radiation sources will be useful not only for finding out about natural materials that contain radioisotopes but also for demonstrating the radiation protection principles in radiation education at junior and senior high schools and in community education.

P03.30
A Bottom Up Experience: The French Qualified Experts Regional Networks

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During IRPA 12 at Buenos Aires, took place a topical session on Networking. This was the opportunity to present a very new French initiative from Radiological protection Qualified Experts, who felt lonely and not well recognised in their hospitals, industries or research centres, to set up 3 regional networks aiming at facilitating feedback experience exchanges and providing them updates on regulations and scientific evidences.

Since then 6 new regional networks have been set up. The 9 networks cover now more than half of the French territory and allow now more than one thousand Qualified Experts to improve efficiently occupational radiation protection in their facilities. A national coordination of all chairpersons of the networks has then emerged at the end of 2010. All networks' representatives have signed an ethical chart during the first official meeting of that coordination in October 2011. Due to the networks efficiency, the French Safety Regulatory Body and the Ministry of labour are strongly supporting these initiatives from individuals both in terms of advertisement and providing resources for the coordination itself.

Furthermore, in a very short time the coordination has became a new partner for many institutions, allowing the Qualified Experts to provide input, through a bottom up approach, to future regulations dealing with all aspects of occupational exposure life in France or to facilitating organising the profession

P03.31
Informatization and Integration of Radiological Protection Optimization Programs

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To develop a radiation protection program, Brazilian radiactive facilities consider national and international standards, guidelines and recommendations from International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and National Nuclear Energy Commission (CNEN), which can be found in several documents published by those organizations through the past decades. This project aims the informatization of radiological protection optimization programs in a single system to offer unified programs and inter-related information in Portuguese, providing Brazilian radiactive facilities a complete repository for research, consultation and information in a quick, integrated and efficient way. According to the user profile in Brazilian companies we created the functional structure to best interfaces, tools and resources, and an efficient browser project to aid information searching. Content includes concepts, definitions, theory, optimization programs, help decision making techniques, information about protection costs, radiation doses and detriment. The servers processing power and the technology of relational databases allow to integrate information from different sources, enabling complex queries with reduced response time. The system follows Web 2.0 standards providing appropriate organizational structure for informatization of radiological protection. Great usage of CSS allows adaptation to other devices, as mobile access. The right criteria to index information ensures its recognition by Internet search engines. Modular structure allows to integrate inter-related elements on research basis. Each module can be adapted independently through updating models where each information is recorded in a single record without redundancy, even though it appears in different subjects or modules. This project uses the combination of multiple technologies, maximizing the resources available in each technology in order to achieve our goals.

P03.32
The European Master's Degree in Radiation Protection (EMRP): The French Implementation

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Initiated within the European project ENETRAP (FP6), EMRP was launched a little two years ago. A consortium of four universities was established (two in France, Czech Republic and Scotland). This article describes the implementation of this Master in France. This training program is based on the academic training program established by ENETRAP to harmonize the training of Radiation Protection Experts through Europe.

EMRP will help the nuclear industry, the medical sector and institutions dealing with ionizing radiations across Europe to ensure a supply of skilled personnel for industries. EMRP is being developed in response to the increasing demand for and the decreasing supply of RPE in Europe. It will be helpful to overcome local skills shortages by facilitating the mobility of graduates throughout Europe.

This EMRP syllabus defines only the 2nd year of a Master's degree program. To attract adapted student profile to the RP field, we have collaborated to the creation of two masters, one in the health engineering and the second one, specific to nuclear activities.

The Pedagogical Council of the EMRP Master is listening to requests from industry and nuclear-related institutions through representatives of EDF, CEA, IRSN, AREVA, ASN, medical sector...

At the end of training, students are immediately operational and the recruitment rate is close to 100%. The teaching methods are based on face-to-face courses, b-learning using webcasted lectures, simulations, serious game and forums through a LMS platform.

EMRP students are also involved in national congress for Radiation Protection. Lately, they were actively involved in mentoring young students through high school international meeting called "workshops of radiation protection".

Two years after the implementation of EMRP program, the relevant findings are:

-Necessity to enlarge the consortium of partners universities,

-Continue to offer case studies that are carried out jointly by students from different partner countries.

-There is a need to improve RP attractiveness as the number of Master's degree programs related to "Nuclear" is increasing

-Requirements of financial resources are increasing because a European Master's program needs more means than solely domestic financial resources.

P03.33
Guidance To Radioactive Contamination Measurements In Health And Research Installation

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The European Radiation Protection and the Spanish legislation establish the necessity to carry out the radioactive contamination measurements in the working areas and the exposure workers. Therefore, some technical documents propose recommendations and instructions to elaborate and to apply different procedures regarding the control and surveillance of the contamination.

However, the lack of a systematic in the measurement methods and the Action and Register Values of common application have been affirmed on several occasions by the Radiation Protection workers in the health and research field installations.

This fact motivated the Sociedad Española de Protección Radiológica (SEPR) to organize a course of *Radioactive Contamination Measurements in Health and Research and Education installations*, carried out in two editions (2008 and 2009).

The technical knowledge and the practical issues shown in this course have been collected in a technical document published by the SEPR in 2011: *Guidance of radioactive contamination measurements in Health and Research installation.*

The aim of this Guide is to harmonize the different measurement procedures of the contamination in the radioactive installations belonging to the indicated fields, proposing common criteria that facilitate training and guidelines in relation with this practice to the Radiation Protection workers of theses installations.

The document has been organized into different chapters presenting an integral vision of the radioactive contamination measurements. A procedure collection has been included that allows to confirm in an experimental manner and with the necessary frequency, that the contamination levels are within the established limits.

At the same time, this document proposes the methods to estimate the derivative doses of possible contamination and to analyze the obtained results. On the other hand, the prevention and protection guidelines to minimize the radioactive contamination incidence in these installations are suggested.

The analysis of different Reference Levels proposed for the evaluated parameters in this Guide, suggesting the values of common application in the indicated installations means an important advance in achieving the harmonization of this practice.

P03.34
A New Approach on Regional Training Courses to Avoid Denial Cases of Shipments

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The transport of radioactive material is an expanding worldwide activity involving the movement of products that are essential and necessary for public health, manufacturing, science, and engineering. In spite of the long established regulation of the safe and secure transport of nuclear and radioactive material, recent years have shown that transport operations are increasingly being faced with delays and denials. It has been identified that training and education should be prioritized considering the link between theoric concepts and its adequate application according to the use of the regulations and focussing the attention in the reviewing of denial cases reported. This paper shows the experience gained in the implementation of a new approach developed on the regional training courses at the America region to avoid denial cases on the transport of radioactive material.

P03.35
Social Networking and Radiation Protection

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Radiation protection specialists exchange experiences on issues of common interest using various means, either in person or using the Internet. In Latin America one of the ways of disseminating the activities was through the Bulletin "Radiation Protection", of which 65,000 copies were distributed to specialists from over 40 countries for 10 years. With the development of information technology has facilitated communication, initially with www.radioproteccion.org website created in 1998 and yielded information on the activities in the various technical cooperation projects and countries of the region. Then he made use of listservs such as the Radiation Protection Network created March 15, 2002 and has over 2,000 members from 32 countries, primarily Spanish speaking and where members can send and receive information about courses, scientific activities, articles, opinions and comments on radiation protection.

But now it makes use of social networks that are forms of social interaction with dynamic exchange between individuals, groups and institutions, involving groups that are identified in the same needs and problems and that are organized to leverage their resources.

Social networking is part of our reality, and professional to do their use to exchange information and improve our relations with the objective to help us improve the radiation protection.

It can be appreciated that various national and international organizations related to our specialty are in the networks as well as professionals working in the field. This paper describes the experience of working in the major social networks: Facebook, Twitter and LinkedIn and its importance for the development of radiation protection. It also provides a range of Internet use to put videos, presentations and photos of the specialty.

P03.36
Education and Training of the Medical Staff on Radiation Protection

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In Romania, as in all industrialized countries, the medical exposure of the population to ionizing radiation is the main way of exposure to man-made sources of radiation . The education and training of the medical staff is an important task, in order to use the ionizing radiation in medicine , with maximum of benefit and minimum of risk. Education refers to both practitioners and prescribers.

For continuous education in radiation protection of the staff from radiation medicine, a national training program is organized by the National Centre for Personnel from Medical Domain , in collaboration with SC EXPERT PRO-RAD srl Bucharest , including four training courses (min. 32 hours , each) on " Radiation Protection in Diagnostic Radiology and Interventional Radiology " , "Radiation Protection in Radiotherapy" , "Radiation Protection in Nuclear Medicine" and "Radiation Protection in Emergency Situations".

All courses are accreditated by the National Nuclear Regulatory Authority (CNCAN) and by the National Collegium of Physicians (CMR).

Several problemmes arrised during the last years :

- the increase of the number specialized (complex) techniques, which need high specialization in the field;
- the extended use of ionizing radiation in paediatric radiology and in interventional radiology;
- lack of appropriate education on radiation protection in school (even at medical universitary level);
- lack of medical physics departments in hospitals.

As it is well known, in 2007, in the journal Annals of the ICRP (Publication 103), the International Commission on Radiological Protection (ICRP) published The 2007 Recommendations of the International Commission on Radiological Protection .These recommendations provide important guidance for our activity regarding the protection against the risks associated with ionizing radiation, particularly from artificial sources widely used in medicine. Many of present radiation protection legislations need revision, according to the 2007 ICRP Recommendations and the education and training on radiation protection should be enforced, accordingly. Some practical proposals are presented.

P03.37
RPO Competency Model for Enhancement of Radiation Protection in Malaysia

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In an overview of the very comprehensive Radiation Protection Officer Certification Scheme in Malaysia, it is apparent that there exist room for further improvement in the competency development of RPOs. This paper is proposing the development of a competency model for Radiation Protection Officer looking into the personal characteristics as this attribute is important towards the successful performance of complex tasks but currently not included in the current RPO certification scheme. A holistic development of RPO competency in all three components, Knowledge, Skills and Attitude shall put the focus on the personal professionalism of the RPO to perform their duties in a "superior" way which will in turn elevate the standard of radiation protection in Malaysia.

Keywords: radiation protection officer, competency, competency model

P03.38
Certificate of Professional Development in Radiation Protection

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This course has been developed by the Centre for Lifelong Learning at the University of Strathclyde and the Association of University Radiation Protection Officers (AURPO) in collaboration with the Health and Safety Executive (HSE) and RPA 2000.

The course started in 2002, originally to assist university RPAs to get accreditation and 41 took the course in the first year. Intake has since settled down to an average of around 20 students/year and students now come from a variety of backgrounds – university sector, medical physics, nuclear sector and general industry. The course is widely recognised as providing valuable training for those wishing to attain greater knowledge and understanding of radiation protection matters and has attracted students from Australia, India, Middle East, USA, Ireland and Africa as well as from the UK.

The course is currently benchmarked against the HSE criteria for the 'Core of Knowledge' required for a Radiation Protection Adviser. It is being further developed to ensure that it also fully covers the Environment Agencies syllabus for a Radioactive Waste Adviser (RWA).

This course has been designed to allow students to study by distance learning through the use of text-based course content with online tutor support (all accredited RPAs) via the University's new unified virtual learning environment myplace. A series of 8 units are released in stages over a period of 6 months and cover the following 8 topic areas: basis of radiation protection; basic atomic physics and biology; detection and measurement of radiation; health and safety legislation; sources of radiation, practices and interventions; control of exposure; organization of radiation protection; management of radioactive materials and waste disposal. Student progress is assessed by various Unit-based activities and five 2000-word assignments completed at the end of the study period.

Successful completion of the course will merit the award of a Certificate of Professional Development in Radiation Protection from the University of Strathclyde.

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P03.39
Training on Radioisotopes Techniques and Radioprotection Aspects at the School of Pharmacy and Biochemistry (UBA, Argentina).

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The employment of radioisotopes is a widespread practice and must be carried out in the framework of radiological safety and in harmonization with the environment.

Since 1960, the School of Pharmacy and Biochemistry of the University of Buenos Aires, Argentina, has offered different courses on methodology of radioisotopes with special emphasis on Radioprotection at graduate and postgraduate level.

From the beginning the courses were targeted to students of Biochemistry and, at the postgraduate level, to Physicians and Graduates in Biochemistry, Biology, or other disciplines related to the medical sciences. In addition, there was a refreshed course offered for licensed professionals.

Through all these years we have been permanently updating the courses and encompassing the international and national guidelines, the continuous growth of nuclear medicine and the development and incorporation of new radiopharmaceutical products and advanced technology equipments.

The goal of these Courses is to enable graduates in biomedical sciences to acquire criteria for the correct application of the radioprotection philosophy with especial emphasis in the importance of this practice as well as the potential environmental impact it implies; planning of professional practices with an adequate training of the human resources involved in and optimization of procedures and practices. Graduates attend 220 lecture and laboratory practice hours. These courses allow them to apply for an individual authorization for the use of radioactive material extended by the Argentine Nuclear Regulatory Authority.

As from 2005 Radiopharmacy is included in the degree in Pharmacy. In 2012 we made the proposal to the ARN to teach a posgraduate course in Radiopharmacy. In addition, in 1997 we began the training of Technicians, and finally in 2009, given the increasing demand for an adequate training of Technicians, we started to teach a 3 year university career for Technicians in Nuclear Medicine.

The more than 45 years of experience in research and teaching in our Laboratory at the University of Buenos Aires, contributes to an excellent professional and technical training of the experts. With the addition of Radiopharmacy at the graduate and postgraduate level, the organization of the University Career of Technicians in Nuclear Medicine, our Laboratory is one of the major contributors to the training human resources in the area of Methodology of Radioisotopes and Radioprotection in our country.

P03.40
Optimisation of Radiation Protection (ALARA): A Practical Guidebook

Economides, S[1]; Gemmill, J[2]; Hardeman, F[3]; Lorenz, B[4]; Nuccetelli, C[5]; Risica, S[5]; Schieber, C*[6]; Schmitt-Hannig, A[7]; Vermeersch, F[3]; Wright, A[2]

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In 2009, the European ALARA Network created a specific working group on ALARA Culture. The objective of the WG is to maintain and further develop the high level of radiation protection by promoting the ALARA culture in all fields of application, implementing the ALARA principle into practice, and analysing feedback from implementing ALARA in various sectors.

One of the activities of this working group is the elaboration of a practical guidebook on optimisation of radiation protection, expected to be published by 2012.

After an introduction on the basic concepts of radiation protection and their origins, the book presents the ALARA process, the main actors and their responsibilities and elements supporting the approach. It then gives many examples of ALARA in practice for workers and public in various exposure situations, for patient protection as well as for emergency and post accident situations.

P03.41
Karlsruhe Chart Of Nuclides - Edition 2012

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In 2012 the new 8th edition of the Karlsruhe Nuclide Chart has been published. It contains data on 118 elements and 3847 experimentally observed nuclides ground and metastable states. The new 2012 edition presents 166 new nuclides and 27 new metastable states. In addition, 479 states have been updated. The element names copernicium (Cn), flevorium (Fl) and livermorium (Lv) have been introduced. Information on the new element 117 is presented.

A unique feature of the chart is colour coded information on main and subsidiary decay modes. The accompanying booklet includes a multi-lingual explanation of the interpretation of the chart (English, German, French, Spanish, Chinese, Russian). In the new brochure, 23 examples have been selected to describe in detail how the nuclide box contents should be interpreted with reference to the nuclide decay schemes.

In addition to the fold-out chart and wall-chart, a new auditorium chart (43 x 316 cm) and a carpet version (100 x 650 cm) have been developed for lecture theatres and for exhibition purposes.

P03.42
Developing Curricula for Radiation Protection Officers

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Everybody seems to be acquainted with what a RPO needs to know. Defining the curricula is obviously an easy task. But is this really so? The author describes a sophisticated method. It begins with identifying the relevant groups of RPOs, a risk assessment for these groups and then defining the appropriate knowledge and skills a course should convey to the participants. At this point you should try to minimize the number of RPO groups in order to develop a course system that is as small and effective as possible on the one hand and on the other hand as differentiated as needed. This can be done by combining groups with similar risk and/or similar knowledge and skills. In Germany this method was succesfully applied to define the curricula for RPOs working with x-ray devices. The outcome will be described in this article.

P03.43
Structured Intercomparison of Clinical Medical Physicists' Education and Training Frameworks in European, North American and Australasian countries

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Purpose: The clinical medical physicist is an essential link of a multi-professional chain, responsible for the effective and safe implementation of radiation-based medical procedures. To ensure that the physicist can provide an adequate service, sufficient education and training in their fields of practice is indispensable. However, a common education and training framework is not available world-wide. Because of this a uniform level of skills and knowledge does not exist. The aim of this study is to provide a structured collection of information regarding the present status of the clinical medical physicist education and training framework in 25 European, 2 North American and 2 Australasian countries. Evaluation of these data can set the stage for free movement of medical physicists among these countries. Methods: For this study, data collection was based on a pre-existing questionnaire prepared by the European Federation of Organizations in Medical Physics (EFOMP) and filled-in either by the corresponding scientific societies-organizations or by the authors. It consisted of three main parts concerning the education and training of clinical medical physics, the different professional levels of medical physicists and the existence of a national register of clinical medical physicists. Results: In the majority of cases, for European as well as North America and Australasian countries, a qualified medical physicist should have an MSc in medical physics and 1-3 years of clinical experience. The training programs are usually approved by a responsible government ministry, a professional body or a university. Education and training takes place in both universities and hospitals and the total duration of the programs ranges from 2.5 to 9 years. In 56% of all European countries and 4 states of USA, it is mandatory to hold a diploma or license to work as a medical physicist. In Australasia there is often a requirement for departments to have at least one medical physicist who holds a recognised certification in medical physics and has been granted a license by an appropriate government body. Generally, there are national registers of medical physicists with inclusion on the register being voluntary. There are renewal mechanisms in the registers, in the majority of the cases based on a Continuing Professional Development (CPD) system. Conclusions: In conclusion, a common policy on matters concerning education and training as well as the practice of the medical physicist profession is generally followed, notwithstanding the presence of a few differences. Attempts to formulate general guidelines are already in progress based on common features, as well as differences, from country to country.

P03.44
Enetrap II: WP5 Develop And Apply Mechanisms For The Evaluation Of Training Events

van Elsäcker-Degenaar, IH*[1]; Draaisma, FS[1]; Sutmuller, M[1]; Stewart, J[2]; Livolsi, P[3]; Fantuzzi, E[4]; Mobius, S[5]; de Regge, PP[6]; Vaz, JP[7]; Ceclan, M[8]

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To maintain a high level of competency in Europe regarding radiation protection and to facilitate harmonisation and (mutual) recognition of Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs) quality assurance and quality control plays an important role. The ENETRAPII project (FP7-EURATOM) aims at developing European high-quality 'reference standards' and good practices for education and training in radiation protection. In work package 5 (WP5) the quality issue is addressed. Therefore WP5 deals with the development and application of mechanisms for the evaluation of training material, training events and training providers by means of a transparent and objective methodology. The results can be used by regulatory authorities to benchmark their national radiation protection training programme and will be communicated to other networks, e.g. EUTERP.

For the mobility of RPEs and RPOs throughout Europe it is important to have a comparison system for training events. WP5 has started with an inventory towards existing comparison methods like regulations and international standards, e.g., ECTS, ECVET and topics addressed by stakeholders. The comparison table for training material will consist of learning outcomes in the three fields, knowledge, skills and attitudes and will be presented at this conference, together with a comparison amongst courses of different training providers throughout Europe. We will form a conclusion about the usefulness of the table for training events.

P03.45
Training and Education in Radiation Protection at the Nuclear Research and Consultancy Group (NRG),Petten, the Netherlands

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Nuclear Research and Consultancy Group, Petten, Netherlands

The Nuclear Research & consultancy Group (NRG) offers a wide range of services to energy utilities, government organizations and various branches of industry - including the nuclear, E&P industry and medical sectors. NRG is a major producer of medical isotopes in Europe.

One of these services is training and education. The training and education is offered both to workers at NRG and to others. All the courses are offered at regular bases and as ‘in-company’ courses. Training is given in the field of radiation protection ((continuous) education and further training) and nuclear (mostly education).

Since the introduction of energy production through nuclear energy in the Netherlands NRG provides education and training to acquire and maintain the knowledge and skills of the personnel of nuclear installations. The unique combination of the experienced staff and the availability of nuclear installations give the courses a surplus value in keeping the different education and training.

The Dutch law requires experts to have training and instruction before they work with independently with radioactive substances and/or X-ray equipment. The law defines several levels of expertise, level 2 being the highest, and level 5 the lowest.

NRG has been accredited as a training institute by the Dutch government, and as such is authorised to run courses and hold examinations at levels ranging from 5 to 3. This makes our range of courses one of the most comprehensive in the country. Anyone who passes an NRG examination at one of these levels will be awarded an officially recognised diploma.

Apart from regular training for radiation protection experts, officers or workers, NRG also gives training and education to particular professions as measurement engineers in the E&P industry, officers in the fire department, medical doctors using X-ray with a patient dose less than 2 mSv, dentists and their assistants. Attendees who pass examination in these courses will also be awarded with an official diploma, recognised by the authority. With this diploma they can state that they have the knowledge to perform the profession. The training in skills and attitude, that are also required for the profession has to be received in their own company.

When one has the knowledge, skills and attitude in radiation protection one has to maintain them to keep up with the changing (inter)national regulations to keep good working practices. In the Netherlands there will be a recognition system for radiation protection experts. One of the requirements is to keep up with the knowledge, skills and attitudes by participating in refresher courses. NRG organises refresher courses with a general theme and with different subjects, like neutron radiation protection, radiation protection in the E&P industry, radiation protection from incidents and disasters and in the field of organisational and administrative aspects of radiation protection.

P03.46
Enetrap II: WP5 Develop And Apply Mechanisms For The Evaluation Of Training Material

van Elsäcker-Degenaar, IH*[1]; Draaisma, FS[1]; Sutmuller, M[1]; Livolsi, P[2]; Fantuzzi, E[3]; Mobius, S[4]; de Regge, PP[5]; Ceclan, M[6]; Stewart, J[7]

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To maintain a high level of competency in Europe regarding radiation protection and to facilitate harmonisation and (mutual) recognition of Radiation Protection Experts (RPEs) and Radiation Protection Officers (RPOs) quality assurance and quality control plays an important role. The ENETRAPII project (FP7-EURATOM) aims at developing European high-quality 'reference standards' and good practices for education and training in radiation protection. In work package 5 (WP5) the quality issue is addressed. Therefore WP5 deals with the development and application of mechanisms for the evaluation of training material, training events and training providers by means of a transparent and objective methodology. The results can be used by regulatory authorities to benchmark their national radiation protection training programme and will be communicated to other networks, e.g. EUTERP.

The first key task in this work package is the development of a comparison method to compare existing training material with existing standards. WP5 has been started with an inventory of topics, items and subjects that needed to be addressed in the education and training of the RPE and RPOs. The comparison table is presented at the IRPA Europe meeting in Helsinki 2010. At this conference a presentation will be given about the use of the comparison table for training material, by comparing different training institutes throughout Europe with each other and the conclusion about the usefulness of the table.

P03.47
"Radiophilia": A Tragic Phenomenon in Diagnostic radiology.

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Diagnostic radiology is one of the most frequently used method in medical imaging that rate of its application is increasing daily. Generally working conditions in radiology departments seem to be normal and risk conception and risk perception about radiation protection standards among experts, physicians, radiation technologists, patients and public are similar so that all radiation safety considerations are respected at all levels. But there are many reasons and there is much evidence that not only the importance of risk conception and risk perception (not meant to Radiophobia) in relation to radiation safety and protection issues are ignored, but there are insignificancy and incuriosity among people somehow have a direct relationship with the radiology as an abnormal behavior of individual and organizational that can be called "Radiophilia". Radiophilia is not a term to describe a phenomenon, but it is an inconvenient truth that is not justified any way. The most important factors that are causing Radiophilia include:

lack of knowledge and awareness on radiation effects among physicians

lack of knowledge and awareness on radiation protection rules, especially justification among physicians

the increasing number of less experienced and careless clinicians who request radiography and their incorrect diagnosis

the increase of radiography requests to raise the income of doctors and centers that do radiography

undermining the importance of ALARA principle among radiation technologists because of their low income-demanding job

lack of knowledge and awareness on radiation effects among patients and their insistence to experience radiography

lack of attention to dose reduction methods among radiation technologists

the increase of radiography requests for traumatic patients and, hence exposing their relatives to radiation due to lack of accessories in the radiography rooms

lack of proper performance of local organizations responsible for radiation protection and failure to provide, follow up, and implement radiation protection rules

lack of proper education and implementation of dose limits among physicians and radiation technologists

lack of digital equipment and PACS systems in many radiology departments

P03.48
Problems With the Pregnancy Question

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In the UK, the Ionising Radiation (Medical Exposures) Regulations 2000 state that 'the written procedure for medical exposures shall include '…procedures for making enquiries of females of childbearing age to establish whether the individual is or may be pregnant…'

Guidance on asking the 'Pregnancy Question' has changed a number of times and this has resulted in variations of application. To investigate this further, a questionnaire was sent to diagnostic radiology and nuclear medicine departments across the UK. Questions asked related to the department's written procedure, the examinations for which the question would be asked, the age of women asked and how the outcome was recorded.

Responses were received from over 300 individuals working in 66 different hospitals. The majority (73.5%) were from x-ray departments, 14.0% were from nuclear medicine and the remaining 12.5% from specialist areas including computed tomography, neuroradiology, angiography and cardiology.

Of the responses received from x-ray departments, 17% ask the question for all examinations, while 83% ask for examinations of specific but differing body regions. Over 30 different age ranges were stated for the 'childbearing age'. The lower age limit ranged between 10 and 16, while the upper limit was in the range of 45 to 65.

The majority (97.6%) record that the question has been asked and the outcome, although the location of these records is not consistent across departments. Also there is a lack of consistency over whether this record is signed and by whom. Use of computerised Radiology Information Systems (RIS) further complicates the issue.

The results demonstrate the large variations between individuals in carrying out this procedure. An additional problem was that even though departments have a written procedure, it is not necessarily being followed suggesting that once a procedure has been learnt by the individual, perhaps during training, it remains with them throughout their career.

These findings raise concern that inconsistent application of the pregnancy procedure is a potential cause of concern or distress to patients, a reason for future litigation against hospitals and a negative influence on radiation protection culture. The solution is for the professional bodies to translate the guidance into a detailed procedure, promulgate this to the professionals and encourage radiography schools to adopt in their basic syllabus.

P03.49
Actions And Impact Of The Iaea Technical Activities In The Field Of Occupational Radiation Protection In Latin America, Europe, Asia And Africa.

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The first International Conference on Occupational Radiation Protection was held in Geneva in 2002. It was organized by the IAEA, which convened the Conference jointly with the International Labour Office (ILO). Since then the occupational radiation protection context has evolved in terms of international recommendations and standards such as ICRP 103 issued in 2007, new IAEA Basic Safety Standards, new technologies (in particular in the medical sector), increasing trend of itinerant workers, implementation of radiation risk management in the NORM industries, feedback experience in decommissioning and post accidental situations.

This paper would present a summary of the activities carried out during the implementation of the International Action Plan on Occupational Radiation Protection with emphasis on actions and results related to the promotion of networking and the work of current regional and international networks; situation with appraisal services and self-assessment tools developed for to assess the IAEA Member States compliance with the relevant safety requirements; achievement of the Member States during the implementation of technical cooperation projects as well as trends and future actions identified for the years to come.

P03.50
Towards Developing a Radiation Protection Culture in Diagnostic Radiology Practice in Nigeria

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Background and Purpose: Previous studies have highlighted concerns about poor adherence to radiation protection guidelines in Diagnostic Radiology service delivery in Nigeria. This study sought to identify reasons for this, and explore the challenges militating against development of a radiation protection culture among medical radiation users in the country.

Materials and Method: 230 self administered questionnaires were distributed to practicing radiographers and Radiologists in public and private clinics to assess the familiarity, knowledge, attitudes, procedures and techniques in radiation protection. Questions also sought information on dose optimization, individual participation, methods and challenges of optimization and protection, quality of personnel, legislation and level of training received by respondents on radiation protection. 155 (67.4%) questionnaires were returned filled. Data analysis was carried out at the 95% confidence interval.

Results: While all respondents claimed familiarity with the ALARA and NCRP guidelines, 119 (76.8%) were not usually involved in radiation protection. Reasons for this ranged from workload because of shortage of personnel to unavailability of protection equipment and personnel. At least 87% of respondents felt that regular monitoring of protection protocols would compel them to implement practice.

Conclusion: The findings are suggestive of a need for attitudinal change among radiation users as a first step towards adopting the radiation protection culture in Nigeria.

P03.51
Inter-knowledge an Innovative Environment for Teaching and Training in Radiation Protection using ENEA ICT: CRI & IES Internship Experience

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The dissemination of knowledge on radiation protection in our millennium is more relevant: the most representative Italian Associations in this field as the Italian Association for Radiation Protection (AIRP), the Italian Association of Medical Radiation (AIRM), carry out a plan to inform the population, students and specific groups. The Department of Environmental Radioactivity Measurements Central Laboratory of the Italian Red Cross (CRI-LC-SMRA) in 2003 initiated a collaboration with The Institute For The International Education of Students (IES) in Rome (Italy), American University Union, for activities Internship cooperating also with the Social Activities, Health, Social and Health of the CRI Central Committee. The Inter-Knowledge Project has among its objectives the promotion and dissemination of intercultural training and orientation for American students, engaged in various sectors, wishing to develop new knowledge in the field of radiation protection. This collaboration made it possible for IES students can live a highly formative academic experience based on research and social.

The trainees have received academic credit from the home university of the most prestigious in the United States. In this context, new teaching methods, based on web technologies and e-learning in terms of platforms, online courses, video lessons and multimedia content accessible via the Internet have been introduced. The new environment, called "Inter-Knowledge", has been designed by ENEA Usability & Media LAB of Rome to manage data, information and knowledge gained by students in Radiation Protection Internship. The virtual e-learning environment is managed by the users, teachers and students, in a collaborative way to produce, in real time, multimedia contents, documentation and courses. All didactical materials can be directly usable with last generation of the mobile devices like: net-books, tablets and smart-phones. The IES (Program Review 2009) has recognized the Italian Red Cross high quality teaching and training given by the tutors and the staff of Central Laboratory. In the 2012 the ENEA E-Learn platform service has been integrated in the National institute of Health (Italy) Portal to disseminate information and knowledge about the Depleted Uranium. This e-learning platform was judged among the 10 best practices in International reported the document CWA 15660 of February 2007, CEN Award "Providing good quality practice for E-Learning 2007" and, moreover, ENEA received the SEE AWARDS 2008, "Sustainable Energy Europe Campaign", for the "Co-operation programmes".

P03.52
Radiological Rollback Of Controlled Areas At Sellafield Site– A Step Change In Contamination Control Culture

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Radiological rollback (RR) process identifies source terms of radiation or contamination within controlled areas and controls them at source to minimise the volume of controlled areas. Former controlled areas are now designated as supervised areas with conditions are under review.

The pilot on Sellafield site was Thorp Receipt and Storage (TR&S). An initial feasibility study was undertaken to determine if RR was possible within TR&S and define the scope of work to implement RR. The largest change was to people's mindset, as RR was changing from over 40 years of custom and practice for entering a radiologically active building at Sellafield.

Significant industrial relations issues were raised by the workforce and confirmation was given by the HR director no changes to terms and conditions would take place as part of the RR pilot. Successful resolution of these issues facilitated successful implementation, which took place in December 2010 and since then a step change in contamination control has been noted by TR&S management and RR project team. There has been an increase reporting of personal contamination attributable to improvements in self monitoring of individuals and a conscious shift to keeping contamination within remaining controlled areas whereas previously low level contamination was tolerated in the areas which are now supervised areas.

The benefits of radiological rollback to TR&S are primary safety benefit of improved focus of contamination containment at source and an opportunity to assess and improve control of current protection. Removal of a boot barrier and shoe change to enter TR&S has made plant access easier for all and a more robust contamination control safety culture, evident by the reporting of low level contamination events on shoes in TR&S main changeroom and at the transition area between the supervised and controlled areas. A volume of 300,000m3 has been converted from controlled to supervised area.

Early and continued engagement of the workforce by RR project team is the reason for positive acceptance of significant changes RR brought to TR&S. The change for RR was 10% physical, 10% procedural and 80% people.

Success of the project within TR&S has lead to the implementation of RR in ThORP (Themal Oxide Reprocessing Plant) by April 2012 with other plants on site assessing the practicalities of implementation.

P03.53
Radioprotection Culture at Nuclear Fuel Plant Pitesti Romania

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Culture as an element of human existence is characterized primarily by accumulating, skills, attitudes, behavior and promotion to something. Nuclear security culture has developed a desire to prepare to cope with nuclear risk, born with the discovery of radioactivity.

Culture of radiation protection is required for the implementation of safety and security in the protection against ionizing radiation.

In the activity of producing nuclear fuel for CANDU based on natural and depleted uranium stakeholders are developing a specific radiation protection culture due the existing radiological risks that can lead to exposure to ionizing radiation. For Pitesti Nuclear Fuel Plant Pitesti (FCN) where nuclear material is both as bulk and as itemized form, individual radiological monitoring as well as the working environment are established in Radiological Security Manual (MSR), in accordance with national legislation and international.

All employees FCN are classified as A and B of exposure to ionizing radiation. Classification is based on work performed and the degree of exposure and specific training for radiological safety is sized for each category.

External workers, contractors and visitors are aware of the entry in the plant on the risks of exposure to ionizing radiation and are properly trained. Basics of radiation protection culture as individual monitoring, communication, rigorous and prudent approach, pro-active action activity are transmitted continuously. In addition the radiation protection culture existed there from the beginning of the comissioning of the plant, but its elements still remain scattered in knowledge, attitudes and behaviors of employees

KEYWORDS: nuclear fuel, CANDU natural uranium, exposure to ionizing radiation

P03.54
Radiological Protection of Patients as part of Safety of Patients: A Healthcare Approach to Safety Culture

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Background: Safety Culture is a widely developed concept in the field of nuclear activities. Applying efficiently the concept to medical exposures requires the introduction of a new perspective including some modern criteria on quality in health.

Several international documents reporting and analyzing accidental exposures in radiological medical practices recognize the lack of safety culture as one of the main causes. However, the understanding of what safety culture is in healthcare settings differ significantly from the nuclear safety approach. One of the factors contributing to the different visions is due to the differences in the meaning and scope given to *safety* in both scenarios.

Purpose: To postulate that a broader significance should be given to Safety Culture in radiological medical practices including the *healthcare perspective in the concept of safety* . This *healthcare approach* could help in achieving a better understanding between regulatory bodies and health authorities for implementing the requirements for medical exposures of the new version of the International Basic Safety Standards (BSS).

Method: The ideas presented in this paper are the result of interesting discussions maintained among the authors as part of the development of a Project of the Ibero American Forum of Nuclear and Radiation Safety Regulatory Organizations focused to the continuous improvement of regulatory programmes for radiological protection of patients.

Results and Discussion: The main elements to be considered in a basic programme for improving safety culture in radiological medical practices are presented in the context of the new proposed approach, including a common language which could be useful to achieve the necessary synergy among the social actors involved in the safety of patients.

P03.55
Radiation Protection Culture: The Case of Serbia

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The paper deals with public perception and understanding of radiation protection issues in Serbia analyzing it in the context of three major events on the crossing over from 20th to 21st century: the Chernobyl Nuclear Plant Accident in 1986, the NATO bombing with DU ammunition in 1999, and the Fukushima Nuclear Accident in 2011. Following the changes in social, economic and political system, the roles and impacts of the main players that are involved in shaping radiation protection culture, changed too. The Chernobyl Nuclear Plant Accident in 1986 occurred in a relatively stable social surrounding: media and scientific experts were under the severe state control and despite some inconsistency in the official presentation of the events, the public confidence in facts and recommendations they were presented with was rather high. The situation in 1999 was significantly different: the main factor influencing the public perception of the event was psychological and the perceptions and opinions were generally shaped due to political position (pro and contra the government) and not based on scientific facts presented by experts. This event is still considered mainly in political and not scientific context. Finally, the Fukushima Accident occurred again in a different social context: the country is in transition, media are generally free, and there are both independent experts and numerous NGOs dealing with environmental issues. But, the public trust in the official reports, as well as in independent expertise, is low and the risks from radiation are generally overestimated.

Nevertheless, there is a strong link connecting all the three events, separated in time by more that two decades. It is the lack of basic scientific literacy and radiation protection culture, both in general public and media stuff, despite the elementary and high school curricula dealing with basics in nuclear physics, effects of radiation and radiation protection. Changes in education system according to Bologna process seem not to be of help, although numerous courses related to radiation effects and protection are incorporated in university curricula, mainly in biomedical and biotechnical sciences, but also in social and political sciences, mainly within arising private educational sector. Another persistent problem is the lack of communication skills within the scientific community, thus the facts presented by scientific experts to general public are often too complicated and difficult to understand by a layman.

Still, the demand for wider public engagement in the environmental issues and the need for higher level in radiation protection culture is recognized both by the government and scientific community, with the important role of nongovernmental organizations.

P03.56
Safety Culture - Reflections from the Nordic Nuclear Industry

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A project aimed at studying the concept of nuclear safety culture and the Nordic nuclear branch safety culture was carried out within the NKS-R/MOSACA-project during 2008-2010. The project also aimed at looking how the power companies and the regulators view the current responsibilities and role of subcontractors in the Nordic nuclear safety culture as well as to inspect the special demands for safety culture in subcontracting chains. Interview data was collected in Sweden (n = 14) and Finland (n = 16) during 2009. In total, thirty interviews were carried out in thirteen different organizations by the authors of the current paper. The interviewees were selected so that they would represent the major actors in the nuclear field, i.e. the regulators, power companies, expert organizations and waste management organizations. Most of the interviewees were experienced with a background in operation, maintenance, engineering or human factors related issues. The interview questions focused on the following content areas: 1) Nuclear safety as a concept, 2) Characteristics and differences of the nuclear industries in Finland and Sweden, 3) Psychological characteristics of the nuclear safety culture at the Nordic countries and 4) Development and current challenges of the Nordic nuclear field. The results provided insight into the nature and evaluation of safety culture in the nuclear industry. In this paper, a subsequent study is presented which extends and summarizes the findings of the original study. Additional interviews conducted in 2011, including the interviewee's definitions of nuclear safety, are taken into account. Thus the purpose of this study is to clarify issues that are shared within the Nordic nuclear safety culture, issues that are ambiguous in the nuclear community and issues that are not agreed on. In this context, also the relation between the definition of nuclear safety and the kind of indicators that the respondent would use to evaluate nuclear safety in a power plant is inspected. Preliminary results show variance in the definitions of nuclear safety as well as in the selection of criteria for evaluation of nuclear safety, and the safety culture implications of differences in definitions and criteria of nuclear safety are thus discussed. The study concludes on providing recommendations for developing and assessing nuclear safety culture.

P03.57
Radiation Protection Culture in Context

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It is absolutely essential for a nuclear company to operate to the highest standards of Environment, Health and Safety (EH&S), from a moral perspective, business viability and to ensure public acceptance. It is increasingly recognised that to deliver such high levels of performance it is necessary to engage with the workforce at the cultural level – ie to seek to embed what is generally recognised as an excellent 'safety culture' leading to a professional management approach to safety at all levels of the organisation .

In order to pursue this ambition within British Nuclear Group, a subsidiary company of the former BNFL which operated nuclear power plants, reprocessing plants and waste management facilities, a model was developed as an aid to training and communication of EH&S. The model involved four specific components of EH&S – nuclear safety, radiological protection, conventional safety and environmental protection. Each of these components has its own specific hazards, characteristics and controls, and to can to some extent be at different levels of safety culture maturity within the same organisation. However, the four components are joined together by a set of common management factors, ie the cultural, leadership and management system factors, which are essential for the successful integration of the control of risks from all the hazards.

This example will serve to illustrate why it is essential to situate radiation protection culture within a common context joining together with the other principal hazards which exist within any organisation.

P03.58
Evaluating Radiation Protection Programs Using the Ten Principles of Radiation Protection

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The familiar triad of "time, distance, and shielding" has been repeated often in radiation protection culture. However, these concepts are far too limited to cover the breadth of radiation protection activities. The three ideas are important, but do not give direction about what to do. For example, they do not help a member of the public very much in the aftermath of a radiological accident like Fukushima or other events that may disperse radioactive material. In the 16 years that have elapsed since the publication of "Ten Principles and Ten Commandments of Radiation Protection," the author has had the opportunity to evaluate radiation protection programs in the context of these principles and commandments. The principles are time, distance, dispersal, source reduction, source barrier, personal barrier, decorporation (internal and skin only), effect mitigation, optimal technology, and limitation of other exposures. The commandments in familiar form are hurry (but don't be hasty); stay away from it or upwind of it; disperse it and dilute it; make and use as little as possible; keep it in; keep it out; get it out of you or off of you; limit the damage; choose best technology; don't compound risks (don't smoke). Extending radiation protection culture beyond time, distance, and shielding permits comprehensive evaluation of radiation protection activities that involve more than external gamma or x-radiation. This presentation uses the the 10 principles and 10 commandments to design and evaluate events including 1) dispersal of radioactive materials include material entering a combined storm and sanitary sewer system; 2) releases from nuclear reactor accidents; and 3) legacy radioactive contamination.

P04.01
Stakeholder Engagement – Regulators And The RP Profession Build A Consensus On Competence Of Radioactive Waste Advisers

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The UK has recently implemented a new set of competencies for advisers to employers who accumulate and dispose of radioactive waste. The European Basic Safety Standards Directive (96/29/EURATOM, "BSSD") requires employers to appoint "qualified experts" to advise them about work with radioactivity that may affect people and the environment. Article 38 of the BSSD requires each Member State to make the necessary arrangements to recognise the capacity of qualified experts. The UK's radioactive waste management legislation falls to the environmental regulators for enforcement. The requirement for holders of environmental permits to use a qualified expert has been in place for some years, but the expectations of the regulators were not defined and disseminated. Over a number of years, the regulators have engaged with the UK's Radiological Protection (RP) profession to develop a consensus approach on what competences should be expected of a qualified expert. By this process of stakeholder engagement the initial arrangements have been developed into a consensus between the regulators and the UK RP profession. The outcome is a defined syllabus and levels of competence for persons who can be recognised for their capacity to act as advisers to employers on radioactive waste management and environmental radiation protection
The arrangements were launched in July 2011 and stakeholder engagement has been extended to ensure that it is the profession rather than the regulator that decides if a candidate is competent. Once deemed to be so, the candidate is then recognised by the relevant regulator. This paper will describe the nature and process of extensive stakeholder engagement that was used in reaching consensus.

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Council Directive 96/29/EURATOM laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation.

P04.02
Stakeholder Engagement: Challenges and Pitfalls

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The concept of stakeholder engagement is noble and commendable; however, the practice is often accompanied by unexpected responses and input that can challenge and sometimes completely derail the process. The IRPA *"Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement"* provides ten principles for consideration in establishing a successful interaction with a diverse group of stakeholders in a wide variety of projects, from rulemakings, to new site development, to decommissioning, and even post-event recovery actions. This presentation focuses on Principle 2: "Initiate the process as early as possible, and develop a sustainable implementation plan," and provides real-life examples of the types of challenges the planners should anticipate. These examples will be discussed in the context of the other nine principles. Options are provided to avoid some of the most common pitfalls by addressing them in the plan before they occur.

P04.03
The Codirpa: A Pluralistic and Multidisciplinary Approach to Post-Accidental Management Facing in New Questions Raised by the Fukushima Accident

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At the last IRPA conference in Buenos Aires (2008), the French nuclear safety authority (ASN) presented the approach implemented for the definition of a national doctrine related to the risk management during the post accidental period following a nuclear accident (so called "CODIRPA program"). The CODIRPA mobilized more than 250 people, including representatives of relevant national administrations and their local representatives, utility and industrial representatives, technical service organisations, nuclear safety authorities from bordering countries to France, NGOs and local elected officials. As a result of this work, the ASN has developed a Guide for leaving the urgent phase, describing French policy, and is currently adapting this Guide for local application. This Guide will be completed by guidelines for the management of the transition phase and of the long term phase.

After the Fukushima accident, the CODIRPA has been reinforced in its legitimacy to address two other challenges:

• a need to analyze the consequences of a significant duration of the emergency phase and to consider the overlapping of the population protective actions against atmospheric releases and deposit ;

• the necessity to consider the significant contamination of the territory and the implementation of post-accidental protective actions at a large scale (tens of kilometers).

P04.04
Implementation of a "Citizens' Workshop" on Domestic Radon

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Background and objective of the citizens' workshop on radon

For several years, the IRSN has been developing a strategy of openness about its work to society. Up until now, this project has essentially been expressed by the development of joint actions with local information committees and environmental associations.

To be able to engage in a dialogue directly with members of the public, IRSN sought to experiment with a new methodological approach by setting up citizen-workshops. To be useful, it was important for this pilot study to cover an issue that is part of the Institute's strategy of openness to society. The topic of radon was therefore selected, because of the usefulness of its results to the internal IRSN working group currently defining strategic priorities in terms of radon-related prevention actions.

The objective of the citizen-workshop that we set up was therefore to identify with the citizens how they perceived the risks of radon as well as the actions and stakeholders they deemed essential to an effective policy of radon risk prevention at home .

The citizen-workshop process:

The citizen-workshop process is inspired by the citizen conferences introduced for the first time in France in 1998. A citizen-workshop allows a group of around 15 citizens to spend two weekends receiving balanced information about the topic under discussion, hearing from experts and different stakeholders in the issue. Following this information and training, the group spends a third weekend drafting their joint recommendations. The principal advantage of this type of process is that it creates a true dialogue between experts and citizens and thus allows the latter to develop their own opinion.

Results: In their joint recommendations, the 15 citizens involved in the workshop proposed a strategy of action combining information and local support. Although the citizens considered that governmental guidelines are necessary, they did not think immediate mandatory regulation is required, given that the impact of radon can generally be reduced by simple actions. They underlined the importance of intermediaries at the local level and stressed the role of specific actors, such as physicians and building professionals. The insights of this citizen-workshop led IRSN to further carry out a pluralistic approach about radon in a French specific area, intended to contribute to the general public's information and awareness and to provide local support to those concerned by this issue.

P04.05
Habits Surveys; an Opportunity to Engage with the Public in the Vicinity of Nuclear Licensed Sites in the UK

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Surveys of the activities carried out by members of the public, which may influence their radiation exposure from operations at nuclear licensed sites, have been undertaken in the United Kingdom by the Centre for Environment, Fisheries & Aquaculture Science (Cefas) and its predecessor organisations since the 1950's. These 'habits surveys' involve essential liaison between the more highly exposed members of the population and the scientists who assess radiation doses to the public near the major UK nuclear sites. The key benefits of the surveys are twofold. First, they provide consumption, occupancy and handing rates that are specific to the areas near each nuclear site in order to undertake more realistic dose assessments than could be achieved by using UK national generic data. Second, they provide the opportunity for stakeholder engagement in discussing with relevant people the radiological risks and the programme of monitoring of food and the environment. The IRPA Principles of Stakeholder Engagement (IRPA, 2008) are broadly followed. Retrospective doses to the public are currently estimated using data collected from habits surveys and environmental monitoring near 26 nuclear licensed sites in the UK and are published in the Radioactivity in Food and the Environment report (EA *et al.*, 2011).

Using specific case studies, this paper will illustrate the differences between radiation doses calculated using data collected from habits surveys and radiation doses calculated using UK national generic data, and it will highlight the importance of engaging with the potentially more highly exposed members of the public in the vicinity of nuclear licensed sites.

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P04.06
Stakeholder Involvement In The Improvement Of Radiation Protection Regulations

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The modern history of regulations for occupational radiological protection in the UK date back to 1985 and last underwent a revision in 1999. Various factors and influences, including the current revision of the IAEA and EC EURATOM Basic Safety Standards, mean that the UK is now at the start of the next cycle of revision, improvement and modernisation. This presentation describes the processes relating to how the Health and Safety Executive (HSE) in the UK have gone about involving a wide range stakeholders and how this will develop as we move towards formulation and implementation of revised regulations in the future. To date stakeholder involvement has been to collate operational, policy, and legal views on application of the current regulations, identify areas for improving legal and technical aspects, minimising burdens on business, providing clarification and simplification where possible, and developing and analysing detailed assessments of the potential health and cost impacts of regulatory options identified. Stakeholder groups include individuals, employees, employers, radiation experts, professional bodies, and government departments, agencies, and regulators.

P04.07
Engagement of Stakeholders to Consider Increasing Alignment of the USNRC Radiation Protection Framework with International Recommendations

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Following the publication of the recommendations of the International Commission on Ionizing Radiation (ICRP) in Publication 103, the staff of the U.S. Nuclear Regulatory Commission (NRC) began an analysis process to determine if there were areas in the NRC regulatory structure where changes should be considered. The results of the analysis were presented in an NRC staff policy paper in December, 2008, SECY-08-0197. The NRC staff proposal was approved in April 2009, to immediately initiate engagement with stakeholders and interested parties to understand benefits, impacts, and burdens that may be associated with possible changes, and to initiate development of a rulemaking technical basis for possible revision of the NRC's radiation protection regulations, as appropriate and where scientifically justified, to achieve greater alignment with the recommendations in ICRP Publication 103.

This paper presents a summary of the methods and processes used by the NRC staff to engage the wide variety of stakeholders interested in NRC's radiation protection regulatory structure, the ongoing efforts to develop specific supporting technical basis information, and the key issues and positions that have been discussed. Stakeholder engagement activities included conferences, symposia, facilitated public meetings, individual stakeholder meetings, web documentation, and provisions for written inputs. The key issues under discussion included: the updates of the scientific information and models supporting dose assessment and compliance; possible revision of dose limits for occupational exposure; possible revision of other limitations on dose, including the 2010 statement for lens of the eye; the use of planning tools (constraints) as part of the radiation protection optimization process; and the interface of general radiation protection requirements with nuclear power reactor specific requirements. The NRC has not yet made a decision to move forward with a rulemaking action.

P04.08
Public Perception of a Low Level Radioactive Waste Facility Proposal : A Case Study during a Planning Application

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A Waste Facility in North Northamptonshire which was already approved for disposal of chemical wastes, applied to the County Council for Planning Permission to dispose of radioactive waste on the site. The proposal was for disposal of low level radioactive waste containing less than 200 Bq gm^{-1} of a range of radioactive elements found in the nuclear and medical industries. The proposal was strongly opposed by local residents, who made strong representation at the open County Council Planning Committee meeting. There was concern about increased lorry traffic, and fact that all waste would come from out of the county. However, much of the evidence presented by the local pressure groups related to their perception of the risks of radiation. In particular, there was a concern that all radioactivity was dangerous, which manifested itself in a heightened anxiety about the degree of hazard associated with very low level waste, both in terms of the ambient dose rate, and the amount of radioactivity leaking into the surrounding countryside. There was also mistrust that the limits would be adhered to, that the site would be properly maintained after the facility was full, and a concern that there would be further applications and extension of the life-time of the facility which would increase risk.

This paper reviews the public presentations and makes some recommendations for future planning applications.

P04.09
Ionizing Radiation: Interfacing Science and the Courts

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The judiciary has not traditionally been identified as vital during stakeholder interactions. However, scientific issues arise in a range of court cases and the rulings of the court will fundamentally affect organizational and/or governmental decision-making. In 2005, the Advanced Science and Technology Adjudication Resource (ASTAR) Center was established in the United States to institutionalize a science and technology capability in the Nation's courts by preparation of resource judges. The ASTAR resource judge program is an effort to enhance the capacities of the courts to resolve complex cases involving intricate or novel scientific and technical evidence.

In 2011, Los Alamos National Laboratory was asked to provide scientific expertise to a proposed ASTAR National Judges' Science School (JSS) on ionizing radiation. A truncated version of the United States' National Planning Scenario #11 Radiological Attack - Radiological Dispersion Devices was used to provide a credible scenario to establish a range of legal issues over which an understanding of radiation could be placed. Based on this, the JSS, *Ionizing Radiation and the Courts*, was prepared.

Presentations for the JSS provide an overview of ionizing radiation, explore natural and manmade sources, decorporation therapy, radiation risk assessment and risk perception, and review the current state of knowledge on how to quantify health and environment effects associated with varying levels of exposure. Additional, more tailored, presentations for the attending state and federal judges cover the cultural differences between science and law, the current state of radiation-related US health and environmental standards, and the legal use of epidemiologic evidence for assessing cancer clusters from the transport of radionuclides.

P04.10
Social Responsibility within an Irradiation Facility: A Brief Account of an Implementation Process Experience

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The *PISI* -Planta de Irradiación Semi-Industrial- is a multi-purpose batch-type category IV irradiation facility with a ^{60}Co source of radiation (1MCi nominal activity), located at the Centro Atómico Ezeiza, CNEA- Argentina. The scope of the present work is to describe the implementation process of the standard ISO 26000- *Guidance on Social Responsibility* at a nuclear installation. The main objective of this project was to evaluate the feasibility of integrating a social responsible behaviour into existing organizational strategies, practices and processes at a facility with specific safety and security requirements. In this framework, our principal goals in a first stage were to recognize our social responsibility, to increase the PISI´s human capital -and thus reinforce our safety culture- and to *engage with society* by strengthening our relationship with the community and main stakeholders.

The ISO 26000 has seven fundamental core subjects which gather under the term *social responsibility*: organizational governance, human rights, labour practices, the environment, fair operating practices, consumer issues and community involvement and development. This standard completes the integration of safety, health, environment, security, quality, good irradiation practices and economic elements in one single management system, thus ensuring all these aspects are taken into account and contributing to sustainable development, health and welfare of society.

Among the positive results achieved since the beginning of this project in 2007, there are several outcomes which stand out: action planning towards the implementation of Social Responsibility at PISI based on a preliminary evaluation of our degree of compliance with its underlying principles and core subjects; stakeholders identification and communication with a selection of them such as customers, community, internal interfaces at the organization, regulatory bodies, unions; the strengthening of the idiosyncrasies of the workers at PISI and the creation of a shared vision of PISI, as we focused on our fundamental resource: people. We consider that the results of the project have been highly satisfactory, contributing to a large extent to reinforcement of the safety culture of the team of work and our connection with society.

P04.11
Stakeholder Engagement in UK Emergency Preparedness and Response

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The UK has a strong tradition of Stakeholder Engagement in decision making in Radiological Protection and in wider societal and environmental matters. This allowed the UK's Society for Radiological Protection (SRP) to take a prominent role, along with the French and Spanish Societies, in developing the Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement adopted by IRPA at IRPA 12. The experience and progress in integrating these principles into everyday RP practice is the subject of an oral presentation "Stakeholder Engagement: the UK Experience" by Bandle A. and Croft JR. A subset of this UK experience is the importance of stakeholder engagement in emergency preparedness and response; and it is this subset that is the topic of this paper.

The paper explores how stakeholder engagement is an integral element of the emergency preparedness framework that is common for dealing with all UK emergencies; from naturally occurring events such as flooding and pandemics, through accidents such as nuclear ones, to deliberate incidents such as terrorist attacks. The UK preparedness and response framework is described and the stakeholder engagement element explored though an example of a Local Resilience Forum (LRF). The links to the long established Local Liaison Committees for Nuclear sites is also covered.

It is one thing to establish a framework for decision making and developing response plans, but successfully implementing these requires on-going dialogue and trust between the various stakeholders. For the responding organisations these attributes can be honed in exercises, but dealing with the different elements of the public depends on a mix of building up trust before the event and being seen to be open and honest during the event. Experience from the Polonium Poisoning incident in London in 2006 will be used to highlight some aspects of Stakeholder Engagement in an emergency response.

P04.12
2010 Helsinki Regional IRPA Meeting Results, Stakeholder Engagement Experience

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Should public perception be the guiding principle in radiation protection decision making? Should principles of radiation protection namely justification, optimisation and limitation be the main criterion for radiation risk reduction or should risk perceptions of the lay public have an impact on the decision taken? Who should have the right to set out the tolerable level of risk?

These are some of the issues that have preoccupied the radiation protection professionals for many years. Already in its infancy radiation protection was described by Lauriston S. Taylor as being: *"...not only a matter for science. It is a problem of philosophy, and morality and the utmost wisdom."* This was true, and is true, as the recommendations of international organisations and regulations set out by national regulators continue to be a mix of state of the art science and value judgements.

To help radiation protection professionals in assessing the value judgements of the stakeholders and successfully engaging with them IRPA have published their Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement. The aim of the Guiding Principles is to include the stakeholders in radiation protection decision-making processes that result in mutually agreeable and sustainable decisions taking into account the principles of radiation protection and the associated value judgements.

The oral and poster presentation given in 2010 Helsinki regional IRPA meeting demonstrates that virtues of stakeholders are now being recognised by the decision makers. This is not to say that stakeholder engagement is necessary in all radiation protection decision making, but it was shown to be a useful tool in radiation protection policy development, and in dealing with controversial issues such as nuclear power plant and waste repository siting and management of contaminated areas. New developments also highlighted the participation of stakeholders in decision making for planned, existing and emergency exposure situations.

The presentations and discussions at 2010 Helsinki regional IRPA meeting highlighted the importance of the stakeholders and the need for radiation protection professionals and their national professional societies to embrace stakeholder participation in radiation protection decision making.

P04.13
The Nuclear Regulatory Authority's experience in stakeholder engagement

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The Nuclear Regulatory Authority of Argentina (ARN) is an autonomous body reporting to the President of Argentina, empowered to regulate and control the nuclear activity with regard to radiation and nuclear safety, non proliferation issues and physical protection and security. Its objective is to establish, develop and enforce a regulatory system applicable to all nuclear activities carried out in Argentina.

In the framework of Decree 1172/2003, related to the accessibility of public information to increase transparency of government actions and specially to promote public involvement, ARN not only has the legal obligation to inform of its activities in an accurate, comprehensive and understandable manner, but the willingness to communicate with stakeholders.

The re-launching of the Argentine nuclear plan in 2006 and the renewed interest of society on the subject highlighted the need to give further assurance on the role and competence of the regulatory body. Therefore it was considered necessary to involve the society further in this programme by achieving greater public understanding and awareness of the nuclear regulatory activities.

In order to optimize the communication channels with society, the ARN launched a medium-term Strategic Communication Plan (SCP).

Regarding external communication, the SCP's objectives are to foster public understanding of ARN's role and activities; to work on the perception of risk by the public; to develop a sectorized policy of training and information in nuclear matters, to manage conflict resolution in the national nuclear area and institutional crisis involving media issues; and to strengthen communications with other national and international institutions and stakeholders. In this sense, open channels of communication need to be constantly maintained.

Due to the media coverage of the nuclear accident occurred at the Japanese Nuclear Power Plant Fukushima Dai-ichi and the subsequent impact on stakeholders, the ARN needed to increase its responsiveness, by reinforcing its methodology and tools for internal and external communication with the purpose of facilitating a greater engagement of stakeholders.

This paper describes the development of the implementation of the mentioned communication tools, in compliance with the commitment the ARN has with stakeholders and the lessons learned up to date.

P04.14
Stakeholder Engagement Through Web Operations

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The Health Physics Society (HPS) has a multifaceted program for reaching out to the radiation protection profession and the public with information about radiation. Beginning in 1996 with the launch of our primary website (hps.org), and now under an umbrella called Web Operations, the Society has expanded outreach with the development and implementation of "Ask the Experts" (providing access to an expert to answer radiation questions); media operations; government and agency interaction; information, reference, and fact sheets; and targeted information for specific groups (teachers, students, health care personnel, first responders, etc.).

In addition to these resources, the Society has added a Facebook® and a LinkedIn® presence, has developed a new website containing easily understandable and factual radiation information for the public (RadiationAnswers.org), and has published a radiation primer.

The results of these efforts can be shown in the data on website visits, media contacts, contact by other groups and associations asking for collaboration or input, and mention of the Society in the mainstream news media and by U.S. federal decision makers.

This paper expands on each of the areas within HPS Web Operations to share the inner workings of what we believe to be a successful stakeholder outreach program.

P04.15
Assessment of the Monetary Value of Man-Sv for Korean NPP Radiation Workers

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The monetary value of the man-Sv for operators of Korean nuclear power plants (NPPs) was calculated using the radiation aversion factor analyzed based on a survey of NPP workers.

Initially, the life expectancy in population of 79.4 years, average age of cancer occurrence of 60 years, average annual wage for electric worker of 56,000 $/year, and nominal risk coefficient induced by radiation of $4.2E^{-5}$mSv were used to evaluate the basic monetary value αbase) resulting in 45.6 $/mSv.

In order to investigate the degree of radiation exposure risk aversion, the subject of the investigation was selected as the working radiation workers in the 10 NPPs in Korea (Kori 1•2, Yeonggwang 1•2•3, Ulchin 1•2•3, Wolseong 1•2). With the cooperation of KHNP and partner companies, a total of 2,500 surveys to 10 NPPs or 250 surveys to each NPP were distributed and collected from currently employed radiation workers. 2,157 surveys were acquired from the 2,500 distributed between August and October, 2010.

The assessed risk aversion factor and the monetary value of the man-Sv from the calculated risk aversion factor were 1.26 and approximately 50 $ in the 0-1 mSv range, 1.38 and approximately 200 $ in the 1-5 mSv range, 1.52 and approximately 1,000$ in the 5-10 mSv range, 1.65 and approximately 4,000 $ in the 10-20 mSv range, and 1.74 and approximately 8,500 $ above 20 mSv.

KEYWORDS: nuclear power plants radiation workers; monetary value; radiation risk aversion factor; survey.

P04.16
An Approach to Stakeholders Involvement in the Preparedness for Nuclear and Radiological Emergency Response & Recovery in Spain

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The elaboration of a generic decision-making strategy to address the evolution of an emergency situation, from the stages of response to recovery, and including a planning stage, can facilitate timely, effective and consistent decision making by the response organisations at every level within the emergency management structure and between countries, helping to ensure optimal protection of health, environment, and society. The degree of involvement of stakeholders in this process is a key strategic element for strengthening the local preparedness and response and can help a successful countermeasures strategy.

A significant progress was made with the multi-national European project EURANOS (2004-2009) which brought together best practice, knowledge and technology to enhance the preparedness for Europe's response to any radiation emergency and long term contamination. The subsequent establishment of a European Technology Platform and the recent launch of the research project NERIS-TP *("Towards a self sustaining European Technology Platform (NERIS-TP) on Preparedness for Nuclear and Radiological Emergency Response and Recovery")* are aimed to continue with the remaining tasks for gaining appropriate levels of emergency preparedness at local level in most European countries.

One of the objectives of the NERIS-TP project is: "Strengthen the preparedness at the local/national level by setting up dedicated fora and developing new tools or adapting the tools developed within the EURANOS projects (such as the governance framework for preparedness, the handbooks on countermeasures, the RODOS system, and the MOIRA DSS for long term contamination in catchments) to meet the needs of local communities".

CIEMAT and UPM in close interaction with the Nuclear Safety Council will explore, within this project, the use and application in Spain of such technical tools, including other national tools and information and communication strategies to foster cooperation between local, national and international stakeholders. The aim is identify and involve relevant stakeholders in emergency preparedness to improve the development and implementation of appropriate protection strategies as part of the consequence management and the transition to recovery.

In this paper, an overview of the "state of the art" on this area in Spain and the methodology and work Plan proposed by the Spanish group within the project NERIS to grow the stakeholder involvement in the preparedness to emergency response and recovery is presented.

KEYWORDS: Decision making process, Emergency preparedness, Recovery, Stakeholders involvement.

P04.17
Reaching Out with "Ask the Experts"

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After 16 years, over 10,000 questions, and nearly 10 million website visits, the Health Physics Society knows that an effective way to engage stakeholders, such as the public and radiation safety professionals, is through our "Ask the Experts" (ATE) feature.

Accessed through our Society website, www.hps.org, and staffed by an editor in chief, 22 topic editors, and hundreds of experts, ATE receives several dozen questions per week in 30 subject categories. Questions come in from sources all over the world: from health physicists about the subtleties of radiation safety, from anxious women who have had radiation exposures during pregnancy, from people concerned about exposures from cell phones and satellite towers, from citizens worried about nuclear power. Experts provide prompt, concise, and scientifically sound answers in an easy-to-understand manner, which are then conveyed directly and personally to the questioners and may be posted on the website.

As a result, ATE has generated many questions and answers of general interest, 19 compilations of frequently asked questions, 22 topical information sheets, and eight reference sheets, all available on the website.

This presentation will summarize the online statistics of ATE and will discuss what we have learned about communicating with the public and members of our own profession.

P04.18
Radiation Risk Perception for the Co-Medical Students

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In faculty of radiological technology of university, the students study but only basic radiology and medical technique but also radiation protection and radiation effect to become radiologic technologists in future. Many Students are produced in the medical field every year and many women are contained in them. They will become the very familiar experts who have knowledge of radiation for the public. We expect to play a role that they explain comprehensively about the radiation exposure and radiation effect for the public. The public that has accurate knowledge would be able to judge whether information is right.

As the first step, a radiation risk perception for co-medical students, in particular students in faculty of radiation technology of my university was analyzed to clear the point which we focus attention to so that they communicate with the public about the radiation exposure and protection. The questionnaire survey of about 150 students in our faculty in 2010 (before Fukushima nuclear power plant accident) and 2011(after the accident) was conducted. 25 radiation and non-radiation related items such as X-ray examination, nuclear power plant, smoking and drinking alcohol were selected. 7 ranking was used to evaluate these “unknown” and “fear”. We had also the students choose 5 times of the “high risk” in 25 items and write these reason. In addition, we asked questions of general interest about the Fukushima Daiichi nuclear power plant accident to them in 2011.

In this research, the perception of students in 2010 is not different from that of students in 2011for the use of medical radiation and nuclear power. There is also no remarkable difference between the perception of students in the first year (Un-learning for radiology) and third year (Learning).

Poster sessions A-B: Area 4

P04.19
The Importance of Effective Communication with the Public and the Media on Issues of Radiological Protection

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As elsewhere in the world, Great Britain is seeking to expand nuclear power generation over the coming years in order to curtail its dependence on increasingly expensive fossil fuels and so that it can continue to meet its internationally agreed obligations to reduce its carbon emissions. But it does so in a world that is coming to terms with the consequences of the Fukushima nuclear accident and in a political and social context of disquiet about the safety performance of the nuclear industry.

By reference to a particular example of the Office for Nuclear Regulation's enforcement work relating to licensees' duties to restrict, so far as is reasonably practicable, exposure of the public to ionising radiation, the benefits of open communication and disclosure by both licensees and regulators alike are discussed.

Assessment by licensees of radiation dose rates at their site perimeter boundaries and the relation of such work to public exposure assessment are used to illustrate why such work can sometimes lead to presentational difficulties, even when the outcome of such assessments suggests that there is no cause for public or media concern

P04.20
Methodology for Comprehensive Monitoring of the Environment and Public Health as an Important Evidence of Safe Nuclear Engineering Development

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The need to assure the safe nuclear engineering development for the national public is an urgent requirement of time. In the light of the renaissance of the Russian nuclear energetic complex, the special comprehensive monitoring is relevant in the NPP areas. The comprehensive monitoring includes both radiation monitoring of the environment and that of the public health.

To assess the environmental radioactivity, the following key tasks are being solved:

• To obtain the sufficient and valid dynamic information on the environmental radiation parameters under control and monitoring, and on radionuclide concentrations in the local foods and water. To catch the changing radiation circumstances.

• To assess internal and external doses to the public induced by man-made and natural radiation exposure, especially taking the NPP contribution into account.

To assess the public health, two approaches are used: epidemiological and clinic. The background health nearby the NPP is assessed using the national medical statistical data over more than decade. The special attention is paid to the frequency and dynamics of the malignant neoplasm morbidity. The transparency and validity of the provided information is an important condition in the course of the comprehensive monitoring.

The selected approaches and criteria for assessment enable not only objective assessment of the radiation situation, environmental conditions and public health, but also help to control changing dynamics, i.e., to conduct monitoring since the beginning of the entire NPP operation cycle and at the stage of new units launch. During our examinations, we get information necessary to identify the extent of potential impact of the many-year operation of the nuclear facilities on the environment and public health.

The proposed methodology and findings of the comprehensive monitoring have extensively been tested during the public hearings among the population living in the areas of the existing and constructed Russian NPPs.

P04.21
Transmission and Dissemination of Radiation Protection Culture to Young Generations

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Since 2007, the Institute of Radioprotection and Nuclear Safety (IRSN), Nuclear Evaluation Protection Center (CEPN), and the center for scientific culture of Franche Comté (Pavillon des Sciences), have implemented "radiation protection workshops" involving French and European high school students. These "workshops" are led by teachers in collaboration with radiation protection experts in the relevant scientific disciplines. The objective of this action is to involve students for an entire school year in multidisciplinary activities related to the radiation protection culture according to local concerns (management of radon risks, radiation protection in hospitals, environmental surveillance around nuclear sites, post-accident management, etc.). To conclude this activity, "international high school student meetings" are proposed to allow students who participated in workshops to present their work and exchange information and opinions with other students and with radiation protection professionals. These exchanges, always very fruitful, are effective in disseminating the culture of radiation protection to younger generations.

For the 2011-2012 school year, the "student workshops" will bring together a dozen high schools, and the international meeting will take place in Nantes in late March, 2012. In view of current events, some of the topics will be related to the consequences of Fukushima accident by drawing a parallel with the feedback experience of Chernobyl. It is to note that Ukrainian and Belarusian schools are involved in this action since several years and exchanges have already been established with the Lycée Français de Tokyo.

The aim of this paper is to present, through feedback from different high schools, how this type of action may enlight young people on main issues of radiation protection, addressing following questions:

- Where is radioactivity and how to measure it?
- What are the modes and levels of exposure?
- What are the health effects of radiation and how to assess low-dose risks?
- What are the means of protection against radiation exposure?

P04.22
Comparing Risks for Communication

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In risk communication activities, risk comparison is often helpful but it could be challenging. We wish to convey complex concepts of radiation to laymen but often this is fraught with ambiguity and confusion, and may be even contradictory. It is essential to know our audience and the situation. As media, especially social media, is playing an important role in influencing public opinion, it is imperative for radiation protection specialists to educate and work with them. We will review some principles of comparing risks, such as using analogies, comparing to standards, comparing to other estimates of the same risk, etc. In this presentation we will give some examples of the use and abuse of risk comparison, and explain the principles behind these. The examples will cover, among others, the Fukushima nuclear reactor accident, rare earth refinaries and issues concerning electromagnetic field sources

P04.23
Public Training on Radiation: Changing Perceptions

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"This is preeminently the time to speak the truth, the whole truth, frankly and boldly… So, first of all, let me assert my firm belief that the only thing we have to fear is fear itself - nameless, unreasoning, unjustified terror which paralyzes needed efforts to convert retreat into advance." Franklin Delano Roosevelt spoke those words in 1933 in his Inaugural Address to a nation suffering through what we now refer to as The Great Depression. However, these same words ring true today in every nation where ever-expanding populations rely on the nuclear industry to provide electricity from nuclear power plants, nuclear medicine from hospitals and a multitude of other benefits in industry. Unfortunately, there exists an irrational fear of radiation throughout much of the general public that may unnecessarily hamper or even completely derail any hopes of a nuclear renaissance unless we act now to educate the masses.

For too many years negative images of the nuclear industry as a whole have been fostered by misinformation and sensationalism dispersed by the mass media – especially through the cinema, the internet and the news outlets. At the same time most experts in the field, while watching such portrayals in disgust, have been just as guilty of effectively misguiding the misinformed because we have withheld what we know about radiation and the nuclear industry: The truth, the whole truth, frankly and boldly.

The East Tennessee Chapter of the Health Physics Society (ETCHPS) has taken the initial steps to fill the massive void that exists in the area of health physics training for the public. Beginning in Oak Ridge, Tennessee, home of the ETCHPS, the public will be invited to attend presentations provided by local Health Physicists, Nuclear Engineers and Scientists. Training will be provided on topics such as: the basics of radioactivity, units of measurement and natural sources of radioactivity including radon in homes; how radioactive material is used in nuclear medicine, nuclear power plants and industry; regulation of the nuclear industry, including risk associated with exposure to ionizing radiation; and, an update to the ongoing situation in Japan. Air samples will be taken and counted along with showing the natural radioactivity associated with everyday products such as KCl, glassware, etc. Also, after the presentations, opportunities to talk directly with the experts will be provided as a vital part of each training session.

The hope is that each attendee will have a better understanding of the naturally radioactive world in which they live and at least a basic familiarity with the controls in place for the use of radioactive material for the advancement of mankind. While neither promoting nor condemning the nuclear industry, we are committed to helping establish a rational understanding of it. We may not necessarily erase all fears, but we will attempt to cleanse the lens through which they view our world by providing them reliable, sound information.

The lessons learned from the efforts spearheaded by the ETCHPS will be presented to the attendees with the hope that they will accept the challenge and do likewise to educate citizens around the globe. Hopefully, our efforts will be the dawn of a new era of engaging with society to foster truth and understanding as it relates to radiation.

P04.24
Effective Procedures and Measures for Public Understandings on Peaceful Usage of Radiation and Atomic Energy

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This study developed a hypothesis model to explain decision-making process among Japanese public on the matter of peaceful usage of radiation and atomic energy. This model was constructed before the 3.11 accident at Fukushima Dai-ichi nuclear power plant. In order to analyze our hypothesis model, a systematic public opinion survey has been planned. Effective procedures and measures for public understandings on this matter in Japan have been discussed, mainly based on the results by the surveys from 2006 to 2010. Japanese opinion of 15-70 years old has been surveyed four times using door-to-door method. Sample number in each survey is 1200. Following items have been obtained through our discussion based on our model and surveys for instance;

- Japanese public lacks a systematic knowledge on atomic energy.

- A main reason of lack of the systematic knowledge in public would be their no- interest on this matter. Their no-interest causes to their less activity to access the related information.

- Providing appropriate information in order to rouse public interest on this matter is effective.

- Grass-roots education on provision of right information is effective to establish a systematic public knowledge. Grass-roots education should be continued in addition to a large scale activity using the mass media.

- A view point of global warming would be one of the most effective keys to explain a merit side of usage of nuclear power plant. It is extremely important for public to receive a set of right information not only from a merit side but also from a demerit side at the same time in order to make their appropriate decision.

After the 3.11 accident at Fukushima Dai-ichi nuclear power plant, we are planning continue the public opinion surveys. Next survey will be conducted in November, 2011, as the first survey after the accident. We will show the post-accident data compared with the pre-accident ones in our presentation.

P04.25
Studies on Risk Perception Involving Radioactive Waste

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The continuity of the Brazilian nuclear program is strongly associated with the definitive solution regarding the final destination of the radioactive waste generated by nuclear power plants currently in operation in the country. In this sense, there is an ongoing project at the National Nuclear Energy Commission for site selection and construction of a national repository of radioactive low-level waste. It is well known that one of the key features for public acceptance of nuclear energy is the belief that radioactive waste can be managed safely, in order to protect human beings from its possible harmful effects in present and future generations. In this sense, it is essential to understand how people perceive the risk associated with radioactive waste and which the main factors driving their attitudes toward its disposal are. One of the ways to achieve this understanding is through opinion polls. In this study, a questionnaire focused on perception of risks associated with the radioactive waste repository was formulated, covering the following aspects: attitudes towards radioactive waste and nuclear power, denial of risk, beliefs, emotional reactions, stigma and trust. Results obtained from a pilot questionnaire application are presented and discussed in this paper.

P04.26
Presenting Radiological Risks to the Public, Schools and Visitors: The Experience at the Joint Research Centre in Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late ‘50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

Communication of radiation risks to workers, visitors and to the surrounding population is a significant task for the Nuclear Decommissioning Unit.

The JRC-ISPRA long Decommissioning and Radioactive Waste Management Programme, spanning over more than 20 years, requires full understanding and acceptance from the local public opinion.

Moreover, it is a JRC task to inform and to communicate scientifically to JRC Visitors, including general public and school students.

Throughout the years, the Radiation Protection Sector has developed a significant number of communication experience, and has put in place a system of presentations and hands-on demonstrations, in order to effectively explain radiological risks to audiences of a different background.

School presentations, site tours and interactive training courses have been developed. Open day demonstration and information points have been created.

This work will present the strategy and the implementation of JRC-ISPRA policy on radiological risks communication towards the population, JRC visitors and visiting students.

P04.27
Information to the Public: Viewpoints on an Index of Environmental Radioactivity

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How can one translate into simple qualitative words the complexity of the results of radioactive measurements in the environment? In 2008, ASN launched an internal reflexion on the ways to inform the public on the radioactivity levels in the environment in order to identify the difficulties in designing a scale or an index of environmental radioactivity levels.

After the presentation of a rather extensive demonstration model by ASN in 2008 to HCTISN (Haut Comité pour la Transparence et l'Information sur la Sécurité Nucléaire), ASN constituted a pluralist working group (WG) in the beginning of 2009 to share its reflexions and to design an index that would meet the following requirements:.

- a communication tool to qualify the information about the radioactivity levels in the environment: normal status, situation needing further investigation/supervision, abnormal situation with counter measures needed;

- consistent with the INES scale;

- easy and quick to derive from the available measured values of radioactivity;

- usable at any time and in any location, whether or not the situation is incidental or accidental.

A provisional index was then established by the WG. The chosen criteria can be used by the public, with simple arithmetic operations from available data in order to determine the level of the index. The HCTISN members, as all the WG members, are asked to produce their viewpoints (September 2011) on the project; an experiment within an exercise is planned (early in 2012), followed by an experimentation on a public panel. The paper (oral presentation) will present the different viewpoints and the first results of the experimentation.

P04.28
Public Demand for environmental Transparency: Challenges of presenting Data of the Radiological Survey of the Environment to the Public

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ASN fosters the implementation of “the public’s right to reliable and accessible information on nuclear security” (TSN Act). Concerning the environment, it ensures that the available information is accessible and shared.

One of the recent significant contributions to providing the public with reliable, centralised information is the launch of www.mesure-radioactivite.fr in 2010. This website issued by the national network under the aegis of ASN, gives the public access to the results of radioactivity measurements carried out by recognized laboratories.

The next challenge is to guarantee the good comprehension of the result of the Radiological Survey of the Environment : - How to inform the public on the radioactivity levels in the environment? - How to translate the complexity of the results of radioactive measurements with simple qualitative words and illustrations ?

After an internal reflexion, ASN presented in 2008 a rather extensive demonstration model of environmental radioactivity levels to the French High Committee for Transparency and Information on Nuclear Security (HCTISN). A provisional index has then been established by a pluralist working group constituted by ASN (2009-2011). The current challenge is to experiment and apply the index on the available data on www.mesure-radioactivite.fr.

The paper (poster presentation) will present the characteristics of the radiological network, the results of the first two years of use and the main developments in progress, as the use and the representation of the provisional index.

P04.29
Don't Say Don't: The Importance of Being Positive When Communicating with the Public

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Communication research has shown that negative messages (e.g., "it's not dangerous") can often be interpreted by the listener without the negative (e.g., it's dangerous). It's difficult enough to communicate about an emotionally charged topic like radiation safety. We don't need to be misinterpreted when we do.

Part of the reason for this is the listener's reaction to a word like "dangerous". The focus on this word is more intense than on other words, and the "not" isn't heard. Human beings have been programmed over millennia to react to danger and react quickly. When we hear a word like "dangerous" our ears perk up. In the process, we can miss the fact that the speaker said, "not dangerous".

Some research has also divided safety communications into two groups:

• that which asks people to do something safe

• that which asks people NOT to do something unsafe

Techniques were evaluated in these two situations and the findings are revealing. In the first case, stressing dangers was more effective in motivating people to start doing something. Conversely, stressing safety was more effective in the second case, where avoidance is the goal.

An example is fear of medical x-ray exams. Here we want to allay fears, so a needed exam is performed. Again, we would stress the danger of not doing so. Apparently, that is a better argument than stressing the exam's benefits.

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P04.30
Radiation Risk Scale – A Tool for Communication

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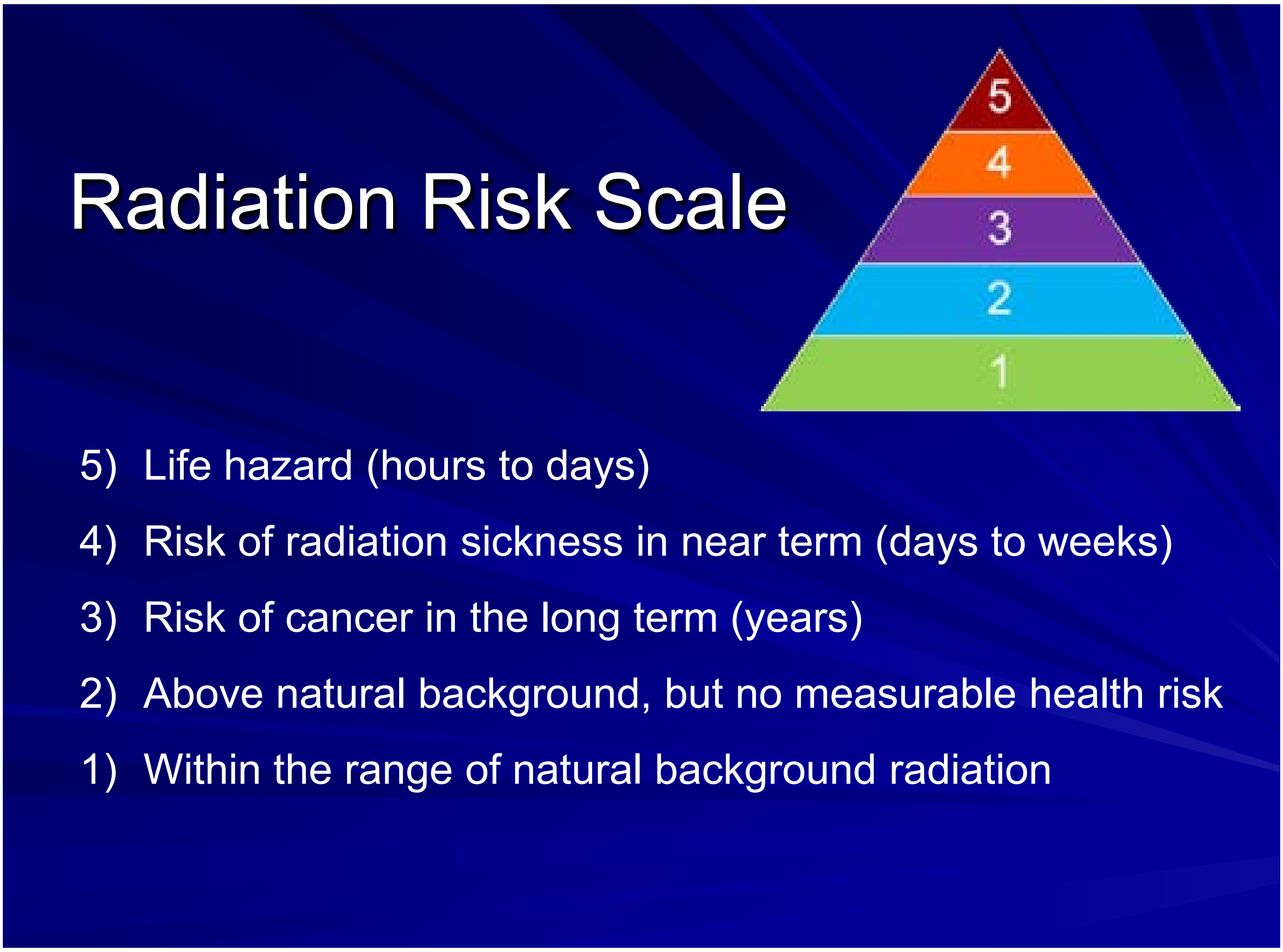
This presentation describes a simple numeric scaling system to communicate radiation risk levels to the public, leaders, and decision makers. Five radiation risk levels comprise the Radiation Risk Scale and encompass radiation levels ranging from natural background radiation up to levels that pose an immediate life hazard. This scaling system offers several distinct advantages: a) It is simple; 2) It conveys meaning and provides a frame of reference immediately; c) It does not require any understanding or use of radiation units or any mention of radiation dose rates or radioactivity levels; d) It is not affected by differences in specific national or international radiation dose limits, concentration limits, or other regulatory standards; and e) emergency managers and responders can use it during an emergency or its aftermath to promote responsible action by the public. The Radiation Risk Scale is intended as a simple and preliminary tool for communicating radiation risks in any given circumstance.



P05.01
Medical Survey after 50 Hz Electric or Magnetic Field Exposure

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Introduction: The European Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields (EMF) should be applicable on 30 april 2012. It introduces measures protecting workers from the risks on the health and safety of workers associated with EMF. The respect of the exposure limit should provide a high level of protection for the established health effects that may result from exposure to EMF, but such adherence may not necessarily avoid interference problems with, or effects on the functioning of medical devices. The objective of article 8, about health surveillance, is the prevention and early diagnosis of any adverse health effects due to exposure to EMF. In any event, where exposure above the limit values is detected, a medical examination shall be made available to the worker(s) concerned.

Possible effects of an EMF acute exposure

If the electric field can be perceptible by a few proportions of people at a level of 2kV/m, only 5% of the people feel a level of 15kV/m as a nuisance. The magnetic field is not perceptible, even at very high level such 10mT at 60Hz. Effects are reliable to induction of currents inside the body. The first manifestation is the magnetophosphenes, for a density of induction currents above 10mA/m^2 , that is the base of the reference level in the Directive. In case of overexposure, a stimulation of the nervous system could appear when the density of induction currents is over 100mA/m^2 , and a serious risk of cardiac rhythm trouble over 1000mA/m^2. A particular attention should be carried to wearers of medical device.

What is the medical examination looking for?

If the limits are respected, no specific examination is necessary, except for workers with medical device. In this case, a specific risk assessment has to be done. In case of accidental exposure, a carefully interrogation has to be done to search the first manifestations described, such as magnetophophenes. The physical examination is required, but no complementary biological or radiological examination is indicated. The most important is to register this overexposure, with the level of intensity and to realize a new risk assessment.

Conclusions: The employer shall take appropriate measures to ensure that the doctor responsible for the health surveillance has access to the results of the risk assessment. The health survey is limited to a careful interrogation and a physical examination, linked to the level of magnetic or electric field, determined by the risk assessment. The results of health survey shall be registered in a suitable form so as to allow consultation afterwards, taking into account confidentiality requirements.

P05.02
Assessment of Public Exposure to 50 Hz Electric and Magnetic Fields of Power Lines in Iran

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The widespread use of electrical appliances makes it impossible to consider residential areas without electric and magnetic (EM) fields at 50/60 hertz (Hz). Power lines near houses, schools, nurseries, babysitters, … is public concern about the consequences of exposure to EM fields.

There is still a problem in front of national organizations for establishing health protection programs for 50/60 Hz EM fields. It is the disparity between exposure limits offered by scientific committees or accepted by different countries. This problem is more amazing by considering that several epidemiological studies, reported an association between prolonged exposure to 50/60 Hz magnetic fields greater than 4mG and an increased risk of childhood leukemia, but ICNIRP limit for exposure to 50 Hz magnetic fields is still 250 times less stringent!

In this research, 50 Hz EM field strengths were measured in residential areas, under and around power lines in Iran. All measurements were done by trained technical teams, by using calibrated field strength meters. Measurements were done out of buildings. Magnetic fields penetrate to the buildings easily, so magnetic field intensities are approximately the same, inside and outside them, sometimes It may be a little more inside, because of usage of electrical domestic appliances. Electric field strengths inside buildings are usually very lower than that, outside them.

The results show that all EM field strength levels are far below public exposure limits, defined by Iranian Regulatory Authority in National Standard “Non Ionizing Radiation-Exposure Limits”, compatible with ICNIRP limits. This was correct even under power lines. But it is shown that in front of considerable buildings near power lines, magnetic field strengths are several times greater than 4mG. Finally it seems that, exposure limits for frequency of 50/60 Hz should be revised and harmonized.

Key words: Electric Field, Magnetic Field, Measurement, 50/60 Hz

P05.03
Gene Expression Profiling of Human HaCaT Keratinocytes Exposed to ELF-EMF Revealing Inhibition of Cell Cycle Progress

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Human exposes to extremely low frequency electromagnetic field (ELF-EMF) from electric appliances. There is rowing public concerns about biological effects especially possible cancer risks of exposure to ELF-EMF. Previous epidemiological studies suggested carcinogenic potential of environmental exposure to ELF-EMF specifically around 50 or 60 Hz. In this study, we performed loop-design microarray experiment and functional bioinformatics analysis to investigate transcript levels of human keratinocytes HaCaT exposed to 60 Hz 1.5 mT ELF-EMF for 4-96hr. The uniform 1.5 mT 60 Hz ELF-EMF was generated by a Helmoltz coil system. The control cells were cultured in the same incubator but shielded by mu-metal outside the Helmoltz coil. Our results showed that there were 7 differentially expressed genes (CDC25B, CDC20, CDC2, CCNA2, CCNB1, PTTG1, CDKN1A) relevant to cell cycle pathway for cells exposure to 96 hr ELF-EMF. CDKN1A (P21) was up-regulated but others were down-regulated in exposure to ELF-EMF. Quantitative real-time PCR analysis of above 7 genes indicated consistent results. Furthermore, the result of cell growth curve showed that ELF-EMF did not affect cell proliferation until 144 hr ELF-EMF exposure. From these results we conclude that genes related to cell cycle progression were differentially expressed for 96 hr ELF-EMF exposure and the decrease of cell growth was observed till 144 hr exposure.

P05.04
Assessment of Public Exposure to Radiofrequency Radiation Near Mobile Phone Base Stations in Iran

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Fast growth of the number of mobile phone subscribers in Iran, over the last few years, is the reason for construction of more and more base stations (BTS) especially in residential areas.

Since BTS antennas emit Radiofrequency (RF) electromagnetic energy, general public have been worried about their health and safety.

This research has been done to make sure that public exposure remain within exposure limits defined by Iranian Regulatory Authority in National Standard "Non Ionizing Radiation-Exposure Limits", compatible with ICNIRP limits.

Since Global System for Mobile Communication (GSM) is used in Iran, therefore RF radiation is measured in GSM frequency band in about 1500 locations and 4500 points, near 300 BTS. All measurements were done by well trained technical teams, by using one calibrated RF survey meter, in areas accessible to public, all over the country, for three years.

The results show that power density levels are far below public exposure limits by a factor of 100 or more. Finally it is concluded that in Iran, BTS antennas are established in compliance with National Regulations.

Key words: GSM, radiofrequency radiation, measurement, power density

P05.05
Assessment of Public Exposure to Ultraviolet Radiation Emitted by Compact Fluorescent Lamps in Iran

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In Iran people are replacing traditional incandescent lamps with Compact fluorescent lamps (CFLs), because they use about a quarter of the power of incandescent lamps and their lifecycle is up to ten times longer. Government encourages public to use CFLs too, for saving energy and reducing carbon dioxide emissions.

Very small amounts of mercury are used in CFLs structures, released to the environment if they are broken, but their lower energy consumption and then lower energy production can compensate it. Some researchers have shown that CFLs can emit ultraviolet (UV) radiation at levels that under certain conditions of use can result in exposures higher than ICNIRP limits.

This research has been done to make sure that public exposures to UV radiation, by using CFLs remain within exposure limits defined by Iranian Regulatory Authority in National Standard "Non Ionizing Radiation-Exposure Limits", compatible with ICNIRP limits.

By using a spectroradiometer, effective irradiance (E_{eff}) of 50 different models and brands of single and double envelope CFLs with different nominal powers were measured. All measurements were made in a dark room at 30 cm distance from bulbs. For some lower power lamps that may be used in shorter distances, I_{eff} were defined in 5, 10 and 20 cm distances too.

The results show that for all lamps, I_{eff} is very low in 30 cm distance such that one person may be over exposed if exposure time is at least 16 hours a day (h/d). But at distances as low as 5 or 10 cm, and with single envelop CFLs, this time may be reduced to 1 h/d.

It is concluded that if people may be exposed to CFL emissions for long periods, or if they are very photosensitive, or if they use CFLs as desktop or bedside lamps, they are better to use double envelop ones. Otherwise for distances more than 30 cm and exposure durations less than 16 h/d, exposure levels are lower than standard limits for all ordinary CFLs.

Key words: CFL, UV radiation, Measurement, ICNIRP limits

P05.07
Does Elastography Enable Accurate Differentiation Of Malignant And Benign Breast Lesions Compared To Conventional Ultrasound?

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PICO

P= patients with breast lesions

I= ultrasound elastography

C= conventional plain ultrasonography

O= differentiation of malignant and benign breast lesions

S= any study design

Introduction: Elastography is a newly developed dynamic technique that uses ultrasound (US) to provide an estimation of tissue stiffness by measuring the degree of distortion under the application of an external force. It is used in conjunction with conventional plain ultrasonography to differentiate or classify benign from malignant lesions such as in breast tumors. Ultrasound elastrography has a wide range of medical application as an investigation tool in diagnosing lesions or cancers. It is based on the principle of physical elasticity in which pressure is applied on the examined medium (breast) in this way it estimates the induced strain distribution by tracking the tissue motion.

Aim: The objective of this literature review is to critically evaluate research studies conducted to assess the diagnostic efficacy and accuracy of ultrasound elastography in classification of breast lesions.

Materials & Method: Literature was searched on different healthcare, scientific, research and general databases according to the guidelines of centre of review dissemination (CRD). These include Cochrane library, Pubmed, Science Direct, Medline, CINAHL, and Library Material. PICO components of the study question were used as keywords to search literature through different databases. Irrelevant studies were excluded by applying inclusion and exclusion criteria filters in results. The main findings, strength and weaknesses of studies were determined by using critical appraisal skill programme (CASP) healthcare tool. Literature was search from 2008 to 2011.

Results: Total 12 studies were selected to include in the literature review. The ability or potential of ultrasound elastography for the better classification of breast lesions was assessed with the help of available evidences.

Conclusion: The combined studies in this literature review concluded that ultrasound elastography is more efficient and accurate than conventional ultrasound.

P05.08
Isothermal Exoemission of CsBr: Efficiency for UV-Skin-Dosimetry

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Method of exoemissive UV-skin-dosimetry is effective, when phenomenon of thermally-stimulated exoemission is used. In this investigation was made an attempt to estimate the efficiency of the wide-band-gap crystal CsBr for the irradiation dose evaluation by means of isothermal relaxational exoemission. Such technique of dose evaluation, that may be interesting at in situ UV-dosimetry for radiation-chemical technologies, is based on quantity estimation of integral exosum – exoelectrons escape due to the energy, released at electronic relaxations of the defects, created by UV-irradiation.

Exoelectron emission (EE) model for CsBr crystal, previously suggested [1], is based on the assumption, that energy of recombination of radiation-created defects is the source of the exoemission phenomenon.

In the frameworks of the above mentioned EE model, recombinations of color centers, created in the crystal by UV-irradiation, and ionizations of electron traps are able to cause isothermal EE. Released energy of recombination (3*6 eV) exceeds the ionization energy of electron traps for CsBr crystal (1.2*2 eV). Radiationless transport of energy to electron F-center (Auger-like process) leads to ionization of the last one and to appearance of exoelectrons, thus isothermal EE of CsBr is determined by recombinations of complementary pairs of anion sublattice defects ([H,F], [V_k,F] - recombinations) in a subsurface layer and Auger-like ionizations of F-centers. Due to decrease of color centers concentration gradients, isothermal EE attenuates with time.

Analytical expressions of temperature-dependent (caused by diffusion controlled [H,F], [V_k,F] - recombinations) and temperature-independent (caused by tunnel [Vk,F] recombinations) components of isothermal EE current were attained. Theoretical value of the resulting decay isothermal EE current is in satisfactory agreement with the experimental one. The obtained decay kinetics of isothermal EE depends on the temperature of UV-irradiation of the crystal.

Analytical expression for isothermal EE current allowed us to estimated the value of integral exosum and to attain the order of exoemission efficiency for CsBr crystal as a skin-dosimetric material: $S \approx 10^6 \div 10^7$ el./Gy•cm^2, that is rather promising for the dose range under 400 Gy (isothermal EE method is restricted to the region where dependence of the integral exosum on irradiation dose is linear).

[1] Galiy P., Mel'nyk O., Radiation Effects & Defects in Solids, 157 (2002) 683.

P05.09
Measurement of RF Power Emitted by 3g Mobile Telephones During "voice over ip" (voip) Communications

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The power level emitted by a telephone during communication over a network depends on numerous parameters: type of use (data, voice, …), quality of the network coverage, technology employed, management of resources by the operator, etc. There have been several publications on assessing the power emitted by 2G mobile telephones during voice communication over a mobile network, but as yet very few regarding 3G mobile telephones, whether R99 or HSPA, smartphones and new types of use. During 2010, 133 voice communications were made in Paris (France) using 3G smartphones (release 99, switching in circuit mode). The power levels observed were extremely weak, on average about 300 times weaker than the maximum power of the equipment, and far below the mean power levels observed with the 2G mode in the same conditions (approximately 1/3rd of maximum power). In the framework of this second investigation, we are aiming to characterise the power emitted by three HSPA 3G smartphones in Voice Over IP communication (i.e. in packet switching mode), compared to the R99 3G voice communications (in circuit switching mode). The power emitted by the equipment during communication is measured in a real-life usage situation by a portable device measuring the power level 20,000 times per second by way of a probe which does not affect the signal emitted by the telephone undergoing the test (normalised power with respect to maximum power). Three 3G smartphones (UMTS – HSPA) from three different manufacturers were used in the city of Paris (France) and in its suburbs, between 9h and 17h, during the period between July 28 and August 04, 2011. In total, 138 voice calls in R99 and 135 calls in Voice Over IP were made. In the framework of this study, the mean power emitted in 3G communications, in circuit switching mode (R99), was 0.22% of the maximum power of the equipment tested. With regard to the calls in packet switching mode (HSPA), the mean power was 1% of this same power, meaning a ratio of 1 to 5 between the power levels of voice and VoIP communications.

P05.10
The Electromagnetic Field of Modern Communication as a Factor in the Environment: Hygiene and Radiobiological Effects

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The presentation discusses the radiobiological effects caused by EMF RF mobile phone, an assessment of the potential adverse impact on the health of users.

The mobile radio communication has become an integral part of our lives. All groups of population are practically constant significant electromagnetic radiation. It's the first time civilization being exposed daily fractional brain of mobile phone users. The brain's become a critical organ. Children were included in high-risk and under the terms of the electromagnetic load on the body can be equated to the professionals.

We considered functional disorders of the mobile phones users, including the syndrome of "electromagnetic hypersensitivity" and state of "situational stress" and experimental investigation of the impact EMP RF on the brain, the possibility of long-term consequences for mobile phone users. Effects on children's and teenager's health were analysed. We considered the problem of standardization of maximum permissible level of EMF of mobile phones.

Basic scientific data for evaluation safety of electromagnetic mobile phones is not enough. There is no data about the possible development of long-term effects in children after prolonged exposure of the developing brain of EMF in the near the antenna field.

On the one hand, there are a total uncontrolled exposure in the general population, which can be considered as significant. On the other hand, we are not seeing expressed mass pathology. While it would be fair to say that this is not an epidemic of "swine flu" to expect a mass clear pathology, and that the process is latent, we are convinced. In this regard, we must persevere in the relevant scientific research and have a reliable regulatory framework that takes into account the changed realities of the electromagnetic effects on the population.

P05.12
The Analysis of Effects of Low Intensity Radio Frequency Radiation by Changes in Functional Activity of Hydrobionts

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It was obtained and analyzed the effects of low intensity radio frequency radiation with frequency 1 GHz (cellular base station) and 10 GHz (satellite broadcasting, radars) with power flux density 50 mkW/cm2 and wide range exposure time by the criterion functional activity changes at ciliates Spirostomum ambiguum, planarians Dugesia tigrina and crustaceans Daphnia magna.

Irradiation of the test organisms was performed in a continuous mode by the generators R2-52 and G4-109. The control of power flux density is carried out by the measuring receiver R3-18. The special software ImagePro 3.5 was used, that allowed to spend a lifetime morphometry of the irradiated planarians regeneration activity and the ciliates` motor activity. Changing the daphnids status was estimated by survival, lifespan, fertility and quality of progeny. The experiments were conducted for each of species in three replications. 20 ciliates, 20 planarians and 20 daphnids in the control groups and 20 at each point of experiment were tested. Thus, more than 1500 ciliates, 540 planarians and 240 daphnids were tested.

The analysis of the effects was produced with unicellular and multicellular aquatic organisms, revealed several patterns. First, it was shown that all the tested species are sensitive to influence of low intensity radio frequency radiation. Second, it was identified that time, which can be considered "Safe" (Subliminal) for the different aquatic organisms being in an electromagnetic fields with the test frequency. Further time exposure increase led to "threshold" drop in most of the investigated functional parameters. It was founded that a long plateau (with different duration for each indicator) after reaching the "threshold" when the indicator was stably maintained significantly lower then the control levels. Finally, the identified effects there were mass character; the most of the tested species alter their functional activity.

The present result was interesting in the issue of biota radiation protection and the common problem of the electromagnetic wave activity to the biota.

P05.13
Evalution of Effect of Magnetic Field on Hetrotrophic Bacteria in Water

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Background and Aim: The effect of magnetic fields (MF) on the number of heterotrophic plate count (HPC) bacteria in water sample which cultivation on the plate count agar culture and compared with control samples.

Methods: Samples of contaminated water exposed to the MF intensity 10, 50, 100, 200 and 300 mTesla for a period of 10, 20, 30, 40 and 50 minutes. Then case and control samples cultured in plate count agar culture in the end, the number of HPC in the case and control samples, counted.

Results: applying 10, 50, 100, 200 and 300 mTesla intensity of MF during the 10, 20, 30 and 40 minutes, statistically significant difference) $p < 0.627$, $p < 0.427$, ($p < 0.054$ and $p < 0.655$) between case and control samples weren't observed, but during 50 minutes ($p <0.003$) significant differences appeared. In the total range if all of the MF intensities will consider in those times, significantly different)$p < 0.000$) between case and control samples observed.

Conclusion: the growth of heterotrophic bacteria in 10, 20, 30 and 40 mT intensity of MF, don't have significant difference. but for 50 minutes, the number of colony of HPC in the case samples increased.

Keywords: magnetic field, Tesla, solenoid, heterotrophic plate count

P05.14
The Effects Of Electromagnetic Pulse On Chemotaxis Of Murine Lymphocytes*

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* This work is supported by National Natural Science Foundation of China, No. 30972430 and No.81072272.

Background and Aim: It has been found in our previous study that electromagnetic pulse (EMP) could increase the lymphocyte number in murine spleen and inhibit proliferation of splenocytes, which suggests EMP induced accumulation of lymphocytes in spleen. This study was aimed to evaluate the effects of EMP on lymphocyte migration.

Methods: Balb/c mice were exposed to EMP radiation. The in vitro migration directed by chemokines SDF-1 of T lymphocytes from spleen was evaluated with transwell assay.

Results: The mice received irradiation of 200 kV/m EMP and sacrificed at designated time points.In vitro migration assays revealed that EMP promoted migration of splenocytes to SDF-1. The enhanced effects of EMP emerged 1d after radiation, reached to its peak at 7d after EMP radiation. In another experiment, the mice were exposed to 200 times of EMP radiation at different radiation times(100-400 times) and migration assays were performed 24h after radiation. It was shown EMP could increase T lymphocyte migration in a dose-dependent manner with the most profound effect at 400 kV/m.

Conclusion: EMP radiation could promote chemotaxis of T lymphocytes in time-dependent and dose-dependent manners, suggesting that EMP could accelerate the recruitment of T lymphocytes to inflammation sites and thus influence the adaptive immunity. It will be interesting to further explore the underlying mechanisms.

P05.15
Experimental Research of the Reaction of the Central Nervous System on Combined Action of Physical Factors Non-Ionizing Radiation of Low Intensity

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The urgency of research is related to the necessity of developing ideas about the reaction of the central nervous system to low-intensity non-ionizing radiation factors that are in the real environment often present simultaneously, providing a combined effect on the body.

Carried out a series of studies on changes in the extracellular impulse activity of neurons in the visual cortex of experimental animals on non-ionizing physical factors (static magnetic field, radio frequency electromagnetic field and sound). Mechanism of the reactions could be different in quality and quantity, as determined by the initial background. They were carried out with a latent period, significantly more than light flash, more and more intensely manifested after turning off factor and consisted mainly in reducing the frequency of impulses. According to the literature, that kind of response characteristic of a neuron peculiar weak irritants (rather subliminal) because of its biological significance. It is known that the reaction on such interventions may be more expressed on the background of the additional load.

Patterns of change depended on the performance in background and in response to the isolated action of light. Inhibition of reflexes was observed at significantly higher frequency of the initial impulses than activation. Influence of magnetic factors was similar to the action of sound (an inadequate stimulus for this area). Inhibitory type of reactions was reported more frequently (the result of reliable group of neurons), and it was enhanced by the combined action of irritant. The basic pattern of change was limited to reduce the frequency of the first phase pulsation of activation and increase in the latent periods of first and second active phase. Other indicators of response to flashes of light remain almost unchanged.

P05.17
The National Register of RF Workers: A long-term, follow-up study

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AIMS AND OBJECTIVES: In 2000 the independent expert group on mobile phones published its report on the possible effects on health from mobile phone telecommunication technologies (IEGMP, 2000) and recommended that a register of occupationally exposed workers be established to facilitate studies into cancer incidence, mortality or other potentially harmful effects. In 2003, the Health and Safety Executive (UK), in consultation with representatives from across industry, established the National Register of RF Workers for those potentially exposed to radio-frequency radiation above ICNIRP guidelines for the general public. Relevant information on participants is retained and maintained in a centralised database, administered by the Institute of Occupational and Environmental Medicine (IOEM). The initial study described here will use the Register to obtain important new information on the health effects of occupational RF exposure.

MATERIALS AND METHODS: All enrolled on the Register have some period of employment working in the environments described above in the period 1961-2010. Job title is used to determine the exposure regime of participants, allowing placement into one of several, broader, job categories. The level of exposure typically experienced by each category is informed by the five-year "Feasibility Study for an Epidemiological Investigation into the Health Effects of Radiofrequency Fields and Radiation" undertaken by the IOEM and the HPA (University of Birmingham, 2003). The study will receive copies of death certificates, and cancer registration or incidence, from the Medical Research Information Service. Underlying cause and multiple-cause coding will be supplied by the ONS for all deaths according to the tenth revision of the International Classification of Diseases (ICD-10).

RESULTS: The mortality experience of the cohort will be compared with that which might have been expected to occur if rates of mortality for the general population of England and Wales had been operating on the study cohort, having due regard to the composition of the study cohort by sex, age and calendar year. Expectations based on person-years-at-risk (pyr) will be calculated using the PERSONYEARS computer program (Coleman et al, 1986). Standard Mortality Ratios will be calculated as the ratio of observed to expected numbers of deaths expressed as a percentage. In calculating P-values and confidence intervals, it will be assumed that deaths occur as a Poisson process (IARC, 1987). Any significance tests will be two-tailed.

P05.18
The Effects of Electromagnetic Fields of Mobile Phones on Children - the Viewpoint of the Russian Committee on Non-Ionizing Radiation Protection

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In Russia there are about 15 million children and teenagers at the age from 5 to 19 years old and almost all of them use mobile devices. Mobile phone is a source of the electromagnetic field, which relates to health hazards.

The specificity of mobile phones as a source of EMF - the direct irradiation of the human brain electromagnetic field in the field of antenna in uncontrolled conditions, without restrictions on duration and frequency of use. Specificity is determined by exposure of the child in the stage of brain development and its greater vulnerability to the effects of harmful environmental factors (as compared with adults). The child, because of the age differences, can't take mobile phone as a source of harmful electromagnetic fields. Child's brain absorbs an electromagnetic energy more than a brain of an adult mobile phone user. Children's brain is exposed, including segments, responsible for their intellectual growth and development.

Since 2001, RusCNIRP (Russian committee on Non-Ionizing Radiation Protection) handled a problem of possible effects of EMF equipment mobile phones for children; the Committee's opinion is taken into account in the current Russian sanitary rules SanPiN. In 2008, RusCNIRP formulated prognosis short-and long-term effects for children using mobile radiotelephones. According to statistics published in 2010, there is a steady increase of the incidence rate of children by diagnosis, as reflected in the 2008 RusCNIRP's prediction as "possible". In its decision in 2011 formulated the basic tenets of RusCNIRP, which serve as the scientific basis for assessing the risk of EMF to children and young people using modern mobile phones, regardless of the communication standard.

P05.19
Postgraduate Education on Hygiene of Non-Ionizing Radiation: Program and Organization for Teaching Process

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The number of the non-ionizing radiation (NIR) sources has been increasing continuously at work places and residential areas. The exposure pattern gets more complicated, the new methods and instruments for measurements and dosimetry are developed, the new scientific data on hygienic NIR assessment at the occupational and general public exposure conditions appears. As a result, raising the level of NIR experts' skill becomes urgent.

Program of postgraduate education on hygiene of NIR was developed and now introduced for sanitary doctors, physicists, engineers of the testing laboratories, ecologists and occupational safety specialists.

The training course lasts for 2 weeks and consists of the following subjects:

- hygiene of electromagnetic field (0–300 GHz) sources, including the environmental electromagnetic pollution aspects;

- hygiene of microclimate and lighting factors;

- hygiene of vibroacoustic factors, including preventive measures for reduction of their adverse effects in occupational conditions;

- safety arrangement of work places equipped with personal computers;

- methods of the hygienic NIR assessment and the conditions of work classification.

Special attention is focused on familiarization with the new methods and instrumentation for measurements and dosimetry of NIR. Methods and means of protection against NIR are also studied.

P05.20
Optical Radiation Risk Assessment And Management

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Purpose of the study: The aim of this work is to report on Optical Radiation risk management at ASL-CN1 Cuneo, Italy, a Local Health-Care Authority in accordance mainly with Italian law, Directive 2006/25/EC concerning Artificial Optical Radiations, Directive 89/391/EEC "Safety and Health of Workers at Work", and the European Standards adopted by the CENELEC/CEN country members.

Methods: In order to assess correctly the risk we developed a procedure in our quality system specifying the roles, steps and necessary data in this process. In order to have the minimum information necessary a number of data collection forms in this procedure have to be filled in by the various roles (manufacturers, head physician, etc), e.g. a general collection sheet enables the monitoring of the introduction of lasers, optical sources and EMF at risk (for whatever purpose), without the prevention and protection measures being assessed and implemented. The risk assessment is mainly performed by matching the information from data forms and literature to asses levels of exposure to optical radiation sources to which workers are likely to be exposed. When data are insufficient, measurements are performed using suitable instruments and protocol (we used Yeti and Ocean Optics radiometer and power meters Wizard 250 Synrad and Ophyr).

Results: We have illustrated a variety of risk assessment results according to Italian law (level of exposures) and a pertinent variety of prevention and protection measures. We have also reported, in accordance with various authors, the classic R = PxI, the product of hazard probability P and its potential impact I. This is useful for a comparison with the non-optical hazard to prioritize the interventions in order to prevent damages and to communicate with non-specialist personnel,such as certain employees, workers' representatives, workers, etc.

Conclusion: In our experience, without a procedures the information provided is not always complete or adequate and the risk process can be particularly highly time-consuming and expensive. A mistaken assessment could lead to selecting protections with too low or too high a level. In both cases it could increase the risk value and the prevention and protection measure cost assessment (eye protector sets, barriers, warning lights, interlocks, training, etc).

P05.21
Assessment of EMF Exposure with a Personal Monitor

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A personal monitor was used to assess EMF exposure during simulation of work activities in a site with rooftop antennas for mobile-telephony and close to a high-power microwave oven.

Introduction: Measurements of EMF intensities are also an important tool in the control of occupational exposure. Nevertheless, in most routine work it is impossible to carry out such measurements. Therefore, the performance of a personal EMF monitor was investigated in this work. This device features shaped response probes and the energy of all signals are frequency weighted in accordance to specific standards, being helpful for multi-frequency sites. In this report, exposure levels registered in a mobile-telephony site and an industrial micro-wave oven are shown.

2. Instruments and Methods: The personal EMF monitor RadMan-XT (Narda), calibrated with ICNIRP's occupational standards, was used. Sensitive to electric (1 MHz to 40 GHz) and magnetic (27 MHz to 1 GHz) fields, this device emits a warning alarm related to the exposure level. As a data-logger it allows continuous monitoring for long periods, depending on the acquisition time. The energy of all signals is frequency weighted in accordance to ICNIRP Occupational Standards and results are displayed as a percentage of this value. The device was attached to the workers clothing in both monitoring cases.

3. Results: The temporal profile of exposure levels registered during worker movement around the mobile-telephony site, clearly show increasing intensities as panel and dish-antennas were approached. Actually, these levels exceeded limit for some period of time, as shown by the results. Intensities of leakage radiation from a high-power (30 kW) microwave oven where registered close to the oven apertures. In this case, registered levels did not exceed occupational limit.

4. Conclusions: Portable EMF personal monitors can be very helpful for controlling exposure in real scenarios. Entering areas with unknown EMF sources can be made safer by using the device to map out field intensities. With its cap properly replaced the device can be used by the worker attached to register exposure. It is always important to preset the audible alarm at safe levels.

P05.22
Non-Ionizing Radiation Measurements in Kenya

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In Kenya there is growing realization by players in telecommunications industry including the Government that effects on the environment by electromagnetic radiation need to be properly addressed as infrastructure continues to develop. However, there is also a realization that public should be aware of actual situations that cause real dangers to avoid un-necessary concern which would hamper telecommunication roll-out. It is for this reason that several initiatives are being undertaken by the industry players to educate the public while carrying out a thorough evaluation of existing infrastructure to ensure their safety.

This study therefore was an initiative to evaluate the NIR levels of Base Transmitting Stations (BTS) in selected parts of Kenya to ascertain whether their cumulative radiation poses any danger to those living near the transmitters. The results are in the form of calculations, power measurements and analysis that were carried out to determine the possible levels of radiation exposure at the BTS which was then evaluated for safety. Noting that the World Health Organization (WHO) recognized ICINRP guidelines have more stringent limits and were hence used to form the basis of this evaluation.

The meters used for this exercise were Narda Radiation Hazard Meter (RAHAM) and a Spectran Spectrum analyzer. The RAHAM had 3MHz to 18 GHz frequency range. This meter was mainly utilized for carrying out both spatial and time averaged measurements within the given frequency range. The spectrum analyzer used had a hyperlog antenna model 7060 with a frequency range 30 MHz to 6 GHz. This meter was operated in peak mode. The analyzer was meant to take frequency specific exposure levels. This feature comes in handy when one need t to know each facility contribution to the total exposure.

Exposure level measurements were taken at various sites (65No.) and the data recorded were the operator name, GPS coordinates, max hold, average exposure and the comparison percentage with the ICNIRP limit. All measurements are expressed in milli-watts per square meter (mW/m^2). The maximum hold refers to the maximum instantaneous signal exposure while the average refers to the six minute average signal level. The percentage of ICNIRP limit obtained ranged between 0.0022 % and 0.3700 %.

All sites were within one percent (1%) of the World Health Organization recognized ICNIRP guidelines. And these measurements are evident that the public in these areas is safe.

Wide sample size measurements have so far been done and the final paper will enumerate the detailed analysis to statistically reflect significant number of the operating BTSs in Kenya.

P05.23
Measurements of Electromagnetic Fields Near Cellular Base Stations (BTS) for Radiation Protection Purposes

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This document presents information on radio wave exposure levels from base station antennas in mobile communication networks in Kenya. The wireless technology has become the most effective means of communication in the world today. This technology has vastly led to the establishment of cellular base stations (BTS) in the developed and developing countries. Although it seems highly unlikely that the low levels of RF radiation from base stations would have significant biological direct adverse effects on health, the possibility of harm from exposures insufficient to cause important heating of tissues cannot yet be ruled out with confidence. The objective of this study is to collect baseline data on radio waves near cellular base stations which will be assessed in context of the International Commission of Non-Ionizing Radiation Protection (ICNIRP) guidelines for radiation protection purposes. Hand-held density meter and spectrum analyzer were used to measure power density of narrowband radiofrequency signals which were compared with calculation assuming an inverse square law dependence of power density upon distance from antennas. The highest measured power density among the total measurements at a single frequency in the GSM 900 and GSM 1800 band was 13.4 mW/m^2 at a frequency of 952.4 MHz, corresponding to 0.28% of the ICNIRP exposure limit for the general public. The maximum power density at single frequencies varied between <0.000001 and 13.4 mW/m^2, thus with a variation of at least seven orders of magnitude. The median value was 0.01 mW/m2 (0.0002% of the ICNIRP 1998 guidelines).The results showered no significant exposures to the public; they were within the ICNIRP limits. The radio waves exposure information that is presented in this project will act as a representative also for similar base station configuration networks in future.

Keywords: Radiation, ionizing, protection, exposure, power density, frequency.

P05.24
Non Ionizing Radiation Protection Infrastructure and achievements of Regulatory Authority in Iran

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According to Radiation Protection Act of Iran (RPAI), which was ratified by the parliament in 1989, National Radiation Protection Department (NRPD) was empowered to Regulate Radiation activities and sources including Non Ionizing Radiation (NIR). NIR division has been established in 1988 in NRPD and is responsible for control of NIR application. In the exercise RPA, the standard "Non Ionizing radiation –exposure limits" was approved in 2005. Many activities have been done by NIR division for protection of public and workers against harmful effects of NIR such as; Establishing NIR measurement and calibration laboratory, Issuing regulation and guidance, promoting public awareness, cooperation and coordination with other relevant authorities .In this paper, mission, kinds of activities, achievements and future plans of NIR division is explained.

P05.25
Methodology of the Tests on Efficiency of the Means for Biological Protection against Non-Ionizing Radiation (by the Example of EMF and Infrasound)

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The methodical guidelines for sanitary-epidemiological and medical-biological tests of the means for protection against radiofrequency electromagnetic field and infrasound in laboratory conditions have been worked out. The guidelines are suitable for the protective means founded on "traditional" technology (the reflection or absorption of the incident energy), but can be applied for means made using "non-traditional" technologies when there is no sufficient physical explanation.

Assessment of the protective means efficiency, based on the result of the instrumental studies (measurements) and medical-biological studies of the organism reaction to the exposure, is a particular feature of the method. This allows using it in the cases of the complex exposure conditions.

The criteria for the protective means efficiency assessment, requirements for test system setup and laboratory premises, dosimetry, sample selection and statistical data manipulation are described.

The basic criterion is the factor of decreasing of electromagnetic field or infrasound intensity, which must be more than 1 (one) taking into account the measurement uncertainty. The additional criterion is an absence of statistically significant difference ($p < 0.05$) in controlled medical and biological indexes between experimental (with installed protective mean) and sham-exposed and cage control groups of laboratory animals.

Medical-biological studies are conducted to control the organism reaction to the affecting factor as a reaction of the critical systems, which are known as the most sensitive to such influence (central nervous system, cardiovascular system, immune system).

The guidelines were approved during the protective means tests in occupational conditions.

P05.25
Clearobot, An Automated Robot Performing Final Radiological Surveys In Radiological Facilities

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Final radiological survey is the process leading to the final release of a radiological facility from regulatory controls. This process implies the execution of hundreds of direct and indirect measurements, especially in large area nuclear facilities. Measurements to be performed are highly specific, near to the detection limit.

The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

One of the first JRC-ISPRA's radiological facilities to be released from regulatory controls, in 2010, was the Radiochemical Hot Laboratory (RCHL), and its release was made possible after the execution of thousands of direct analyses on flat surfaces, mainly facility's floors, with the aim of a complete description of the final radiological status of the laboratory.

An automated procedure, performing several direct dose and contamination measurements over several points over large surfaces may significantly ease the final release process, greatly reducing the need of human intervention in the final release step.

The present project involves the development of a small robot, equipped with a high-efficiency scintillation detector, able to autonomously perform a series of dose and contamination measurements, hence mapping a large surface according to a specific monitoring plan.

The proposed automated robot system (CLEAROBOT) is designed to be able to:

· Carry a scintillation detector, in predetermined conditions, over a large area and execute measurements in identical geometry conditions

· Divide a large floor surface into several elemental units, and perform a minimum number of measurements in a given surface, with a pre-determined MDA

· Autonomously map, subdivide and recall the geometry of a given area to be measured

· Store and save dose and contamination measurements' results related to every single elemental unit, and reach a specific MDA level before moving to the next position

· Monitor a large floor during long periods, as requested, including nights and weekends

The proposed prototype system, mainly based on commercial robots available on the market, is able to improve the radiological measurement process during final radiological surveys for large surface facilities' release, significantly reducing personnel doses and workload, and significantly improving detection accuracy.

P05.26
A Material Carbonization as a Mechanism for Protection from Direct High-power Laser Beam

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Plastic materials used for commercial laser glasses and goggles melt if exposed to direct laser beam. If irradiated long enough (depending on the laser intensity), the beam drills a hole in the protective filter, thus letting-through the full power of the beam. This poses a significant risk if high-power lasers are used. We are presenting a new material which can be used for protection from high-power unexpanded laser beams. The main constituent is gelatin doped with several compounds that make the material elastic and absorbing at the laser wavelength of 532 nm used in our experiments. Layers can be produced enabling good visibility for normal work, while protecting the eye from the direct and scatted radiation. Material carbonizes (instead of melting) If irradiated directly, thus making the surface opaque. This additionally reduces the intensity of the transmitted beam. We have tested the material up to the power of 3W of direct unexpanded beam, and transmitted laser intensity was at the safe level for more than 10 seconds.

P05.26
Characterisation of Worker Dose Uptake during the Decommissioning of the Magnox Power Station at Bradwell

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Bradwell site was operational between 1962 and 2002, and was declared defueled in 2005. Decommissioning activities are on-going and work over the last few years has seen substantial progress towards leaving the site in a condition suitable for long term Care and Maintenance (C&M). Bradwell, alongside Traws, is currently one of the Magnox stations most advanced in the decommissioning process; entry to C&M is planned for early 2015. In general, decommissioning health physics could be regarded as different from normal power operation in that the tasks to be performed are unique and generally not repetitive. Potentially, the value of prospective risk assessment is greater in the decommissioning environment because of this. This short study trends collective and individual dose from 2000 to present. It aims to establish a series of dose distributions that characterise dose uptake and may be loosely comparable across Magnox decommissioning sites and other sources of similar information, such as that produced by UNSCEAR. The purpose of the characterisation is to assess the effect of different work types on collective dose, average individual dose and highest exposed individual and so aid in better collective and individual dose prediction and risk assessment.

P05.27
Selecting Medical Laser Diodes Radiation Eye Protectors

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Laser Diodes are widely used in medical application, as physioterapic and surgery treatments. Even though not strictly monochromatic, these devices emit radiation with a peak usually presenting a FWHM in the tens of nanometers.

We considered in particular the problems related to the selection of the eye protectors:

- quantity (1 or 2 pairs of goggles, generally supplied with the device, are not sufficient in that there may be more than two people in the Laser Controlled Area or LCA)

- they may not be specific for different roles and needs of those operating in the LCA (Medical staff, sedated patient, non-sedated patient, LSO)

- quality (a wrong protection level scale number LB or R and protection wavelength range)

We took into account the frequency of the peak centre and the FWHM values in function of certain parameters (selected power or energy, frequency, temperature, hours of continuous use, age, etc.). By means of a suitable spectrum-radiometer and power meter, we thus analyzed the variations in emission peaks of many laser diodes.

Furthermore, this led us to reconsider the adequate selection of barriers and eye protectors since the optical transmittance and resistance to laser radiation depends upon the wavelength of incident radiation.

The measurements performed enable us to reconsider the choice of filters and barriers to take account of non-monochromatic emission and variations due to parameters (time temperature, power, etc.)

We show that the goggles supplied by sellers for Laser Diodes were sometimes partially out of the wavelength range of protection needed.

P05.28
Chronic Lymphocytic Leukemia and Non-Ionizing Raditation-Case Report

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During past years we are faced with new forms of energy. The influence of non-ionizing radiation on human health is still not well understood. As a preventional field of medicine, occupational medicine has a problem to detect correlation between desease and workplace hazard.

The aim of this case report is to consider a possible occupational disease-chronic lymphocytic leukemia (CLL) caused by non-ionizing radiation.

The conclusion is that CLL, in the most of cases, can not be correlate with exposition to non-ionizing radiation. In this case report we couldn`t declare chronic lymphocytic leukemia as occupational disease.

P05.29
Radio Frequency Fields in Our Surroundings – Measurements in the Frequency range of 80 MHz-3 GHZ. Are Measurements Sufficient to Meet Peoples Concern?

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Introduction: The recent years there have been a growing concern in Norway regarding exposure to electromagnetic fields from different telecommunication systems. To some people`s opinion, the exposure guidelines set by ICNIRP are too high. There have been several local debates about installation of mobile antennas. People believe that wireless networks will represent a danger in the long run. How can authorities meet this concern?

Measurements: Relatively few measurements have been published in this field. During 2010 the NPT and the NRPA performed measurements of electromagnetic fields to map the real exposure levels from fixed antennas in our normal living environment. Exposure from different telecommunication systems in the frequency range of 80 MHz-3 GHz were included in the study. The following systems were included: Radio and TV transmitters (FM, DAB and DVB-T), public safety radio network (TETRA), mobile broadband (CDMA), mobile telephone (2G, 3G and 4G), cordless telephone (DECT) and wireless network (WLAN). Measurements were performed indoor in dwellings, in- and outdoor in kindergartens and schools, indoor in office buildings and outdoor on street level in urban environment. All measurements were well below the ICNIRP guidelines. Outdoor values are fairly higher than indoor values. Wireless network contributes the smallest part of the exposure, while base stations for mobile telephone contribute most even though the levels are low compared to the ICNIRP guidelines.

How to meet peoples concern?

The answer to this question may be to educate the population. Knowledge about the real exposure levels and continuously updated scientific review of possible adverse health effects is important. Information to the public and integrated planning of antennas is necessary. According to the Norwegian Radiation Protection Regulations all exposure shall be as low as reasonably achievable, even though the levels are low. The role of the authorities is to put science up against the destiny of individuals. How can we justify this? What role do NGO´s and media play?

Results form the measurements and how to inform the population will be addressed in the paper.

P05.30
Can Earth's ULF Magnetic Micropulsations Induce Brain´s Spurious Activities - Preliminary Study - ?

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We present in this paper some preliminary studies on how the Earth's ULF – Ultra Low Frequency magnetic micropulsations might interact with the human brain's activities. Magnetic micropulsations are magnetospheric plasma wave eigenmodes that are generated at the Earth's magnetosphere and, via magnetospheric - ionospheric coupling induce ionospheric currents, and this ionospheric current pattern creates surface geomagnetic perturbations, which in turn induce the Earth's surface electrical currents easily detected by ground based magnetometers. These wave modes are basically of Alfvén type, and can be generated or enhanced, for instance, by magnetic storms, situation where they are more intense and, in principle, might be felt by a more magnetic sensitive human brain. Here, we also show how the modes are generated and present theirs basic physical properties. Finally, we compare the magnetic field level at the brain with the micro pulsation magnetic intensity.

KEYWORDS: Sun – Earth Interaction, Space Weather Forecast, Alfven Waves, Ultra Low Frequency Geomagnetic Micropulsations, Brain´s Magnetic Field, SQUID, Crime, Depression.

P06.01
New PWR Shutdown Technology at DC Cook 1,2 Achieves Outage Dose Performance Improvement in 4 Outages from WANO 4th Quartile to Top Decile

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In October of 2010, DC Cook established a new US record for the lowest collective work dose received during a 32-day refueling outage of 38.4 REM for a 4 loop PWR. The success was a culmination of a collaborative process with a new technology based solution, to substantially improve the quantity of reactor coolant corrosion products in the DC Cook-1,2. This integration also resulted in improving safety-related primary circuit component reliability and fuel performance. DC Cook Unit 2 repeated the exceptional low dose refueling outage with 36.4 REM.

Reactor coolant system erosion, corrosion and wear of components and piping systems is the primary source of neutron activated materials which if not mitigated, deposit throughout the reactor coolant primary system. These corrosion products are known to degrade fuel and component performance, and elevate plant radiation levels and consequently, the costs of operations. The investment in the technology and change process at DC Cook has yielded greater than 4: 1 benefit to cost ratio for every Unit 1 and Unit 2 outage.

DC Cook identified and examined a new innovative solution to the impact of corrosion product transport and build-up in the PWR primary circuit. The focus has been on leveraging this new solution derived from: 1) emerging technology from USA nuclear R&D laboratory, and 2) the applied engineering experience of chemical engineering consultanting firm. DC Cook identified and implemented a series of actions which has resulted in a sustained reduced in radiation source term for Unit 1 and Unit 2 since 2002, which has achieved sustained reduction in radiation source term, improvement in component and fuel performance and reliability. DC Cook received a strengthen in occupational dose reduction from the Institute of Nuclear Power Operations (INPO) in 2011.

This paper will present the changes and challenges in the use of a new engineered solution applied to PWR shutdown and coolant clean-up methodologies. In addition, the optimization of worker dose reduction and fuel reliability will be discussed with comparison with similar designed PWRs.

P06.02
ALARA Achievement:Fourth Quartile to Top Decile in Six Years at Cook Nuclear Plant

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After the use of the PRC-01 resin for four cycles and beyond, the inventory of fuel in the reactor core has benefited from the source term removal effectiveness of the specialty resin. In prior cycles, one third, two thirds, etc., of the fuel inventory has legacy source term on the cladding which was deposited before the use of the specialty resin.

Co-60 removal at Cook Unit 1 has been accomplished by implementing a combination of optimal shutdown/start-up sequence with the use of specialty media (PRC-01 and PRC-01M) in the Cook CVCS demineralizer vessels. The implementation was accomplished through a collaborative process with outage management, chemistry, RP organizations and a chemical engineering consultant providing the chemical engineering expertise and specialty media. The goal of the specialty media use is based on its design to mitigate the formation, transport and deposition of extremely small (<0.01 um) electrostatically charged colloids, which largely create the Cook Unit 1 source term challenge.

The U1C23 CRUD burst peak was 0.181 uCi/g. This was better than the predicted Unit 1 cycle 23 CRUD burst peak of 0.75 uCi/g. Operations and Chemistry performed early mechanical degas procedures well. The CRUD burst was accomplished within 48 hours after reactor shutdown.

During the CRUD burst, RP was able to track real-time the in-plant dose rates on the letdown line piping, E. RHR Pump – contact and E. RHR Exchangers with telemetry electronic dosimeters. A new software program was used to collect and analyze the dose rate data. The telemetry electronic dosimetry data was compared with archived cycle 21 and 22 CRUD burst data.

One of the most important site accomplishments with the CRUD burst and shutdown chemistry results was the ability to allow outage workers into upper and lower containment shortly after the CRUD burst procedure was completed. The reactor coolant Co-58 activity levels are plotted on a RP/ALARA decision chart for use in the OCC to determine when workers can enter the upper and lower containment (0.5 uCi/g and 0.25 uCi/g, respectively). The 0.181 uCi/g Cook Unit 1 CRUD burst fell essentially below both RP containment RP/ALARA hold points for the first time in the history of Unit 1 refueling operations. This precluded the need to hold outage critical path activities in the containment: a significant achievement for the operations, chemistry, engineering and RP source term removal team!

P06.03
Temporal Evaluation of the Natural Uranium Released by an Uranium Mine

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The Ore Treatment Unit is a uranium mine which is currently disabled. During the period 1982 to 1995 the mine produced about 1200 tons of ammonium diuranate ($NH_4U_2O_7$). The drainage acid existence in deposits of waste causes the metal and radionuclides leaching of these deposits. The facility has an interface with the environment through the Antas River where effluent release after the treatment is authorized. This work aims to evaluate the temporal variation from natural uranium release from Antas River between the years 1999 to 2004. The analysis of natural uranium activity concentration in soluble and particulate fraction made weekly in this period were analyzed through statistical tests, for example: times series, Z test for two means, monofactorial variance analysis (using Tukey test as a complementary test) and Pearson correlation analysis. In this period the mean of activity concentration was 0,15 Bq/L for soluble fraction and 0,07 Bq/L for particulate fraction. The concentrations to soluble and particulate fraction were statistically different (Z_{cal} = 16,46 and Z_{tab} = 1,96), with higher concentrations in soluble than in particulate fraction. Furthermore, no linear correlation between fractions was identified (Pearson R^2 = 0,03). In evaluating of monthly average concentration, both fractions showed a tendency to reduce the activity concentration in this period. The time series evaluation to soluble fraction showed two distinct phases of the year, one with values that tend to be higher than average and other with values that tend to be lower than average. The evaluation showed an increase of activity concentration from middle of June that lasted until the end of November.
In this fraction the time reduction of activity concentration begins in early December and lasts until middle of June. For the particulate fraction also has a increase phase that begins in early October and extend until the last week of February. The reduction period, begins in early march and runs until late September. With these results we conclude that there is seasonality in the activity concentrations of natural uranium in effluents released and there is a decreasing trend in these concentration released.

P06.04
A Model to Measure the Dosimetric Risks: An Application to the Operators of Gammagraphic Inspections

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A probabilistic model to assess and prioritize the radiological aspects of accidents that can occur during gammagraphic controls has been developed using EDF experience/feedback and classical methods employed in risk analysis.

An analysis of EDF feedback obtained within its NPPs has allowed us to identify the main scenarios of radiological accidents. Each scenario consists of a sequence of events associated with probabilities. These probabilities are either estimated from frequencies defined by statistical data or are elaborated from templates for those cases that have poor feedback. The scenarios are then characterized by a risk factor which is defined as the product of the dose level and its probability of occurrence. The whole scenario thus represents a complete model which can also be applied to real or simulated situations to know their level of risk. The final outcome is a means to build and support a hierarchisation in terms of dosimetry for activities, work places, past incidents, simulated events, etc.

It will be shown, using examples, that this model has been applied to the following studies :

- To choose between different types of equipment in order to limit the danger of exposure for workers (tags, dosimeter, ...).

- To assess the severity of incidents so as to better identify their priorities for treatment and to propose solutions/remedies.

- To evaluate different regulations from the viewpoint of radiological risk.

Finally, we present the latest findings obtained from a study of accident scenarios that are specific to gammagraphic inspection operators and their teams. We will show that the experience/feedback from the last 10 years at EDF NPPs can be enhanced by a quantitative analysis of risks linked with each event.

In conclusion, it will be shown that the basic principles of our method can be further generalized to other activities that have dosimetric importance. This ultimately allows us to envisage a comprehensive mapping of radiological hazards that exist in an NPP. This mapping helps us to develop "decision tools" that are built on a robust and structured vision of radioprotection that is expected by EDF/DPN managers.

P06.05
Regulatory Framework and Technology Development for Advanced Fuel Cycle Facility in Korea

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Operation of nuclear power plants (21 units) in Korea are generating about 700 MTU of spent fuels annually. The inventory of spent fuels in Korea was estimated about 11,734 MTU at end of 2010, and the spent fuel pools in NPPs won't be available about a decade later due to the saturation. As a long term of spent fuel management plan in Korea, fast reactor and advanced fuel cycle research and development plan were approved by 255th meeting (22.12.2008) of Atomic Energy Commission (AEC). The approved advanced fuel cycle (AFC) R&D plan is that the uranium and TRUs are recovered from PWR spent fuels using pyrochemical processing (pyroprocessing), and formulate metal fuels for utilizing at the Gen IV-SFRs. Heat load elements (Cs, Sr) are removed from the spent fuel and it reduces the repository burden up to 1/100. The fission products (FPs) are also recovered and transferred to a repository. As a result of pyroprocessing, both repository efficiency and U usage can be increased significantly. The recycling of recovered resources can increase uranium usage efficiency, decrease radiotoxicity, and reduce high-level waste volume. Eventually, pyroprocessing can reduce the 300,000 year of spent fuel management period up to 300 years.

Korea Atomic Energy Research Institute (KAERI) is now constructing PRIDE (inactive demonstration facility) facility for the pyroprocessing research using inactive materials. The KAERI has the construction plan of Advanced Pyroprocess Facility with engineering scale that are composed of decladding, voloxidation, electroreduction, electrorefinning, electrowining, fuel fabrication, and waste salt treatment process in near future.

The Korea Institute of Nuclear Safety (KINS) has been conducting the research project to develop regulatory framework for AFC facility by reviewing Atomic Energy Act (AEA). The regulatory technology development for the AFC facility are consisted of the establishment of the AFC licensing regulatory system, the establishment for the AFC criteria and standards, and the development of the safety evaluation technology for the AFC system. Using the result of this research, KINS will prepare a comprehensive set of safety standards including radiation shielding and protection, criticality, chemical hazards, fire and explosion, off-gas treatment, and high-level and low-level radioactive waste management.

P06.06
Health Assessment of Nuclear Workers from Areva NC – La Hague: Preliminary Results

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A morbidity study of nuclear workers from Areva NC is carried out in France. It is based largely on data collected from Occupational Medicine services of AREVA NC using the software called "Chimed" implemented since 1994. For each worker, all incident health events, as well as administrative data, were registered in the Chimed database, during medical visits with an occupational physician. Age and calendar year - standardized incidence rates (IRs) were estimated for major categories of diseases and for some specific pathology.

The study included 4387 workers employed in the site of AREVA-NC – La Hague between 1999 and 2009. Most employees were men (85%). A total of 2303 incident diseases were registered for 1671 workers. Traumatic lesions were the most frequent for men (IRs=1514 cases per 100,000 person-years). Diseases of the muskulosqueletal system and connective tissue were the first major cause of disease for women and second for men (IRs=1158 cases/ 100,000 p-y for women; IRs=1306 cases/ 100,000 p-y for men).

The Chimed database provides an overview of the health status of the Areva-NC workers. At this stage, only workers with a statutory position were included in this analysis but it will be extended to all AREVA-NC – La Hague workers.

P06.08
Information System on Occupational Exposure and ISOE Database

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Since 1992, the Information System on Occupational Exposure (ISOE) has supported the optimization of worker doses in nuclear power plants worldwide. A prerequisite for applying the principle of optimization to occupational radiation protection (ORP) is appropriate and timely exchange of data and information on dose reduction methods. To facilitate this global approach to work management, the OECD Nuclear Energy Agency (NEA) launched the ISOE programme with the objective of providing a forum for radiation protec-tion experts from nuclear electricity utilities and national regulatory authorities to discuss, promote and co-ordinate international co-operative undertakings for ORP of workers at NPPs. Since 1993, the International Atomic Energy Agency (IAEA) has co-sponsored the ISOE programme, thus allowing the participation from non-NEA member countries. ISOE operates in a decentralized manner. A Management Board of representa-tives from all participating countries, supported by the joint NEA and IAEA Secretariat, provides overall direction. Four ISOE Technical Centers (Europe, North America, Asia and IAEA) manage the programme's day-to-day technical operations.

Official participants to the ISOE programme include (as of August 2011) 66 utilities in 26 countries (320 operating reactors, 40 shutdown reactors) and regulatory authorities in 24 countries. The ISOE database itself include information on occupational exposure levels and trends at 401 operating reactors in 29 countries, covering about 91% of the world's operating commercial NPPs. The database is available to partici-pants through the web-based ISOE Network.

As a routine mechanism to explore common interest fields, the ISOE create and mandate expert groups to improve the information exchange between participants and allow all members to use the feedback experi-ence from all participating authorities and utilities. As an example, an expert group was established to pro-vide guidance to the nuclear community on the best practices of work management in NPPs. The report, "Work Management to Optimize Occupational Radiological Protection at Nuclear Power Plants", was pub-lished in 2009. It provides practical guidance based on the operational experience within the programme. In addition, two expert groups on NPP water chemistry and source-term management and ORP in severe acci-dent management following the incident at Fukushima were established recently.

This paper provides details on the products available through ISOE and ongoing activities, including the types of data available through the ISOE database.

P06.10
High Dose Tasks Robotization. Application to Water Filter Change

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For several years, EDF R&D has studied the robotization of high dose tasks. The first step was to make reviews of concerned operations and of the robots used in Nuclear Power Plant (NPP) Worldwide. Then, application cases, like water filter change, were studied.

First, high dose operations are still remaining in nuclear industry in France. Study, based on dose data, for workers getting more than 10 mSv on two periods of 12 months between 2005 and 2009, shows that it is possible to identify few tasks that lead to major individual doses. The concerned tasks are: reactor pressure vessel head opening/closure, logistics, SG preparation/operation, valves maintenance and insulation installation/removal.

Moreover, robots are used in many industries, and also in nuclear industry worldwide, but not really in France. So, an international review was made in order to know the robots used in NPP, and to determine if those kinds of robots could lead to a decrease of the individual dosimetry, especially for the tasks identified earlier. Finally, five types of robots were identified: AUV's (Autonomous Underwater Vehicle), Crawler, Suction/magnet Robot, Anthropomorphic arm and Snake arm.

High dose tasks and types of robots that could be lead to a dose reduction were defined. As a first application case, EDF (Electricity of France) studied the robotization of several operations of water filter change in 900 MWe PWR in France. These operations are currently done manually in ventilated protective suit. Contact dose rates are about 100 mSv/h and can reach 600 mSv/h. The operation is done in orange or red area. During the whole operation, the integrated dose is around 1 man.mSv as a total for two operators. This operation is done once a year.

The R&D study conducted to the design of a mobile platform, with all the needed robotics devices for the operation. This robotic platform is able to operate automatically in order to have operator as far as possible from the high dose area. It was chosen to robotized only the high dose subtasks. The robotization of all this tasks implies a potential dose reduction of 50% (0,5 man. mSv) for the whole operation.

This demonstration proves that this robotic concept works for this kind of operation. Extension to an industrial demonstrator was studied to estimate needs and costs. Demonstration in NPP could be planned in the next few years.

Major dose reduction for higher dose tasks could be expected with robotization. Studies to conclude on it will be conducted in the next years.

P06.11
A Portable Gamma Imaging System dedicated to the Detection and the Direct Visualization of Hot Spots (mainly 60Co) in Nuclear Power Plants

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In a nuclear power plant (NPP), the localization of radioactive hot spots is a major issue, as they are responsible for a significant part of the doses received by the workers, especially during maintenance operations. They are mainly due to the presence in the water of activated corrosion products, 60Co / 58Co, as well as some other radionuclides, and hence are encountered in pipes.

Since 2010, EDF and CEA LIST have been adapting a new generation gamma camera, GAMPIX, to have a dedicated portable tool available for this use. This system enables to superimpose a gamma image with a visible image, in order to locate radioactive sources in a given area.

GAMPIX is based on three main components: the Timepix pixellated chip, hybridized to a 1 mm thick CdTe substrate, a coded mask and a USB module to connect the control computer. With this configuration, the weight of the system can be as low as 1 kg, compared to 10 to 40 kg for existing gamma cameras on the market.

On-site measurements at the Tricastin EDF NPP, combined with specific developments at CEA LIST, have been carried out in order to meet the particular environmental and radiological conditions experienced in such industrial facilities: the relatively high energy of 60Co (1.17 MeV and 1.33 MeV) and the existence of an ubiquitous background. The particular improvements performed include the optimization of the coded mask, the methodology of measurement along with the software treatment of the images. Specific developments have also been carried out in order to enable the portable use of GAMPIX, like a camcorder.

This presentation focuses on the results obtained with the adapted gamma camera during the NPP campaigns.

Main conclusions are:

• The GAMPIX gamma camera is very easy to handle, it is an actual portable instrument, and the images are obtained in a very short time (several seconds to a few minutes for the data acquisition, and the same for the data treatment);

• Even if they were dedicated to the qualification of the camera, the tests carried out showed useful results such as the leakage lines along a lead protection, the observation of a wrong location of a hot spot in a pipe (compared to its identified position).

• The measurements were mainly carried out on a tripod, however the possibility of acquiring an image in the camcorder mode has been demonstrated.

GAMPIX is still under development, the next stage will be to analyze the gamma image in order to roughly assess the energy spectrum of the source.

P06.12
UK Arrangments for Radiation Protection

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Introduction

Dose reduction for nuclear workers is keenly progressed within the UK nuclear industry since inception of nuclear power in the late 1950s

Dose reduction in the UK

Regulators are keen to see doses reduced further, making performance indicators and reviewing event reports to ensure lessons are learnt and broadcast to other sites.

Radiation Protection Advisor

In our regulations since 1985, radiation protection advisors (RPAs) have a raised profile.

RPAs must develop and retain competency to maintain accreditation and have to reapply, demonstrating knowledge and competence, every 5 years:

Arrangements for radiation protection on nuclear sites

Employers must provide safe work arrangements, protective equipment and adequate supervision. Dose targets have incentives and are presented widely, including to the local community.

Positive 'No Blame' safety culture to reduce radiation dose

Prompt investigation, event reporting and learning

Appoint Duly Authorised Persons

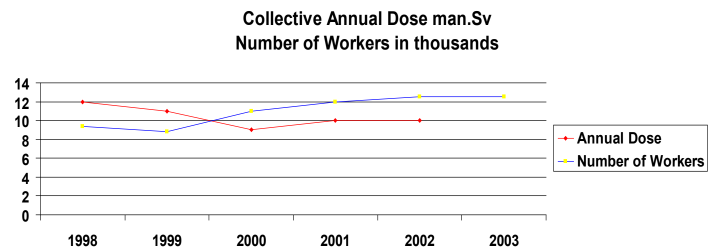
Focus for improvements in dose restriction

Health physics work with production departments and add radiation safety advice to ALL work with radiological implications

Dose reduction since the start of IRR99

It's difficult to compare doses received with time:

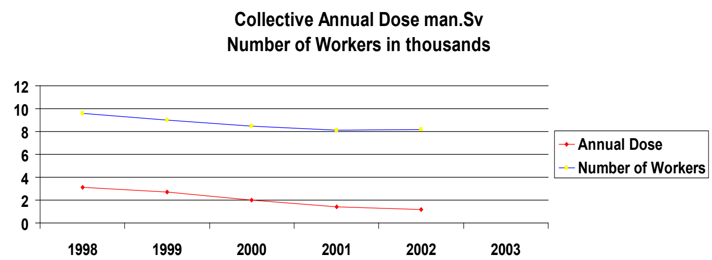
- Arrangements for monitoring dose differ at most sites
- Sensitivity of dosimeters improved and gave rise to apparent dose reductions.
- Dose statistics are not readily available
- As plant ages dose rates will increase.



Sellafield

'a decrease in collective dose against an increase of work (number of workers)'

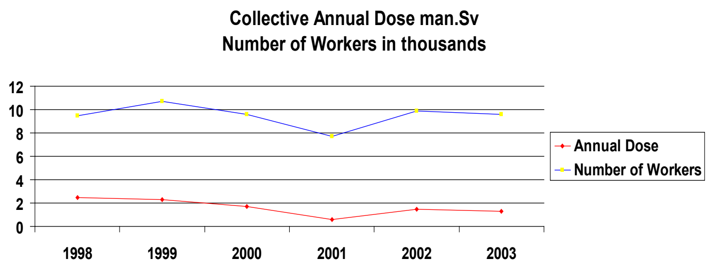
Magnox



'a marked decrease in annual dose'

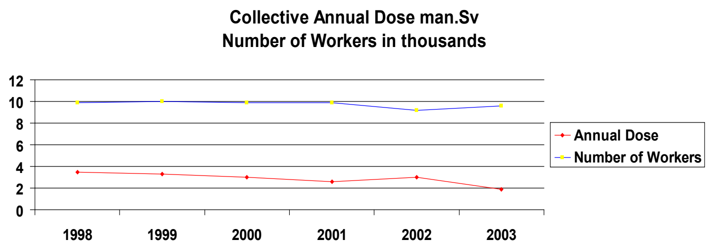
Poster sessions A-B: Area 6

British Energy



'annual dose decreasing against a background of increasing reactor life'

Ministry of Defence



'a marked reduction in dose'

Reduction in collective dose since IRR9

Radiation levels rising on operational plant

The UK has adopted a sound system of radiation protection

The RPA role is key in establishing sound advice

Industry generally goes much further to reduce radiation dose that monetary value, to gain support of regulators and work force.

P06.13
Suggestions on the Improvement of Regulatory Activities on Nuclear Equipment in China

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As we all know, the nuclear energy is a very clean energy compared to the fossil energy. Effective defenses against potential radiological hazards should be established and maintained in the nuclear power plants. So, the related activities on nuclear equipment, which are the cores of the entity barriers of the nuclear power plants, should be well controlled by the vendors, the owner of the nuclear power plants as well as the regulatory body. This paper aims to introduce and analyze the good regulatory practices of Chinese government on the nuclear equipment, and the author intends to bring some suggestions on the improvement of such regulatory activities. The author also hopes that it will be useful for the new entrants who want to introduce the nuclear power plants and other countries who want to intensify the regulation on nuclear equipments.

P06.14
Estimation of Environmental Release of NPP Based on Containment Measurements

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In the past few years a new method for estimation of environmental release in a containment overpressure type accident at NPP was elaborated in the Hungarian Academy of Sciences Centre for Energy Research. In case of large break loss of coolant accident (LOCA) a significant amount of radionuclides are released within a short period of time into the containment from the primary circuit. A fraction of these nuclides can get into the rooms of the NPP by leakage due to increased pressure of the containment and eventually can get to the environment through the ventilation systems. Devices measuring the release from the ventilation stack may be saturated in these cases. Moreover, a part of radionuclides can get directly to the environment via the rooms of the secondary circuit.

The calculation method is based on measurements of the overpressure in the containment and the dose rate of radionuclides released to the containment. The initial rates of different nuclide activities in the containment can be estimated considering the gap activity and activity that may be released from the fuel matrix itself due to clad failure. Radionuclides released from the primary circuit can get partly to gas phase or liquid phase. This distribution rate is nuclide dependent, while the time dependence of the initial rate of different nuclide activities can be calculated by taking into account the radioactive decay, wash-out by the sprinkler system and deposition to the containment's walls. For the dose rate calculations the dose conversion factors for the position of the high range dose rate meter in the containment have to be known, for both gas and liquid phase.

In this way, based on the calculated dose rates for 100% fuel failure and on the measured dose rates, the actual activity concentration of each radionuclide in the containment's atmosphere can be estimated. The leakage emission from the containment is a function of overpressure that is also measured, thus the actual activity release rates from the containment can be estimated for each radionuclide.

An on-line, real time calculation code that performs calculations on the above method has been developed and put into operation at the Hungarian nuclear power plant.

P06.15
Radiological Protection During a PWR Refuelling Outage

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Refuelling outages take place every eighteen months at Sizewell B (SZB) Power Station. During an outage, the fuel is moved from the reactor pressure vessel to the fuel building enabling a large number of inspections and maintenance work to take place across the plant. Every third outage, the reactor coolant level is reduced to a lower 'mid-loop' level to allow inspections on the primary side of the circuit. In the autumn of 2011, refuelling outage 11 (RFO11) commenced at SZB station, this outage was a mid-loop outage with the addition of two large projects to replace the pressuriser heaters and a reactor coolant pump (RCP) impellor. These two projects were a first at SZB, and in the UK. This paper describes the radiological protection methods employed to ensure the safety of personnel working inside the reactor building during the outage.

The expected radiological conditions at the primary side steam generator platform, around the pressuriser and on the RCP platform during the mid-loop phase are described, along with personal protective equipment, radiological monitoring and communication requirements. Reactor coolant levels are at a minimum during the mid-loop phase resulting in significant ambient dose rates at the working platforms of the three projects; for example underneath the pressuriser general dose rates were 1-2 $mSvh^{-1}$. The heater replacement took 16 days with a maximum individual external dose of 4.2 mSv. The collective dose for the project was approximately 98 man.mSv involving approximately 100 personnel). As a heater was removed from the bottom of the pressuriser significant levels of beta contamination were generated in the work area (4 $kBqcm^{-2}$). To prevent contamination spreading outside of the local area a number of methods were employed and these are addressed in the paper. Good undress and monitoring procedures were vital to preventing a large number of personal contamination events.

The specific issues at the steam generator and RCP work platforms are discussed with a focus on the procedures used to control dose uptake and a spreads of contamination. The total cumulative dose for the 50 day outage was 492 man.mSv with a maximum individual dose of 4.2 mSv. This paper aims to provide the reader with an insight into the tasks carried out during a typical PWR outage, the radiological conditions in the containment building and the methods employed to ensure exposure to ionising radiation remains ALARP throughout the outage.

P06.16
ALARA Design Concept of SMART Reactor for Standard Design Approval

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Small modular reactors (SMRs) are part of a new generation of nuclear reactor being developed worldwide. One of the beneficial advantages of SMR is the easy receptivity of advanced design concepts and technology. SMART (System integrated Modular Advanced ReacTor), a small sized integral type PWR with a thermal power of 330 MW, is an advanced SMR. Since several groups within a SMART design organization (e.g,. mechanical engineering, main component design, system design, safety analysis, radiation protection groups) are interested in SMART reactor design and equipment selection, an ALARA evaluation team was installed in order to control and review all of design products within SMART organization. The ALARA evaluation team ensure that these groups are adequately represented in the review of the design of the facility and the selection of equipment. A coordinated effort by the several functional groups within SMART organization is required to ensure that plant features will permit the goals and objectives of the ALARA program to be achieved.

Design concepts and plant features should reflect consideration of the activities of plant personnel that might be anticipated and that might lead to personnel exposure to substantial sources of radiation. Radiation protection aspects of decommissioning should be factored into planning, designing, construction, and modification activities. Plant design features should be provided to reduce the anticipated exposures of plant personnel to these sources of radiation to the extent practicable.

Specifications for equipment should reflect the objectives of the ALARA program, including consideration of reliability, serviceability, limitations of internal accumulations of radioactive material, and other features addressed in this guide. The SMART design based on ALARA concept for standard design was completed by the end of 2010.

P06.17
Dispersion Modelling of Routine Atmospheric Discharges from Proposed UK New Nuclear Build Site Locations

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The consequences of the routine discharge of radioactive material to the atmosphere from new build nuclear power plants (NPPs) planned for the UK are of significant interest and concern. As a result, the RPII is currently undertaking a comprehensive assessment of anticipated doses to the Irish population arising from such discharges. Here, the results of atmospheric dispersion modelling which has been performed to simulate these discharges are presented. These results will be used as the radiological input to the dose assessment, the results of which will be presented elsewhere.

Emissions from the eight currently proposed new build site locations have been simulated over a 21 year period (1990-2010 inclusive) using NOAA's HYSPLIT model. Similar use of a deterministic model for this type of climatological application has previously been demonstrated. HYSPLIT was driven by ERA-Interim reanalysis meteorological data from ECMWF with spatial and temporal resolutions of 0.75 degrees and 6 hours respectively and a model domain covering the northern hemisphere. Emissions were modelled as a 3-dimensional particle distribution (horizontal and vertical). HYSPLIT was run with constant one unit per second release rates for 13 radionuclides, each with a typical half-life, and belonging to one of three representative groups (particulates; iodines; and noble gases, H-3 and C-14) determining deposition characteristics.

The results have been used to derive annual average atmospheric transfer coefficients (CTA) for air concentrations (s/m^3) and deposition (s/m^2). CTAs have been mapped for Western Europe. Time series of CTAs for receptor locations of interest have also been plotted. CTAs can be considered as scaling factors which can be multiplied by annual emission rates to assess the long-term impact of routine discharges. CTAs have been calculated separately for each location to enable use of site-specific release rates.

Modelling over a recent 21 year period has ensured that the results are representative of the long-term climatology. This also enables the intra- and inter-annual variability to be assessed and, subsequently, the most conservative, realistic scenario to be identified for use in the dose assessment. PC CREAM 08 will be used to calculate doses. It is noted that the dispersion model PLUME included in PC CREAM 08 is unsuitable for calculations at distances greater than 100km from release locations, further necessitating the work presented here.

P06.18
Prospects for Nuclear Energy in Kenya under Vision 2030

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Overcoming energy poverty is one of Kenya's greatest challenges. Majority of Kenyans currently have no access to modern energy services and technologies. The challenge is thus to find appropriate and reliable solutions for providing energy sources for social and economic development. This study intends to focus on the development of nuclear power technology plans under the Kenya 2030 vision. This research project intends to investigate the advancement stages that Kenya has undertaken towards the implementation of nuclear power plants and thereafter recommending some energy policy considerations. A background review of energy in Kenya, future trends predictions, establishment of nuclear vision, technology development, research collaboration, international co-operation and construction of nuclear power plants methodological strategies are overviewed and projected through the 2030 vision using various models. For sustainable development, several measures including improvements in energy efficiency and recommendations of energy policy considerations will be studied. The study will provide a useful starting point for policy makers interested in the state of the ecosystem.

Keywords: Kenya, energy, environment, nuclear, power, plants

P06.19
Permitting of New Nuclear Power Stations: The Environment Agency's Role at Hinkley Point C

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In 2008 the UK Government announced that new nuclear power stations should be part of the country's future generation mix. The Environment Agency (EA) and the Office for Nuclear Regulation (ONR) are responsible for ensuring that any new nuclear power station built and operated in England and Wales meet high standards of safety, security, environmental protection and waste management. In response to a Government request, the EA and ONR established a new pre-licensing process called Generic Design Assessment (GDA). We have been assessing two Pressurised Water Reactor (PWR) designs in GDA, Westinghouse's AP1000® plant and EDF and AREVA's UK EPR.

In July 2011, the UK Government's National Policy Statement for Nuclear listed eight sites that were considered potentially suitable for new nuclear power station deployment by 2025. Following designation of the National Policy Statements, EDF Energy's NNB GenCo Ltd submitted three environmental permit applications to the Environment Agency for the operation of two UK EPR units at Hinkley Point in Somerset. The applications relate to discharges and disposals of radioactive waste, operation of standby power supply systems, and discharges of cooling water.

This paper focuses on the Environment Agency's work on new nuclear build, on GDA and site specific permitting including lessons learned and issues raised. It also covers our input to the new planning regime for major infrastructure projects in England and Wales.

P06.20
NEA Workshop on Good Practice in Effluent Management for New Build

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The OECD Nuclear Energy Agency has for some time been working to help our member countries assure that the construction and operation of nuclear power plants is carried out in a safe and secure fashion. To help achieve this end, the NEA's Committee on Radiation Protection and Public Health (CRPPH) asked how optimisation and best available techniques (BAT) would be assessed and implemented for the management of effluents from new plants. To answer this question, the CRPPH established the Expert Group on Best Available Techniques (EGBAT) to develop a preliminary report, and organised a workshop, to be held in January 2012, to invite regulators, operators and reactor vendors to discuss their understanding of best approaches to effluent management.

The Expert Group investigated effluent discharges and discharge management specifically from the precursors for the following reactor types, seen as the most likely for new build in some regions of the world: AP1000, CANDU, EPR, and ESBWR. The report considers the principles of optimisation related to projected individual and collective doses to members of the public and the principles of "best available techniques" for effluent management during the life cycle of a new reactor unit.

The workshop will focus on achieving a broad understanding of the practical aspects of effluent management regulation and application, with a view to support the development of a document summarising a collective view of "good practice". The overall objective of the workshop will be to identify those optimisation and BAT effluent management aspects on which there is agreement, and on which there still remain questions for example:

• What are the aspects of effluent management that characterise good practice?

• Building a bridge between good operating practice for Gen 3 to New Build

• What aspects of monitoring and reporting could use some form of harmonisation, and why?

• If you had no constraints to improving your system, what would you change? What priority would you identify to selecting from such a list of possible improvements?

P06.21
Radioanalytical Determination of Fe-55 and Ni-63 in Environmental Samples

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Both Fe-55 and Ni-63 are activation radionuclides which are determined, in different and complex matrices in the process of nuclear installations dismantling. Usually, low detection limits are required and an increase in the amount of sample used in the determination process is one of the ways used to attain this goal. This increase in the amount of sample produces obviously an increase in the chemical and radioactive interferences that produce lower separation yields and erroneous determinations due to measurement interferences.

In the literature we can find several works about Fe-55 and Ni-63 separation. Most of them are based on the use of ion exchange and a specific resin for nickel after precipitation of iron and nickel as hydroxides. Complex matrices and the increase of sample amount produce more hydroxides that can interfere in the separation, mainly in nickel separation due the required pH between 8 and 9 that produces a precipitate difficult to pass into the nickel resin.

In the proposed method and in order to avoid the presence of theses cations that produce hydroxides, a previous step in the separation is used: iron and nickel are precipitate together, iron as hydroxide and nickel as a complex with dimethylglyoxime. In this method only a pH of 6 is enough to precipitate iron Fe(OH)3 and the nickel- dimethylglyoxime-complex, maintaining the rest of cations in solution. To improve the iron separation a step of liquid-liquid extraction with diisopropyl ether is carried out after the use of an anion resin. Nickel, after precipitation and passed through the same column as for iron, is passed through the specific Ni-resin.

To determine radiochemical yields, aliquots of the separated nickel and iron are taken to measure by atomic absorption. Results must be corrected by the Iron previously determined in the sample. To solve the matrix effect problem the method of standard addition is used in the AA measurements in complex samples. The chemical yield of iron using this procedure is around 90% and around 80% for nickel. The remainder of the sample is measured by liquid scintillation counting.

This method has been validated by application to spiked environmental samples and by participation in intercomparison and in proficiency test.

In this paper, the chemical method used and the results obtained for chemical yields and validation process are presented.

P06.22
Remediation of a Radium-Contaminated Facility with High Radon Levels

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AMEC have carried out remediation of a facility for legacy contamination resulting from the sites previous use as a luminising works. The works involved the decontamination of building fabric, excavation works and the preparation for disposal of arisings (including characterisation, size reduction and packaging of resulting contaminated waste).

Various decontamination techniques were employed throughout the works, including novel innovative techniques developed specifically for challenges encountered during the works. All clean wastes undertook clearance monitoring before their removal from the controlled areas, `as soon as reasonably practicable`, to minimise risk of contamination. The clean wastes were double-bagged, characterised and then assigned to an agreed disposal route for removal from site. All contaminated waste arisings were packaged at the workface and placed in segregated lay-down areas, to minimise the risk of cross contamination. The wastes were double bagged and collected into the lay-down areas before being characterised and disposed of into one of two types of containment for removal from site.

A comparison was made of real-time monitoring data and a more traditional air sampling and decay counting technique. It was found that there was good agreement between the measured radon daughter air concentrations made by the different methods. Estimates are also presented of the calculated unmitigated dose uptake for workers with and without the use of respiratory protection equipment.

Real-time monitoring data shows the rapid increase in radon levels overnight when ventilation measures were inactive and the marked effect of use of air handling units on the radon concentration.

P06.23
Entombment - Still an Option and Potential Implications

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The paper will address the past and recent implementation of the entombment as a strategy for decommissioning of relatively small nuclear facilities. It will discuss the safety and other long-term aspects related to the use of this option. It will also elaborate on the application of the existing international safety standards (e.g. International Atomic Energy Agency) and in particular the ones on radioactive waste disposal (e.g. Specific Safety Requirements No. SSR-5).

Poster sessions A-B: Area 6

P06.24
Decommissioning in the Non-Nuclear Sector.

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In England and Wales the keeping and use of radioactive material and the accumulation and disposal of radioactive waste, is regulated under the Environmental Permitting Regulations 2010.

When an operator wishes to stop using radioactive material or wishes to move from site they will usually submit an application to "surrender" their permits. In the case of regulated sites, the operator will need to convince the Environment Agency that there is no radioactive legacy left on site before a surrender will be granted. If the operator proposes that very small amounts of radioactive substances are to remain on site, these will need to be characterised appropriately to ensure they meet the criteria for exemption.

Sites with a legacy of radioactive contamination from past practices often become suitable for development. The use of radioactive material and the disposal of radioactive waste may have taken place before regulations were in force. This may lead to developers and land owners having to deal with potential accumulation and disposal of radioactive waste from such practices.

This paper will outline the regulatory control of radioactive waste and guide operators on what the Environment Agency expects from an operator who applies to surrender a permit. It will describe the issues surrounding land contaminated with radioactivity and how to develop appropriate remediation strategies – referring to known issues for particular types of site.

Phil Fahey, September 2011.

P06.27
Regulatory Challenges Of Decommissioning In The UK

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The Nuclear Industry in UK contains facilities in all phases of the life cycle and work is in progress on a new generation of reactors. The scale of this work represents significant challenges for existing licensees, contractors and regulators. Decommissioning is an issue that needs consideration in all phases from design to actual decommissioning operations. There are opportunities to learn from existing experience that enable application in the new build arena as well as options for existing decommissioning plants. This is currently under consideration within ONR, including revisions to our current Technical Assessment Guides. The paper will review the development of our regulatory approach and how this has been applied to a number of examples that capture the breadth of work within the UK. The examples will include regulation of aspects such as the Magnox reactor decommissioning programme and contrast with situations involving high hazard facilities. The intention is to explain how effective regulation has to balance the need to enable hazard reduction through decommissioning activity while maintaining effective safety consideration through the ALARP process.

P06.28
Data Collection on Occupation Exposure at Nuclear Power Plants under Decommissioning - Challenges for the Information System on Occupational Exposure

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Since 1992, the Information System on Occupational Exposure (ISOE) is a network of utilities of nuclear power plants and of regulatory authorities. The network serves as a platform for international experience feedback on occupational radiation protection in nuclear power plants in operation as well as under decommissioning. The ISOE pro-gramme includes 66 utilities in 26 countries (320 operating reactors, 40 shutdown reac-tors) and regulatory authorities in 24 countries. The ISOE database itself includes information on occupational exposure levels and trends at 401 operating reactors in 29 countries. The main activities of ISOE include experience exchange on occupational radiation protection at nuclear power plants, the annual collection and analysis of occupational exposure data in nuclear power plants and publication of related annual reports and the organization of regional and international symposia on occupational radiation protection and the implementation of the ALARA concept.

Up to now the means for the annual collection of data related to the occupational exposure of the personnel in nuclear power plants are mainly reflecting the situation of nuclear power plants in operation. Such operation is characterized by a high level of standardization of jobs and task to be performed; this allows - with limitations - the comparison of data of different years for a specific nuclear power plant and of data of different nuclear power plants and the identification of potential lessons learned to support a systematic experience exchange among the ISOE participants. Different to the situation for nuclear power plants in operation the occupational exposure at nuclear power plant under decommissioning (same as of all other nuclear facilities) is strongly resulting from jobs and tasks and the related working conditions; which vary significantly from year to year at one nuclear power plant and are also very different for different nuclear power plants. Accordingly, a data collection cannot easily be based on standardized jobs and tasks and any conclusions on lessons learned to support the experience exchange is difficult.

Within this contribution the challenge of how to design a systematic collection of data on occupational exposure within the ISOE is presented. The findings of the Task Group on Decommissioning activity within the ISOE Working Group on Data Analysis are presented including a new concept for a data collection and the approaches included to support a data based experience exchange on radiation protection aspects during decommissioning.

P06.29
The Requirement For Proper Storage Of Nuclear And Related Decommissioning Samples To Safeguard Accuracy Of Tritium Data

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Large volumes of potentially radioactive waste materials are generated during nuclear decommissioning that require accurate characterization prior to final waste sentencing. One of the radionuclides that is often widely disseminated is tritium which requires specific measurement as the nuclide is volatile and cannot be reliably linked to a waste fingerprint. These characteristics also potentially impact on its migratory behaviour during sampling and sample storage. The extent of any tritium redistribution will depend on the form of ^{3}H present in different materials. Tritium contamination can be classified as weakly-bound and strongly-bound ^{3}H depending on its ease of release from the matrix. Weakly-bound tritium is readily lost at temperatures up to 100 °C and can exchange with atmospheric water vapour at room temperature. However, the loss of strongly bound tritium is not significant even at room temperature. Strongly bound ^{3}H exhibits slow exchange and diffusion rates as the ^{3}H is trapped within mineral lattices. The characteristics of any potential receptor materials are a significant factor affecting the degree of ^{3}H cross contamination. Porous hydrophilic materials will be more contaminated by absorption, diffusion and isotopic exchange reactions and the magnitude will be controlled by storage temperature and sample containment. As samples may contain different forms of ^{3}H , cross contamination and loss of ^{3}H may be a concern during storage and sampling procedures. For quantitative ^{3}H analysis supporting waste sentencing (nuclear and related) strategies, reliable sampling and storage are required. The degree of ^{3}H loss and cross-contamination can be reduced significantly by careful selection of the storage conditions. These involve (1) storing samples in airtight and vapour tight containers at the point of sampling, (2) storing samples in a freezer (3) and effective segregation of samples with different ^{3}H activity concentrations to prevent ^{3}H loss and cross contamination.

P06.30
Challenges For The RP Team During The Transition-Phase From Operation To Dismantling And "Green Field" Restoration.

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This paper discusses the challenges and possibilities for the radiation protection teams planning and operation during the transition-phase, from operation to dismantling and "Green Field" restoration for the Barsebäck NPP.

The two ABB built BWR:s at the Barsebäck site was shut down 1999 and 2005 after a political decision. The practical dismantling and decommissioning was however decided not to be started until the Swedish repositories should be ready due to the original time plan, in app. 2020. This gave the organisation some benefits but also many challenges.

This paper describes the different problems the organisation faced under the waiting-time but also some glimpse of the RP planning for the coming dismantling period.

Areas discussed:

· How to remain the personnel and knowledge under such a long period ?

· How to prepare the station for the dismantling, decontamination or not, other possibilities ?

· Focus on individual doses or on collective dose ?

· Save occupational doses or/and reduce the environmental impact ? Conflicts ?

· New work areas, extremely large components, site restoration, groundwater problems and more.

· Characterisation of building, land, materials and components.

· Waste handling.

· Competence problems with the new contractors, contractors not used to work in NPP:s.

P06.32
The Role And Conclusions Of The Health Protection Agency (HPA) Regarding The Partial Delicensing Of The Oldbury Power Station Nuclear Licensed Site.

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The Health Safety Executive (HSE) appointed the HPA to perform an independent final site survey of the area to be delicensed around the Oldbury power station nuclear licensed site. The HPA also examined the licensee's methodology and conclusions drawn from analysis of the licence holder's data to ensure that all conclusions drawn are valid.

The Oldbury nuclear licensed site consists of the twin Magnox reactor power station and adjacent land (total 71 ha) located on the southern bank of the River Severn estuary, eleven miles north of Bristol. The area to be delicensed was relatively large consisting of around 32 ha all of which were situated outside of the site security fence. Much of the area was relatively inaccessible due to either being marsh land or densely wooded. In addition a large part of the area had been designated a Site of Nature Conservation Importance (SNCI), making access difficult.

The power station was constructed in the 1960s and first generated electricity in 1967. It remained operational at the time of the partial delicensing; however no part of the power station site fell within the area to be delicensed. The application area was sub-divided into a number of smaller zones for the purposes of the delicensing. These were:

- A Silt lagoon and its associated raised bund
- Open undisturbed grass and woodland
- Roads and car parks
- Oldbury technical centre and Oldbury Conference centre

The Data Quality Objective system was followed with this being the first site in the United Kingdom to be granted a variation in license based on this methodology. The validation of the assumptions made using these methods are discussed as are the conclusions drawn by the license holder.

The HPA's sample and measurement results are presented and the levels of agreement with the license holder's results are presented. The overall conclusions relating to the No Danger criterion of a risk of less than 1 in a million are reported.

P06.33
Decontamination and Decommissioning of UK Pharmaceutical R&D sites: a Radiological Protection Perspective

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The UK pharmaceutical R&D sector has for many years been a major 'small user' of radioactive materials: usage of the traditional life-sciences radionuclides predominates although recently scope has extended to include PET imaging materials. However, the current economic climate and other drivers have led to major reassessments of established medicines/drug discovery paradigms and the result has been further rationalisation within the sector, leading to the closure and divestment of some well-established R&D sites.

Radiological decontamination and decommissioning of such premises before disposal is essential: it is not only a legal requirement, but is also an expectation of all involved stakeholders including purchasers, site neighbours and shareholders. Such operations present a variety of challenges: more stringent regulatory requirements, timescales, costs, site history, accessibility of records, loss of local expertise and non-radiological hazards to name but a few. This paper reviews the radiological decontamination/decommissioning strategy adopted by a major UK pharmaceutical company prior to the recent disposal of two major R&D facilities.

P06.34
Application Of ISOCS In The Measurement Of Bulk Plutonium Contaminated Waste During Decommissioning.

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Perhaps the most significant yet sometimes underestimated aspect of decommissioning is the measurement and management of the waste generated. There are a variety of techniques applied that require the need for sampling and measurement. In this project the approach taken was to reduce the sampling requirement and apply a bulk assay technique i.e. the measurement of 200 litre waste drums. This method has often been applied to fission / activation product waste but in this case the project was the decommissioning of Plutonium contaminated waste. The usual technique applied to such bulk waste is neutron counting. However the detection sensitivity is such that waste will always fall into the Intermediate Level Waste category. To improve on this a gamma counting technique was investigated. Using Canberra's ISOCS modelling system and inputting variations such as bulk density, materials, activity distribution it can be shown that the computed efficiencies for ^{241}Am and ^{239}Pu plus their uncertainties allow Low Level Waste detection to be achieved.

P06.35
Radiological Protection Arrangements for Decommissioning the complex Nuclear Site at Dounreay

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The Dounreay site is situated on the north coast of Scotland, mainland United Kingdom, and is operated under contract to the UK's Nuclear Decommissioning Authority (NDA) by Dounreay Site Restoration Limited (DSRL). DSRL is a wholly-owned subsidiary of UKAEA Limited which is part of the Babcock International Group. Dounreay was instrumental in fast breeder reactor research and fuel reprocessing plant development. The site's business is now one of safe decommissioning and remediation.

To support the timely and financially constrained safe decommissioning, processes and personnel need to be focussed on achieving the business objective. DSRL also requires an independent assurance function, but has embedded some of the assurance function and 'projectised' staff to support project delivery to achieve the business objective.

This paper discusses the evolution of the current arrangements and the expectations for the future, including a review of challenges and successes. The paper also describes some of the decommissioning projects that have benefited from the proactive support and the enhanced controls that have evolved over recent years.

The paper concludes with a review of the lessons learnt during the evolution.

P06.36
Radiological Control Programme During Decommissioning Projects At Necsa

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The present nuclear generation is becoming increasingly aware of the necessity of dealing with nuclear liabilities resulting from the operation of redundant nuclear facilities namely waste management, decommissioning, site remediation, etc.It is no longer accepted that such liabilities be left as a safety, financial and technical burden to future generations.

Decommissioning of nuclear facilities represent one of the most complex sources of occupational exposure and is therefore a priority area for applying specific radiation protection and safety principles, in particular the optimization approach. Even though appropriate safety precautions are implemented in operational facilities, it is sometimes difficult to maintain a safety culture during decommissioning due to the great diversity of different safety disciplines applicable and it therefore requires the development of a dedicated framework of radiation protection principals.

Although radiation protection during decommissioning of nuclear facilities is based on the same radiation protection principals as during its operational period with the objective of ensuring proper implementation of the as-low-as-reasonable-achievable (ALARA) principal, and ensuring adherence to legislative and regulatory requirements to radiation safety, personnel-, environmental- and public protection, there is a definite different and challenging approach towards the application of these principals during decommissioning.

Necsa has a strong Safety, Health, Environmental and Quality (SHEQ) Management System, supported by instruction documents specifying the requisite due process for implementing this system to ensure compliance with legislative and regulatory requirements.

The purpose of this presentation is to discuss RP controls specifically during decommissioning of radiological facilities at Necsa, lessons learnt during decommissioning and the different application between RP controls during decommissioning and operational facilities.

P06.37
Airfed Suits in Nuclear Decommissioning - Safe Working Practices

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Airfed suits (AFS) are widely used for protection from radioactive particulate contamination, especially during decommissioning. There are competing risk factors in AFS use, including:

- radiological risks;
- minimising radiological waste and managing disposal routes;
- appropriate radiation and contamination monitoring, and decontamination; and
- non-radiological risks, including physiological risks from the suits themselves.

In autumn 2011 the Office for Nuclear Regulation (ONR) is publishing guidance to promote a clearer understanding of the physiological and ergonomic challenges affecting the use of AFS. This covers all the stages of AFS use, from planning, selection and training through working to reviewing and improving, based on the Plan-Do-Check-Act cycle. The Health and Safety Laboratory (HSL) ran a collaborative project for ONR and nuclear industry stakeholders which gathered evidence and information to support and create this guidance.

There were two distinct evidence gathering processes. First, assessing practical AFS use at decommissioning sites provided evidence on all aspects of how AFS are used and managed. We used direct observation, procedure reviews, discussion groups and surveys. Many examples of good practice were found during the workplace assessments, and were used in the guidance. Areas where practice offered room for improvement, or where information was felt to be lacking, were also used as topics in the guidance. Second, laboratory trials at HSL investigated the physiological and ergonomic effects of wearing AFS ensembles in different environments. These trials used different ensembles provided by the sites, and simulated workplace activities based on decommissioning. Data from the trials were used to give recommended maximum safe entry durations and recommended water volumes needed for rehydration. The many factors that need to be considered when planning entry durations were also included in the guidance.

Outcomes at different stages of the project were reviewed and discussed with the industry stakeholder group, who also participated in creating the guidance.

In this paper we describe key points from the guidance, and how we gathered evidence to support them. We discuss the constraints placed on managing the physiological and ergonomic risks by the decommissioning environment and the necessary radiological protection. We also consider the balance between engineering and behavioural controls needed for safe working with AFS.

P07.01
Experience Feedback from Events Notified in Interventional Radiology : A Necessary Improvement of Radiation Protection of Patients and Staff

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Several events in interventional radiology had been notified to ASN since 2007. Among these events, three of them involved patients, including a cohort, for which deterministic effects were observed. The dose received was, respectively up to, 20 grays to the skin in case of overlapping beams or 15 grays to the brain. Five events concerned operators with significant doses exceeding the annual dose limits, either for effective dose, 27 mSv/year for an orthopaedic physician, or for extremities, 875 mSv/year to hand for a digestive physician.

Lessons learned from these events reveal several failures: a misunderstanding in the use of the X-ray equipment and incomplete optimisation procedure, an inadequacy between the devices used and the acts realized, an inadequate management of equipment settings with insufficient appropriation of manufacturer interventions, a poor knowledge of the dose delivered and radiation deterministic effects induced leading to a lack in patient follow-up. The consequences for operators are wrong practices on radioprotection point of view, bad use of personal or collective protective equipments

The tasks assigned to qualified expert and medical physicists are determining to improve the radiation protection of staff and patients in interventional radiology, particularly for professionals who are particularly and regularly exposed due to their expertise and for long-duration interventional radiology procedures. Users training, doses monitoring received by patients or workers particularly for extremities, also represent a major avenue for progress.

P07.02
Cardiovascular Dosimetry Following Radiotherapy Treatment using Hybrid Computational Phantoms

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Purpose. Many studies have shown an increased risk of cardiovascular diseases following radiotherapy. To date, cardiovascular retrospective dosimetry is based on the use of a "representative" patient's CT images or simple mathematical phantoms. Here, patient modelling is performed with hybrid computational phantoms in order to achieve personalized and detailed heart dose calculations, particularly for the coronaries. Such a method is intended to reduce the dose uncertainties in the case of dose-effect relationship studies.

Materials and Methods. Six patients were selected: three were modelled from their CT images and three from Digitally Reconstructed Radiographies (DRRs). The modelling was carried out with a 3D Computer-Aided Design software. The patient models are hybrid computational phantoms in which a detailed heart model, with the complete coronary tree, the ventricles and the atria, is inserted. After voxelization of the computational model, a pseudo-CT imaging modality is built from the model and imported into the ISOgray Treatment Planning System (TPS) to allow calculation in clinical conditions (Figure below). First, the method validation is carried out by assessing the morphology and dosimetry agreement between the initial patient and her computational model, using respectively the Dice index and relevant dose indicators. Then, a cardiovascular dosimetry is performed to study more precisely the dose to the coronary arteries with dose-volume histograms, following the radiotherapy treatment plan.

Main results. When 3D anatomical information is available, the computational model is very close to the initial patient in terms of morphology and dosimetry, which validates the method. When patient models are built from DRRs, the dosimetry on the model is not systematically better than on a "representative" patient's CT images, depending on the ballistics. In the breast radiotherapy context, coronary doses are systematically higher than heart doses, as reported in the literature. However, in this study, the coronary doses are obtained with a complete realistic model whereas using patient CT scans, only small fractions of the coronaries can be identified.

Conclusion. The coronary arteries are easily delineated on the model allowing a detailed dosimetry study. However, the modelling needs some improvement and the study has to be realized on more patients before concluding on the interest of computational model in comparison to a "representative" patient CT.

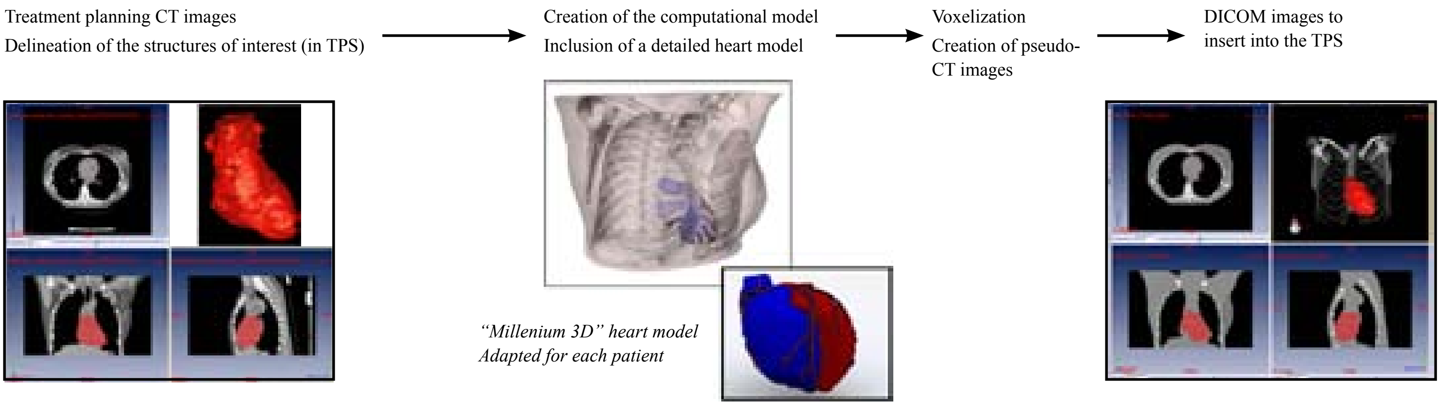

Figure. Creation process from CT images of a computational model including a detailed heart.

Poster sessions A-B: Area 7

P07.03
A Comparison of CT Imaging Protocols for Diagnostic vs Radiotherapy Applications

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Background: CT imaging continues to be the fundamental imaging modality used in Radiotherapy. As well as providing the necessary electron density information for dose calculations, it provides excellent morphological information for delineations. CT provides excellent spatial and temporal resolution. Poor soft tissue contrast causes challenges in delineation of treatment volumes and organs at risk for some treatment sites.

Purpose: Detailed comparison of diagnostic vs radiotherapy CT imaging protocols with the aim of enabling radiotherapy specific image optimisation.

Materials and Methods: Existing diagnostic and radiotherapy CT imaging protocol recommendations by various manufacturers and different scanner models were compiled and compared for head and neck, chest and abdomen regions for adults. Also reviewed were the corresponding published basis for diagnostic and radiotherapy imaging protocol optimisation procedures.

Results: Comparison of diagnostic vs radiotherapy CT imaging protocols showing various optimisation approaches by different manufacturers will be presented. The significance of deviations by the users from the broad international clinical guidelines for developing diagnostic imaging protocols in their pursuit for the optimal settings will be summarised. Variations in the standard procedure for arriving at these settings will be presented.

No clinical guidelines for CT imaging in radiotherapy applications were identified by this review. It will be demonstrated that any associated approaches to optimisation of imaging protocols are mostly based on procedures borrowed from diagnostic imaging where the optimisation criteria is more dosimetrically restricted.

Conclusions: Guidelines for diagnostic CT imaging protocols are available and in further development for example by AAPM. Similar recommendations for radiotherapy CT imaging protocols are required.

P07.04
Design of Radiation Safety System for Shanghai Proton and Heavy Ion Radiotherapy Facility

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The first Proton and Heavy Ion Radiotherapy Facility, named Shanghai Proton and Heavy Ion Radiotherapy Facility (SHPT), is being built as major consist of Shanghai Proton and Heavy Ion Hospital and will be completed in 2014 according to current schedule. Radiation safety is the crucial for SHPT and is highly concerned both by the hospital staff and the related publics. For providing safety measures to meet the safety requirements specified by China national safety regulations, radiation safety has been considered systemically and radiation safety system has been designed for SHPT.

The layout of SHPT, main parameters describing the beam features and machine operation modes, are specified. Beam losses scenarios, radiation sources including primary beams, second particles and activations are considered for the radiation safety. Radioactivities in materials of components, cooling water, air, shielding wall, soil and groundwater, are evaluated both with Mont Carlo simulation and analytical methods for the environmental safety assessment of SHPT. These radioactives form a residual radiation field, which induced by the activations of the materials. Both external dose resulted from gamma and neutron and internal dose induced by the residual radiation are evaluated. The radiation safety system designed includes mainly radiation shielding system, personnel safety system, and radiation dose monitoring system according the above radiation safety considerations. This paper focus on the description of the radiation safety system designed and the design related methods.

P07.05
Safety Analyses of Over-dose Exposure Accident in Radiological Therapy by FMECA Technique: use of Fuzzy Logic Techniques

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As well known, High Dose Rate brachytherapy techniques deliver a very high dose to patient, so mistakes can lead to radiological over-dosage with the potential for clinical adverse effects. In this paper the results obtained in the safety analyses carried out by Failure Modes Effects and Criticality analysis are reported. FMEA is a powerful qualitative tool for systematically identifying the initiating event and the root causes of unacceptable outcomes, though this tool has difficulties to identify accident sequences and dependences between equipment or human actions. To make up this lack of information, Fuzzy methods have been used to retrieve useful data on how to improve the system performance through the identification of the weakest parts. The integrated use of these mythologies can allow to extend to the verification of the entire radiotherapy process and to avoid the incomplete implementation of quality assurance programs.

The obtained results allowed to characterize the critical points of the radioprotection systems, highlighting especially which types of failures principally contribute to the evaluation of occurrence frequency of high dose rate exposures of the patient. Moreover, it has been possible to suggest the introduction of suitable operating procedures that reduce the over-dose risks

P07.06
Evaluation Of Radiation Safety Reports For Brachytherapy Equipments In Korea

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Purpose: To evaluate approved radiation safety reports for brachytherapy units completed by 38 radiation oncology departments in Korea, thereby providing current structural shielding design of brachytherapy facilities and their compliance with national and international guidelines.

Materials and Methods: Manual search of 38 radiation safety reports was conducted at the Korea Institute of Nuclear Safety (KINS) to collect information including brachytherapy unit manufacturer, year of report completion, drafter information, half-value-layer (HVL) as well as exposure rate constant and treatment time used for workload calculation.

Results: Total of 38 radiation safety reports for 39 brachytherapy units currently (2010) being operated across Korea were evaluated. The installation of brachytherapy unit was increasing until 2001 but began to decrease thereafter. Nucletron (63.2%), Varian (13.2%), MDS Nordion (10.5%), Bebig (5.3%), Buchler (5.3%) and Shimadzu (2.6%) were manufacturers supplying brachytherapy units at the time of report completion. 18 reports (47.4%) comply with international and national regulations which mandates inclusion of personal information and qualification of the person who prepared the report. 11 (61.1%) of 18 reports mentioned above were processed by the institution itself while seven (38.9%) were completed by outsourcing companies. With the introduction of outsourcing companies, reports completed by agencies began to increase from 6.7% (1990-1999) to 33.3% (2000-2009) and currently (2011) there are 13 outsourcing agencies available. Exposure rate constant used for Iridium-192 sources were in the range between 0.469 - 0.59163 R•m^2/Ci•hr and 0.48 R•m^2/Ci•hr was most frequently used (44.7%). Many reports (28.9%) assumed treatment time as 40 hours/week which is used for linear accelerators. From those that calculated treatment time, 100-200 min/week (15.8%) and 600-700 min/week (15.8%) were most frequently observed. Concrete thickness of 4.1cm (23.7%) and 4.3 cm (28.9%) suggested by NCRP report 49 as well as lead thickness of 0.6 cm (47.3%) also referenced from NCRP 49 was most frequently used HVL for Ir-192 sources.

Conclusion: Brachytherapy equipment installation is decreasing in Korea since 2001 where majority of units are supplied by Nucletron. 47.4% included personal information of the person who completed the report. With the introduction of outsourcing agencies, more reports are being processed by external agencies. Most frequently used exposure rate constant value for Iridium-192 source was 0.48 R•m^2/Ci•hr. 44.7% of reports assumed treatment time within the reasonably acceptable range of 100-600 min/week. NCRP report 49 was most frequently used reference for HVL values of concrete and lead.

KEYWORDS: radiation safety report, brachytherapy, workload, HVL

P07.07
Verification of Dose Calculation Accuracy on MV Cone Beam CT Images using HU-density Conversion Method

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Megavoltage Cone Beam Computed Tomography (MV CBCT) with highly developed radiotherapy technique was applied into conventional linear accelerators and provide volumetric images at one rotation of the linear accelerator for real-time application of patient condition into RTP and can be directly registered to a reference CT dataset which is usually Kilo-voltage Fan-Beam Computed Tomography (kV FBCT) and can be used to adjust patient set-up error and even dose calculation. However, patients scattering, beam hardening and softening effect caused by megavoltage energy can cause cupping artifacts, distortion of HU-density relation. The primary objective of this study is that improvement of dose calculation accuracy when we applied MV CBCT images calibrated using HU-density correction for reliable application of MV CBCT images into dose calculation. To define HU-density relation, cheese phantom offered 12 electron density plugs was used to acquire kV FBCT, MV CBCT images. From the relation of HU-density based on the cheese phantom images at the same electron density plug, MV CBCT image set was corrected. A realistic patient-equivalent phantom was used to calculate dose distribution based on corrected MV CBCT images on Coreplan RTP. Dose distribution was evaluated using difference map displayed in this article and percentage differences of dose difference map were calculated. As a result, total error of dose difference was reduced fewer than 3%.

P07.08
Comparison Study of the Partial Breast Irradiation Techniques; Dosimetric Analysis Depending on Various Tumor Locations in Patient's Breast

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Partial Breast Irradiation (PBI) technique involves radiation beam delivery techniques that use a limited range of treatment volumes and is treatment approach as an alternative to whole breast irradiation technique. The present study was investigated to suggest the optimal treatment modalities for classified tumor locations into eight sections based on PBI treatment. Treatment planning was performed on the CT dataset of six patients who had received lumpectomy treatments. The tumor location was classified into eight sections according to the quadrants of breast and into the superficial, deep direction. 3D-conformal radiation therapy (3D-CRT), electron beam therapy (EBRT) and helical-tomotherapy (H-TOMO) were utilized to evaluate dosimetric effect depending on each tumor location. For quantitative evaluation, Conformation Number (CN), radical Dose-Homogeneity and the dose delivered to healthy tissue were calculated. Kruskall-Wallis, Mann-Whitney U and Bonferroni method was applied as statistical analysis. In the analysis of the treatment planning for each modalities and tumor location, H-TOMO considered inactive method in PBI technique because no evaluation index achieved superiority in all tumor location except CN. Furthermore, the irradiated volume of heart received more than 2.5Gy was maximized above 90% in all tumor location during H-TOMO except Lower Outer Quadrant-Superficial case. However, EBRT showed good sparing effect, acceptable target coverage in Lower Inner Quadrant-Superficial (LIQ-S), Lower Inner Quadrant-Deep (LIQ-D) cases. Ultimately, EBRT could be advisable method to treat LIQ-S, LIQ-D cases rather than 3D-CRT, H-TOMO because of the acceptable target coverage and the greatly lower dose to surrounding tissue.

P07.09
Monte Carlo Methods and Accuracy of Treatment Planning Systems in Radiotherapy

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Radiotherapy is a complex process involving many steps, with the accuracy of each step having an impact on tumor control and on complications to normal tissues. Dose calculation is a step of this process and its accuracy is crucial to the quality of the treatment planning. MonteCarlo (MC) codes offer a dose calculation method known to be very accurate when used to verify treatment planning accuracy. MC methods plays an important role in high conformational radiation therapy (such as Intensity Modulated Radiation Therapy), where reduced margins are often used, dose gradients may be steep near critical structures and/or inhomogeneous zones and a higher level of accuracy is desirable in dose calculation. Conventional dose calculation algorithms may not accurately predict dose distribution in inhomogeneous zones due to the lack of accurate electron transport calculation and to the charged particle disequilibrium characterizing such situations.

In this contribute a package for radiotherapeutical applications based on the GEANT4 Monte Carlo toolkit will be presented and utilized in some cases of interest, such as irradiation with small fields on low density materials. Both small field size and low tissue density produce a lateral electronic disequilibrium which could not be evaluated correctly by the algorithms implemented in commercial treatment planning systems, whereas MC codes showed a quite better accuracy in such cases, on the basis of agreement with experimental data.

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P07.10
Evaluation of Polyethylene Phantoms Filled with Water in Peripheral Dosimetry in Radiotherapy

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Humanoid phantoms, made of polyethylene and filled with water, were developed for the use in peripheral dosimetry in radiotherapy. Three of them represent infants of different sizes (2, 5 and 10 years) and three are adult size (female in early pregnancy, late pregnancy and one male). The peripheral doses from two adult male phantoms, humanoid and an Alderson, submitted to a radiotherapy cranial beam, were compared. For 18 MV beams the doses in anthropomorphic were higher within the range of 2.5 to 27%, except for the dose in the heart, about 40% higher in anthropomorphic, due to the fact that in the humanoid region corresponding to lungs is filled with water. For 15 MV the difference decreased and for 6 MV there was an intertwining of the curves of the doses of both phantoms. In regions close to the beam the doses differed by up to 13%, which allows the humanoid phantom to be used to estimate doses in the regions where induction of cancer by radiation occurs more often. In more remote regions, the differences observed in the comparison of doses between the phantoms can be taken into account when the humanoid phantom is used. The humanoid phantom has the advantages of being lightweight and easy to handle, as well as has a low cost. The uncertainties in dosimetry grow with increasing the distance from the beam - in the thyroid was observed uncertainty of 0.7% and 5% in the testes. In peripheral pediatric dosimetry during the application of different clinical techniques for cranial treatments, the dose to the thyroid, compared to the dose delivered to the isocenter, was 0.2% for radiosurgery with cone or mMLC, 0.28% in IMRT sliding window, 1.4% in IMRT step and shoot, 2.9% for compensator-based IMRT and 0.23% in VMAT. It was observed that the positioning verification for cranial treatment added 0.13 cGy to the thyroid, for each pair of double-exposure portals. The fetal dosimetry in the treatment of breast cancer showed that different field settings and accessories produce quite different peripheral doses. The presence of wedge filter in the treatment of breast cancer increased by up to four times the fetal doses in the region and it is important to use a lead shield in the abdomen region, because with it the attenuation of radiation is significant and the embryo / fetus can be protected. It is recommended to use humanoid phantoms in the estimation of doses, in order to conduct clinical staff to choose the best treatment technique, create protective shields or even transfer the patient to a more suitable machine. We would like to thank to Fundação Araucária and CAPES for financial support.

P07.11
Monte Carlo Simulation of Out-of-Field Dose Distribution in Carbon-ion Radiotherapy with Passive Beam

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The National Institute of Radiological Sciences (NIRS) has achieved remarkable results in clinical trials and clinical practices for cancer treatment with carbon-ion radiotherapy at the Heavy-Ion Medical Accelerator in Chiba (HIMAC). These successful results allow the patient to live for a longer time and allow younger patients to receive this radiotherapy. While, undesired exposure which patients received during the treatment are continuously investigated. Based on our previous studies, the total secondary exposure doses in out-of-field volume per a treatment in carbon-ion radiotherapy with passive beam were comparable to or less than those in 3D-CRT and IMRT. In particular, as the position became closer to the field edge, the total dose equivalents in carbon-ion and proton radiotherapies were obviously less than those in 3D-CRT and IMRT.

Now, our concern has shifted to the investigation on the assessment of the secondary cancer risk of patients receiving carbon-ion radiotherapy. No publications on the risk assessment of patients receiving carbon-ion radiotherapy are available at present, and several investigations on the risk assessment in proton radiotherapy have published. In the publications, the risk was estimated based on various risk models and dose distributions from the treatment planning system, measured data and calculated data by Monte Carlo simulation. Our other concern is the epidemiological study of patients receiving carbon-ion radiotherapy. In the dose estimation on the epidemiological studies, Monte Carlo simulation plays an important role because the treatment planning system can provide dose distribution only in/near the irradiation field and the measured data are limited. Moreover, since particles which influence the out-of-field dose in carbon-ion radiotherapy, are not only stray primary carbon ion but also secondary neutrons and various secondary charged particles, the distribution of the factor related to the risk such as LET and quality factor is needed as well as absorbed dose. Monte Carlo simulation is more suitable for estimating these distributions.

This study is the first step in the risk assessment and epidemiological study in carbon-ion radiotherapy with passive beam at NIRS. In this presentation, we show 1) validation of the our calculational model with the Monte Carlo code, PHITS to simulate the dose and quality factor in water phantom by comparing with our experimental data, 2) distributions of dose and quality factor in phantom and 3) identification of partial contribution of each radiation type to the total dose.

P07.12
Radiotherapy Bunker Design: Realistic Orientation Factors and Duty Cycles Based on Machine Usage Data

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Introduction : In the design of radiotherapy bunkers, both the orientation factor (OF) and duty cycle (DC) are taken into account when calculating the shielding required. At present, these factors are typically based on assumptions and estimated average values. A method of determining realistic OFs and DCs is described, and was used to determine current values at our centre.

Method: The range of gantry angles for which the treatment beam is incident on a particular primary barrier was determined geometrically from construction plans for seven linear accelerators. A simple program was created to interrogate the treatment management system (TMS) and extract the total number of monitor units delivered to each barrier over a one year period. From this, current OFs and DCs were calculated for each linear accelerator and compared to estimated values. OFs specific to each energy were also determined to inform future designs. A previous bunker design calculation was repeated using the TMS determined factors for that particular linear accelerator to determine the significance of the differences. Results: For the walls and ceiling of each bunker, the TMS determined OF was found to be lower than the estimated value of 0.25 for 19 of 21 barriers with a range from 0.13 to 0.27. As a result, the majority of time averaged dose rates adjacent to these barriers and therefore the required thickness of shielding have been overestimated in design calculations. For one typical bunker, to achieve the same external dose rates as in the initial design calculations, the primary barrier thickness can be reduced by an average of 140mm . For the floor of each bunker, the OF was found to be significantly higher than the currently assumed value of 0.25 with a range from 0.32 to 0.54. As a result, dose rates to the floor and the required thickness of shielding could be significantly underestimated in design calculations. There was a significant variation in the OFs for a particular barrier between each of the linear accelerators, thought to be due to variations in casemix. As beam energy increases, it was found that the average OF for the walls increases whilst the OF for the floor decreases. For all accelerators, the DC was found to be between 0.04 and 0.06, significantly lower than the estimated value of 0.10.

Conclusions: A method to determine OFs and DCs from actual machine usage was used to audit estimated values used previously at our centre, which were found to be significantly different from the currently assumed values. There was considerable variation in the orientation factors between each linear accelerator, due variations in the casemix, determined by the energies available and imaging capabilities. To avoid significant over or underestimates in barrier thicknesses, a thorough analysis of local and current orientation factors and duty cycles using this method is recommended.

P07.13
Lessons Learned From Significant Events In Radiotherapy

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As part of the French national radiotherapy plan, the French Nuclear Safety Authority (Autorité de sûreté nucléaire - ASN) has set up since July 2007 a system for the notification of significant radiation protection events affecting a patient and a scale for rating events, known as the ASN-SFRO scale, which was developed jointly by ASN and the French Society of Radiation Oncology (Société Française de Radiothérapie Oncologique - SFRO). Significant events are:

• any adverse situation or any malfunction on an organisational, material or human level arising during the treatment of a patient in radiotherapy, having led to the realization of treatment that does not comply with the prescription in terms of the delivered dose (compliance with the total prescribed dose with a tolerance margin of +/-5%, and compliance with the planned overall treatment time and/or fractionation, taking into account the potential clinical or technical constraints involved in the treatment of a patient or the absence of systematic dose errors for several patients, regardless of the value of this dose error.).

• or any adverse situation or any malfunction on an organisational, material or human level arising during the treatment of a patient, having led to deterministic effects which were unforeseeable in view of the therapeutic strategy agreed upon with the patient.

The characteristics of the events reported to the ASN since July 2007 end the lessons learned will be presented.

P07.14
Radiotherapy Safety and Quality Management System

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In the framework of the French national measure program for radiotherapy, the Ministry of Health has entrusted the French Nuclear Safety Authority (Autorité de sûreté nucléaire - ASN) with the development of a ISO 9001 quality management system. The principles and methods set up jointly with healthcare professionals aim to ensure control of both radiotherapy safety and quality.

The system essential requirements are made mandatory pursuant to ASN decision no. 2008-DC-103 dated July 1, 2008. In support of the regulatory evolutions, ASN has published two guides: one dealing with the risk self-assessment (n° 4) and the other with radiotherapy care safety and quality management (n° 5).

These works reflect the French regulatory requirements (certification of health facilities, accreditation for the practice of radiotherapy) and international works (WHO, PAHO, ESTRO and IAEA).

The objective of the approach is to better define the responsibilities of staff in the care of patients, to standardize working practices and treatment in the radiotherapy unit, to better reflect the risks (a priori and a posteriori), to share and communicate about the failures and to improve the monitoring of safety indicators and quality (timeliness, non-compliance, etc.) through a process of continuous improvement.

The radiotherapy units are encouraged to adopt a overall approach to care organisation, in which the safety organisational, human and quality dimensions are the integrated management system mainstays.

More quality and safety culture in treatment centres will develop, more patient’s confidence in their radiotherapy will be enhanced.

P07.15
Development of a New X-ray Source System using Ultraviolet Laser for Medical Treatment

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In the U.S., there have been some reports that the risk of recurrence of cancer may be reduced by using a small X-ray source for the postoperative irradiation of breast cancer. Since the X-ray source used for this radiotherapy is an electronic brachytherapy source and not a radioisotope, it is also easy to handle. The X-ray source is very small and so it can be inserted into the human body and can irradiate the affected part directly. However, external voltages from 20 to 50 kV are used to generate X-rays from the X-ray source. Therefore, using the X-ray source within the body poses a safety risk of electric shock in case of failure. We have developed a new X-ray source system in which X-rays are generated using a $LiNbO_3$ crystal and ultraviolet laser. The $LiNbO_3$ crystal combined with a quartz plate is first irradiated with an ultraviolet pulsed laser of 300 nm wavelength or less. The electrons produced from the $LiNbO_3$ crystal collide with a Cu foil target in a vacuum, generating X-rays. The key advantage of the new X-ray source system is safety for medical treatment since no voltage is used, and there is no remarkable rise in heat in the X-ray generating part. Therefore, the new system offers safer radiotherapy than using an X-ray source with external voltage

P07.16
FMEA in Developing a QM Program in Protontherapy

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Radiotherapy technologies significantly improved in the recent years, reaching a very high degree of complexity and sophistication. The rapidly increasing use of newer techniques, including hadrontherapy, is expected to represent an added value for the patient in terms of clinical outcomes; however it places new demands on quality assurance programs, as well as new attitudes and approaches for patient safety. This study aims to contribute at increasing the safety of patients undergoing hadrontherapy, through proactive analyses of the risk of incidents, "near misses", and, in general, events leading to a deviation from the adequate treatment, in terms of over- or under-dosage. Failure Mode and Effects Analysis (FMEA), a prospective tool successfully applied in industry, and recently recommended by the International Commission for Radiological Protection for use with modern radiotherapy techniques [ICRP, 2009[1])], is considered.

The radiotherapy process based on the use of active scanned proton beams for fixed target irradiation is described, and the detailed process tree of the treatment process presented. In particular, the stages: i) assessment of patient, ii) decision to treat, iii) treatment protocol prescription, iv) positioning and immobilization, v) simulation, imaging and volume determination, vi) planning, vii) patient set-up, are analysed and finally, potential failure modes, their causes and effects are identified and discussed.

1. International Commission on Radiological Protection. Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies, ICRP Publication 112. Annals of the ICRP 39 (4), Elsevier, 2009.

P07.17
Upgrading QA/QC Programme in Radiation Therapy in Croatia: Results of the IAEA CRO 6008 Project

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Modern radiation therapy requires utilization of sophisticated equipment in radiotherapy environment as well as implementation of advanced external beams techniques such as 3D conformal radiotherapy and intensity modulated radiotherapy. This enables better optimization of dosimetric plan which might considerably improve the outcome of radiotherapy treatment. Therefore, radiotherapy chain is constituted of large number of activities involving different professionals (radiation oncologists, radiation technologists, physicists) and possibility for random as well as systematic error is significant. This necessitates quality control (QC) of every part of the radiotherapy process, as it helps to detect errors and provides instant remedy.

International Atomic Energy Agency (IAEA) CRO 6008 project: 'Upgrading QA/QC in two radiotherapy departments in Croatia' started in 2008 at radiotherapy departments of University hospitals Osijek and Rijeka. Existing QA/QC programmes were upgraded and harmonized and as such they became a part of department's periodic routine. At the same time, survey of QA/QC written protocols existence was conducted among radiotherapy departments at the national level. The lack of written protocols was identified and the joint programme is planned to be extended to the national level. Furthermore, to survey the situation in radiotherapy and to promote importance of the QA/QC programme, two types of audits according to the protocols developed during the project were conducted. One audit judged mechanical and radiation parameters of linear accelerators and simulators and the other was dedicated to audit different parameters of treatment planning systems (TPS) according to the IAEA guidelines. Analyze of the collected data for mechanical and radiation parameters of radiotherapy machines showed variety of results for tested parameters. Some out of tolerance values were found and corrections were recommended. Audit of TPSs showed that commissionings were done in a good manner in all centres. It can be concluded that more attention is given to the dosimetry than to the quality of mechanical and radiation parameters.

One of the audits purposes was on-site sharing experiences between medical physicists working at radiotherapy departments, especially in the light of national equipment renewal. This was also an effort on building awareness of QA/QC importance which would hopefully results in establishing uniformity in QA programmes among radiotherapy centres in Croatia. The next step following this project will be aimed to further upgrade and harmonize QA/QC programmes all over Croatia using help of radiation protection regulatory body and national professional societies.

P07.18
Application Of ALARA Principle In Minimizing The Exposure Of Operator Of Radiotherapy Co-60 Units

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The paper deals with the exposure of operating personnel of radioactive radiotherapy Co-60 sources due to the leakage radiation escaping from the head when the beam is off. The personnel spend some time in the treatment room as well as at the control panel in preparing the machine and patients for the treatment. These persons always receive a certain exposure from leakage and scattered photons. Although the exposure in terms of the effective dose is usually relatively low, it can be further reduced applying one of basic principles of radiation protection – ALARA, using the data about the distribution of the ambient dose equivalent in both the treatment room and control panel. The results obtained from the measurement of the ambient dose equivalent rate have been analyzed in such a way as to optimize the movement of the personnel in the radiation field which showed some specific distribution which is characteristic for each installation since this distribution depends not only on the radiotherapy head and its position but also on the design and structure of the radiotherapy treatment room. Three different radiotherapy facilities have been scrutinized and it has been shown that the effective dose of the personnel can be reduced by as much as more than 50%.

P07.19
Comparison of Peripheral Doses in Head and Neck Cancer: Tomotherapy versus Rapid Arc

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Introduction: Radiation therapy plays a very important role in treating about half of cancer patients. It is well known that some of the patients cured with ionizing radiations (either X-ray based or with charged particles), can later develop a treatment induced secondary malignancy in organs located at a distance from the original tumor. It is therefore very important to establish the doses that are absorbed in those distant organs. These doses are also known as "peripheral doses". In this study we investigated the doses to several peripheral organs, when delivering an head and neck cancer treatment, with a Linac (Rapid Arc) versus a Tomotherapy (TT) device, both operating at 6MV. Tomotherapy is a dedicated IG (image guided) / IM (intensity modulated) treatment modality where dose distributions are delivered to the patient in a helical fashion, while Arc delivers a 3D dose distribution with a single 360 degree gantry rotation.

Materials and methods: The measurement of the peripheral doses was performed with thermoluninescence dosimeters (TLD) loaded in an anthropomorphic male Rando Alderson (RA) phantom. More than 200 TLD chips (TLD, LiF:Mg,Cu,P, from Poland) were placed in organ-simulated positions. The TLDs were distributed within the different organs as uniformly as possible in order to guarantee a three dimensional coverage of the volume. The TLDs were calibrated at doses of 100 mGy, 200 mGy, and 700 mGy using a Cs-137 source and the response of each detector was corrected for the individual sensitivity factor.

The Rapid Arc treatment was delivered at the university hospital Leuven, while the TT unit was located at the university hospital UZBrussel. We delivered a single treatment fraction of 2Gy.

Results and conclusions: Table 1 shows the equivalent dose, per Gray delivered, for the different peripheral organs.

Organs	Eq. dose (mSv/Gy) - Arc	Eq. dose (mSv/Gy) - TT
Lungs	4.65	4.35
Kidneys	0.94	0.65
Liver	1.44	1.04
Spleen	1.30	1.00
Pancreas	0.98	0.61
Stomach	1.45	0.99
Small intestine	0.69	0.44
Colon	0.57	0.43
BLADDER	0.29	0.32

Table 1: equivalent doses, per Gy delivered, for Arc and Tomotherapy

We marked in blue the organs for which a statistically significant difference was measured. In the case of TT we also performed a specific measurement to assess the dose of imaging used to position the patient. A mean dose of about 11mSv was measured.

Future work includes further analysis of the data, in order to estimated risks of secondary malignancies and further imaging doses characterization. Also, we plan to include Cyberknife in our analysis.

P07.20
Evaluation the Effect of Treatment Unit on Results of Treatment Planning Systems in External Beam Radiotherapy

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Introduction: One of the priorities of quality assurance programs in a radiotherapy department is the entrance of new Treatment Planning Systems (TPS) along with discussion and evaluation of their calculations. Because of these reasons, it is necessary to evaluate the dose calculation accuracy of different treatment planning systems in variant body regions. As understand and eliminate the effects of other factors on treatment planning system results is important. The aim of this study was to evaluation the effect of treatment unit on results of treatment planning systems in external beam radiotherapy.

Material and methods: The methodology was based on IAEA TEC-DOC 1583, that used 002LFC CIRS anthropomorphic phantom that representing the human thorax, and 6 test cases that simulate some chain of external beam radiotherapy treatment planning activities. The phantom was scanned in center, using computed tomography and six test cases were planned on 3D treatment planning systems witch imitate different irradiation geometry found in conformal radiotherapy. The dose were measured with ion chambers and the deviation between measured and TPS calculated dose was reported.

Results: A total of 12 clinical test cases dataset for 6MV photon energy and two treatment units including SIEMENSE PRIMUS and VARIAN clinic 2100C/D were produced, which amount of differences in two test cases was meaningful. The maximum difference between results of two treatment units was 12.3%. The differences of other test cases were in 3% agreement criteria.

Conclusion: The main reason of observed difference in results of two treatment units was base on systematic errors or incorrect of TPS dataset in one or two of units. Because importance of the accuracy of TPS results. These studies show necessity of performed periodic tests like this in reasonable time, for radiotherapy centers, to appreciate the possibilities of their systems and understand its limitation. It is better that measurement doing on more than one unit and for same units. But if the same unit was not available, measurement on different unit can be useful to understand the systematic errors and evaluation of TPS accuracy.

P07.21
MOSFET Dosimetry for Evaluation of Gonad Shielding during Radiotherapy.

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PURPOSE: Evaluation of gonad shielding in order to minimize gonadal dose of patients undergoing radiotherapy by using MOSFET modality.

MATERIAL AND METHODS: We measured gonadal dose of 9 patients who underwent radiotherapy for rectal cancer in the department of radiation oncology of Seoul National University Hospital between June 2009 and August 2011. 6 MV and 15 MV photon beams emitted from Varian 21EX LINAC were used for radiotherapy. In order to minimize exposed dose caused by scattered ray not only from collimator of the LINAC but also from treatment region inside radiation field, we used box-shaped lead shielding material. The shielding material was made of the lead block and consists of 7.5 cm × 9.5 cm × 5.5 cm sized case and 9 cm × 9.5 cm × 1 cm sized cover. Dosimetry for evaluation of gonad shielding was done with MOSFET modality.

RESULTS: By protecting with gonad shielding material, average gonadal dose of patients was decreased by 29.88 % compared with reference dose outside of the shielding material. Average delivered gonadal dose inside the shielding material was 0.01 Gy.

CONCLUSIONS: By the result of MOSFET dosimetry, we verified that gonadal dose was decreased by using gonad shielding material. In compare with TLD dosimetry, we could measure the exposed dose easily and precisely with MOSFET modality.

P07.22
The Influence of Spatial Fractionation in Beam Delivery on Responses of Normal Brain, Brain Tumor and Vascular Endothelial Cells

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The ideality in radiation treatment of tumor is to deliver radiation energy only to the tumor cells excluding the neighboring normal cells. The novel radiation therapy techniques have been devised to enhance the tumor-to-normal cell dose ratio and approach the ideality. The commercial radiation therapy machines, whether the machine works for intensity modulated radiation therapy, image-guided radiation therapy, proton therapy or the others, employ millimeter-sized broad beams. The microbeam radiation therapy (MRT) studies for the past years have demonstrated that the normal tissue can be better saved by employing discrete micron-sized beams instead of a single continuous broad beam.

In this study, we investigated the influence of spatially-fractionated beam on the cellular response as compared to that of continuous beam. Gliosarcoma cells (ATCC, CRL-2200), astrocytic glial cells (ATCC, CRL-2005) and vascular endothelial cells (ATCC, CRL-2161) were selected for the investigation considering that the MRT studies suggested the brain tumor be the subject of MRT. The 200 kVp bremsstrahlung X-rays from YXLON model 400-D08 were delivered at various dose levels to the cells in vitro through the beam collimator of down to 100 µm in width. Clonogenic cell survivals were counted under varying beam fractionation modes.

Under the condition that the fraction of beam opening area is maintained constant, the cells less survived with the greater number of beam sectionings. "Bystander effect" was identified as a key element responsible for the observation. The dimension of beam shields was a significant element in sparing non-targeted cells, which include the normal cells and the vascular endothelial cells residing in normal tissue. Better control of tumor cells and more sparing of normal and vascular endothelial cells conflict each other in designing the spatial fractionation of the beam. Since the vascular endothelial cells are more radio-sensitive than the normal brain and brain tumor cells, sparing of the vascular endothelial cells residing in normal tissue should make the primary requirement in finalizing the spatial fraction pattern of the beam.

P07.23
Evaluation of Polyethylene Phantoms Filled with Water in Peripheral Dosimetry in Radiotherapy

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Humanoid phantoms, made of polyethylene and filled with water, were developed for the use in peripheral dosimetry in radiotherapy. Three of them represent infants of different sizes (2, 5 and 10 years) and three are adult size (female in early pregnancy, late pregnancy and one male). The peripheral doses from two adult male phantoms, humanoid and an Alderson, submitted to a radiotherapy cranial beam, were compared. For 18 MV beams the doses in anthropomorphic were higher within the range of 2.5 to 27%, except for the dose in the heart, about 40% higher in anthropomorphic, due to the fact that in the humanoid region corresponding to lungs is filled with water. For 15 MV the difference decreased and for 6 MV there was an intertwining of the curves of the doses of both phantoms. In regions close to the beam the doses differed by up to 13%, which allows the humanoid phantom to be used to estimate doses in the regions where induction of cancer by radiation occurs more often. In more remote regions, the differences observed in the comparison of doses between the phantoms can be taken into account when the humanoid phantom is used. The humanoid phantom has the advantages of being lightweight and easy handling as well as its low cost. The uncertainties in dosimetry grow with increasing the distance from the beam - in the thyroid was observed uncertainty of 0.7% and 5% in the testes. In peripheral pediatric dosimetry during the application of different clinical techniques for cranial treatments, the dose to the thyroid, compared to the dose delivered to the isocenter, was 0.2% for radiosurgery with cone or mMLC, 0.28% in IMRT sliding window, 1.4% in IMRT step and shoot, 2.9% for compensator-based IMRT and 0.23% in VMAT. It was observed that the positioning verification for cranial treatment added 0.13 cGy to the thyroid, for each pair of double-exposure portals. The fetal dosimetry in the treatment of breast cancer showed that different field settings and accessories produce quite different peripheral doses. The presence of wedge filter in the treatment of breast cancer increased by up to four times the fetal doses in the region and it is important to use a lead shield in the abdomen region, because with it the attenuation of radiation is significant and the embryo / fetus can be protected. It is recommended to use humanoid phantoms in the estimation of doses, in order to conduct clinical staff to choose the best treatment technique, create protective shields or even transfer the patient to a more suitable machine. We would like to thank Fundação Araucária and CAPES for financial support.

P07.24
Radiation Safety Practice in BPKM Cancer Hospital, Nepal

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Objective: The objective of this work was to evaluate all the safety procedures toward the radiation protection for workers in the radiation oncology department.

Materials and methods: The annul thermoluminescent dosimeters (TLDs) reports for five years of the staffs were evaluated, radiation surveys were done in the control consoles, radiotherapy machines room and waiting areas of all machines using Aloka survey meter.

Results: The five years TLD reports shows that the whole body dose of the individual staffs is found within the annual dose limit except the accidental exposures. Radiation exposures in the working areas are also safe limits.

Conclusion: The radiation safety practices for radiation protection are satisfactory and the radiation workers of the departments are found working within safe limit.

Key words: Radiation protection and safety, ICRP, Dose limits, TLD, radiation devices.

P07.25
Study on Radation Protection and Dose Distribution of γ Knife Stereotactic Radio Therapy System

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Objectives: This study aims to evaluate the radialogical safety of SRRS γ knife stereotactic radio therapy (SRT) system and the treatment room.

Methods: We performed dose rate instruments to measure leakage radiation outside the SRT system and the treatment room and to acquire the dose distribution by thermoluminescent dosimeters under the operating condition.

Results: The dose rate of every directions about 5 centimetres close the nose of the SRT system and 100 centimetres far from the target are among 0.50-8.76 μGy/h and 0. 80-2.80 μGy/h seperately. Under the running status, the one of measuring points on the west wall which is face directly to the target has had the highest dose rate in the treatment room. Other measuring points are /or close to the Natural background level.

Conclusions: The leakage radiation dose rate of γ knife SRT system is under the GuoBiao safe standard(GBSS) in China. The shielding safewall of the treatment room is too thick to according the optimization of radiation protection.

Key words: stereotactic radio therapy; dose distribution; shielding design; optimization of radiation protection

P07.26
Traceability of Proton Therapy Beam Obtained from TESLA Accelerator Installation

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Successful radiotherapy treatment strongly depends of the patient absorbed dose evaluation and the possibility to define metrological source characteristics very clearly. Conformal radiotherapy requires tumor dose application with expanded uncertainty of ±5 % (k = 2). It is particularly important to reduce uncertainty during therapy beam calibration as well as to apply all necessary ionization chamber correction factors. Our experience and metrological programs defined in the frame of proton therapy channel development within the TESLA Accelerator Installation are presented in this paper. Results of absorbed dose unit transfer from national primary standard to secondary standard are also given. Obtained standard combined uncertainty for absorbed dose determination for 65 MeV proton beam is 2.51 %, so the expanded uncertainty is a little bit above the prescribed value, being 5 % (k = 2).

P07.27
Haemodialysis and Sequential I131 Ablation Therapy for Metastatic Follicular Ca: A Radiation Protection Perspective

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Objective: Providing high activity radionuclide therapy for a patient on haemodialysis has several important radiation protection perspectives. Safe compliance with appropriate occupational and environmental legislation are both a necessity and a challenge.

This case summaries the specific challenges for I131 sodium iodide treatment of metastatic follicular cancer in a patient who regularly undergoes haemodialysis at a site external to the treatment centre without the appropriate Environmental Permit (applicable to EPR2010) or the former Authorisation Certificate (applicable to RSA93).

Methods: The likely clearance characteristics of I131-sodium iodide was researched in a literature review in planning the radioisotope administration and haemodialysis programme. The retention at given intervals was estimated in preparation for the first therapy episode. The 24hr uptake scan was analysed in determining the activity to be administered.

First and second radionuclide therapy episodes (5209MBq, & 5413MBq) were administered as in-patient stays at the treatment centre encompassing the first three post-administration haemodialysis sessions. The in-patient stay was extended to include the fourth haemodialysis session for the higher activity third episode (7513MBq)

Regular Dose-Rate and Ratemeter measurements from set distances from the patient's abdomen were recorded to track the radioisotope clearance characteristics.

All haemodialysis sessions within 7 days of radioisotope administration were carried out in a temporary Radiation Controlled Area following purpose-written Local Rules. Electronic Personal Dosimeters (EPDs) recorded the doses received by the Haemodialysis unit staff, who were not considered Radiation Workers under IRR99 and therefore limited to 300µSv per treatment episode and 1000µSv per annum.

Results: On-board activity on discharge was approximately 550MBq, 430MBq and 350MBq. Summated occupational dose received by all haemodialysis unit staff was recorded as 304µSv, 299µSv & 367µSv for the three episodes. Therefore it is essential to divide the dose over several staff members to restrict individual exposure.

Following initial haemodialysis at the treatment site radioactive waste produced at the Patient's routine dialysis site was below exemption limit for non-Tc99m human excreta disposed in aqueous solution.

Conclusions/Follow-up Following review of radioiodine treatment of a patient on haemodialysis it was appropriate provide Y90-Dotatate therapy for a patient with neuroendocrine metastases whilst on a haemodialysis programme. Following simple radiation protection measures it is possible to provide high activity radionuclide therapy for patients on haemodialysis and still satisfy occupational and environmental radiation protection legislation.

P07.28
Delivered Dose From Photoneutrons In A Head Phantom During Therapeutic Radiation

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Normally radiation oncologic treatment planning does not take into account dose received by patients from induced neutron radiation resulting from high energy radiotherapeutic beams. This information is especially important to estimate health risks, including the possibility of developing secondary cancers. The consideration of neutron dose could permit an optimized management of patient treatment logistics, improving timing, and sequencing of treatment.

The advantages of using Monte Carlo simulations is that they can particularly suited to trace all interactions contributing to the dose to the total patients body, including photoneutron production, providing the most versatile and reliable tool for studying these effects.

This work has developed a comprehensive MCNP5-model [1] simulation to study dose calculations in a multileaf collimation (MLC) photon beam therapy. Points of calculation are located in a phantom head, where the primary irradiation has been directed, but also in the superior portion of the torso. The female Rando anthropomorphic phantom has been used in measurements.

The work is devoted in calculating dose contributions from photoneutron interactions that would not have been accounted for by conventional radiation therapy planning systems.

P07.29
Radiation Dosimetry In The New PET/CT Facility In Morocco

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Medical imaging has been revolutionized by the invention of the Positron Emission Tomography commonly called PET-CT. The basic principle is the injection of a positron-emitting radiotracer suitable to the underlying organic activity under study. The image acquisition is based on the external detection in coincidence of the emitted gamma-rays and a valid annihilation event requires a coincidence within 12 nanoseconds between two detectors on opposite sides of the scanner. The contribution is important for the patient. However, the risk of exposure is significant either for the patient or for the operator. The two main phases that make up our study are:

- The first step requires observation, knowledge of procedures, equipment and technical parameters of acquisitions. It aims to achieve an accurate dosimetric evaluation needed to supervise the doses received by practitioners on the first installation in Morocco (Anoual Radiology Center in Casablanca).

- The second phase aims to evaluate the development of the most vulnerable dosimetric mapping. Then to show the strengths and weaknesses of the theoretical method (mapping) compared to the previous method (practical evaluation).

P07.30
Radiation Risk to Patients from Nuclear Medicine Procedures in Camagüey and Ciego De Ávila Provinces (Cuba) During the Period 2000 - 2005.

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Population radiation dose estimation due to administration of radiopharmaceuticals in Camagüey and Ciego de Ávila provinces was carried out using Medical Internal Radiation Dose scheme (MIRD). Data were gathered on the type of radiopharmaceuticals used, the administered activity, the numbers of each kind of examination, and the age and sex of the patients involved during the period 2000 – 2005. The average annual frequency of examinations was estimated to be 3.65 per 1000 population. The results show that imaging nuclear medicine techniques of thyroid and bone explorations with 13.3 and 12.8%, respectively and iodide uptake with 50% are the main techniques implicated in the relative contribution to the total annual effective collective dose which Sv for the studied period. Radiation risks for the×averaged 95 man Camagüey-Ciego de Avila population caused by nuclear medicine examinations in the period studied were calculated: the total number of fatal and non-fatal cancers was 34.2 and the number of serious hereditary disturbance was 7.4 as a result of 24139 nuclear medicine procedures, corresponding a total detriment of 1.72 per 1000 examination.

KEYWORDS: Effective dose; Radiopharmaceutical; Radiation risk; Nuclear medicine.

P07.31
Radiation Protection Issues Associated With The Administration of I131 Therapy to a Critically Ill Patient on an Intensive Therapy Ward

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A female patient experienced respiratory problems following child birth and was diagnosed with advance papillary thyroid cancer. The patient now critically ill, was transferred to intensive therapy unit (ITU) where she was treated with of I131. Whilst in ITU the patient was constantly monitored and required round the clock nursing care. Tragically the patient died a few weeks later. The body was then embalmed and repatriated by air to Indonesia. This paper describes the radiation protection issues encountered and how they were dealt with.

Staff in ITU had no previous experience working with patients following administration of a radiopharmaceutical and consequently a rapid training program was put in place. One of the first issues encountered was staff attitudes and existing preconceptions about radiation risks. The staff group was quite large (50+) and there was a wide spectrum of views ranging from those who stated they would not accept any additional risk even after training to those who were happy to proceed.

As the ITU ward was not design for I131 patients a large area had be cordoned off and designated a controlled area. The administration of the I131 (2GBq) was by nasal-gastric tube. Arrangements had to be put in place to monitor staff doses and perform contamination checks. Following the death of the patient a further risk assessment were carried out on behalf of the undertakers who had been asked to embalm the body.

The collective staff dose resulting from patient care over the 17days of the treatment was approximately 3.3mSv involving 50+ nursing staff. The dose to the undertakers carrying out the embalming was 27uSv.

The final issue that that had to be resolved was the repatriation of the still active body to Indonesia for burial. Protracted discussions took place with the Indonesian embassy and advice sort from UK Civil aviation authority. The *technical instructions for the safe transport of dangerous goods by air* published by the International Civil Aviation Organization state that precautions for carrying radioactive material do not apply to radioactive material implanted or incorporated in a person or live animal. Therefore following embalming the body was transported by air to Indonesia.

P07.32
Radiation Dose to Patients from 18F-FDG PET/CT Examinations and Discussion on Dose Reduction Strategies

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The use of PET/CT has been increasing substantially in the past few years. ^{18}F-FDG PET/CT provides both functional and anatomic information and play an important role on diagnosis and treatment of patients. 18F-FDG PET/CT results change the management of patients and becoming an essential part of routine oncology practice. Many oncology patients underwent several times PET/CT exams during their staging, treatment response evaluation and fallow-up. The aim of this study is to estimate radiation dose to the patients retrospectively and to discuss dose reduction strategies in the routine clinical practice. Methods: Patient doses were estimated by using established dose coefficients for ^{18}F-FDG (γ^{FDG}_{E}= 19 µSv/MBq) for PET and CT doses were getting from the operators' console of the PET/CT scanner for each exam. Results: Average ^{18}F-FDG activities of 370 MBq were administered, which resulted in estimated average effective doses of 7.0 mSv. We usually use from vertex to mid thigh CT examination for anatomical correlation and average CT dose was 8.6 mSv per exam. The effective dose for each whole-body ^{18}F-FDG PET/CT examinations was 15.6 mSv. There were an average 1.8 scan per patient (range 1 to 6) leading to a mean cumulative effective dose per patient of 28 mSv (range 12.4 to 93.6 mSv). Since we do not perform diagnostic CT examination as a part of routine FDG PET/CT exam, these patients usually had prior or afterwards diagnostic CT exams which results additional CT doses of 14-19 mSv per exam and cumulative dose can be as high as 350 mSv. Conclusion: Awareness of magnitude of the effective doses from PET/CT, especially CT part of the exams and its associated risks for deleterious health effects, each exam must be justify discussion with referring physician and nuclear medicine physician together and exam procedure must be optimized by using guidelines and dose reduction strategies according to each patients special condition.

P07.33
Radiation Protection Organisation in the General Electric FDG-Radiopharmaceutical Facility at the Joint Research Centre in Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

Since 2003, a Radiopharmaceutical facility has been set up in JRC Cyclotron Laboratory, in collaboration with General Electric Healthcare, for the production of (^{18}F)FDG. This Radiopharmaceutical Laboratory has been the first FDG production facility to be officially authorized by the Italian Health Ministry and has been operating since 2003 without any interruption.

The paper is a review of Radiation Protection activities performed in the Laboratory during its 8 years of operation: issues and outcomes in workers' Radiation Protection will be reviewed, annual doses to the Laboratory Operators and their optimization throughout the life of the facility, set-up and modification of internal standard operating procedures, as well as the evaluation of internal and extremity doses will be discussed.

Poster sessions A-B: Area 7

P07.34
Radiation Protection in a PET/CT Installation. The Design Change to Optimize Radiation Protection.

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Introduction: In the recent years, In Romania, positron emission tracers were often used in the clinical practice. FDG is the most widely used radiopharmaceutical in the medical imaging modality positron emission tomography and produces 511 KeV gamma rays in the positron annihilation reaction. This physical feature makes radiation doses very important. The installation of a PET/CT scanner in our Nuclear Medicine Department, allow us to apply differently radiation protection measures adapted to the system. The process of the optimization of protection is implemented by means of detailed assessment of all the jobs, to reduce the doses as much as reasonably achievable, taking into account social and economic factors

Material and method: In this paper we describe the consecutive stages that must be taken in account in the Nuclear Medicine Department from Oncology Clinic, in respect to the most relevant radiation protection aspects. A global evaluation of the exposure situation is carried out to determine if the individual and the collective dose targets are satisfied Design changes were required to optimize radiation protection. Design modifications include the creations of the:

• hot cell for prepare injectable solution,

• ventilation systems that create pressure areas controlled

• uptake room

• post-scan room for patient

• buffer zone that separates the waiting room and high exposure area

These facilities contribute to both optimizations of the scan and to staff protection. The purpose of the shielding is to limit the amount of radiations reaching by the patients, workers, visitors and nearby sensitive radiations detectors, such as gamma cameras or unexposed film.

Results: The design of a PET/CT center hinges on a number of factors: site, floor loading, size of the rooms available, traffic pattern inside the building, heating and cooling, electrical and water supply, etc. Conclusions: Design can greatly influence shielding costs and ease of use. Optimization of radiation protection must be taken in account both in the construction phase and in the operational phase. The quality of the management will be change by establishing specific procedures to ensure monitoring and implementation of the ALARA

P07.35
Physiologically Based Pharmacokinetics Model for Dose Estimations of 18F-FDG Examinations

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In recent, Positron Emission Tomography (PET) has become one of very useful methods for diagnoses in nuclear medicine because of its imaging characteristics, e,,‡. positron emitting radiopharmaceuticals having very short half-lives and biokinetics inside patient bodies. Among the radiopharmaceuticals used in PET, 18F-fluoro-deoxy-glucose (18F-FDG) is typical one and widely used in PET facilities. The doses of internal exposures for the patients in 18F-FDG examinations can be calculated by using data tables in ICRP Publication 106 in which 18F-FDG biokinetic parameters and calculated absorbed doses are shown for organs. As biokinetic models, compartment models have been used for calculating cumulated activities in organs on internal dose assessment in radiation protection. On the other hand, physiologically based pharmacokinetics models (PBPK model) have also been used as biokinetics models which can describe the kinetics of pharmaceuticals physiologically using physiological parameters such as blood flow, organ volume, etc. in pharmacokinetics field. In this study, a PBPK model was made and applied for internal dose estimation on 18F-FDG examination based on biokinetic data in ICRP Publication 106. As biological parameters, organ volumes, blood flow rates, pharmaceutical concentrations, partition coefficients of blood to organs were considered for the calculations of cumulative activities of organs related to 18F-FDG biokinetics. The values of physiological parameters were referred from ICRP Publication 89 and other references. The other parameters were set as fitting ICRP data. By solving the simultaneous differential equations of the model numerically, the time dependencies of pharmaceuticals concentrations and their integrals were calculated. Adjusting these parameters, the differences of patient body sizes and physiological conditions could be considered in the calculations not only for absorbed fractions of mathematical or voxel phantoms but also biokinetics of radiopharmaceuticals for dose estimations.

P07.36
Radiation Protection Procedures For Y-90 Microspheres Therapeutic

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INTRODUCTION / OBJECTIVES: Radioembolization with yttrium-90 (^{90}Y) microspheres uses beta radiation to treat liver tumours. In our hospital this technique involves a multi-disciplinary team composed of nuclear medicine and interventional radiologists' specialists and medical physicists. Since August 2010 the TheraSphere ® system (MDS Nordion) was implemented and until today 12 treatments were made.

The aim of this work is to describe the specific radioprotection procedures necessary to implement this technique and to make a critical analysis following the AAPM - American Association of Physicists in Medicine's new recommendations.

MATERIALS AND METHODS: For the implementation of this technique, which involves the manipulation and administration of radioactive material, all the general rules, defined by legislation, regarding the licensing of facilities and authorization to import and to storage radioactive material have to be followed. It is also necessary to establish radiation protection procedures and assign responsibilities for the various process steps: reception and storage of the microspheres until administration, preparation of the administration kit, verification after administration and storage management of the associated waste.

For each treatment carried out, the medical physicists' tasks include: activity verification, measurement of the administered activity and all the radiation protection procedures, including radiation survey of the room and the team. These responsabilities require the medical physicists' presence throughout the all procedure.

Given the recent recommendations of the AAPM for this technique, the adopted procedures have been reviewed and adjusted.

RESULTS / CONCLUSIONS: In 12 therapeutic treatments performed until now, there were no spills or contaminations in the angiography room, microspheres kit cart or protections drapes. After measuring radiation on hands and feet, none of the professionals involved presented values above of the background radiation.

For all patients, the administered activity was higher than 90% of the initial activity. This is consistent with the AAPM recommendations.

We can conclude that the initially adopted procedures allowed these 12 treatments to be performed with safety and quality. With the recent recommendations of the AAPM new improvements will be introduced on our procedures.

P07.37
Whole Body Clearance Rate Determinations for Post-surgical DTC I-131 Treatment Patients

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Whole body clearance rate for post-surgical DTC I-131 treatment patients have been investigated using a real-time based dosimeter with a video display from a remote location. Most recently, larger dosages, up to 200 mCi (7.4 GBq) I-131, have been routinely administered for post-surgical thyroid cancer patients. Whole body clearance rate is an important issue for the blood toxicity and other non-targeted organs, including salivary glands, gastric mucosa, and lactating mammary gland, etc. Inside the shielded I-131 therapy ward, we have recently equipped with a wall-mounted, energy-compensated dosimeter that can display the dose rates and video image in real-time basis in our office. This radiation monitoring system (RMS) is mainly used for checking environment dose rate at a 1-meter distance from the body before releasing a patient (< 70 μSv/h). This RMS detector can also be used to determine dose rates time-profile of a patient after I-131 is orally administered. A larger source-to-detector (STD) distance is preferred to minimize the I-131 bio-distribution uncertainty from time to time. Due to the maximum room size constraint, a 3-meter fixed STD is established for this whole body clearance rate study. After I-131 is orally administered, the patient would stand up at the 3-m red-marked line for 1-minute data acquisition at some specific times. Iodine-131 clearance rate was then determined by these dose rates time profiles that are mostly affected by the patient's thyroid tissue remnant uptake, renal function, the rhTSH usage, and frequency of bath-room trips, etc. Before the patients were discharging from the I-131 therapy ward, usually less than 2 days, we have conducted a total of 10 post-surgical I-131 treatment DTC patients, with dosage up to 200 mCi (7.4 GBq), for this whole body clearance rate study. Based on this preliminary result, the whole body clearance rate measurements yield an average effective half-live of 10.6 +/3.1 hours. First 24-hour period whole body clearance rate is then estimated to be 79.2%, ranging from 61.1 to 89.1%, among these 10 patients. As a conclusion, we have demonstrated that the I-131 whole body clearance rate can be estimated by using a built-in dosimeter within the excluded I-131 therapy ward that can be operated remotely in our office.

P07.38
Measurement Of Neutron Fluxes In A Medical Compact Cyclotron Room With Boron-Containing Water Self-Shielding

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The spread of PET has caused a surge in the number of compact medical cyclotrons used for production of radiopharmaceuticals. Some cyclotrons have a self-shield, and the presence of self-shielding greatly reduces the neutron flux discharged into the room housing a cyclotron. The cyclotron at our hospital has a self-shield of boron-containing water. The amount of induced radioactivity in the boron-containing water shield of a compact medical cyclotron has not been reported yet. In this study, we measured the photon and neutron dose rates outside the self-shield during cyclotron operation.

The thermal neutron flux outside a cyclotron with a self-shield was about 10^2 cm^{-2} s^{-1}. The radioactivity of the wall of a self-shield type cyclotron falls below the clearance level. For ascertaining the radiation safety of the public and of workers, safe management of radioactive waste is critical for successful operation and decommissioning of accelerator facilities.

P07.39
Improving Radioprotection in a Cyclotron & PET Center

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The Uruguayan Center of Molecular Imaging (CUDIM) started on May 2010 offering clinical examinations with PET/CT to all the Uruguayan population.

The main purposes of CUDIM are not only focused in diagnostic studies, but also in research, development of new clinical protocols and PET tracers and specialized training of human resources.

The facility includes a chemistry unit, a clinical department and a pre-clinical area allowing the development of new PET tracers from cells to human beings. To achieve our goals, we have the adequate equipment to synthetize a variety of different radiopharmaceuticals, performing high quality controls.

The area dedicated to radiopharmacy include a PET Trace Cyclotron (General Electric-GE), a 120 m^2 GMP area organized in laboratories for the production of ^{18}F (FDG and fluoride), ^{11}C (Methionine and Choline) and ^{68}Ga (DOTATATE and Gallgas).

The synthesis of radionuclides is performed in modules placed inside hot cells and shielded laminar flow hoods. The facility has rooms for animal facilities, cell culture and animal surgery and a trimodal camera PET / SPECT / CT (Triumph, GE) for small animals. The medical area has two PET/CT cameras (Discovery STE with 16 slices and Discovery 690 with 64 slices from GE) for image acquisition.

The objective of this work was to improve radiation protection issues mainly for the exposed staff.

The production of radionuclides and radiopharmaceuticals must fulfil radiation protection and pharmaceutical quality requirements. A centralized monitoring radiation system (Medismarts) has been installed in five selected points including the cyclotron vault, the hot cells, area of quality control, chemical development laboratory, dispensing laboratory, PET/CT rooms and the air extraction system.

All the laboratories are provided with portable monitors (GM, Biodex).

All the exposed staff members carry films and TLD rings. Dose dispensing is manually performed, being a critical operation in the whole process.

Also labelling of ^{68}Ga-DOTATATE is manually performed.

The centralized radiation monitor system was enlarged to twelve acquisition points allowing full registration of all the areas involved (production, dose dispensing and administration. Personal digital dosimeters have also been distributed to exposed personal.

A shielded dispensing system was introduced to diminish radiation doses. During labelling of ^{68}Ga-DOTATATE a purification step on a solid phase column was identified as critical concerning irradiation to the staff. An additional shielded system was designed to reduce radiation dose.

Due to all the modifications introduced to reduce radiation doses in the staff involved in production and quality control, a decrease in 60% of the original expose dose was obtained.

Acknowledgements: IAEA for the technical cooperation.

P07.40
Design and Setting Up of the Unit of Molecular Imaging of Large Animals at the National Centre for Cardiovascular Research.

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Molecular imaging is an emerging discipline in biomedical research. Visualization and quantification of the function of certain organs by PET / MRI / CT is proving to be a tool of great importance in the study of human diseases. These techniques are today in a highly mature state in the clinical field and are now being rapidly developed for use in biomedical (preclinical) research.

Currently, the most developed molecular imaging technique in research, and the most significant from the perspective of radiation protection (RP), is the PET, combined with anatomical imaging, mainly by CT. In order to set up this technique (or others, such as SPECT) in a biomedical research centre, the RP requirements associated with the handling of high energy gamma sources (PET) and X rays (CT) must be met (equipment, shielding, dosimetry, waste management, training, etc.).

The aim of this paper is to describe the setting up of the Unit for Molecular Imaging of large animals at the National Centre for Cardiovascular Research Carlos III (CNIC). Throughout the paper describes the most important imaging techniques to be used with the latest equipment, as well as the future of PET-MRI combination, its application in large animal research and the implications for the design of the units, calculation Shielding, radiation sources and waste management.

These measures also need to be evaluated and adjusted to meet the specific requirements of research centres in terms of biosafety, animal health and welfare, etc.

This study has been conducted by specialists from the RP and molecular imaging fields.

P07.41
Shielding Studies for Radioactive Isotopes Used in Nuclear Medicine

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This paper presents the results of the study made about the dose distributions existing near the interfaces between different materials put together, which are reached by a radiation field of different energies. As a result, the surface dose rates on the hands of personnel who operate some radioactive sources used in nuclear medicine are shown. An effective and low cost method to reduce these doses, as an enhancement to the common existing shielding has been proposed.

For the study of the dose distributions, measurements with Radiochromic films and radioactive sources with similar energies to those used in Nuclear Medicine have been made. A simple assembly has been made to reproduce the common geometries in a hospital. Besides this, here it has been simulated in detail, using Monte Carlo techniques, the assembly in which measurements were made, and other geometries that represent the shields used in PET and SPECT. For the simulations, GAMOS/GEANT4 and PENELOPE codes have been used, obtaining consistent results with both. The results also show a correspondence between experimental measurements and the Monte Carlo simulations.

The study is based on the fact that the distribution of doses in a material due to an incident radiation field, depends among other factors, in the mass density and in the atomic number (Z) of the material; because of this, if there are inhomogeneities in the material or this is composed of various materials, such dose distribution will be drastically affected, and besides, the greater the difference in density and in the atomic number between the materials, the greater the change in the distribution. A typical case in which appears this situation is when a shield for radioactive materials is in contact with skin. Monte Carlo simulations performed have shown that in the vicinity of the medium changes there is a disturbance of the dose distribution with respect to the step behavior that one naively would expect. The dose distribution profile shows an intense and negative dose gradient (deposited energy) as we move from high-Z material (shielding) to the lower Z (muscle or skin) and extends, according to the energy of the particles, distances of several hundreds of microns in the material of low Z. These distances are well above the minimum distance of 70 µm established by the Nuclear European Society from which the dose should be asses.

These dose gradients at the exit of the shielding, as well as the proposed method to reduce them, have been studied and tested both with the performed experimental measurements and with the carried out Monte Carlo simulations.

P07.42
A Measuring tool for Protective Environment and Behavior Against Radiation Hazard from PET-CT

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This paper aims to develop a standardized measuring tool for protective environment and behavior against radiation hazard in order to prepare basic data for finding ways of reducing radiation doses from the use of PET-CT which is a source of high levels of radiation exposures.

The overall explanatory adequacy of items that measure the necessity of protective environment against radiation hazard for items for radiation technologists, patients, radiation technologists and for that which apply commonly was found to be 44.99%, showing that the items satisfactorily measure the degree of necessity of protective environment against radiation hazard. The overall explanatory adequacy for items that measure the necessity of protective behavior against radiation hazard was found to be 50.68%, showing that they satisfactorily measure the degree of necessity of protective behavior against radiation hazard. Therefore it is deemed that if the items devised in this paper are applied at medical facilities that use PET-CT equipment, the environment or behavior against radiation hazard would be relatively objectively measured.

P07.43
Effect of Patient Morphology in Paediatric Nuclear Medicine Dosimetry Based on 3d Whole-Body CT Images

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In nuclear medicine, radiopharmaceuticals are incorporated into the body and distributed through biokinetic processes. Thus, each organ can become a source of radiation delivering a fraction of emitted energy in tissues. Therefore, to ensure the radiation protection of the patient, dosimetry must be calculated accurately and realistically. This is all the more important for children since they are more sensitive to radiation than adults and more exposed, notably, to cancer risks. The absorbed doses currently available are based on the MIRD (Medical Internal Radiation Dose) formalism and standard mathematical models classified by age groups of 1, 5, 10 and 15 year. However, the anatomy of these phantoms is more or less realistic. Moreover, they have a fixed geometry although patient morphology can vary significantly. Finally, assumptions were made for the transport of electrons by the MIRD committee and the International Commission on Radiological Protection (ICRP). Indeed, it was considered that electrons were absorbed locally in the source organ itself.

To study the effect of children morphology on absorbed doses from radiopharmaceuticals, we have realised patient–based dosimetry using whole-body CT images and Monte-Carlo calculations. The CT images of paediatric patients in the five year group (2 to 7 years) were obtained from the Institut Curie (Paris, France). Organ segmentation was realised using the delineation module of ISOgray™ (DOSIsoft) and voxelised patient-based phantoms were created. Different radiopharmaceuticals currently used in paediatric nuclear medicine were considered, which biokinetic was taken from ICRP Publication 53, 80 or 106. The absorbed doses to the target organs were determined using the OEDIPE software, a personalised internal dosimetric tool developed at IRSN, associated with MCNPX Monte Carlo code. The results were compared to the current published values and the different parameters that could influence the discrepancies - such as code, voxel effect, morphology – were analysed. Finally, this study has allowed the assessment of the uncertainties around the reference values.

P07.44
Radiation Shielding in a PET/CT Department: Use of Optimisation Techniques

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Shielding requirements were calculated for a new clinical PET Centre to restrict radiation dose levels to within appropriate dose constraints and keep doses to As Low As Reasonably Practicable (ALARP). Positron annihilation gammas in clinical imaging give rise to high dose rates from penetrating 511keV photons requiring substantial shielding. Multiple radiation sources in multiple locations are involved i.e. mobile patients are located in uptake holding bays and scanner rooms throughout their patient journey through the department.

Radiation doses were calculated for a complex configuration of sources from the department plans. An iteration technique was then used to investigate the effect of changing barrier thickness on radiation doses to different staff groups and other persons, taking into account weighted occupancy factors in different locations. Optimisation of the shielding design was achieved by assessing compliance with the proposed dose constraints and by use of a cost benefit analysis (CBA) model using calculated collective dose, associated detriment and shielding cost model.

The shielding level just complying with the dose constraints levels corresponded well with the optimum CBA solution.

The CBA method indicated that the cost of complying with the dose constraints could be defended and indicated that the shielding solution selected was close to the optimum. The CBA method was useful to establish at what level further increases in barrier thickness were not required.

Elaine Woods, David Gallacher, Jane Mackewn,

Keywords: PET/CT Shielding, Shielding Optimisation

P07.45
Evaluations of Occupational Exposure During Bone Scan Procedure

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Bone scan is widely used as a frequent screening test, imaging of the skeleton using radiopharmaceuticals. Nuclear medicine staff may receive considerable radiation dose. The study aimed to evaluate the staff radiation during bone scan procedures. Radiation dose was evaluated during 19 bone scan procedure for three technologists.. A Technetium generator (Syrtec) was used for injection in Alnilain Diagnostic Center, Khartoum, Sudan. All patients were scanned using MiE single head gamma camera. A *5 mCi* of ^{99m}Tc-MDP was injected intravenously. Staff dose was measured using Thermoluminescent Dosimeters (TLD-GR 200). The TLDs were placed over their right hand and chest. A computer program was developed, allowing calculation of the staff organ dose equivalent. The mean chest and hand doses for the three adult staff were *64.4 mGy, 6.3 mGy* respectively. The staff organ doses received by the lung, bone marrow, colon and stomach were of magnitude of *0.77 mSv*, and the skin dose is equal *0.032 mSv*, hence only *15.4 mSv* is received by the staffs' organ what is within the acceptable dose limit. Chest doses was higher than hand doses because of direct handling with the injected patient and leaning the patient during submitting to scanning procedure.

P07.46
Evaluation of Radioactivity Decontamination from Different Materials for Surfaces of a Generally Purpose Radioisotope Laboratory.

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Radioactive contamination constitutes a risk to exposed workers health and there is no other way than removing it in order to reduce the hazard. Laboratories assigned for generally purposes like quality control of radiopharmaceuticals, may require decontamination much more frequently than other environment. Additionally, demands concerning efficiency of decontamination are more rigorous in order to avoid human exposure. Nevertheless, research related to surface decontamination of non sealed radioactive sources in these areas, and particularly this kind of surfaces exposed to solvents commonly used for routine radiochemical purity quality control, is very limited. The aim of this work was to evaluate the effectiveness of radioactive decontamination from commonly used materials employed for laboratory surfaces. In addition we also evaluated how solvent spills can modify it. Three types of surfaces were evaluated for decontamination effectiveness: stainless steel (S) and Dupont®Corian® (C) both suitable for laboratory stands, and a vinil-based multipurpose flooring (M, Mipolam 300). Radioactive material was eluted from a $^{99}Mo/^{99m}Tc$ generator and samples of the surfaces were controlled contaminated with a drop of this eluted, previously measured in a dose calibrator. The same procedure was repeated with samples of surfaces previously treated with solvents: acetone, methyl-ethyl-cetone (MEK), ethanol (EtOH) and methanol (MeOH). All wet radioactive contamination was allowed to dry previous to any decontamination procedure. Afterwards the activity was removed with cotton pieces rinsed in water with a neutral commercial cleaning agent. Residual activity was assessed using a Geiger–Müller survey meter at 1cm from the surface until the same signal was obtained twice. The removed activity was calculated from the measurements obtained of all the cottons pieces in a calibrated solid scintillation counter using a ^{99m}Tc standard source. To evaluate the efficiency decontamination from all the surfaces the percentage of removed activity (%RA) was calculated. Preliminary data showed that for untreated surfaces C has the highest %RA followed by S and finally M with the lowest percentage (84%, 76% and 61% respectively). In the case of solvent-treated surfaces samples the %RA from C decreased for almost all cases (64% with acetone, 67% MeOH, 77% EtOH) with the exception of MEK that resulted in a better %RA (96%). On the other hand, %RA for M was higher when previously treated with both MEK and acetone (70% and 73% respectively). Conclusion: According to these preliminary results Dupont®Corian® is the most suitable surface for stands of a generally purpose radioisotope laboratory that uses different solvents since it is better decontaminated with standard cleaning agents. Further research is needed to compare M with other candidates as well as for evaluating other working simulated conditions.

Poster sessions A-B: Area 7

P07.47 Determination of Optimization Means of the Radiological Protection in Cyclotron and Nuclear Medicine

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The modern increase of use of positron radioisotopes exams makes necessary measures to avoid unnecessary worker's exposure in nuclear medicine and cyclotron services. Thus, the radioprotection procedures must develop means of optimizing the worker´s doses. This study has as objective to determine means of optimizing the radiological protection in general and of the Occupationally Exposed Individuals (OEI) in nuclear medicine facilities and cyclotrons.

The materials used were: Geiger-Müller and scintillator detectors, dosimeters for personal use and surface decontaminator materials. The methodology was: radiometric survey, surfaces and individuals monitoring, smear method, packed WIPE-TEST and workers' radiation doses evaluation monthly.

An evaluation of all radiometric surveys in both sites was performed and the results are that the OEI in nuclear medicine is more exposed to radiation than OEI in cyclotron. The main reason is that the nuclear medicine worker works for longer periods, with a wider range of radiopharmaceuticals of different energies. This worker also deals directly with the radiopharmaceuticals, either in handling or in administering it to the patient. The work at the cyclotron is mostly automated with the use of mechanical arms with tweezers, leading to constant measure of Back Ground (BG) on its dosimetry. In this paper we tried to highlight that in a radioactive facility the Radiation Protection is mandatory and that much can still be done to ensure the health and welfare of the workers.

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P07.48
In-patients Receiving 90Y-Dototoc / Dotatate Therapy: Dose Rate Analysis & Radiation Protection Advice

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Objective: Patients receiving ^{90}Y-Dototoc / Dotatate for cancers expressing somatostatin receptors are treated as an inpatient procedure being discharged at around 45 hours post treatment (two night stay). A dose rate assessment and analysis was undertaken to determine if this time period could be reduced thereby benefiting the patient and freeing up the single occupancy room sooner for use.

Method: Dose rate measurements were taken on thirteen patients (12M:1F). Administered activities ranged between 4860 - 5200 MBq with an average 5060 MBq. Dose rates were recorded at distances of 0.5 and 1.0 m from each patient on right and left hand sides at various times up to 48 hours post therapy.

Results: Average measured dose rates at 1 m (and max-to-min ranges) immediately after therapy were 7.2 (20-3) and 8.2 (20-4) µSv.hr^{-1} for right and left hand sides respectively. At 24 hours dose rates were 1.5 (4-1) and 1.5 (3-1) µSv.hr^{-1} for right and left hand sides respectively. A single exponential decay model was fitted to the data to give calculated dose rates as a function of time.

Conclusion: Based on the data obtained it was proposed to discharge patients after a minimum of 24 hours post therapy and extend the restrictions / instructions (from three to four days) set out in the patient instruction sheet given at discharge. This has been agreed with the Radiation Protection Advisor.

P07.49
Radiation Safety in Nuclear Cardiology: Current Knowledge and Practice - Results from the 2011 ASNC Member Survey

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Background: Nuclear cardiology accounts for >10% of the entire ionizing radiation burden to the United States population, however few data are available describing current nuclear cardiology practice and its impact on patients' radiation exposure.

Methods: We conducted a survey among members of the American Society of Nuclear Cardiology (ASNC) members of nuclear cardiology protocols, radiation safety practice, and knowledge in 2011. Geographically-stratified random-sampling methodology was used, and the response rate was 19.5% (73/374 invitees).

Results: Fifty percent of respondents' practices use Appropriate Use Criteria and 33% reported including radiation dose tracking in reports. The most popular nuclear stress testing protocol is low-dose rest Tc-99m followed by standard-dose stress Tc-99m, used in 58% of studies and 89% of laboratories, followed by dual-isotope imaging, used in 15.6% and 22%, respectively. Low-dose stress-first imaging was used in 7.3% of studies and 13% of laboratories. 51% reported employing one or more techniques to reduce radiation. 27% of respondents reported using attenuation correction or prone imaging. While 93% of physicians responding reported having read an ASNC statement on radiation safety, 22 of 46 physicians surveyed provided no response to a question as to how many chest x-rays the most common nuclear stress testing protocol is equivalent, and among the 24 physicians responding, 17 underestimated radiation from nuclear imaging, 3 overestimated it, and only 4 answered appropriately (17% of respondents, 9% of all physicians surveyed).

Conclusions: Contemporary practice of nuclear cardiology is characterized by underutilization of existing approaches to ensure justification and optimization of ionizing radiation use, and by gaps in practitioners' knowledge relating to radiation safety.

P07.50
Improving Safety in Radiation Therapy

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Exposure hazards from radiation therapy and CT have been identified as one of the top ten-technology hazards for 2012. The rate of reported incidents in radiation therapy is low, but problems are likely under-reported for many reasons. The complexity of modern radiation treatment has also with all likelihood contributed to errors. There is a risk for "black box" errors, where users of the treatment device or treatment planning system are unfamiliar with the algorithms or internal operations of the equipment, therefore changes made on the outside of the "box" impact the performance of the equipment and patient outcome.

IAEA Radiation Protection of Patients Unit is developing a voluntary safety reporting system that will allow the radiation therapy provider to share their experiences in relation to medical events and near misses. This system, Safety in Radiation Oncology (SAFRON), allows the provider to report incidents and near misses in a database without revealing identity, assigning blame or issuing punitive fines. SAFRON is designed to allow sharing of information about events in order to improve the education and understanding of incidents, in an effort to prevent future incidents.

The International Atomic Energy Agency's efforts in this area are focused on the development of the SAFRON system to collect and evaluate events to improve patient outcomes through education in all radiation therapy centres. By subscribing to voluntary actions, facilities can evaluate and capture both incidents and near misses. By sharing this information, professionals in radiation therapy can be aware of potential problems and take corrective action to mitigate errors. Reviewers of the poster will gain knowledge of SAFRON's objectives, processes, implementation, reporting and opportunities to participate in providing and reviewing information.

P07.51
Sensitivity Analysis of Influence Parameter on Radiological Risk for LINAC facility

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Generally, radiological risk is expressed as product of the frequency of events and consequence associated with possible states of a system. The frequency is derived as the frequency of the initial event times the probability of the state and the consequence is obtained as measuring or calculating exposed doses due to the incident of states. However, because of insufficiency of reporting of accidents in LINAC treatment facility, it is hard to assess probability with statistical data of incidents or accidents during treatment procedure. We made a survey with methodology of Delphi for complementing insufficient statistical data of event tree analysis. The consequence which is exposed dose to worker and public is calculated by using MCNP with modeling the LINAC treatment room and gamma spectrum of LINAC beam. Then we assessed total radiological risk and also performed sensitivity analysis of influence parameters such as shielding, access control, distance from radiation source to receptor and exposed time, etc.

P08.01
Towards Harmonization: Implementing the WENRA Safety Reference Levels for Storage

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The Western European Nuclear Regulators' Association (WENRA) has 2011 issued the final version of the "Waste and Spent Fuel Storage Safety Reference Levels". The objective of WENRA is to strive for a harmonized safety level of nuclear facilities within Europe and these Reference Levels are a benchmark method to demonstrate the achieved level for the regulatory system and the implementa-tion as well. The development of these Safety Reference Levels started in 2006 and was accompanied by ENISS, the European Nuclear Installations Safety Standards Initiative, a FORATOM based special organisation of nuclear operators. ENISS had discussed these Safety Reference Levels very intensively with WENRA in a very constructive way. The implementation of the SRLs is now via national action plans which reflect the different situation within the Member States of WENRA. A key issue is the Periodic Safety Review (PSR), well known from NPPs, but so far not common for non-NPP nuclear installations, which is now mandatory according to the above mentioned SRLs.

The paper will discuss the implementation of the SRLs from the operator's perspective and will give examples for their verification.

P08.02
INSC Assistance on Improvement of Safety of Waste Management and Decommissioning Worldwide

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As part of the Instrument for Nuclear Safety Cooperation (INSC) implementation the European Commission provides extensive assistance to countries in the field of safety of radioactive waste management and decommissioning. The programme is directed at ensuring the safety of radioactive waste management facilities and activities and provides assistance to national nuclear regulatory authorities and operator organizations. Assistance is based on EU legislation, international safety standards and calls upon the extensive expertise and experience within Member States of the EU. It is also designed to address countries needs in waste management, remediation and decommissioning and to support the development of sustainable infrastructure in the beneficiary countries. This paper describes the current INSC programme until 2013, key areas of cooperation, trends and lessons learned.

P08.03
Calibration Validation by Montecarlo Simulations of a Total Gamma Counting Tunnel for Clearance Purposes

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The Joint Research Centre of Ispra is one of the research centres belonging to the European Commission, and was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in the past years or are currently being decommissioned. The license for the centralised Radioactive Waste Management Station includes clearance for historical and post operations solid materials.

As a license requirement for clearance, measurement and characterization of the material must be performed to verify that the radioactive concentration is below the established threshold levels given by the Italian Nuclear Safety Authority.

The final survey on the potentially clearable material lots is performed through a commercial total gamma counting tunnel composed by 8 plastic scintillators. Calibration is obtained by a dummy container through a set of calibration measurements.

A Monte Carlo model of the gamma counting tunnel has been validated. Effects on the calibration transfer function of the non-homogeneity of matrix and calibration sources in the dummy container have been investigated by Monte Carlo at different photon energy emissions. Finally, a safety factor is determined in order to take into account such effects.

P08.04
Clearance at JRC-Ispra

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The Joint Research Centre of Ispra is one of the research centres belonging to the European Commission, and was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in the past years or are currently being decommissioned. The license for the centralised Radioactive Waste Management Station includes clearance for historical and post operations solid materials.

As a license requirement, a clearance procedure encompassing methodological approach, measurements techniques, responsibility assignations and data traceability had to be established.

The paper will present the documentary body prepared, submitted to and revised by Italian Nuclear Safety Authority that now allows the JRC Ispra to release different types of material from Site.

P08.05
The Delicensing of Nuclear Licensed Sites in the United Kingdom

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In the UK sites, rather than specific facilities, are licensed for the purpose of carrying out certain operations. The framework for licensing is the Nuclear Installations Act 1965 (as amended) (NIA65). The licensing aspects of the NIA 65 are administered by the Health and Safety Executive (HSE) and delegated to their agency, the Office for Nuclear Regulation (ONR). Over the last few years, applications for sites or parts of sites to be delicensed and released from their duties under the NIA65 have been increasing as sites are no longer needed for licensable activities.

We present the legal framework for licensing with particular reference to delicensing of Nuclear Licensed Sites in the UK, the development of a definition of 'no danger' which is the test for delicensing in the NIA65, and the regulatory approach that is taken by the ONR in arriving at a decision. In addition we will highlight some of the challenges that have been met during the delicensing of some sites or parts of sites in the UK. These sites have been used for a variety of operations under the NIA65 and present different challenges in the demonstration of no danger. Despite the challenges encountered licensees for the sites and parts of sites have demonstrated compliance with the HSE's criterion and these sites have been successfully delicensed.

P08.06
Exemption and Clearance: Progress made in the Argentine Regulatory System

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With the aim of optimizing the regulatory effort in Argentina, the Nuclear Regulatory Authority (ARN) evaluated two worldwide concepts used in the radioactive waste management field: "Generic Exemption Levels" and "Generic Clearance Levels". The analysis covered the study of international in force references, the evaluation of the scenarios and parameters used to derive the generic levels, their degree of conservatism, the trivial doses involved and finally the possible adoption of such levels in the Argentinean Regulations.

The ARN Director´s board approved these Generic Exemption and Clearance Levels on the years 2007 and 2009 respectively, recommending the development of regulatory implementation guides, which are currently available in the website.

The objective of this paper is to present the progress made in the past two years in relation to these topics and to present the results of the specific requests received from users of radioactive material.

Since the approval of the Generic Levels to the date, the ARN received two exemption requests. The first one, regarding the practice of dismantling lighting rods with ^{241}Am, which after an exhaustive analysis the exemption was not granted given that the activity of the material exceeded the Generic Levels as well as the dose criterion of 10µSv/y. The other case regards the international trade, distribution, usage and final disposal of lighting products with radioactive material (^{85}Kr and ^{232}Th). In Argentine regulation, exemption does not apply to international trade, as explained in the AR 7 Regulatory Guide. The others stages of such case are currently under evaluation and further information is provided in the full paper.

Concerning clearance, there has not been any request yet. However, in the future the ARN expects to receive this kind of requests from nuclear power plants and other facilities related to the nuclear fuel cycle, as well as more exemption orders from small users like research laboratories, medical or industrial facilities.

As a result of the implementation of these generic levels, the ARN expects to optimize the radioactive waste management as well as all the related regulatory efforts taking into account that there is no need to control radioactive materials that produce trivial doses in the public and environment.

P08.07
Oak Ridge National Laboratory's "Authorized Limits" Process for Unrestricted Release of Exempt-Level Radioactive Materials

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The mission of the Oak Ridge National Laboratory (ORNL) is to deliver scientific discoveries and technical breakthroughs for clean energy and global security. As a United States (US) Department of Energy (DOE) facility, ORNL must comply with DOE rules and regulations regarding radioactive materials. These rules, however, do not provide levels at which volume-activated radioactive materials are below any level of concern – a so-called "exempt" level.

The ORNL is host to the two most powerful neutron sources in the world for open research – the Spallation Neutron Source (SNS) and the High-Flux Isotope Reactor (HFIR). All experimental samples will, to some extent, become radioactive; many samples will remain radioactive for extended periods of time. Recognizing that scientists want to receive their sample materials back, many who have no license to receive radioactive materials, ORNL applied to the DOE for what is known as an "Authorized Limits" approval. Under the Authorized Limits process, any sample cleared from DOE control could cause a dose of no more than 0.01 mSv to a researcher working continuously with the sample over a period of one work year (2000 h) and would have less than exempt-quantity activity for all other US licensing and transportation requirements. The resultant activity limits are also less than the exempt consignment values listed in International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material, TS-R-1. Though the values in the IAEA standard are non-binding on countries, they "establish standards of safety which provide an acceptable level of control of the radiation, criticality and thermal hazards to persons, property and the environment that are associated with the transport of radioactive material."

Activities are calculated using validated and verified techniques and confirmatory measurements are made prior to clearing any samples. Recipients have signed agreements that they understand what they are receiving and that they will provide appropriate notifications to regulators and stakeholders (e.g., institutional, city, or county). The Authorized Limits process provides a mechanism that recognizes that we must engage with society as we responsibly live with radiation.

P08.08
Validating A Clearance Approach For NPP Containerized Materials And Big Items

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Some years ago, a clearance methodology, based on non - parametrical statistics and MARSSIM, was developed n Spain to demonstrate the compliance with the EU standards for scraps release (Radiation Protection - 89) . This methodology was applied using a standard commercial multi - probe gamma device. Now, this methodology has been updated and applied on a single portable gamma spectrometer, mathematically calibrated, using the AAS (Adding- A- Source) approach. The methodology is used to develop a set of Standard Operating Procedures for the future routine works.

The tests were designed to ensure the compliance with a set of Data Quality Objectives and to improve the Clearance Standard Operating Procedures and to use ISO 11929:2010.

The container test was performed inserting in the inner volume of a "clean" container Co-60 and Cs-137 sources separately. Those sources were placed in different positions and gamma spectra were obtained. This approach is used to analyze the effect of the maximum heterogeneity allowed by the standards considering the maximum averaged volume in each measurement is 1 t.

For this reason the whole container volume (around 2 m^3) was divided in three parts and the detector was placed in six places (three on each side). With this configuration two gamma spectrometric measurements corresponding one container third were obtained. Each measurement was mathematically calibrated using the corresponding MCNP model with commercial code supplied by the gamma spectrometer supplier.

In the case of big items the sources were placed on different locations and separately and, as the previous case, on the surface of a big massive part and the corresponding gamma spectra were obtained. Also the measurement were mathematically calibrated with commercial code

The results were statistically analyzed, the lognormal Transmission or Attenuation Factors were characterized, evaluated and the applicability and usual calculation of uncertainties were analyzed according well sounded statistical methods based in Sampling Theories.

This paper will present the main conclusions of the works.

P08.09
Radiological Characterisation and Elimination of Waste from the CERN Accelerator Complex

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Radiological characterisation is required for the transport, handling and elimination of radioactive material from the CERN (European Organisation for Nuclear Research) accelerator complex. Since CERN has accelerators with a wide energy range up to 3.5 TeV (the current LHC beam energy) as well as electron/positron (the former Large Electron-Positron collider LEP) and proton beams, the radiological characterisation is a challenging task.

The characterisation of activated components is performed by a combination of Monte Carlo simulations and analytical activation calculations. The FLUKA Monte Carlo code is used to describe the radiation field in particle accelerators. The radiation field is determined by the energy spectra of the various activating particles, including neutrons, protons, charged pions and photons. Taking the material composition into account, the JEREMY code folds these spectra with isotope production cross-sections and - along with the time evolution- yields the radionuclide inventory. Due to the high energies of the particle beams, spallation reactions contribute significantly to the radionuclide inventory.

The radiological characterisation of contamination is based on calculations similar to the ones for activated components as well as on a zoning concept with contamination surveys.

The normalisation of the radionuclide inventory is performed by dose rate measurements, by gamma spectroscopy of samples or by a total gamma measurement with a free release monitor.

The legal framework for radiation protection at CERN has recently been revised substantially with the two Host States of CERN as an international organisation, namely France and Switzerland. The impact on the elimination of radioactive waste, e.g. free release limits, will therefore be discussed in the contribution.

Results of a dedicated validation experiment for the JEREMY code are shown. Then first results of the characterisation of ion exchange resins and steel components are presented. Measurements of the radionuclide inventory are compared with the predictions by FLUKA/JEREMY and the results are interpreted within the legal frameworks of elimination towards France and Switzerland.

P08.10
Estimation of Ratios Among Corrosion Products in the Reactor Coolant of a PHWR and its Inference for Spent Resins

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Radioactive waste management requires knowledge of the radioactivity content in terms of the concentrations of relevant radionuclides. The radionuclides of interest can vary according to the requirements of radioactive waste management of each installation where they are generated and/or the national regulations.

In Argentina, the Nuclear Regulatory Authority (ARN) has required to Nuclear Power Plants operators the implementation of a characterization system of radioactive waste including an evaluation of the activity concentration for several radionuclides. This characterization system will be implemented using the scaling factor method. The scaling factor (SF) method is a recognized approach widely used which is based on the development of a correlation between easily measurable gamma emitting nuclides and nuclides which are difficult to measure (mostly alpha and beta emitters). As the scaling factors are NPP dependent, the intention of the ARN is to understand and recognize in advance the particularities of the Plants, related to the determination of scaling factors in radioactive waste, as well as their theoretical estimation.

Currently a study is being developed in one of the two Argentine Nuclear Power Plants, Central Nuclear Atucha I. The nuclear reactor is a unique German PHWR design with 357 MWe which is in operation since 1974. The objective of the study consists in the theoretical estimation of the amount of the corrosion products iron, cobalt and nickel, generated in the reactor coolant. As all corrosion products, they are transported in the water coolant through the reactor core and are activated by neutron flux generating many radionuclides particularly ^{55}Fe, ^{60}Co, ^{59}Ni and ^{63}Ni, which are of particular interest for radioactive waste management. As these elements have similar chemical properties, it is reasonable to consider that their processes of transport, deposition and ion exchange are equal, meaning that the retention of each radionuclide in the cleaning system is proportionally the same. In this way, a rough approach is to consider that the calculated ratio between activities of each radionuclide respect to ^{60}Co, in the reactor coolant, will be the same that the ratio measured at the spent resins.

Under the assumptions mentioned above, the activity of radionuclides, in the reactor coolant, was calculated and the ratios resulted, respect to ^{60}Co, are in reasonable agreement with values of SF for spent resins found on bibliography. The next step will be the experimental confirmation of the calculated ratios.

P08.11
Activities Of The Radiological Protection Technical Unit In Relation To Radioactive Waste Management

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ENRESA is the national company in charge of radioactive waste management in Spain and undertakes the removal and conditioning of the radioactive wastes generated at the country's nuclear and radioactive facilities, as well as those produced at non-regulated installations. The company has a Radiological Protection Technical Unit (RPTU) that was set up in 1990 in response to a requirement by the Nuclear Safety Council (the Spanish regulatory body), thus having more than 20 years of experience.

The missions of the RPTU are as follows:

• Radiological characterisation of radioactive wastes (measurement, calculation…).

• Segregation and conditioning of radioactive wastes.

• Evaluation of the radioactive waste management methods used by the radioactive facilities (segregation, characterisation, calculation of activity…).

• Radiological risk assessment.

• Establishment of radiological protection measures (cordoning off of areas, radiological surveillance, protective equipment, working time...) for the recovery and removal of radioactive material.

• Radiological control of personnel.

• Emergency response.

• Personnel training.

It also carries out the following activities:

• Disassembly and conditioning of lightning rods with radioactive headers.

• Removal of ion smoke detectors.

• Removal of radioactive wastes from radioactive facilities.

• Removal of radioactive sources from radioactive and non-regulated facilities.

• Venting of sources of Kr-85.

• Removal of disused teletherapy units.

• Characterisation of activated parts from accelerators.

• Removal of materials from non-regulated installations.

• Special activities.

• Interventions in response to incidents and emergencies.

This article describes the human and technical resources of the RPTU and the activities it performs.

P08.12
The Environmental Radiological Surveillance Programme of the El Cabril Low and Intermediate Level Radioactive Waste Disposal Facility

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The Spanish low and intermediate level radioactive waste disposal facility is operated by the Empresa Nacional de Residuos Radiactivos (ENRESA) and is located in the province of Córdoba. The disposal facility is based on a multiple barrier system. The conditioned radioactive wastes, incorporated in containers with concrete, are placed in cells that are covered by a concrete slabs, this being covered in turn by a layer of topsoil at the end of the operating phase of the facility.

The facility entered into operation in 1992 and since then an Environmental Radiological Surveillance Programme has been carried out in the surrounding area. This article describes the scope of this programme, based on the different exposure paths, and the type of samples that are taken and the analyses that are performed. Every year a report containing the results of the programme is submitted to the Nuclear Safety Council (the Spanish regulatory body). This article also includes the results obtained over the period in question.

P08.13
Application Research of Decontamination Process of Primary Coolant Pump in Nuclear Power Plant

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In decontamination process of primary coolant pump in nuclear power plant, three kinds of nuclear decontamination methods were applied and compared. Dose rate reduction factor (DRRF) range of ultrasonic decontamination process, chemical decontamination process and ultrasound - chemical united decontamination process are 1.49--6.38, 10.22--176 and 7.39--56.31 separately, and decontamination factor (DF) range are 1.65 -->1980, 1.9-->421.9 and 145-->37033 separately. The corrosion depth of two kinds of stainless steel samples which were treated by ultrasound - chemical united decontamination process are less than 100nm. So ultrasound - chemical united decontamination process can be used as an optimized decontamination process for primary coolant pump.

Keyword:Decontamination process, Primary coolant pump, Nuclear power plant

P08.14
Study on Minimization of Radioactive Wastes in the Mo 99 Production

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Brazil is currently planning to produce Mo-99 from fission of LEU targets. The planned EOI activity of Mo-99 is 160 TBq (4.5 kCi) per week to meet the present domestic demand of Tc-99m generators. All radioactive waste streams from the production plant will be transferred to the waste management facility in the site for treatment and storage. The number of waste streams that will be generated in the plant and the characteristics of each stream depend on the processes of U target dissolution and Mo separation that will be adopted, details that are yet pending decision. However, the total activity of the actinides, fission and activation products that will be present in the wastes can be predicted based on the yields of fission and activation data for the irradiation conditions, such as composition and mass of U targets, irradiation time, neutron flux, production schedule, etc., which were in principle already established by the project management. To predict the activities that will be handled in the waste treatment facility, the commercially available code SCALE 6.0, from RSICC, is being used to simulate the irradiation of the targets and the decay of radioactive products. Furthermore, it is considered that for a given Mo-99 output, different waste compositions and activities can be generated if the irradiation conditions are changed. This implies that, from the point of view of waste management, the production of Mo-99 can be ¡¥optimized¡¦, for instance, lowering the activity of long-lived actinides by reducing irradiation time and increasing the mass of U targets in each production batch. These changes can impact the long-term safety of the wastes but also significantly affect the production costs. This paper presents the findings of this research, which is aimed at contributing to the design of the Mo-99 production in the country.

P08.15
Surveillance of Radioactive Discharges from the Centre of Isotopes of Cuba

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The handling of unsealed radioactive sources in the Centre of Isotope of Cuba leads to radioactive discharges which are under radiological surveillance as a guaranty for comply with the authorized limits for the Regulatory Authority. This paper summarizes the findings from control and monitoring of these releases applying the international standards and recommendations, covering the period of 15 years. A radiometer Berthold LB 2040 with a Geiger Müller detector is used for measurement activity concentrations of ^{131}I in airborne releases. A spectrometric system with HPGe detector is used for measurement concentrations of gamma radionuclides in waste waters. The energy and efficiency calibrations of this system are carried out with a set of solid point radioactive sources and cylindrical ^{133}Ba and ^{152}Eu liquid volume sources (with 425 mL), respectively. Solutions used for elaboration of cylindrical sources are certificated by the National Metrological Institute of Hungary. Pure beta emitters are measured using a method of liquid scintillation. ^{131}I and ^{32}P are the most representative radionuclides in waters. The measurement method employed allows in a relative short time and with smaller than 10% of uncertainty to detect any deviation of the safety procedure and good practices. In the 61% of the measurements of liquid effluents we have to apply the reducing sources principle, due to the very conservative character of the authorized clearance levels. A prospective dose assessment for airborne discharges is used to characterize the annual radiological impact to public. The results obtained show a good agreement with the dose constrains.

P08.16
Analysis of Air Discharges from a PET Radiopharmaceuticals Production Center Based on a Cyclotron

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The control of air discharge contamination in the Nuclear Medicine Center “San Gaetano”, Bagheria (Italy) provided with a cyclotron for the production of radiopharmaceuticals is based on an automatic system of air sampling and measurements. Among these, particular importance for the assessment of dose to the population are the measurements devoted to air activity concentration controls at the outlet of the chimney and inside the cyclotron vault during irradiation. Other controls are made with respect to air discharge from the hot cells of Radio-Pharmacy laboratory, from PET diagnostics rooms, radioactive waste storage, and so on.

The frequency of sampling are set as continuous with respect to the chimney discharge and cyclic for other areas (e.g. 1 minute every 8 minutes). The gamma-ray spectrometric measurement are made on-line and for a short time (1 minute) by using a Marinelli beaker filled with sampled air and a shielded NaI(Tl) 2”x 2” scintillator. An automatic analysis based on counting values in specific ROIs (one Region Of Interest for the photopeak, two ROIs for background) allow to determine a concentration value to be compared with suitable alarm or limit values. The use of this system allow us to have for each rooms almost 180 values per day from 2002, year of the start of operation with the cyclotron, until 2011. For the outlet of chimney the data are about 720 per day. Therefore, the concentration values are very numerous and a software analysis is needed. In this work is presented the analysis of the main data and are highlighted some criticalities of the system that have been happened some years ago.

An evaluation with a common Gaussian Plume air dispersion modelling code allow us to verify the no-radiological significance of the potential dose to population reference group, sited more than 100 m away from the plant, even with the higher concentration values. A proposal for optimization of plant operations, with the provision of air compressing systems for both hot cells and cyclotron vault besides a change in the position and height of the chimney is also described. This operation is planned to be implemented in the center in the next months.

P08.17
Transfer of Tc-99 from soils to Rice and Upland Crops

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Tc-99 (Technetium-99) is a beta emitter and its half life is as long as $2.1x10^5$ years. In an operating nuclear reactor, its fission yield is comparatively high. The medical use of Tc-99m is another source of Tc-99. Accordingly, Tc-99 is considered important in the environmental impact assessment for radioactive waste. In addition, some amounts of Tc-99 can be released into the environment from reprocessing plants and through reactor accidents. Arable soil can be contaminated with Tc-99 if it is released into the atmosphere or terrestrial aquifers. In food chain dose assessment models, soil-to-plant transfer of a radionuclide is generally be estimated using a parameter called transfer factor (TF), which is defined as the ratio of the plant concentration to the soil concentration. In this study, greenhouse experiments were performed to measure TF values of Tc-99 for rice and three upland crops. They were grown in lysimeters or pots. Experimental soils (four soils for rice, two soils for soybean and another two soils for Chinese cabbage and radish) were collected around a nuclear site and air-dried. Dried soils to fill the upper about 20 cm were thoroughly mixed with a Tc-99 solution using a mixing machine. This is to simulate the top soil being mixed with deposited radionuclides by plowing in the real field. For rice, soils in the lysimeters were flooded. The TF values of Tc-99 for the upland crops were not significantly different between soils. For the edible parts, mean TF values were $1.8x10^{-1}$, $9.0x10^{-1}$and $9.6x10^{0}$ for dry soybean seeds, fresh radish roots and fresh Chinese cabbage leaves, respectively. Soybean stems and leaves as a whole had two orders of a magnitude higher TF values than the seeds, whereas radish leaves had about 30 times higher TF values than the roots. The TF values for dry rice seeds (brown rice) and straws were in the range of $5.4x10^{-4}$ – $2.5x10^{-3}$ and $5.3x10^{-1}$ – $1.3x10^{0}$, respectively, for four different soils. This great difference between the two parts indicates a very low mobility of Tc-99 to seeds as also observed in soybean. Plant uptake of Tc-99 was much lower in rice than in the upland crops because Tc-99 is reduced to immobile forms such as TcO_2 in anaerobic conditions, which occur in flooded soils. There are considerable differences between some of the present values and the corresponding IAEA values. For more realistic estimations of the plant uptake of Tc-99, it is necessary to use as many site-specific TF data as possible.

P08.18
Seaweed Transfer into Foodstuffs

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A number of radionuclides are discharged into the Irish Sea from the Sellafield nuclear fuel reprocessing plant in Cumbria as authorised by the Environment Agency of England and Wales. However, the prevailing currents in the Irish Sea mean that some the presence of these radionuclides can be detected in foodstuffs harvested in Scotland. In Scotland, it is known that of these radionuclides released from Sellafield can concentrate in seaweed which can then be used as a fertiliser and soil conditioner. This practice has been prevalent in Scotland in the past and is known to still be carried out at the present time. There are also some instances where animals graze seaweed directly from the foreshore. This combination of circumstances therefore provides a route for radionuclides discharged into the Irish Sea to transfer into terrestrial foodstuffs. The presence of positively identified radionuclides in the environment in remote areas of Scotland has drawn interest from the public and media. As most monitoring programmes tend to be focused around nuclear sites assuming continual dilution with distance, the absence of specific data on habits and environmental concentrations at remote locations where novel pathways exist resulted in a review of the monitoring programme for radioactivity in Scotland.

In 2006, the Scottish Environment Protection Agency together with the UK's Food Standards Agency funded a study to identify the extent of seaweed use in Scotland, understand the practices adopted, the extent to which food grown on seaweed treated land is consumed by individuals and to estimate potential radiation doses from ingestion of these foodstuffs. The radionuclide of primary interest is technetium-99 (^{99}Tc) due to relatively high historic discharges from the Sellafield nuclear site and measured concentrations in seaweed collected along the northwest coast of the British Isles. Samples of seaweed, soil, crops and animal products were collected in 2006 and 2007 from 20 locations from the northwest coast of Scotland and offshore islands, including Orkney and Shetland. Radiation doses were estimated using measured concentrations of ^{99}Tc in foodstuffs and consumption data. The highest estimated doses from this pathway are of the order of a few microsieverts (µSv) and the majority of the estimated doses are at least a factor of 100 lower. To place the doses in context, they are at least an order of magnitude lower than the dose from naturally occurring radionuclides in a typical UK diet and are small compared to the annual dose limit for members of the public of 1000 µSv per year. The doses estimated from this study would not justify a major programme of continuous monitoring. The data from current monitoring programmes could however be used to identify any trends which might suggest a requirement for changes to the programmes.

P08.19
Standardised Reporting of Radioactive Discharges from AWE Sites. A View from a Nuclear Site with Multiple Discharge Outlets

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In May 2010 the Environment Agency and Scottish Environment Protection Agency published Radiological Monitoring Technical Guidance Note 'Standardised Reporting of Radioactive Discharges from Nuclear Sites'. The Guidance provides good practice to nuclear operators on how they should assess discharges for reporting to the Environment Agencies and supports the practicable implementation of parts of the European Commission's recommendation (2004/2/Euroatom) for standardised reporting. Although a defence site, AWE have been asked by the Environment Agency to consider how their Guidance may be implemented.

The paper reviews how the guidance may be applied across a site with multiple discharge points, many with sampling arrays, and multiple measurements within each reporting period.
The paper quantifies the reported discharges for a number of scenarios based on the guidance and finds that, for whichever set of assumptions are made, reported discharges will be greater than at present. The paper discusses the appropriateness of the Environment Agency approach and considers the likely public perception to step wise changes to reported discharges based on changes assessment methodologies.

P08.20
Comparison of Sampling and Analysis Procedures for NORM in Produced Water Discharged from Oil Platforms North Sea

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A liaison group was established in 2008 comprising competent authorities from Norway, the UK, Denmark and Germany, with responsibilities for regulating the accumulation and disposal of NORM wastes arising from the extraction of oil and gas in the North Sea area. This group has met on a regular basis to discuss issues of joint interest. One area of interest is the discharge of NORM-containing produced water into the marine environment. The total activity of Ra-226, Ra-228 and Pb-210 discharged is reported to the Radioactive Substances Committee of the OSPAR Commission, on an annual basis. These data are used to make overviews of discharges to the North-East Atlantic.

There are indications that these data not only reflect actual differences in discharges but also differences in approach to producing and reporting the data. It is important that these differences are understood otherwise the reported data may give a distorted view of the contribution made by each country to the total discharge and give a false picture in relation to discharge trends.

There are a number of factors that may contribute to the uncertainty of the reported data, including sampling technique, analysis methodology and reporting. It is not clear which of these factor has the greatest influence on reported data. A better understanding of these factors should help improve the accuracy of the reported data, increase confidence, and subsequently help to protect the environment. Therefore, a project has been commissioned to compare the sampling and the analysis procedures applied in Norway, UK, the Netherlands, Denmark and Germany. A second project will also assess the uncertainties associated with the reported data and develop recommendations for a standard methodology for sampling and measuring produced water. This paper provides an overview of the results of these projects.

P08.21
Radiological Assessments of the Public: the Challenge of Assessing Changes to the 'Critical Group' at Sellafield

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Routine discharges of radioactive waste in the UK are made under authorisation or permit and dose assessments of the public are regularly published (e.g. RIFE 2010). In the vicinity of the Sellafield reprocessing plant in Cumbria, exposure pathways to the public have included radiological assessments to identify representative persons (formerly critical groups) including children. In ICRP terms, such people are considered to represent those potentially most exposed. Such assessments may include estimation of annual and life-time doses from the consumption of foodstuffs such as seafood. This work has been carried out since at least the early 1980s (Leonard & Hunt 1985). The purpose of this study is to attempt to follow some of those observations from 1981 to 2011.

The challenge of identifying such people through personal contact, use of diary records and duplicate diet samples is summarised, together with an overview of how doses can be calculated. Additivity of doses from e.g. external exposure (Leonard and Hunt 1988) and multiple anthropogenic sources e.g. atom bomb fallout and the Chernobyl reactor accident are also briefly considered as well as exposure to enhanced levels of natural radioactivity e.g. Po-210.

Conclusions are drawn from the findings of how the make-up of the Sellafield seafood critical group has changed over time.

P08.22
Methodology for Comprehensive Monitoring of the Environment and Public Health as an Important Evidence of Safe Nuclear Engineering Development

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The need to assure the safe nuclear engineering development for the national public is an urgent requirement of time. In the light of the renaissance of the Russian nuclear energetic complex, the special comprehensive monitoring is relevant in the NPP areas. The comprehensive monitoring includes both radiation monitoring of the environment and that of the public health.

To assess the environmental radioactivity, the following key tasks are being solved:

· To obtain the sufficient and valid dynamic information on the environmental radiation parameters under control and monitoring, and on radionuclide concentrations in the local foods and water. To catch the changing radiation circumstances.

· To assess internal and external doses to the public induced by man-made and natural radiation exposure, especially taking the NPP contribution into account.

To assess the public health, two approaches are used: epidemiological and clinic. The background health nearby the NPP is assessed using the national medical statistical data over more than decade. The special attention is paid to the frequency and dynamics of the malignant neoplasm morbidity.

The transparency and validity of the provided information is an important condition in the course of the comprehensive monitoring.

The selected approaches and criteria for assessment enable not only objective assessment of the radiation situation, environmental conditions and public health, but also help to control changing dynamics, i.e., to conduct monitoring since the beginning of the entire NPP operation cycle and at the stage of new units launch. During our examinations, we get information necessary to identify the extent of potential impact of the many-year operation of the nuclear facilities on the environment and public health.

The proposed methodology and findings of the comprehensive monitoring have extensively been tested during the public hearings among the population living in the areas of the existing and constructed Russian NPPs.

P08.23
Assessing the Health and Environmental Impact of the Naval Nuclear Propulsion Programme

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The Naval Nuclear Propulsion Programme (NNPP) leads to the unavoidable production of radioactive waste, including the radionuclides Co-60, H-3 and C 14; some of which undergoes controlled release to the marine environment. What are the radiological implications of this and should the public be concerned?

The Radiation Protection Group in Dstl carries out a large scale assessment of environmental impacts associated with the NNPP, focussing on potential radiation doses to members the public who consume food stuffs collected locally to submarine berths or spend time on potentially contaminated beaches. We collect sediment and biological samples from around the world, analyse them and carry out an assessment of the radiological risks to both humans and non-human species. Our expert advice enables MOD to demonstrate the safe operation of nuclear powered submarines; proving that there is no detrimental impact on human health or the environment and demonstrating compliance with UK Legislation.

The annual survey programme is undertaken on behalf of the Defence Nuclear Safety Regulator and is conducted as far afield as Diego Garcia, where Dstl have worked in collaboration with US Navy in a habitat which is ecologically sensitive and highly protected.

The poster provides an overview of the NNPP, the sampling strategy, survey methodologies and interpretation of survey data. It shows how the work of Dstl is essential in enabling MOD's continued use of the submarine fleet in UK submarine berths and foreign ports such as Singapore.

P08.24
Internal Radiation Doses of the Public around Tianwan Nuclear Power Plant Caused by Intake of Uranium and Thorium Radionuclide

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Purpose: There are about 1.08 million permanent residents in the range of 30km away from Tianwan Nuclear Power Plant (TNPP). To analysis the diet structure and to estimate the internal radiation dose of Residents in vicinity of TNPP before its commercial operation within the area of 30km, to provide scientific base for evaluation the impact of nuclear power plant radiation on residents.

Method: Survey target group are those local residents living in the range of 30km away from TNPP over 6 months. The actual effective number is 19,138. Stratified random sampling method was adopted. The survey includes basic personal circumstances and the diet. According to the Food Category Principle and Internal Radiation Does Estimation Method in UNSCEAR 2000 report, the consume amount of public milk products, meat products, grain products, leafy vegetables, root vegetables and fish products in different survey areas and of population categories are calculated. the concentration of uranium and thorium series radionuclides was Calculated, and internal radiation dose was Analysed using dose conversion factors.

Result: According to the survey result, Fishermen consume much more fish products and grain products than the rest of the population, while urban residents consume more milk products. Milk products consuming are increasing in line with the distance increasing, but the fish products and grain products consuming is decreasing contrarily to the distance increasing. Public around TNPP consume more grain products , leafy vegetables and fish products, compared to the world average food consumption. Committed dose equivalent is 691$\mu Sv \bullet a^{-1}$ to children, the figure is 327$\mu Sv \bullet a^{-1}$ to adults, 536$\mu Sv \bullet a^{-1}$ to the fishermen. The dose in children and adults living around TNPP is 3.5 times and 3.0 times of the world average. In the category of adults, the internal committed effective dose is decreasing from fishermen to salt farmers, urban residents and farmers.

Conclusion: ^{210}Po, ^{210}Pb and ^{228}Ra are the key nuclides which affect the internal radiation dose of by diet fishermen and live on food from the outcome, It should be pay more attention for the internal radiation dose estimation and evaluation for the fishermen, because of their living around the TNPP and the dietary pattern; we should Investigate the regular changes of dietary status and recipes, because Dietary structural features and some high activity of radionuclides content in the food maybe the contributor to the high resident committed dose equivalent.

P08.25
Comparison of Air Dispersion Modelling Techniques in Calculating Effective Dose in an Urban Environment and Meeting Regulatory Requirements.

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The cyclotron and PET Radiopharmacy facility on the St.Thomas' Hospital site releases short term spike discharges of radioactive gases five days a week over the year. The discharge point is a 55metre stack on the East Wing of the hospital. Surrounding the discharge point are wards, residential buildings, the Evelina Children's Hospital, the staff day nursery, the Houses of Parliament and high profile hotels. A robust calculation of effective dose was required.

Calculations based on in-house methods and on the HPA W63 methodology have produced a wide range of annual effective dose (3mSv to 0.007uSv). This depended on the equations used and assumptions made, despite a constant source term. The regulator expressed a lack of confidence in the W63 model to predict a realistic dose to critical groups in an urban environment.

To satisfy the regulator, the Trust engaged experts to model stack discharges using ADMS computational modelling and to perform wind tunnel modelling. A 1:200 scale model of the St Thomas' site and key surrounding buildings was made in house.

The comparison of these techniques will help substantiate if carrying out wind tunnel modelling is justified for all facilities discharging radioactivity in to the atmosphere in urban environments. Dose conversion factors will be established.

Realistic dose estimation has a direct impact on the discharge limits imposed in the site permit and enables a proportionate assessment of BAT. It will help define stack height requirements and establish an appropriate level of abatement measures which is appropriate and justified. A risk assessment and system of work will be produced for outside workers re-cladding the East Wing, who will be working in proximity to the discharge point. Comparison of techniques will establish modelling uncertainties. Results will be produced by end February 2012. On site measurements of gamma shine at air intake points will supplement modelling results.

David Gallacher, Susan Chadwick

Key words: Air dispersion modelling, urban environment, effective dose, BAT, regulator.

P08.26 Importance of Soil Type on Internal Distribution of Radiocaesium and Radiostrontium in Barley, Oat and Wheat

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The release of radionuclides to the atmosphere can result in deposition of the radionuclides directly to terrestrial ecosystems. Following deposition, uptake from soil will also contribute to the activity that is internalized in plants and further transported in the terrestrial ecosystems. These two processes are of concern in the nutrition chains, cereals-bread-human and in feeding stuffs-cow-milk-human.

The aim of this study was to quantify the internal distribution of (1) direct wet deposited ^{134}Cs and ^{85}Sr in wheat and (2) root uptake of ^{137}Cs, from Chernobyl accident, in barley and oats, as well as the dependence of distribution on soil type.

Wheat crop was grown at the Ultuna meteorological and agricultural field station (Uppsala County) and land management was in accordance with regional agricultural practice. The trial had a randomized block design with 1×1 m^2 parcels with three replicates. ^{134}Cs and ^{85}Sr were deposited on wheat at three different growth stages by a rainfall simulator. Barley crops was grown at Helganbo (Uppsala County) and Möjsjövik (Uppsala County) and oat crops was grown at Björke (Gävle County), Hille (Gävle County) and Möjsjövik (Uppsala County) all places were in Sweden. Both crops were grown in accordance with regional agricultural practices. Sampling was made in the last growing stage from an area of 1 m^2 and the different plant compartments (stem, head, husk and grain) for all crops were dried. Samples were placed in plastic jars and the activity was measured by High Purity Germanium (HPGe) detectors, calibrated for this sample geometry.

The preliminary results indicate that the lowest distribution of ^{137}Cs was found to the head and grains of barley and oat grown on loamy clay soil type. There is an indication that the distribution of ^{134}Cs to the head and grains in wheat is not related to the time from the deposition of ^{134}Cs to harvest. It was found to that the distribution of ^{134}Cs to head was higher in the husks then to the grains. For ^{85}Sr it was seen that at a deposition at harvest the highest amount was distributed to the husks compared to the grains. However, at a deposition at the growing stage "flowering" a higher amount was distributed to the head.

Factors that influenced distribution of radionuclides were the soil type, type of radionuclide and time interval between deposition and harvest.

P08.27
Environmental Gamma Spectrometry for Polish Nuclear Power Plant – Preliminary Considerations

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Poland faces a choice of an environmental radiation monitoring systems (ERMS) for newly designed Nuclear Power Plant (NPP). Contemporary radiation monitoring systems can be based on gamma detector cooperated with Multichannel Analyzer (MCA). That solution will give a tool for very fast assessment on radiological situation around NPP and allows authority to react in case of radiological circumstances. The level of radioactive isotopes of cesium and iodine must be the subject of permanent monitoring because of their large amount in the hypothetical radioactive elements fallout from NPP. Thus ERMS must be high sensitive for the mentioned radionuclides simultaneously should be flexible to give an contingency to react to others radionuclides that can be present in radioactive fallout. The separate issue is a noble gases monitoring. The above radionuclides are taken into consideration because of their dominant role in the radioactive fallout after nuclear disasters in “Grand Slam”: Windscale, TMI, Chernobyl, and Fukushima.

Two types of gamma detector were examined for their further implementation for the ERMS. The pre-calibrated HPGe detector was applied to cooperate with Inspectot2000 MCA while the second spectrometric system was based on LaBr scintillation probe combined with Tucan 8k MCA. The mockup experiment was fulfilled with stainless sample obtained by neutron activation using Am-Be source with strength of 1.5 10^7 n/s. In results of activation radionuclides of Co58, Co60, Cr51, Fe59, Mn54 occurred in the sample. They were a source of gamma photons with energy ranging from 320 keV through 1332 keV and several other belonging to that limits. Basing upon the above source of gamma radiation the efficiency calibration of LaBr probe was done and two series of separate measurements were performed on both spectrometric systems. During each gamma spectrum analyzes peak net area, total area, background, resolution, efficiency, and activity were determined. These data allows to estimate Lowest Limit of Detection (LLD) and Relative Minimum Detectable Activity (MDA_r). Both of those parameters are useful for assessment spectrometric system ability. The LaBr probe shows better LLD and MDA_r than HPGe detector however its resolution is worse by one order of magnitude. Thus preliminary test shows that LaBr with MCA could be taken into consideration as the future environmental gamma monitor for newly designed Polish Nuclear Power Plant.

P08.29
Comparison of Gaussian Standard Deviation Methods and ADMS code for Environmental Impact Assessments

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In order to quantify dose impact on members of the public in case of atmospheric releases in normal and off-normal conditions, companies operating in the nuclear domain use simulation codes in addition of in-situ measurements.

Dose impact depends strongly on dispersion of radionuclides in atmosphere. Many parameters are involved in dispersion characterization such as wind velocity and direction, rain, diffusion conditions, distance to the point of observation and stack elevation….

Traditionally, atmospheric dispersion evaluations in France were made by using basic DOURY's or PASQUILL's Gaussian standard deviations methods. The improvement of computing abilities allows calculations with much more elaborated models such as AMDS able to consider structured wind and temperature profiles, effects of roughness and relief.

The aim of this study is to compare Atmospheric Transfer Coefficient (ATC in $s.m^{-3}$) calculated with the two codes around various AREVA sites by using their real characteristics such as stack elevation, local annual meteorological scheme and reference groups.

Ratios of ATC are plotted as a function of distance and stack elevation. The discrepancies are analyzed in detail by using individual ATC versus distance curves corresponding to single stability and wind velocity couple.

In addition, ATC calculated with the 3 methods are confronted to routine in-situ measures led by operators all year long. Because AMDS allows a strong parameterization of calculations, influence of the evolution of different parameters such as roughness, release temperature and release velocity at stack is studied.

KEYWORDS: Radiological impact on environment; Doury, Pasquill ,AMDS;

P08.30
Public Exposure during the normal operation of a PET Radiopharmaceutical Production Facility

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The aim of this work was to estimate the effective doses to the individuals of the public due to the normal operation of a PET radiopharmaceutical production facility. The facility studied was the Section of Research and Production of Radiopharmaceuticals (SECPRA) of the Development Centre of Nuclear Technology (CDTN/CNEN) in Belo Horizonte, Brazil. The facility has a cyclotron GE PETtrace 8, capable of accelerate protons up to 16.5 MeV, with two targets dedicated to production of fluorine-18. The yield for production of F-18 is about 9 Ci in 2 hours of dual beam irradiation. The main contribution to the public exposure is the radioactive gas released by the chimney of the facility during the 2-[18F]fluoro-2-deoxy-D-glucose (^{18}FDG) synthesis and during pre-irradiation process. For the dose assessment during the routine production of FDG, a run in a maximum condition was performed and the gas activity released was reported. The same process was adopted for dose assessment during the pre-irradiation. The concentration of the radionuclides F-18 and N-13 in air was estimated and the effective doses to individuals of the critical group from inhalation and external exposure were assessed. The total effective doses for an individual of the critical group, in the two most unfavorable scenarios studied (production of FDG and pre-irradiation in a maximum condition) were, respectively, 0.48 uSv and 0.37 uSv. Considering in one year 180 productions of FDG and 100 pre-irradiations in a maximum condition, the total effective dose to individuals of the public was less than 0.20 mSv, which is minor than the dose constraint established by the Brazilian regulatory authority (0.3 mSv). We can conclude the estimates were sufficiently conservative to consider the safe operation of the facility.

P08.31
Preliminary Study for Annual Release Limit of Gaseous Radioactive Materials from Pyroprocess Facility

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The Pyroprocess is an advanced spent fuel retreatment technology enables maximizing usage of uranium. Korea has been studying the Pyroprocess which is a proliferation resistant technology from 1990's. The Pyroprocess facility treats spent nuclear fuel consisted of large amount of complex radionuclide. Before the facility is introduced, therefore, the radiological effect has to be assessed. However, the facility is currently conceptual level and any regulatory criterion has not been provided.

In this study, as a preliminary study, we determined the annual release limit of gaseous radioactive materials from the facility. The inventory of radionuclide in spent fuel was calculated from ORIGEN code and initial release source term was derived with several facility specified assumptions. Annual release limit of gaseous radioactive materials is obtained which meets dose goal by in manner of decreasing from the initial source term. The result of this study is expected to contribute to license procedure of the Pyroprocess in near future.

Keywords: Pyroprocess, Spent nuclear fuel, Exposure dose, Radionuclide inventory

P08.32
Fire Test Evaluation using the Kerosene and Aviation Fuel

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The USNRC performed the evaluation about the transient fire for the TN-68, HI-STAR 100, and LWT cask after the fire accident generated in the Howard Street railroad tunnel of the Baltimore on July 18, 2001. Greiner of the Nevada University and Lopez of the SNL, and etc. perform the researches about the fire accident using the Jet fuel after the airplane terror on September 11, 2001. In this paper, the transient fire test was performed by using the Kerosene and Jet-A-1 as the fire source under the compartment condition in order to evaluate the flame temperature in the fire due to the release of the Jet fuel according to collision of airplanes, and the fire due to the release of the kerosene according to the impact of vehicle. The transient fire test was performed by using the scaled down model of the metal storage cask under the condition of the test result in which the temperature is the highest measured. The burning time of the Jet-A-1 was shorter than Kerosene. And the flame temperature in the Jet-A-1 was high measured than the kerosene. The ventilation openings became bigger; the fuel consumption rate became bigger. Therefore, the flame temperature was high measured in case the size in the ventilation openings was big. In the compartment fire, the flame temperature was gradually increased.

P08.34
The Development of Stylized Inadvertent Intrusion Scenarios for a Purpose Built Near Surface Disposal Site for Radioactive Waste

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The Environment Agencies' Near Surface Guidance on Requirements for Authorisation (NS-GRA) requires an assessment of the potential consequences of inadvertent human intrusion into a planned near-surface disposal facility after controls on the site have ceased. The NS-GRA considers that inadvertent intrusion into a near surface facility is essentially inevitable, although the timing and nature of the inadvertent intrusion is impossible to predict. It therefore suggests that the consequences are explored through a series of separate stylised scenarios, but does not define the scenarios.

The Scottish Environment Protection Agency (SEPA) asked the Health Protection Agency (HPA) to provide guidance on appropriate stylised inadvertent intrusion scenarios for purpose built near surface facilities for radioactive waste, including identification of key parameters and appropriate exposure pathways. These scenarios will then be used by SEPA as a reference when evaluating specific proposals for this type of facility.

This paper describes the development of a set of stylised scenarios for the assessment of inadvertent intrusion into a purpose built disposal facility located at between 15 m and 65 m depth. The scenarios were developed using the International Atomic Energy Authority (IAEA) ISAM methodology and discussions with relevant experts as a starting point. The resulting long list of exposure scenarios and exposed groups was then combined into five stylised scenarios, involving a total of eight exposed groups.

The five stylised scenarios are: exposure to waste that has been extracted from the facility (borehole scenario); exposure as a result of tunnelling into the facility (tunnelling scenario), exposure as a result of open cast mining to the facility (surface excavation scenario), controlled intrusion into a facility by an expert and uncontrolled intrusion into the facility by a curious worker.

P08.35
Radioactive Waste Management Facilities and Assessment of their Safety in Estonia

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This paper will provide a time-line overview of the progress on radioactive waste management facilities in Estonia following the 1991 declaration of independence. Several important factors and the promoting means will be addressed. Overview is also given about the safety assessments of the radioactive waste management facilities. Republic of Estonia has managed to solve the problems related to the historical radioactive waste sites and has worked a lot in area of the policy development. The following steps also include starting of the process of the final disposal for radioactive waste in Estonia.

P08.36
Safety Assessment Methodologies in Disposal of Disused Sealed Sources Using Borehole Concept: Zaria Case Study

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The paper develops safety assessment model appropriate for use in calculating doses to a resident farmer living in the far future in the vicinity of a borehole disposal facility around Zaria environs in Nigeria. Doses are assumed to arise from potential releases from the disused sources disposed in the borehole facility having inventories typical to those found in the African countries. A list of features, events and processes (FEPs) was developed, relevant to Zaria biosphere and an assumed requirement to calculate doses to the farmer via abstraction well water. An 'interaction matrix' was also developed to help define the FEPs and to identify the relationships between them. These relationships define how radionuclides escape from the container, migrate and accumulate in biospheric media, thereby giving rise to radiation exposure. The doses to the farmer were calculated using GoldSim computer model. The model presented is probabilistic in nature that will reflects the current state of knowledge about the site by using probability distributions to capture what is expected (average or central tendency) and the uncertainty (standard deviation) associated with input parameters. The model was then run using Monte Carlo simulation over 100 realisations in each case. Each realization represents a possible combination of input parameter value. The output estimated values of contaminant release rate, concentration in environmental media and resulting doses to human receptors are obtained. Statistical summaries of the result were then compared with regulatory performance objectives (dose constraint). Initially the average value was found to be 0.76mSv/yr, which is greater than the dose constraint (0.3mSv/yr). This was found to be due to the daughters of ^{241}Am radionuclide especially ^{239}Np which has a Total Effective Dose Equivalent (TEDE) of 0.761mSv/yr. The ^{241}Am inventory was then reduced to a value (2.95MBq) that gives a dose limit of 0.296mSv/yr.

P08.37
An ALARP approach to Human Factors and Ergonomics

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This paper presents a synopsis of an ALARP optioneering study, decision and prior risk assessment for the processing of 30-year old HEPA ventilation filters wrapped in PVC. It describes how this safety adviser / RPA lead approach was developed to enable a pragmatic means of incorporating basic ergonomics and human factors into risk assessments and ALARP. The approach taken resulted in a holistic assessment which both determined and justified a suitable method to accelerate significant hazard reduction whilst protecting the workforce. Acceptance of the proposal was facilitated by early engagement of stakeholders.

P08.38
Planned near surface radioactive waste repository impact on productive aquifer system - case of Ignalina NPP

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IAEA safety documents recommend assessing the safety framework of groundwater abstraction in the proximity of nuclear facilities. The main task of this presentation is to provide the results on the re-calculation of Visaginas town wellfield well protection zones (WPZ), since the Visaginas town wellfield is installed close to the site of planed near-surface repository for low and intermediate level radioactive waste in Lithuania.

The numerical model used in this study is based on three-dimensional finite-element code FEFLOW 5.0 which allows modelling of groundwater flow and contaminant transport in a layered three-dimensional system. The calibrated model of Visaginas wellfield recovers the groundwater flow in the Quaternary and Upper-Middle Devonian multi-aquifers systems.

The evaluation of well protection zones for wellfields exploiting groundwater is currently determined by the Lithuanian legal documents. The groundwater modelling results of this study show that third sub-zone of WPZ should be 1000-1100 m away from the wellfield fence. The long axis of WPZ extends for 4500 m from north to south and for approximately 3000 m from east to west.

Only with a very high wellfield capacity (pumpage rate till 63 900 m^3/day), the wellfield capture zone during 50 operation years would reach the Stabatiðkë site, where near-surface repository for low- and intermediate-level short lived radioactive waste will be built.

The predicted doses obtained by human due to ^{14}C and ^{129}I in drinking water after 100 years from Stabatiðkë repository closure should be below the dose constraint (0.2 mSv/y).

P08.39
Integrating World Reference Base Soil Maps into Biosphere Risk Assessments for Radioactive Waste Repositories

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Many countries plan the long-term disposal of waste from the nuclear fuel cycle in deep geological formations. Within the long-term safety assessment compliance with safety criteria has to be demonstrated. This includes considerations on the release of radionuclides from the repository, migration through the host rock and dispersion in the biosphere, where they may cause exposure to humans via various pathways. The geosphere biosphere interface (GBI) may be represented by the transport of radionuclides in groundwater used for irrigation and as drinking water in addition to subsurface groundwater entering the biosphere by of capillary raise or a spring.

To determine radionuclide uptake through ingestion of food, inhalation of dust particles in air and external exposure, the contamination of surface soil by radionuclides in groundwater has to be assessed. Soil properties like soil texture, pH, redox potential and content of organic substances influence the distribution of radionuclides between water and soil, as well as the accumulation of radionuclides over long time frames. The transfer of radionuclides from soil to plants is likewise determined by soil type and properties.

Soil parameters used in biosphere models like transfer factors from soil to plant or distribution coefficients are often presented for a certain soil in publications or are collected for the soil types sand, loam, clay and organic in data bases. To integrate these parameters with biosphere models, we propose the use of maps from the European Soil Bureau showing the distribution of World Reference Base for Soil Resources soil types in Europe.

The WRB soil types are condensed to sand, loam, clay and organic soil classes for the combination with radionuclide parameter data bases. Depending on the soil model used within the biosphere model, the maps may be modified further to show, for example, waterlogged and dry loam soils. Satellite images and ESB soil maps are visualized with the Google Earth software. This allows the distinction between natural and agricultural regions. The purpose of this work is the assessment of soil activity concentrations and biosphere dose conversion factors calculated from biosphere models around a nuclear waste repository with a high geographic resolution. .

P09.01
Recent Recommendations on Emergency Exposure Situations and a Discussion on Setting Reference Levels

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Expert Group on Implementation of New International Recommendations for Emergency Exposure Situations (EGIRES) of the Working Party on Nuclear Emergency Matter (WPNEM) has been mandated by the Committee of Radiation Protection and Public Health (CRPPH) of the OECD Nu-clear Energy Agency to investigate issues in, and approaches to, the implementation of the new ICRP recommendations and revised Basic Safety Standards of the IAEA for emergency exposure situations, specifically nuclear/radiological emergencies includ-ing accidents and consequence man-agement for malicious acts. This also includes the application of optimisation of protection strate-gies, setting of reference levels and the inclusion of stake-holder input in this process. The expected output of the expert group is to prepare a report on issues covering mentioned topics.

Emergency exposure situations, as defined by the ICRP, are unexpected situations that may require urgent protective actions, and perhaps longer-term protective actions to be implemented. The Com-mission continues to recommend optimisation and the use of reference levels to ensure an adequate degree of protec-tion with respect to exposure to ionising radiation in emergency exposure situations. Setting reference levels is a responsibility of national authorities and reference levels represent the level of dose or risk, above which it is judged to be inappropriate to plan to allow exposures to oc-cur and for which therefore protective actions should be planned and optimized.

EGIRES decided to analyze the established processes for optimization of the protection strategy for emergency exposure situations and practical implementation of reference levels concept in several member states of the NEA by performing a survey. It is planned to collect information on the defini-tion of optimization strategy in different countries, optimization of protection for different protec-tive actions and also optimization of urgent protective actions. In addition, national criteria in set-ting reference levels, its use, relevant processes including specific triggers and dosimetric quantities in setting reference levels are focus points that will be evaluated.

Benefits expected from the work of the expert group will be useful to find a path and even common understanding of surrounding issues in emergency exposure situations with the inclusion of national perspectives and also to discuss stake-holder involvement.

Poster sessions C-D: Area 9

P09.02
Medical Treatment of Radioactive Material Intakes at AWE

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The main radioactive hazards present in the workplace at AWE are plutonium americium, uranium and tritium. Accidents involving these materials could have serious short- and long-term consequences and thus medical intervention must be considered in appropriate situations. Actions that have recently been taken to update AWE's medical treatment procedures include:

• Clarification of the appropriate dosimetric quantity and unit to use for deterministic effects.

• Collaboration with a specialist centre, the Royal Brompton Hospital, on whole lung lavage following inhalation intakes. This included a re-evaluation of the risks of WLL on the basis of experience gained at the hospital.

• Determining the potential for DTPA to enhance kidney toxicity from uranium and thus providing guidance on DTPA administration in mixed plutonium/uranium intakes.

• Enabling staff involved in higher risk work with soluble plutonium to self-administer DTPA by nebuliser.

P09.03
Creation of Quick Internal Dose Assessment Graph Following the TIARA Project for Ingestion and Wound Pathway in Emergency Situations

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Following the *Treatment Initiatives After Radiological Accidents (TIARA) project* and the publication of the *Dose Assessment of Inhaled Radionuclides in Emergency Situations* booklet, a study has been conducted by the laboratory of the Radiation Protection of Workers and Monitoring Unit (RPMWU) of the International Atomic Energy Agency (IAEA) as part of the emergency procedures to complete this booklet for the Ingestion and Wound pathway.

These graphs were requested for the need of the RPMWU laboratory and allow a quick triage of a large number of people getting internally contaminated. All the calculations were performed on IMBA professional plus software and include the following radionuclides: Am-241, Cs-137, Co-60, I-131, Ir-192, Tc-99m, Pu-238, Pu-239, Po-210, Ra-226, Se-75, Sr-89, Sr-90, Depleted Uranium, Natural Uranium, Yb-169 for both ingestion and wound pathway. The methods of measurement include, depending of the radionuclide: whole body measurement, urinary excretion, fecal excretion and thyroid measurement.

The newly created figures will allow the RPMWU laboratory to quickly assess the committed effective dose (E(50)) of the person in case of emergency, and could eventually complete the already existing graph of the TIARA project for the inhalation pathway.

P09.04
New Calixarene Formulations for a Quick Uranium Skin Decontamination

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Cutaneous contamination can be regarded as the second highest contamination pathway in nuclear industry. The entry of actinides such as uranium into the body can occure through intact or wounded skin that can induce a high internal exposure and severe damages to kidney and liver. Despite those higher risks for nuclear workers, no specific emergency treatment for cutaneous contamination has been developed. .

In a recent work at IRSN, a topical pharmaceutical form was developped to treat skins contaminated by uranium: an oil-in-water (O/W) nanoemulsion displaying calixarene molecules, known for their actinides chelation properties. The efficiency of the nanoemulsion for uranium extraction was demonstrated by *in-vitro* and *ex-vivo* studies. *In-vitro* experiments showed that the calixarene formulation was able to extract up to 80 ± 5% of uranyl ions from a contaminated solution. These results were confirmed by *ex-vivo* studies, using Franz cells. An extraction capability of uranyl ions up to 99 ± 1% after a time of contact of 24h between the calixarene formulation and a uranium solution filed on wounded skin was achieved.

However, that formulation is not the best suitable galenic form for a topical delivery because of its liquid form. So the objective of that study is to adapt the liquid nanoemulsion formulation to a more efficient topical delivery system. We choose to modify the external phase of the nanoemulsion by jellifying the system as a function of the temperature. Biopolymers like HydroxyPropylMethylcellulose (HPMC) and MethylCellulose (MC), inert for the skin and commonly used in pharmaceutic and cosmetic industries, were choosen and added to the initial liquid formulation so that the new formulations, liquid at cold temperature, jellify when they get in touch with the skin. Indeed, the skin temperature is above the point of gel of the biopolymers in the new formulations.

We verified that the physico-chemical caracteristics of these new formulations were conserved in terms of droplets size, pH and stability as a function of time. In addition, these new formulations were tested by *ex-vivo* experiments to remove uranyl ions from an aqueous contaminated solution and compared to the initial liquid form. Results showed that the new calixarene nanoemulsions extracted up to 98 ± 1% and 99 ± 1% of uranium when using HPMC and MC respectively. These latter results demonstrate the potential interest of these delivery systems for uranium skin decontamination.

P09.05
Order of Medical Management of local Radiation Injure in Russian Federation

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Experience of Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency shows that in general local radiation injures happen during execution of professional duties. So, often local radiation injures are effect of influence of ionizing radiation as occupational condition.

Until March 2011 Russian Federation did not have Order of medical management in case of acute and chronic occupational diseases, and it was the reason for difficulties of emergence medical management.

Ministry of Health and Social Development of Russian Federation takes active measures for developing occupational medicine and also for radiation-hazard industry.

The twenty-third of March 2011 Ministry of Health and Social Development of Russian Federation signed order No 233n «Order of medical management of acute and chronic occupational diseases».

To continue with this document experts of Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency work out Order of medical management of local radiation injures.

The Order allows to create effective system of medical support of local radiation injures, which includes first aid, emergency, specialized and high-technology treatment, occupational diseases examination and rehabilitation treatment.

P09.06
Radioprotective Drugs in the System of Radiation Protection of Exposed Radiation Workers and Population in the Case of Nuclear Accidents

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Radiation workers can be exposed to most significant radiation risks during the early stage of radiation accidents at nuclear power stations. The determining factor in the development of acute radiation injury is the external radiation due to radioactive waste. There is the possibility that workers may be exposed to lethal doses of radiation within the next few hours after the start of a serious nuclear accident. Radioprotector indralin issued by government agencies has been developed as a agent for prevention of the acute radiation injuries. Indralin (preparation B-190), being a radioprotective drug of emergency action, is designed to prevent the acute radiation damage upon exposures to a high dose rate of ionizing radiation (>1 Gy/hour) and particularly to reduce the risk of mortality from emergency exposures at the doses that cause severe and extremely severe forms of acute radiation sickness. According to the DRF, the expected radiation protective effect of the radioprotector for humans is up to 1.5. The preparation causes no complications of dyspepsia that occur when using radioprotectors cystamine or amifostine. Indralin does not reduce the tolerance to thermal exposures in the range of up to 40° C when performing a moderate-level physical activity or affect the labour productivity of exposed workers under hypoxia. The second most important factor of exposed radiation and emergency workers in these situations is the intake of iodine radionuclides via inhalation. The main way of an effective protection consists in the iodine prophylaxis. This paper provides relevant data on the time span of effective usage of stable iodine preparation - Potassium iodide tablets. The experience of the Chernobyl accident has shown that the levels of the inhalation intake of other radionuclides - fission isotopes, neutron activation products, plutonium and transuranic elements (TUE), were within the frameworks of emergency regulations. The alimentary route of the radionuclide intake in these cases did not represent any radiological interest. To prevent resorption of cesium and strontium radionuclides in the gastrointestinal tract (due to the retrograde intake from the respiratory system), Ferrocene and Adsobar or Algisorb are administered correspondingly. Sodium-calcium and zinc salts of DTPA (Pentacin and Zinkacin) are applied to fight against the incorporation of plutonium, TUE, rare- and alkaline-earth radionuclides. Key radiation protection measures of the exposed population at the areas of radioactive fallouts from the accidents at nuclear power stations are primarily defined by organizational measures of a sanitary nature: the organization of radiation monitoring of drinking water and food products; the ban on their consumption (particularly, dairy products of local production) in the case of radioactive contamination above the allowed radiation levels.

P09.07 A Study on Radioactive and Nonradioactive Aerosol Behaviour

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Aerosols belong to the most dangerous forms of radioactive and nuclear substances, with regards to their ability to spread. Radioactive aerosols are suspensions in air of liquid or solid particles with diameters ranging from 0.001 to 100 microns; these particles are either formed by a radioactive material or the radioactive material is attached to the surface of a non-radioactive particle. It is important to know physical behaviour of these aerosols, for example if we need to predict possible consequences of a terrorist radioactive dirty bomb attack, to design an equipment protecting against these agents or to estimate internal and external contamination by these substances.

The experiments were carried out in a radon-aerosol chamber at SUJCHBO. This chamber is a device for studying physical behaviour of radioactive and non-radioactive aerosols. It is separated from the ambient atmosphere by a sophisticated air-exchange system and enabled us to perform the experiments at pre-defined climatic and ventilation conditions. A radon emanator was used as a primary source of the radioactive atmosphere. Maximum concentration of radon reached in the chamber during the experiments was 2 MBq•m^{-3}.

The aim of this study was to compare both the deposition rates of several test aerosols and also their particle size distribution dynamics (e.g. time evolution of the mode and the standard deviation). Pairs of radioactive and non-radioactive aerosols having the same original particle size distribution were compared. Several types of polydisperse aerosols were generated by two methods – nebulization, or evaporation followed by condensation. Monodisperse aerosols were produced from the polydisperse aerosols using electrostatic classification. Each of the aerosols was injected into the chamber filled either by the particle-free laboratory air, or by a highly radioactive radon atmosphere. Radioactivity of aerosol particles was continuously monitored during the experiments. The preliminary results of the comparison between radioactive and non-radioactive aerosol have been found in a qualitative agreement with theoretical predictions with regards to the influence of radioactivity on particles deposition and size distribution dynamics.

P09.08
Design of Optimised Systems for Monitoring of Radiation and Radioactivity in case of a Nuclear or Radiological Emergency in Europe

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In the aftermath of the Chernobyl nuclear accident in 1986, many European countries installed monitoring systems for radioactive contamination in the environment. These systems are linked together through a network and serve the purpose of providing early warnings against nuclear accidents. Many of the older monitoring systems require updating, and some areas would benefit from new networks built with state-of-the-art technology. The European Commission funded a research project, DETECT that had as primary objective the development of a tool to optimise the deployment of environmental radiological monitoring devices to be used during nuclear emergencies, in some cases in conjunction with portable devices. This tool helps to ensure that nuclear regulators and nuclear emergency response organisations can quickly detect any accidental or incidental release of radioactivity into the environment.

This contribution will elaborate on the outcome of the project as its implementation across Europe and will provide a live demonstration of the DETECT Optimization Tool (DOT) during the conference.

P09.09
The Application of Web GIS abd Google Earth for Emergency Response and Relative Training

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INER (Institute of Nuclear Energy Research, Taiwan) has developed an Emergency Response Information Integration System (ERIIS) by using Web GIS and Google Earth. ERIIS can integrate and display the required information and data on the windows of Web GIS and Google Earth in the same monitor screen at the same time. The data integrated by Web GIS include atmospheric dispersion evaluation results, dose assessment results, and radiation survey results. ERIIS also can provide convenient accident location input methods, including digits input and map position input that can save the response time of evaluation and decision making. Google Earth is very useful to public communication that can easily announce the information which the public need to know by internet. From the experience of testing ERIIS, we can find that the visualized data will be understood more easily and quickly. Modern information technologies provide many ways to benefit emergency response.

Key words: Web GIS, Google Earth, Emergency Response Information Integration System,

P09.10
Orphan source recovery in Genova – Italian Fire Fighter Experience

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Every day, hundreds of thousands of containers are moved in the world. Most of them contain metal scraps sent to melting plants or metal refineries.

In order for this kind of containers to be transported, the law requires importers to put them through a radiological test, and, several times, abnormal radioactivity levels are registered.

During the trip and before the controls, a lot of people and workers deal with these containers, sometimes representing, without their knowledge, a very serious health threat. Moreover, when radioactivity is found in a shipment, the law and international agreements don't allow to send it back unsafe.

At the end of July 2011, the Italian Fire Brigade has experienced a real professional intervention: the recovery of a Co-60 radioactive source (150 GBq) hidden in a container, coming from a Middle East country, unloaded in Genova (Italy).

For the very first time in history, recovery and shielding of the source have been conducted on site exclusively through the use of electromechanical remote systems, in order to prevent fire fighters from absorbing a significant effective dose. The source, able to cause more than 2 Sv/h of effective dose rate to a person who comes in contact with it. A really small object in a tangle of copper scraps tens of tons heavy.

The aim of this article is to show the pre-operative phase, devices and equipment used, the organization, planning and radioprotection assessments. The most important phases of the ten-day-long intervention will be presented.

In addition, the authors will be able to illustrate the activities through a complete report with the help of videos and photos.

P09.11
Approach to Source Terms Estimation Released into the Atmosphere during Accidents of Nuclear Power Plants of Design Information Unknown

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If detailed specifications of a nuclear power plant are unknown due to the absence of the information sharing and a severe accident happens in the nuclear power plant, it might be very difficult to analyze and prepare hazards of the accident. It is necessary to perform analyses and make preparedness on hazardous effects for such an unknown plant in advance. Source terms released into the environment are needed to evaluate damage and effects due to accidents of nuclear reactors. There are various methods to evaluation the source terms, which usually require detailed specifications. In this study, a framework for approach to estimate source terms released into the atmosphere is set up for an arbitrary nuclear reactor with design specifications unknown due to the absence of information sharing.

Estimated source terms would be utilized to assist the decision-making or policy-making in case of the accident. It might be sufficient that the estimation of source terms could provide the decision maker with ranges of effects from a macroscopic point of view such as minimum or maximum. Source terms released into the atmosphere would be dispersed and then fallen into the soil or the water. Radioactive exposure would occur through exposure pathways. As a preliminary stage, source terms released only into the atmosphere are focused on in this study. Source terms from Chernobyl accident and Fukushima accident are analyzed and utilized to set up the framework for approach to estimate source terms released into the atmosphere. In the framework, the use of ORIGEN/ARP code is made to estimate core inventory, which could give a variety of information on other fission products. As a case study, source terms for nuclear reactors of thermal powers 100MWth and 3000MWth are estimated. Those are compared with each other and analyses for procedures of approach to source terms estimation are performed. It would be used to identify and improve weaknesses of the framework for approach to source terms estimation.

Keywords: Source Terms, ORIGEN, Decision-making, Chernobyl, Fukushima

P09.12
A Web Tool For A Real Time Follow Up Of A Criticality Accident In A Nuclear Fuel Factory

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In the factory that ENUSA owns at Juzbado, enriched uranium is handled, therefore there is risk of a criticality event in the facility. For that reason, in the emergency plans and procedures, the tools for the mitigation of the consequences of such an accident are included.

In this work a new tool for the follow up of the consequences of a criticality event outside the facility is explained. This tool, using as an input the time after the accident and the weather data given by the met tower (wind speed and atmospheric stability) gives the dose rate for both external and internal exposure, the activity per air volume of each isotope due to the emission of the fission products. The tool is customized for use in the ENUSA's factory site and can be very helpful to plan the actions to take in emergency situations. The tool is based on web application. Its main advantage is that the only thing that is needed is a web browser so, the use of this tool is possible inside and outside the facility.

The making of this tool is included in an improvement plan, that right now ENUSA is developing in all the emergency equipment, facilities and procedures.

P09.13
Nuclear Security Arrangements for the 2010 FIFA World Cup in South Africa: Part 1: A General Overview (Concept of Operation and Lessons Learned)

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Nuclear security arrangements as part of the overall security arrangements for major public events is growing rapidly to protect people, property and the environment from malicious acts involving nuclear or other radioactive material.

The 2010 FIFA World Cup was held in South Africa from 11 June to 11 July 2010 and presented numerous challenges:

· Monitoring 10 stadiums with fan parks spread over the country, and

· Monitoring 6 ports of entry ranging from border gates, international airports to sea ports.

With limited resources available, the South African government requested assistance from the IAEA in terms of the Assistance Protocol. This resulted in significant training, equipment and financial support from several sources, largely the IAEA and the USA. Optimization of competent RP personnel was still required given the size of the operation.

The concept of operation was to establish source detection capabilities, radionuclide identification, effective communication infrastructure and technical decision protocols to support radiological, emergency and medical response measures through three lines of defence at each monitoring point.

Preparations took place over several months to ensure readiness before and during the tournament.

Presented hereby are overviews of the different aspects of the operation, along with the outcomes and lesson learned.

P09.14
The Creation of the National Alliance for Radiation Readiness (NARR) – Bringing Together Public Health and Radiation Control

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Conference of Radiation Control Program Directors, Troy, United States

In June 2008, the Centers for Disease Control and Prevention (CDC) and the Conference of Radiation Control Program Directors (CRCPD) sponsored a roundtable entitled ”Communication and Teamwork: Keys to Successful Radiological Emergency Response”, which recommended the development of an alliance of organizations to expand the nation’s radiological emergency preparedness capabilities, and to elevate recognition of the roles and responsibilities of public health agencies in a radiological emergency. In April 2009, the roundtable was followed by a workshop entitled “Alliance to Expand Radiological Emergency Preparedness in Public Health” with the aim of building an alliance among professional organizations for sharing radiological emergency preparedness resources, tools and information. An exploratory committee concluded that a National Alliance for Radiation Readiness was a necessary and viable undertaking, and drafted a mission, vision, purpose, structure, governance, and business plan. The NARR was launched in March 2001.

A Steering Committee consisting of representatives from the Association of State and Territorial Health Officials; the National Association of County and City Health Officials; the Council of State and Territorial Epidemiologists; the Association of Public Health Laboratories and the Conference of Radiation Control Program Directors with support and technical assistance from CDC drafted the vision, mission and primary objectives.

The vision is to become a more protected, resilient nation through a comprehensive and integrated approach to radiological emergencies. Our mission is to enhance radiological preparedness capability and capacity in public health and health care systems through a coalition of organizations committed to improving the nation’s ability to prepare, respond, and recover from radiological emergencies at the local, state, and national levels.

The primary objectives of the NARR are

• To build radiological emergency preparedness, response and recovery capacity and capabilities by supporting the development of mechanisms for sharing resources, tools, training, and performance measures and guidelines; and

• To serve as the unified “voice of health” in radiological preparedness in national dialogues on radiological emergency issues, provide input to governmental policy development, and raise awareness as needed to resolve radiological emergency preparedness and response issues.

The NARR was formally launched in the midst of the response to the Fukushima Daiichi accident. Membership in NARR facilitated the collaboration among the various agencies and organizations that traditionally do not collaborate and resulted in the preparation of several products including the passenger radiation screening protocols to be used at the ports of entry.

P09.15
Development and Utilization of Gamma-ray Shielding Suit Excellent Easy-to-wear

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A lot of radioactive substances were released by the accident of the 1st Fukushima nuclear power plant of Tokyo Electric Power Company. And those have contaminated the surface of every matter in the plant and circumference environment. When working in the environment polluted with the radioactive matter, we will take time, shield, and distance into consideration for radiation protection. Wearing a shielding suit is one of the measures. But, a gamma-ray shielding suit which is heavy and misery to wear reduces working efficiency. It brings long exposure hours for the same work. It is important to maintain easy-to-work. A gamma-ray shielding suit with sufficient shielding efficiency was developed and produced commercially. The main material is the rubber containing heavy metals, such as a tungsten alloy. That is sandwiched by the foaming structure rubber with feel nice and good flexibility. The suit contains two parts, a sleeveless jacket and shorts. The body trunk from a neck to a crotch was covered. 10% of gamma ray was shielded by the present material which has 4 mm thickness on the irradiation experiment using a cesium-137 gamma-ray source. In the preliminary result of experimental evaluation, the dose inside the gamma-ray shielding suit was reduces to 75 % of the dose outside the suit at a real work place of the quake-absorbing building in the power plant. At that place a lot of low energy photons were produced by scattering with building materials, as a result, it got high shielding efficiency. From now on, it will step toward utilization through the detailed shielding examination in the power plant.

P09.16
Evaluation of the Emergency Planning Zone for Nuclear Power Plants in Taiwan After Fukushima Daiichi Nuclear Accident

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There are three nuclear power plants operating in Taiwan, Chinshan, Kuosheng, and Maanshan; the fourth one, Longmen, is under construction. According to government regulations, the emergency planning zone (EPZ) of the nuclear power plant (NPP) has been announced within 5-km radius for all plants, and must be reevaluated every 5 years. In 2011, the EPZ of the three operating NPPs requires to be reevaluated. However, due to the Fukushima Daiichi nuclear accident happened in Japan, the Taiwan government started to consider the natural disasters and pay attention to the potential threatening of the simultaneous multiple unit malfunctions. In this study, we calculated the source term data including inventory, sensible heat content, and time duration based on the server accident and the design-based accident of multiple units in one NPP, and collect meteorological data around the NPPs in the recent five-year interval. The effective dose and thyroid dose together with the individual risk and societal risk were calculated using the MELCOR Accident Consequence Code System 2 (MACCS2) developed by Sandia National Laboratory. The EPZs were estimated as a function of distance from the sites under the consideration of the population distribution and the reasonable risk which can be tolerated in terms of social economy. The results showed that the EPZs of the three NPPs should be enlarged from 5 km legislated in the Nuclear Emergency Response Act in Taiwan to a suitable 8-km radius. Subsequently, the emergency response plan (ERP) has to be re-schemed correspondingly.

P09.17
DSTL RADSAFE Exercise

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RADSAFE is a UK mutual support company which provides an emergency response in the event of a road/rail transport accident involving radioactive materials belonging to a company member. DSTL (Defence Science and Technology Laboratory) forms part of the emergency response cover on behalf of the Ministry of Defence membership.

As part of its obligations as a RADSAFE member, DSTL undertook an exercise on its Porton Down Range in Wiltshire in December 2009. The aim was to test its RADSAFE 'Level 2' response to a road traffic accident involving radioactive material. This poster describes the exercise.

Good communications and decision-making are of vital importance in emergency situations. An essential part of the exercise was the interaction of DSTL's responders with the emergency services, particularly the Fire and Rescue Service. Information exchange with the owner of the package involved was also a key element. Real radioactive sources were used to inject realism into the scenario.

The exercise was a successful demonstration of DSTL's ability to respond to a transport accident. Valuable lessons were learned, in terms of both exercise organisation and emergency response.

P09.18
Dimensioning of Norwegian Nuclear and Radiological Emergency Preparedness and Crisis Management

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In emergency planning, it is always a challenge to form a preparedness that provides the best protection based on the resources available. Therefore, in March 2010, the Norwegian government decided on a set of six scenarios with different kinds of nuclear or radiological events in order to provide a basis for prioritising needs and planning future development of nuclear and radiological preparedness.

The scenarios qualitatively describe events with different consequences, and each represents distinct aspects towards crisis management.

The six scenarios:

I. An event at a foreign radiological or nuclear facility that results in a large airborne release that may reach Norway and affect larger or smaller parts of the country

II. An event at a Norwegian radiological or nuclear facility that results in a large airborne release

III. A local event in Norway or close to Norway with no relation to existing facilities

IV. A local event evolving over time

V. An event with a large release to Norwegian marine environment or marine environment close to Norway, or a rumour or suspicion of considerable marine or terrestrial contamination

VI. A severe event abroad without direct consequences for Norwegian territory

The set of scenarios is an important tool for public services, county governors, municipalities and other authorities involved in nuclear and radiological emergency preparedness. It raises consciousness on different needs in different situations regarding crisis management and provides a comprehensive approach towards emergency preparedness planning.

P09.19
Use of the SCALE-SAS1 Code for Dose Rates Calculations in Case of a Criticality Accident

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Within the framework of the development of a simple tool allowing to calculate dose rates due to a criticality accident, a database was built, containing estimations of dose rates at different distances behind various shields and for various criticality accident source terms.

Natures and thickness ranges of shieldings are representative of nuclear plants dealing with fissile materials. The diversity of studied shieldings allows modelling of any type of nuclear plant where a criticality accident could occur.. The shieldings thickness range (0 to 3 m) has been chosen, according to simplifying hypotheses, to allow the whole of a nuclear plant to be taken into account.

During the Tokaï-Mura accident (1999, Japan), most of the irradiated people were living at several hundreds meters from the accident's location. Therefore, estimating a criticality accident's dosimetric consequences outside the installation is just as important as estimating them inside the plant. Consequently, within this study, dose rates have been estimated up to a maximum distance of 1 km from the location of the accident.

The S_N determinist SAS1 module of SCALE4.4a code has been chosen in order to obtain fast dose rates calculations. Given the peculiarities of the engaged calculations, and a lack of qualification for studied configurations (thick shieldings and large distances), the SAS1 module has been validated against MCNP5, the stochastic code chosen as a reference. This work has highlighted several key parameters in the agreement between these two codes; a few rules of use have been defined for the preparation of SAS1 input data.

The purpose of this poster is to present the methodology used to constitute the tool's database from dose rates values behind thick shields and at large distance obtained with the SCALE-SAS1 code. A few validation results, for some chosen configurations, are also presented.

P09.20
UK Emergency Preparedness and Response Arrangements: The Role of the Nuclear Regulator

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The precautions taken in the design and construction of nuclear installations in the UK, and the high safety standards in their operation and maintenance, reduce to an extremely low level the risk of accidents that might affect the public. However, all nuclear installation operators prepare, in consultation with local authorities, the police and other bodies, emergency plans for the protection of the public and their workforce, including those for dealing with an accidental release of radioactivity. These are regularly tested in exercises under the supervision of the Office for Nuclear Regulation (ONR).

In the event of an Off-Site Nuclear Emergency, Emergency Centres will be established at National, Local and Site Response levels bringing together multi-agencies and Government Departments.

ONR is responsible for regulating nuclear safety. In the event of an emergency ONR is responsible for monitoring the activities of the operators and advising the Government Technical Advisor and central government and devolved administrations. Using its statutory powers, ONR would inspect and review the activities of the operators to ensure that they are taking all reasonable steps both to restore the plant to a safe state and to minimise the risk to the general public. On being notified of an emergency, ONR would send Response Teams both to site and to the appropriate off site facility who would monitor the situation and the steps taken to restore control.

ONR would set up its own Incident Suite at its Headquarters to provide a technical assessment capability and to support the Chief Nuclear Inspector and the ONR Response Teams that have been deployed. This would allow ONR to make independent assessments of the likely course of the accident and its consequences, and to consider any implications for other nuclear installations.

P09.21
Assessment of Dose Rates due to a Criticality Accident - Influence of Source and Protections

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In the event of a criticality accident, exposure to ionizing radiations of workers located close to the accident site can be consequent. Moreover, as in the case of the Tokai-Mura criticality accident (Japan, 1999), significant dose rates can be reported at large distances from the place of the accident (several $mSv.h^{-1}$ at several hundreds meters). In order to study the radiological consequences of such an accident, the exposure has to be estimated, not only for workers located in the accident vicinity, but also for other on-site workers and for population living in the surrounding area.

As a consequence, operators of nuclear plants dealing with fissile materials must add to their regulatory files, maps of dose rates and doses likely to be received in case of an hypothetical criticality accident, inside and outside of the concerned plant.

As a technical support to the French Nuclear Safety Authority (ASN), the Institute for Radiological Protection and Nuclear Safety (IRSN) has developed an expert support tool, allowing to quickly assess the dosimetric consequences in case of a criticality accident.

This tool includes a database of dose rates calculations for numerous configurations of sources of criticality accident and biological protections, for distances up to 1 kilometre from the source. On the basis of dose rates (from neutrons and secondary gamma emissions) comparison, influence of source type (metallic, solution…), of shielding nature and thickness, and of distance from the source has been studied.

The proposed poster presents and analyzes some dose rates due to neutron and secondary gamma radiations obtained with this tool, depending on different parameters of the configuration (nature of the source, nature of the biological protections, and geometry).

P09.22
UAS Gamma Spectrometry for Detection and Identification of Radioactive Sources

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INTRODUCTION: The project aims to develop a gamma-ray spectrometry system for detection and identification of radioactive sources from an unmanned helicopter. This system fills a gap between man portable measurement systems and full-sized airborne systems, and complements the car driven measurement systems. The system fills a unique role in many measurement scenarios and can ensure that the measurements can be made by the human operator at safe distance.

With an unmanned helicopter, one can achieve both a high spatial resolution and good range, and be able to approach a source closely, providing good sensitivity with a relatively small instrument. Combined with a camera, it is also possible to visualize and identify the objects. The operating range allows for measurements to cover a larger area in less time than e.g. man-portable measurement systems.

METHOD: The Unmanned Aircraft System (UAS) MD4-1000 (microdrones GmbH) is a quadrocopter (four rotors) equipped with compensating software, which gives a stable ride and relatively simple operation, considerably easier to control than a traditional R/C helicopter. This microdrone is operated by a pilot on ground or by a pre-set route based on GPS track points.

Detector choice is limited by the payload weight of 1200g. A commercial mini-detector system, such as type CZT, is small and opens the possibility of adding a collimator, to enable measurement in very strong radiation fields.

Validation of the system will be done by comparison with gamma flux from point sources and by comparison with previously measured radiation field in southern Sweden. Monte Carlo simulations are performed by the modification of a computer code, previously developed at Linköping University for HPGe in-situ gamma spectrometry.

An established way of presenting real-time spectrometric data is by using so-called waterfall chart, but there are also developments on the same theme, such as the deviation display.

RESULTS: The measurement system fills a gap between man-portable measurement systems and full-sized airborne systems, and complements the car-driven measurement systems. The system may fill a unique role in many of our contingency scenarios in terms of accessibility, versatility, efficiency, and is advantageous from the viewpoint of radiation protection as it can be controlled at a safe distance.

The measurement system will be able to be controlled by a person with a short pilot training. The system will cope with measurement tasks up to one hour at a time, and with several battery sets, it is only required to change batteries between mission sessions. This provides a good stamina. If the helicopter is controlled manually, it provides for a technically limited search area of approximately 3 square km.

P09.23
International Data and Information Exchange Systems to support the EU Member States during Radiological and Nuclear Emergencies

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During the early phase of a large-scale accident with release of radioactivity to the atmos-phere, it is essential to notify and inform competent authorities as early and as adequately as possible to allow decision makers to define appropriate countermeasures.

The Chernobyl accident taught us that international information exchange should be carried out in a harmonised and consistent manner. Although several European countries already had developed automatic monitoring networks by 1986 and in some cases established bilateral agreements to exchange this information, the size of the accident demonstrated the need to extend such schemes to the continental scale. It became important to have commonly agreed international data formats and procedures in place.

Over the past 25 years, the European Commission has worked on improving the rapid ex-change of information and monitoring data. For the early phase of emergency support, it has focused on the early notification system ECURIE (European Commission Urgent Radiologi-cal Information Exchange) and EURDEP (European Radiological Data Exchange Plat-form):

• During the early phase of a large-scale accident, it is essential to notify threatened coun-tries as early as possible. ECURIE is the official EU notification system that alerts the 27 EU Member States, Switzerland, Croatia and Macedonia. In addition to the first alert, the system provides a continuous flow of information during the accident. A very important recent achievement is the agreement by the IAEA and EC to use a common data format, the International Radiological Incident eXchange (IRIX) format.

• The EURDEP system has been designed to facilitate transmission of large datasets from environmental monitoring networks, thereby taking away the burden from national crisis centres to manually report and transmit such data. Many participating organizations make their data continuously available on an hourly basis. The collected data can be analysed and accessed, also by the general public, by means of a simple web graphical interface. On-going developments focus on globalisation of the system in collaboration with the IAEA, and on refinement of the measurements by applying filters for various natural background components.

Starting from the legal background, we describe the current status and the planned future de-velopments for these information systems, with an emphasis on our experience during the Fu-kushima accident and the lessons we learnt from it to improve them. In particular the remote-ness of this accident resulted in air concentrations above Europe that could not be detected by the automatic gamma dose-rate monitoring networks, with public concern as a consequence. In order to remediate for this, more efforts are being undertaken to further harmonise and automatically exchange results from high volume air samplers (HVAS) on an international level.

P09.24
The use of Atmospheric Dispersion Models During Nuclear Emergency Exercises in Belgium

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Training people in how to react in case of nuclear and radiological events is one of the most difficult and important challenges in the emergency preparedness. Many dissimilar parties with distinct background are involved and will react differently. Although first-responders are regularly involved in small incidences (e.g. fires, car accidents, or small incidents with chemical hazardous materials) the experience with and involvement in radiological emergencies is limited due to their low frequency. For this reason emergency exercises which involves all participants need to be organised on a regular basis. The preparation of a radiological emergency exercise requires careful planning, which includes the clear identification of the goals and objectives. Each exercise should be designed, developed, conducted and evaluated accordingly. To test the implementation of radiological emergency procedures and protocols, first-responders from different disciplines and other stakeholders like local/national authorities have to work together.

Different strategies are applicable when organising radiological emergency exercises. When applying a table-top approach only limited cost and resources are required. However it lacks realism and does not provide a true test of the capabilities and capacity of the emergency management system. Field exercises are more realistic and provides an in depth deployment of plans, procedures and staff capabilities. Both approaches are however effective for reviewing plans, procedures, and emergency policies and are a good way to acquaint key personnel with emergency responsibilities, procedures, and one another.

Working with real radioactive sources and/or large contaminated surfaces during an exercise is rather difficult to justify when following an ALARA and environmental safety policy. However, measuring radioactive contamination and exposure is an important part of the triage and monitoring procedures during a radiological emergency. To overcome this problem, it is recommended to use dedicated atmospheric dispersion models which are able to simulate different types of radioactive exposure and radionuclide contamination.

In this paper we will elaborate on the development and implementation of emergency exercises in Belgium and describe the advantages and disadvantages of the use of different atmospheric dispersion models for training purposes during an exercise. Challenges for the further development of tools for exercise preparation related to the simulation of measurements will be discussed.

P09.25
Improving the Swedish Emergency Radiation Protection - Increased Ability through Exercises

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Sweden has hosted radiological emergency preparedness exercises several years starting with Barents Rescue in 2001. In 2006 the Swedish Radiation Safety Authority (SSM) conducted an exercise called DEMOEX in Halland, south western Sweden. This exercise was meant to be the start of a series of yearly exercises and was followed by the exercises BERTIL and LärMät. DEMOEX was conducted in such way that it revealed the true status of the Swedish radiological emergency preparedness and areas in need of improvement were discovered.

The series of LärMät exercises have since 2007 annually been conducted to increase the ability in certain areas, specifically to face the challenges of a globalized world with changed expectations and goals of the radiation protection in Sweden.

Sweden is a relatively small country and is therefore forced to build a different type of preparedness compared to larger nuclear power nations. The Swedish emergency preparedness is limited to a small number of specialists which are expected to solve a large number of scenarios. This called for specialized close reality exercise scenarios, presenting problems with contamination as well as handling HASS-source accidents and antagonistic use of such. The exercises and training has been focussed on presenting scenarios and problems and allowing participants to experience a large variety of situations. This is an attempt to quickly raise the ability on a national level without compromising with the quality of the education. This work describes and explains the exercise campaign conducted in Sweden 2006-2011, the ways of planning such exercises and the conclusions drawn. The next step and next level of improvement, realized in the yet to come exercise REFOX, is also presented, describing Sweden's next series of exercises, which will be a scientific effort within the area of Technical Threats.

P09.26
Enhancing europe's capability to respond to and recover from nuclear or radiological emergencies - NERIS Platform

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In recent years, major improvements have been made internationally (i.e. within IAEA and OECD/NEA) and in Europe (i.e. within the Euratom Framework Programmes) in the field of nuclear emergency and post-accident preparedness and management. This notably includes advances in decision support tools, and improved methods for information and data exchange as well as participative governance through the setting up of local-national cooperation processes. Despite these improvements, remaining challenges have to be addressed, concerning preparedness at the local level, methods for rapid and effective exchange of information or emerging topics of interest, especially after the Fukushima accident.

In this perspective, the NERIS Platform was created in 2010 combining researchers, operational communities and relevant stakeholders. Its objectives are:

- Improving the effectiveness of current European, national and local approaches.

- Promoting more coherent approaches in Europe through the establishment of networking activities.

- Maintaining and improving know-how and technical expertise among all interested stakeholders in Europe by developing a supranational training programme.

- Identifying needs for further developments and addressing new and emerging challenges.

To date, 37 organisations from 20 countries have already joined the Platform. Two working groups have been created so far:

- A working group on « the practical implementation of the ICRP recommendations » to develop guidance and adapt existing Decision Support Systems to the new approach for emergency and recovery preparedness and management.

- A Working Group on « processes and tools for emergency and rehabilitation preparedness at community level » to develop user-friendly processes and tools to assist communities in preparing for local cooperation.

The NERIS Platform also supports organisation of training courses and users group of decision support systems are welcome to be supported under the umbrella of the NERIS Platform.

The R&D Committee is elaborating the strategic orientation of the Platform based on the new areas of interest identified by the Working Groups and expectations and demands from the Partners. The Platform is managed by a Management Board of 10 members who reports to the General Assembly of the Platform constituting of all members of the Platform.

The presentation will describe the Platform and its operation with a global overview of the NERIS activities.

P09.27
Support to the Radiological Group during a Nuclear Emergency

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Tecnatom has developed a group of computing tools devoted to facilitate the radiological emergency group the performance of its corresponding tasks, which have been implemented in the Spanish NPPs.

These tools can be used mainly for two purposes: Technical Support during a real emergency or a drill and Training of the radiological emergency group.

This is achieved providing mainly the following functions aimed to help the Radiological Protection expert performance: visualization of all the radiological parameters of the plant that are useful to achieve an accurate radiological plant assessment, display of their evolution during the emergency, visualization of alerts and alarms when a radiological value is reaching a critical value, calculation of external doses in a real or simulation mode, display of different diagrams and flowcharts to guide the user in the tasks performance, utilization of calculation tools to assess the user in the decision making process, record of all the main events and calculations made during the exercise or emergency and the implementation of a communication system that allows the user to send messages by e-mail and fax.

Conclusion:

It has been observed that the quality of training has improved considerably thanks to the utilization of this methodology that combines the theoretical lessons and procedures revision with the performance of practical exercises using these tools. Besides, the management of the radiological emergency group and its performance has also improved during drills, which have been confirmed in the drill evaluation reports.

P09.28
Dose Assessment Following Radiation Accidents At The Prima Facility

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PRIMA (Padova Research Injector Megavolt Accelerated) is the name of the ITER Neutral Beam Injector testing station currently under construction in Padua (Italy). PRIMA consists of two facilities named respectively SPIDER (Source for Production of Ion of Deuterium Extracted from RF Plasma), which represents the ion source, and MITICA (Megavolt ITER Injector Concept Advanced), the main system. During the past years different studies have been devoted to the analysis of the main safety issues related to occupational radiation protection of workers at PRIMA facilities[1-3].

In the present paper the analysis of the possible external exposure and internal contamination following a radiological accident is presented. The dominant event is a postulated fire affecting a significant portion of the facility and involving radioactive material, which is released into the environment. Radioactive material released into the area may pose both internal and external contamination hazards to people operating in the facility or personnel dedicated to emergency operations. The amount of involved radioactive material is derived from past analysis [4]. External exposure assessment is carried out with HOTSPOT code simulating a general fire scenario, while internal dose assessment is performed using OLINDA/EXM code evaluating absorbed doses to the whole body and the main organs at risk. Our analysis indicates that even in case of a severe radiological accident (worst case scenario), and considering both external and internal exposure, the annual dose for workers and emergency team is far below the Italian limits of 20 mSv and 100 mSv respectively.

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P09.30
Estimation of Source term released using Non-linear Regression Analysis

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In case of a nuclear power plant accident, the radiological consequence to the environment is highly dependent on the characteristics of source term released. This source term can be estimated from the operational status of the nuclear power plant, while it is usually not so easy to know the safety parameters because of the failure of the internal measurements system in the nuclear power plant. Another useful method to predict the source term released is the feedback of the environmental measured data into an analytical radiological consequence modeling near the accident site. The objective of this study is to predict the source term release rate based on the non-linear regression analysis using the simple Gaussian plume model. Four different non-linear least squares methods are tested for the tracer experimental data conducted at Yong-Gwang nuclear power plant site to obtain the optimized source term release rate and the horizontal and vertical dispersion factors from the experiment. The results show that we could predict the source term released within acceptable errors and the non-linear regression method is helpful for the estimation of source term released and the decision making when taking appropriate and prompt countermeasures in case of a radiological emergency or a nuclear accident.

Keywords: nuclear accident, non-linear regression, source term

P09.31
The Role of Enresa in Nuclear and Radiological Emergencies

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ENRESA is the national company in charge of radioactive waste management in Spain. The company was set up in 1984, and one of its missions is to intervene in the event of a nuclear or radiological emergency in support of the national civil defence system and security forces, in the manner and under the circumstances determined by the competent bodies and authorities.

ENRESA's interventions are based on the Basic Nuclear Emergency Plan and the Basic Directive on radiological risk.

ENRESA's activities are carried out within the so-called Radiological Group, directed by the Nuclear Safety Council (the Spanish regulatory body), and relate fundamentally to management of whatever radioactive wastes might be produced. Its main functions are the radiological characterisation of the wastes, their conditioning for transport and transport itself. Likewise, it will define the best method for management of whatever special wastes might be generated.

Another of ENRESA's activities relating to emergencies is participation in training courses for the State security forces, fire brigades and medical personnel on radiological or nuclear emergencies and on accidents in the transport of radioactive material.

This article describes the ENRESA organisation for emergency response and participation in these training courses and exercises and drills.

P09.32
Modeling Of Tritium Dispersion From Accidental Release Postulates Of Nuclear Power Plants.

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This study has the aim to assess the impact of accidental release of tritium postulate from a nuclear power reactor through environmental modeling of aquatic resources. In order to do that it was used computational models to simulation of tritium dispersion caused by an accident in a CANDU reactor located in the ongoing Angra 3 site. The CANDU reactor is one that uses heavy water (D2O) as moderator and coolant of the core. It was postulated, then, the LOCA accident (without fusion), where was lost 66 m^3 of soda almost instantaneously. This inventory contained 35 PBq and was released a load of 9.7 TBq/s in liquid form near the Itaorna beach, Angra dos Reis – RJ. The models mentioned above were applied in two scenarios (plant stopped or operating) and showed a tritium plume with specific activities larger than the reference level for seawater (1.1 MBq/m^3) during the first 14 days after the accident.

P09.33
What Nuclear and Radiological Emergency Management can Learn from Non-Nuclear: a Case Study

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Nuclear and radiological emergency management is often separated in terms of organisation and tools from conventional emergency management dealing with crisis situation resulting from natural or man-made events. However, in particular for a severe nuclear event or a large crisis situation, both have to deal in the early phase of the emergency with similar problems.

Within the German Security Research initiative, the integrated project SECURITY2People (Secure IT-Based Disaster Management System to Protect and Rescue People) aims at exploring the needs for and the structure of an integrated risk management system that is applicable for all types of emergencies and at all levels of emergency management from the local to the Federal Government. The following functionalities will be included:

• Role-based information management;

• Decision support at all levels of management;

• All types of simulation techniques;

• Applicability in training, exercises and operation.

One key aspect of the project is the development of tools that are applicable on the strategic and tactical/operational level serving the needs of rescue organisations but also administrative emergency management organisations. In this respect strategic decision making is supported by top level simulation models and knowledge data bases supported by a key performance indicator approach that allows a first estimation of the resources necessary to carry out the decision selected on a strategic level. Furthermore, a third-party application was integrated into S2P providing the simulation of first responder teams (fire brigade, rescue service) in real-time. Besides the usage in a real emergency, this provides the unique possibility to perform exercises in a realistic manner.

Nuclear emergency management so far is restricted to the strategic level, missing the link to operational simulation.

The paper discusses the current status of the S2P project and highlights the potential for the use in the nuclear emergency management, in particular training and preparedness as the system allows the “real” simulation of recommendations provided by the decision making team or decision making software components.

P09.34
An Introduction to the UK Government Decontamination Service

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The UK Government Decontamination Service (GDS) is part of the Food and Environment Research Agency (Fera) and funded by Department for Food Environment and Rural Affairs (Defra).

The GDS remit is as follows:-

• Providing advice, guidance and support to those responsible for dealing with the consequences of an accidental or deliberate release of Chemical Biological Radiological or Nuclear (CBRN) and hazardous materials;

• Facilitating quick access to an assured Framework of specialist suppliers able to offer decontamination and related services in response to a CBRN or major HazMat incident.

• Advise the Government on the national capability for the decontamination of buildings, infrastructure, transport assets and the open environment.

The GDS programme is driven by requirements from central Government, set out in the Protect and Prepare strands of the counter terrorism strategy CONTeST. The framework of specialist suppliers has been set up to provide a decontamination response to a CBRN or major HazMat incident.

GDS work to increase the capabilities offered by the framework of specialist Chemical, Biological and Radiological suppliers taken from industry. This is carried out through research and development, cross Government working and planning. Research and development is supported by academia, international partners, industry, the MOD and other Government Departments. Cross working between GDS and other Government departments promotes a joined up response, these include; the Environment Agency, Health Protection Agency, Local Authorities and first responders. GDS planning is supported through the exercising and testing of the framework of specialist suppliers and the production of guidance and training.

GDS testing of decontamination capabilities is carried out using paper based, base line case studies, and live deployment exercises. The results from these exercises are taken to drive future work and advise central Government. The programme of work delivered by GDS aims to support and strengthen UK resilience.

I would like the opportunity to submit this abstract to raise awareness and encourage discussion amongst the world's experts in radioactive surveying, decontamination and waste management. I propose to give examples of past exercises and real incident response to aid discussions, questions and answers.

P09.35
Adaptation of The International Approaches to Establishment and Development of Documents on Emergency Planning and Preparedness of FMBA Units

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Harmonization of the national regulatory basis for radiation safety assurance with the associated international requirements is one of the relevant issues today.

The paper deals with the approaches to development of the unified set of documents on emergency planning and preparedness for emergency medical and sanitary teams (EMST) under FMBA of Russia at the territorial, regional and federal levels. The target objects to apply the set of documents developed are EMSTs specialized both in medical assistance and in radiation and hygienic actions in case of the radiological accident. Such teams are established within the medical and sanitary units, centers of hygiene and epidemiology under FMBA of Russia, research institutions etc.

The development of the unified set of documents results from the necessity of explanation of the international recommendation mechanisms; implementation of NRB-99/2009 and OSPORB-99/2009 provisions; clarification of responsibilities and tasks of the FMBA territorial bodies in case of the radiological accident; and address issues of radiation protection of the medical staff under radiation exposure due to their occupational.

The documents under development include the typical regulations for activities of the FMBA units; working protocols of the emergency medical and sanitary teams; action plans; ranges of the property stocks; programs of the personnel educations; analytical and reporting documents; job descriptions etc.

The main regulatory and methodical documents on emergency planning and response being supported and applied by the FMBA units must be included in the Russian system on prevention and activities in cases of emergencies and in the Branch system of the State Atomic Energy Corporation “Rosatom”. The documents developed should comply with the principle of continuity of the legal and regulatory basis of FMBA of Russia.

P09.36
Analysis of the Practicability of the External Emergency Planning in Germany based on Experiences from the Fukushima Accident

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The Fukushima accident was characterized by long term, unplanned radionuclide releases which – as in various other countries – are not considered in emergency planning in Germany. As the Fukushima plant is situated at the coast, most of the radioactivity was transported over the sea and did not affect the countryside. The following question is raised: How would the radiological situation develop with time and which consequences are expected if the NPP would have been situated inside the country, far away from the sea? For a corresponding analysis, the course of the radiological contamination of the environment and the dose to man were simulated with the decision supporting model RODOS assuming that the Fukushima accident would have happened in two NPP sites in the north and the south of Germany during summer/autumn and winter time. Real weather conditions were taken into account for the dispersion calculation. In addition to the Fukushima source term three additional release scenarios were assumed to simulate severe, long term releases up to 30 days. Our results demonstrate that emergency planning needs some significant modification because basic assumptions are insufficient for accidents with long term uncontrolled releases: A distance of 25 km for the planning zones might be too small. The concept of early countermeasures has to be reviewed because sheltering should not be introduced for more than 2 days and the intake of iodine tablets might be recommended repeatedly. The monitoring strategy has to be reviewed with respect to reflect the dynamic development of the radiological situation during the release phase and the uncertainty of long term dose estimation considered with regard to the introduction of countermeasures. Our analysis will be the basic study for a critical evaluation of emergency planning in Germany.

P09.37
FMBC-NRPA Cooperation In Medical Radiological Emergency Response In 2005-2011

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Since 2005, several collaborative research- and practical activities are being carried out within Russian-Norwegian cooperation in regulation of safe nuclear energy use. The partners in this collaboration are Burnasyan Federal Medical Biophysical Centre (FMBC) and Norwegian Radiation Protection Authority (NRPA). The above mentioned activities are aimed at improvement of medical and sanitary preparedness of the FMBA's medical units in the Northwest Russia. In the course of works, the regulative and methodical basis of the medical emergency response for the SevRAO sites has been improved; operational and medical criteria have been developed to establish the rapid response plan and early application of protective measures at SevRAO facilities. These criteria were later being tested during the medical and sanitary and public health response exercises conducted at Andreeva Bay (2006), CTF "Ostrovnoj" and Gremikha village (2009).

Severe climatic conditions of the Arctic, remoteness, difficulty of delivery and deployment require the special solutions of the operative response:

• Practical skills of the staff of the regional medical units to provide the qualified medical care to victims of the radiological accident in hospitals and clinics;

• Effective expert support and medical consultative assistance by using the up-to-date (mainly, satellite) communication systems;

• Integration of the technical support centers and emergency centre under FMBA of Russia (EMRDC) into the emergency response system of the State Atomic Energy Corporation «Rosatom»,

• Interaction of the personnel and emergency engineering services with medical and hygienic services under FMBA of Russia;

• Cooperation with Murmansk regional medical units.

Presently, our collaboration is focusing on solutions for, relevant for the Northwest region, problems connected to radiation safety regulations for radiological emergency response in case of potential accidents during transportation of radioactive materials. We are also looking into regulations regarding mitigation of potential radiological consequences.

During the practical activities in 2010 and 2011 on the response in case of radioactive material transportation accident, the following topics are under testing; organization of information exchange with use of the available state of the art communication means; procedures of the regulatory response; telecommunication of expert groups, and the test-based development of consolidated assessment of emergency consequences. The organized by the project, accident-scenario based, seminars for the personnel of the regional management, centers of hygiene and epidemiology and regional and local medical units of FMBA of Russia, are helping to increase the potential of the regulatory response, and contribute to consolidation of the available response powers in the region.

P09.38
Recommendations of the Iodine Prophylaxis to the Russian Public in Case of the Radiological Accident

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In 2010, "Recommendations on the Iodine prophylaxis to the public in case of the radiological accident" were approved in Russia. These recommendations include the clarified basic principles of organization and implementation of the iodine prophylaxis. The document defines the intervention levels as the protective measure not related to violation of normal life of the population, determines the start time and duration of the preventive measures, includes the up-to-date risk estimations due to radioactive iodine isotope intakes (131-135I) by persons of various age, and «benefit-risk" assessment due to prophylactic administration of potassium iodine tablets and alternative medicines of the stable iodine, includes information on the advised dosages and contradictions when using the stable iodine by different population groups.

These guidelines establish: 1) dose levels to initiate the iodine prophylaxis on the basis of the committed dose to the thyroid induced by the radioactive isotope intakes (taking medical and biological consequences of the accident at the Chernobyl NPP into account), 2) dosages of the protective medicine depending upon the age and ability of the next administration. The following committed doses to the thyroid due to inhalation of radioactive iodine isotopes are established as the dose levels for the iodine prophylaxis planning: 50 mGy for children (2-fold reserve for potential radioactive iodine intake via breast milk is introduced); 250 mGy for adults up to 45; 2500 mGy for adults over 45 years (the iodine prophylaxis for such persons is aimed at prevention of the deterministic effects of radiation exposure).

The following age groups and dosages of the protective medicine have been introduced: infants up to 1 year (new-born and children who are breastfed) – 16 mg; children from 1 to 3 years – 32 mg; children from 3 to 12 years – 64 mg; teenagers from 13 to 18 years, adults up to 45 years, lactating mothers, adults over 45 years – 125 mg. Establishing of the preventive iodine prophylaxis area is permitted, i.e., before the radioactive release, evaluation of its parameters and duration prediction.

P09.39
IAEA Safety Guide On Criteria For Use In Preparedness And Response To Nuclear Or Radiological Emergency And Application In A Severe Reactor Emergency

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A rigorous assessment of experience in States has shown that there is a need for consistent international guidance on taking protective actions and other response actions, and for placing this guidance in a context that is comprehensive for decision makers and that can be explained to the public. Such guidance was developed by the International Atomic Energy Agency, based on lessons learned from experience and related scientific knowledge, and published as a Safety Guide. The Food and Agriculture Organization of the United Nations (FAO), the International Labour Office (ILO), the Pan American Health Organization (PAHO) and the World Health Organization (WHO) are joint sponsors of this Safety Guide. One of the primary objectives of this Safety Guide is to present a coherent set of generic criteria (expressed numerically in terms of dose that can be projected, or dose that has already been received) that form a basis for developing the operational criteria needed for decision making concerning protective actions and other response actions to protect emergency workers and the public in the event of a nuclear or radiological emergency.

Generic criteria have been established on the basis of generic optimization in consideration of the range of conditions that prevail in an emergency. Generic criteria are established for urgent protective actions and early protective actions, as well as for other response actions such as medical management that may be required in an emergency. The recommendations presented in the Safety Guide address health consequences due to external exposure and internal exposure of specific target organs, for which the generic criteria were developed.

In addition, a framework of operational criteria is provided. The operational criteria are values of measurable quantities or observables that include operational intervention levels (OILs), emergency action levels (EALs), specific observables and other indicators of conditions on the scene that should be used in decision making during an emergency. The goal of developing the operational criteria is to determine OILs that can be directly compared with environmental measurements, and EALs that can be directly compared with facility conditions. These OILs and EALs form the basis for protective actions and other response actions that do more good than harm, while recognizing the uncertainties in a way that ensures all members of the public, including children and pregnant women, are protected in accordance with the latest international guidance. The Safety Guide provides examples of default operational criteria; however, these examples are for the full range of possible radiological or nuclear emergencies and specific OILs should be developed in advance, if possible, for use in specific types of emergencies. The application of the framework to develop operational criteria for use during a severe reactor or spent fuel pool emergency will be described.

P09.40
The IAEA's Incident and Emergency System

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The impact of any nuclear or radiological emergency with off-site consequences rapidly becomes of regional and global concern. The need for prompt international notification, information exchange and cooperation, as well as international assistance in the case when capabilities of States might be exceeded, calls for an international focal point and coordination mechanism. In addition, effective emergency response requires appropriate international framework and efficient national emergency management systems that are built on international standards and guidelines. The IAEA plays a central role in facilitating these requirements.

The responsibility for response to a nuclear or radiological incident or emergency and for the protection of workers, the public, property and environment rests with the operating organization at the level of the facility concerned, and with the State at the local, regional and national level. Proper management of nuclear or radiological emergencies requires prompt actions to mitigate the effects. States are also responsible for establishing appropriate emergency management programmes, deciding upon and taking effective response actions, and ensuring that resources are available for preparedness and response.

The article will discuss in detail the international emergency preparedness and response framework and the IAEA's central role in it, which currently includes: prompt notification of the emergency to Member States and relevant international organizations; exchange and/or provision of official information to Member States and international organizations; coordination of international assistance, upon request of the State concerned; and provision and/or coordination of public information that is timely, accurate and appropriate.

P09.41
Nordic Nuclear Safety Research (NKS) Programme: Nordic Cooperation on Nuclear Safety Issues

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Nordic cooperation on the prospects of the peaceful exploitation of nuclear energy, and on nuclear safety, first saw light at the beginning of the 'atomic age' following the Second World War. Over the years that followed, an initial unsystematic collaborative effort between countries sharing an ancient cultural heritage has developed into a Nordic platform for cooperation and building/maintaining competence in nuclear safety. The current Nordic Nuclear Safety Research (NKS) programme has two main branches: The NKS-R programme on reactor safety, including decommissioning and safety culture, and the NKS-B programme on emergency preparedness, including radioecology and radioactive waste.

NKS activities may take place in the form of research and development projects, exercises and seminars to address relevant issues of common Nordic interest. Dissemination of activity outputs through NKS reports and the establishment and maintenance of networks allows for the sharing of expertise and experience across the Nordic countries. By keeping vital networks in tune between the Nordic authorities, scientists and other stakeholders, the region's potential for fast, coordinated and targeted response to urgent issues is strengthened. Provision of common grounds for understanding in cross-border issues is an important task of the NKS network to maintain trust in Nordic authorities and to facilitate harmonization in responses and recommendations.

Through a flexible organisation the network can rapidly adapt to emerging issues, new challenges and sudden events. This was reflected for instance in the initiation under the NKS framework of activities dealing with radiological terror threats nearly a decade ago, while in 2012, NKS will organise a seminar devoted to the lessons learned from the Fukushima accident. Ensuring knowledge and expertise for the future is a priority task, which NKS addresses by promoting the involvement of students and young scientists in all its activities. Experience has shown that new problems will emerge in relation to nuclear and radiological safety and it is already clear that technological improvements are needed for existing management tools. Through the NKS programmes, the opportunity exists for the next generation of Nordic nuclear safety workers to develop their careers and to meet the challenges that lie ahead.

P09.42
Analysis of the Structure of Medico-Sanitary Consequences of Radiation Accidents for Carrying out of Protective Measures

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The analysis of mechanisms of formation of radiation factors allows to predict medico-sanitary consequences (MSC) of radiation accidents. However it is not enough for organization protective measures.

On the basis of urgency of their elimination medico-sanitary consequences represent one of the basic consequences of radiation. The structure of MSC is characterized by the following:

- size and character of arising sanitary losses;
- victims need in different kinds of medical aid;
- conditions of medical-evacuation measures holding in an accident zone;
- sanitary-and-hygienic and sanitary-and-epidemiologic conditions which have developed as a result of an accident;
- breach of activity of treatment-and-prophylactic, sanitary-and-hygienic, antiepidemic elements;
- breach of the population life-support in the zone of accident and neighboring areas;

The structure of medico-sanitary consequences of accident includes:

- number of the injured;
- works for providing them with medical aid;
- sanitary-and-hygienic measures;
- measures to supply with medical provision;
- work for restoration of the functioning of the controls and etc.

The leading factor in this structure is the number of the injured that is why for calculations to define indicators of risk of medico-sanitary consequences of accident occurrence they accept number of the injured.

The structure of medico-sanitary consequences depends on the character of possible radiation accidents, on processes that determine the peculiarities of their development, on the type and nature of radiation factors which have formed as a result of an accident, on models of their formation and on the mechanism of their effects on human health.

For example numerical values that characterize the sources of emergency risk can be taken as parameters of probability of radiation accidents, these numerical values are directly dependent on the performance of probability; the values of the indicators characterizing efficiency of protective barriers and systems can be taken as parameters of radiation factors probability; and population density indicators in the zone of influence of emergency object can be taken as parameters of probability of influence of radiation factors on the state of health of the person.

P09.43
Updates To UK Emergency And Recovery Advice Following Changes In International Guidance

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HPA is undertaking a project to update and consolidate its advice on radiation emergencies and recovery. Current advice was published in 1997. Since 2007, the International Commission on Radiation Protection (ICRP) has issued a set of recommendations to elaborate its guidance for emergency exposure and existing exposure situations. It is expected that the European Basic Safety Standards, when published, will also reflect the ICRP recommendations. The new ICRP guidance represents a marked change in approach, moving away from the previously held concepts of practices and intervention. Emphasis is placed on the need to consider optimisation of whole protection strategies using reference levels of residual dose. These new concepts as well as the relevant lessons identified in the aftermath of the accident at the Fukushima site in Japan in 2011 will be included in the new UK advice document. The scope of the UK advice includes reactor and transport accidents as well as releases from waste stores, reprocessing and defence activities.

Revised advice on the basis for the initiation of emergency countermeasures, both in planning for emergencies and in responding to actual events, is being developed. Aspects being considered include the implications for levels of protection and countermeasure extents of criteria based on averted dose for individual countermeasures or criteria based on levels of residual dose for an entire protection strategy. As there are currently no radiological criteria for the withdrawal of emergency countermeasures, these are also being developed for application in the UK. Transition from emergency to existing exposure situations will necessitate the formulation of additional guidance for optimising protection strategies and these will be based on reference levels of residual dose as defined by ICRP. Due to the potential impact of the advice, a wide range of stakeholders are being consulted at all phases of the work programme, based on the IRPA guiding principles for stakeholder engagement.

The advice document will contain guidance for emergency planning and response, criteria for the withdrawal of emergency countermeasures, factors to consider during the transition to an existing exposure situation and the management of long term contaminated areas. It is the first time that the whole spectrum of advice will be presented in a single publication, which is expected to be published in 2013, following a public consultation process.

P09.44
PACE (Probabilistic Accident Consequence Evaluation) – a Tool for Assessing the Ranges of Consequences of Potential Accidents at Nuclear Sites

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In response to the plans to build new nuclear power stations in the UK, the HPA has undertaken a major update of the tools and approaches for modelling accidental releases of radioactive material to the environment that were developed and used 15-20 years ago

One aspect of the planning process in the UK is the assessment of radiological consequences for a range of potential accidents that may occur, both for a generic plant design and for subsequent site-specific proposals. PACE has been developed by HPA to provide the high quality probabilistic assessment tool required internally to review and conduct such assessments and, by eventually making PACE available commercially, allow others access to this advanced capability.

A PACE evaluation begins with a release scenario provided by an appropriate expert authority. PACE models the postulated release from a particular site for a sequence of meteorological conditions that characterise the broad range of potential weather conditions that may occur at the time of the accident. This dispersion can be modelled using a Gaussian plume model or the UK Met Office NAME III Lagrangian atmospheric dispersion model. The consequences assessed by PACE include the radiation doses received by the population, the numbers of health effects in the population, the economic costs of health effects and the costs to agriculture, industry and tourism. PACE also accounts for effects of mitigating actions such as sheltering, evacuation and restrictions on food.

PACE has been developed within the commercial ESRI ArcGIS™ Geographic Information System. This approach enabled the developers to concentrate on the radiological and modelling challenges whilst still providing the sophisticated map based interface for handling inputs and displaying the results expected of a modern product.

P09.45
When I Heard the Words 'Contamination' and 'Instruments' This is not what I had in Mind!

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On 17 March 2011 at 12:45 a shipment of airfreight which had come from Hong Kong, having originated in Tokyo, Japan caused a Project Cyclamen alarm at a major UK airport. Project Cyclamen is designed to pick up any radioactive material entering the UK at the various sea ports and airports around the UK. The load was spread over 4 air freight pallets and the manifest described it as 'musical instruments'. These belonged to an orchestra who had returned early from their tour of Japan on 15 March 2011 following the earthquake and subsequent tsunami on 11 March 2011. A further two air freight pallets which were part of the same shipment arrived at the airport on 18 March 2011.

As the appointed radiation protection professionals for the government department responsible for homeland security, two Nuvia Limited Radiation Protection Advisers (RPAs) duly jumped into a car and drove to the airport's freight terminal. Local security officers had determined of the presence of iodine-131 and caesium-137, with dose rates approximately 10 times background levels.

What followed was a week's intensive work to try and determine the reason for the alarm, the source of the radioactive material and then to try and unload, monitor and decontaminate all of the items on the 6 air freight pallets. The timeframe for this work was somewhat shortened by the need of the aforementioned orchestra to play a live concert on the evening of the 25 March. The work involved liaising with the regulatory authorities, ensuring the commercial aspects were in place, working with handlers at the airport who were contracted to the carrier to move the items around the airport, as well as other agencies, RPAs and stakeholders.

It was found that the plastic sheeting used to wrap the air freight pallets had detectable levels of radioactive contamination on them. Using high-resolution gamma spectroscopy on a smear taken from the packing materials the contamination was found to include isotopes of iodine, caesium, technetium and tellurium. The contamination was wide spread on the packing materials and cargo nets, however relatively little contamination was present on the flight cases of the items being shipped.

P09.46
SINAC – Simulator Software for Interactive Modelling of Environmental Consequences of Nuclear Accidents (2nd Generation)

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The SINAC programme system was developed to follow the consequences of radioactive releases of a (hypothetical) nuclear accident. Atmospheric dispersion, plume depletion by dry-out and wash-out, cloudshine and groundshine doses, dose consequences of inhalation and ingestion, early and late health effects are computed in the software. Effects of the introduction of countermeasures are also taken into account.

The SINAC system – developed in our Institute in the 1990's – has gone through a lot of development in the last few years according to users' needs and to the Hungarian and the international regulations and protocols of radiation protection. Continuous development ensured that the SINAC environmental simulator was used as an interactive expert system in the Hungarian Atomic Energy Authority Centre for Emergency Response, Training and Analysis in the last decade.

Since the latest requirements on the programme that were based on principles set forth one and a half decades ago, could have been met only by considerable compromises in the future, it was claimed in 2009, that the course of development of SINAC should be reconsidered, and a new version should be created using the potentials of the present-day information technology. The common goal of several years of development was to obtain easily usable, flexibly developable software that gives results comparable to those of other software products being developed in international collaboration.

The structure of the second generation of the SINAC system has been created, the modules of the programme have been defined. It has basically three functions: it has to handle the input data of calculations, execute the calculations, and visualize, save the results. A comfortable and transparent interface to set the parameters of calculations was created. The parameters can be stored, since they might be needed at analysing the results, and they also have to be reloadable as well, so that new calculations can be performed using them. The module responsible for executing the calculations according to the input data and forwards the output data to the visualization module was implemented. The progamme has comfortable and transparent user interface to select the data to be displayed and the way of visualization.

The structure of the new programme version in the current development phase is presented in this paper.

P09.47
Hospital Preparedness for a Radiological Terrorist Event

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Purpose: Radiological incidents present uniquely challenging scenarios for hospital emergency planning and response. Radiological terrorism has been recognized as a probable scenario with high impact and hospitals are being educated to deal with this threat. The purpose of this paper is to present the hospital's experience preparing staff and infrastructure for response to a Radiological Dispersal Device(RDD) explosion.

Methods: Rambam Health Care Campus has been designated to treat casualties from RDD explosions. Even for an experienced healthcare provider that knows how to respond to mass casualties from terrorist events, the fact that radioactive materials are involved impose changes in the management of the patients. In order to deal with this challenge the national authorities organize drills to simulate the response to RDD events. Such an exercise has been organized for January 18, 2012. During the last 9 months, several sessions were coordinated to train the staff, including nurses, physicians, medical physi cists, radiation technologists, radiation protections officers, and clerical staff. The trainers' task was to educate the hospital caregivers on the different aspects of radiation protection, decontamination procedures, operation of radiation monitors and on the behaviour in the suspected contaminated areas. A major task was to explain that radioactive exposure to the staff in such scenario is minimal and if the correct protection measures are observed, no health threat is expected. Staff was instructed on how to wear the protective suit and also how to undress it in the decontamination station. Special attention was given during the different training sessions to the fact that injuries caused by the explosion are the ones to be treated first since they will determine the survival of the patient and not the exposure to the radioactive materials in the RDD.

Results: More than 100 persons attended the training sessions. The hospital staff was divided into groups according to their specialty and task when responding to such an event. Different areas of the hospital were signalized, contaminated or clean including areas in the emergency room and operating theatre. Different scenarios were discussed and changes to the checklists were adopted.

Conclusion: Responding to a terrorist event is a stressful task and even more when radioactive materials are involved. Up to now no such situation has actually occurred in any hospital. The hospital staff has been prepared for this type of event and this was tested during the exercise.

P09.49
Moss Biomonitoring in Radiation Exposure Assessment

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Key words: Moss, Biomonitoring, Radionuclides, Radiation Exposure, Assessment, Croatia

This paper aims to provide insight into the Atmospheric Deposition of Heavy metals and Airborne Radionuclides in Croatia by using the Moss Biomonitoring Technique. Study was particularly undertaken in order to measure and define radionuclide concentrations in CRO terrestrial moss before any significant changes that could occurred as a result of dry and/or wet deposition processes after long range transboundary radioactive pollution.

Moss samples were collected during the summer 2010 from 123 locations in Croatia evenly distributed over the entire country. Sampling was performed in accordance with the LRTAP Convention - ICP Vegetation protocol and sampling strategy of the European Programme on Biomonitoring of Heavy Metal Atmospheric Deposition.

The 22 moss samples were subjected to gamma-spectrometric analyses for assessing activity of the naturally occurring radionuclides ^{40}K, ^{232}Th, ^{226}Ra, and ^{238}U, as well as the artificial ^{137}Cs. The samples were dried, homogenized, placed into standard counting vessels of 125 cm^3 and weighted. The loaded vessels were sealed and stored for at least 4 weeks to allow the in-growth of gaseous ^{222}Rn (3,8 day half-life) and its short-lived decay products to equilibrate with the long-lived ^{226}Ra precursor in the sample. At the end of the in-growth period, the samples were counted. The activities of ^{40}K, ^{232}Th, ^{137}Cs, ^{226}Ra, ^{238}U and ^{7}Be were determined by using a low background HPGe detector system coupled to 8192-channel CANBERRA analyzer. Detector system was calibrated using gamma mixed standards supplied by Eckert & Ziegler (Analytics USA).

Preliminary results on the selected samples from CRO 2010 moss biomonitoring survey may serve as a valuable tool for Radiological Exposure Assessment that can help to establish a “background pollution levels” – related to the possible effects from potential future contamination events.

Conducted research on the Atmospheric Deposition of Airborne Radionuclides in Croatia by using the Moss Biomonitoring Technique demonstrates the potential for simple, accurate, reliable and affordable environmental radiation control / protection and will be continued.

P09.50
A Rapid Method for the Determination of Low-Level Strontium 90 in Emergency Situation

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Strontium-90 is one of the most important long-lived radionuclide with high-energy β-ray as the fission products of ^{235}U and ^{239}Pu. Since its chemical characteristics are very similar with calcium, it can be accumulated mainly in the bones, teeth and cause damage in blood-producing cells of animals and human. Therefore, it is essential to precisely detect low-level ^{90}Sr in environmental and biological samples for both environmental protection and emergency preparedness.

An unique extraction chromatographic column (BtBuCH18C6, 4',4''(5'')-di-tert-butyldicyclo-hexano-18-crown-6) on Teflon powder with sample loading was prepared to separate ^{90}Sr from the environmental matrix. Strontium were efficiently retained in 8 M HNO_3 medium on the column and easily eluted with water. The flow rate is controlled to 0.5mL/min. The separated solutions were free from most of the matrix elements K, Ca, Ba, Y, La, Ce and Cs from different samples. The method were successful in isolating 89±2% ^{90}Sr and directly measured with liquid scintillation counting. The whole analyses time is less than 6 hours which is promising for radiological emergencies. The detection limit of ^{90}Sr in biological samples is below 0.01Bq/g. The feasibility for the determination of ^{90}Sr was proved by analysing IAEA-156 and IAEA-375 reference samples, the measured values agreed with the recommended reference value.

P09.52
Evaluating the Use of Radiation Portal Monitors to Screen Livestock during Radiological Consequence Management Operations

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During the Fukushima Nuclear Power plant accident thousands of farm animals were killed, not by radiation but because they were left to starve to death as the Japanese government had no plans or methods to deal with livestock following a radiological disaster. The United States (US) could face a similar dilemma. During a disaster response, the Federal guidance document the National Response Frame/Radiological Annex assigns the US Department of Agriculture the responsibility of controlling, assessing and decontaminating the affected animals. For humans, plans and equipment exist to evaluate the amount of contamination. For animals, Federal, state and local plans are limited. In addition, equipment designed for animals is virtually non-existent. Equipment and methods need to be developed to screen livestock for potential contamination so that they can be evacuated from the affected areas. As part of a project sponsored by the National Institute of Food and Agriculture, Texas A&M University is designing a portal system for screening livestock during radiological consequence management activities. To evaluate the best detector type, number and placement, Monte Carlo N-Particle (MCNP) simulations have been employed to create a photon transport simulation of a cow standing within a press chute. This has allowed us to estimate a minimum detectable activity of approximately 0.4 µCi for Cs-137. Furthermore, this project is also evaluating the use of pedestrian portal monitors to screen animals. This poster will present the MCNP simulation as well as the results of the pedestrian portal work.

P09.53
HERCA' Activities in Nuclear Emergency Planning and Response: From Chernobyl to Fukushima

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HERCA is a voluntary association of the Heads of the European Radiological protection Competent Authorities, with 46 members from 28 European countries officially participating. HERCA's main goal is to improve the practical implementation of radiological protection in the participating countries, and do this within the framework set out by international organisations and the EU.

From its very start in 2007, HERCA had identified the lack of a harmonised cross-border approach in response to serious nuclear or radiological events as one of the top priorities to solve. The importance of this issue has to do with the high probability that the radiological consequences of any such accident or incident will affect neighbouring countries. The Chernobyl accident painfully demonstrated that this notion "neighbouring country" should not be interpreted restrictedly.

Up till early 2011, HERCA's efforts in the field of nuclear emergencies have been concentrated on "domestic" accidents, accidents happening somewhere in Europe, a "Chernobyl-type" of accident. HERCA wants to end up with a uniform way of dealing with any serious radiological emergency situation, regardless of national border lines. Existing regional harmonisation efforts –such as the one from the Nordic countries- and agreements –such as the 2007 "Five country agreement" between Belgium, France, Germany, Luxembourg and Switzerland-, serve as inspirational examples for this ongoing work.

When in March 2011 the accident at Fukushima Dai-ichi NPP's started, it rapidly became clear that our national assessments and responses to such "distant" accidents could also dramatically be improved by a more rapid exchange of information, a better coordinated and more harmonised implementation of countermeasures, and, even in the absence of direct radiological consequences, a more coherent communication. HERCA assisted in sharing radiological data and informing on the actions undertaken at national level. It also issued a statement, reassuring European citizens on the absence of any direct (sanitary or environmental) radiological impact from the ongoing accident.

Our presentation will cover HERCA's achievements in the field of "domestic" accidents, such as the approved guidance on the practicability of early protective actions. It will further focus on the issues and shortcomings in the radiological evaluation and response to the Fukushima accident in Europe, as well as on issues concerning European residents and travellers in Japan, all from the perspective of the radiological protection Competent Authorities. It will present remedial actions that have been undertaken or are under construction in order to improve, through harmonisation, our response to accidents of the "Fukushima-type", including in the field of public communication. It will further comprise an outlook on HERCA's ongoing and future coordination and harmonization efforts.

P09.54
Dose Reconstruction after the Overexposure of a Nuclear Diver Handling Mistakenly Highly Activated Materials

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During the 2010 outage of the Leibstadt nuclear power plant (Switzerland), a diver performed maintenance work in the fuel transfer pool. After completing his work, he recovered an object and placed it into a basket to be lifted. While the basket was reaching the surface of the water, the radiation alarm was triggered, and the basket lowered again. As a result, the diver's ring dosimeter measured a personal dose equivalent *Hp(0.07)* of 1.1 Sv to the right hand while whole body dosimeters indicated *Hp(10)* values between 19 and 40 mSv at the chest and abdomen. The object was identified as a lost piece of a dry tube of 30 cm length that had been unnoticed in 2006 outage. This study aimed at assessing both diver's skin dose to the hand and effective dose by performing dose reconstructions based on analytical calculations and Monte Carlo (MC) simulations associated with numerical phantoms.

For reconstructing the circumstances of the exposure, interviews were conducted with the diver and the plant staff. The activity was estimated by comparing dose rate measurements at several distances of the object under water with dose rate per unit activity of ^{60}Co calculated in water using MicroShield and MCNPX. The geometry and composition of the object was available and implemented in the calculations. The activity was also obtained through activation calculation using the object composition and the neutron fluence on the dry tubes after 22 years residence in the core. For the hand, the absorbed dose at 0.07 mm tissue depth was calculated with MC considering various distances between skin surface and object. The effective dose derived from dosimeter measurements was compared with the one obtained by MC using the ICRP reference voxel phantom and different positions of the objet relative to the phantom.

The average activity of the object was 1.8 TBq (range, 0.9-2.8 TBq). The skin dose to the hand in contact with the object was calculated between 3.5 and 13.9 Sv depending on the scenarios. For a likely handling time of 45 s, the contact skin dose was 7.5 Sv (range, 5.3-10.4 Sv). Those values are not compatible with the 1.1 Sv measured by the ring dosimeter. However, if the object was not in contact but located 2 cm from the ring (a plausible scenario), the calculated dose is then between 1.0 and 3.3 Sv. The effective dose was estimated to 28 mSv combining dosimeters from routine monitoring and 14 mSv using MC simulations associated with the male phantom.

In conclusion, we retained a calculated skin dose of 7.5 Sv for the hand, corresponding to the most probable maximum dose. For the effective dose, the value of 28 mSv derived from individual routine monitoring was registered because the uncertainties related to the positions of the object during the diver's move make hard to obtain a better estimate. MC-based dose reconstructions provide valuable information when phantoms measurements are not feasible due to radiation safety limitations.

P10.01
Radioactivity and Health Impacts of Some Terrestrial Vegetables and Fruits in Oil and Gas Producing Areas in Delta State, Nigeria

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The concentrations of ^{137}Cs, ^{238}U, ^{232}Th and ^{40}K as well as the derived health impacts in fourteen species of edibles vegetables and fruits in oils and gas areas, Nigeria have been measured using a high purity germanium, (HPGe) detector system. For the vegetables, the mean activity concentration wary between 36.48 - 68.02; 2.33 - 5.18; 1.26 - 2.98 and 0.27 - 2.47 Bq/kg, while the mean Annual Effective Dose resulting from the consumption of these vegetables also have the range of 17.75 - 33.09; 51.20 - 113.82; 68.20 - 161.00 and 0.27 - 2.52 µSv/yr for ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs respectively. For the fruits, the mean activity concentration wary between 31.22 - 61.91; 1.17 - 2.67; 0.10 - 1.60 and 0.70 - 6.30 Bq/kg, while the mean Annual Effective Dose resulting from the consumption of these vegetables also have the range of 15.19 - 30.12; 25.71 - 58.68; 5.41 - 86.60 and 0.71 - 6.42 Sv/yr for ^{40}K, ^{238}U, ^{232}Th and ^{137}Cs respectively. The results of this study can be considered as a first step towards calculating the baseline levels of radioactivity in those foodstuffs in Nigeria. The overall results are low and still within the range obtained elsewhere and no significant radiological hazard was found. Meanwhile regular monitoring is necessary due the presence of man-made ^{137}Cs to avoid the cumulative effects.

Keywords: Radioactivity, foods, Health Effects, HPGe spectrometer, Oils and Gas Areas, Nigeria

P10.02
Outdoor/Indoor Exposure to Terresterial Radiation Atkadugli Town, Nuba Mountains, Sudan

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We report on the outdoor natural radiation background exposure in Kadugli city, in the Nuba Mountains, western of the Sudan. The number of population in the city is $0.5*10^6$ persons approximately. In this work a commercial Gamma Scout survey meter for environmental radiation measurements, was used to scan the absorbed dose allover the city. The survey meter was held 1.0 m above surface. The city was divided into five sub-areas (North, West, South, East, and Center), and twenty readings were taken in different locations and averaged for each sub-area. The effective dose was then calculated based on a value of 0.2 for the occupancy factor for the outdoor radiation exposure. It was found that the values of the absorbed dose ranged from 50-400 $nSv.h^{-1}$, with a mean value equals 185$nSv.h^{-1}$ for the whole city. The corresponding effective dose was found from calculations to range from 87-701 $\mu Sv.y^{-1}$, with a mean value equals 324 $\mu Sv.y^{-1}$. These values are small relative to other locations in the region marked as high radiation background areas (HRBA) like Lake Miri or Uro village, but when considering the world's average value for effective dose, estimated by the UNSEAR which is ~70 $\mu Sv.y^{-1}$, the effective dose in Kadugli city is almost 5-folds higher.

Key words: Natural radiation background, dose rate, effective dose, Nuba Mountains.

P10.03
Influence of Measurement Position on Cosmic-Ray Induced Dose Inside a Learjet Type Aircraft

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Cosmic radiation induced dose is considered as occupational exposure on the recommendations of the International Commission on Radiological Protection (ICRP) for those aircrew members which can receive more than 1 mSv accumulated dose in one year. The radiation doses received by aircrew are measured or estimated by computational programs witch, generally, don't consider the influence of position inside aircraft in the dose rate. Some authors made studies on this subject using computational simulation of commercial aircrafts, but few of them made this analysis with direct measurements, neither on smaller aircrafts. In this paper we report the measurements onboard a Learjet-type aircraft in well controlled flight conditions: at the same altitude and around the same geographic coordinates. The measurements of dose rate were performed in several positions inside aircraft, close and far from pilot locations and were made using one WENDI¡V2 neutron probe and one proportional counter, allowing discriminating between neutron and non neutron components. The results show that the neutronic component is attenuated in the back part of the aircraft, close to fuel depots, but the non neutronic component appears to have the opposite behavior. One hypothesis to explain this behavior is the neutron absorption by the fuel with consequent production of capture gamma rays. There is some compensation between these two components so that the total amount of dose rate decreases slightly close to the fuel, but the amount of this effect is lower than ±1% of the mean value. Therefore, this effect would not need to be considered for practical purposes in dosimetry onboard of this type of aircraft. The experimental flight was made on a flight test aircraft from the Brazilian Air Force, stabilized on 40000 feet altitude.

P10.04 Review and Cross-comparison of Matroshka Phantom Measurements in Different Compartments of the International Space Station

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Astronauts working and living in space are exposed to considerably higher doses and different qualities of ionizing radiation than people on ground. Matroshka, a European Space Agency experiment under coordination of the German Aerospace Centre, is the most comprehensive effort so far in radiation protection dosimetry in space using an anthropomorphic upper torso phantom known from radiotherapy treatment planning to map the dose distribution throughout a simulated human body on board the International Space Station (ISS). Absorbed dose and dose equivalent measured by nuclear track detectors and miniature thermoluminescence dosimeters embedded in a regular grid and at the site of vital organs are combined with detailed numerical models to allow for estimation of effective dose. Monte Carlo simulations using the transport codes FLUKA and GEANT4 that provide calculations of particle fluence and dose for various radiation environment conditions further support the experiment and improve cancer risk projections for future long-term space exploration beyond the Earth's magnetosphere. The paper presents a review and cross-comparison of data acquired during four missions between January 2004 and March 2011, in which the phantom has been installed in different compartments of the Russian and Japanese segments of the ISS: outside and inside Zvezda, inside Pirs and inside Kibô.

P10.05
Hazards and Countermeasures on Extended Space Missions

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Humanity has always been fascinated with the stars and planets; and with advancing technology most of the myths were replaced with the realities of space science, from curiosity leading to exploration and even considering colonization. The objective is landing humans on planet Mars.

The technology of getting into deep space beyond the protective layers of the Van Allen belts are available for inanimate objects, but not yet fully developed for humans. The main drawback and limiting factor is galactic radiation effects over long time periods, as prolonged space travel has become synonymous with radiation dose and associated risk.

This presentation discusses the various hazards of space travel, reviews the possibilities of astronaut protection and the countermeasures that are currently being researched, to reduce these hazards.

KEYWORDS: Radiation Protection for Astronauts; Space Missions; Missions to Mars; Hazards in Space

P10.06
Dosimetry Onboard Spacecraft Using Passive Detectors

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Cosmic radiation represents an important health risk for astronauts, especially during long-term missions. The exposure level onboard spacecraft is several hundreds times higher than that on the Earth's surface, several times higher than onboard of aircraft. Accurate determination of exposure level and evaluation of the impact of space radiation on human health is important in order to secure the safety of the astronauts and minimize their risks.

To estimate the radiation risk during the mission, it is necessary to measure dose characteristics at various compartments of the spacecraft and also in the phantoms simulating human bodies. Due to some convenient characteristics, combination of thermoluminescence and plastic nuclear track detectors is very suitable and often used for the measurements of absorbed dose, dose equivalent, and spectra of linear energy transfer.

Since 2005 our passive detectors have been exposed onboard of International Space Station at various compartments and also on the surface and inside the tissue-equivalent spherical phantom MATROSHKA-R. This contribution presents results obtained during last 6 years, covering half period of the solar cycle including its minimum. Variation of dosimetric quantities with the phase of the solar cycle, occupation mode and time, and shielding thickness will be discussed. Daily values of absorbed dose and dose equivalents ranged from about 200 to 450 µGy/d and from about 350 µSv/d up to almost 1mSv/d, respectively, depending on the position inside the spacecraft and period of the exposure.

The data on dose distribution in real space flight conditions can contribute to our understanding on space radiation and could improve radiation protection of the spacecraft crew members.

P10.07 Radiation Dose Mapping in the European Columbus Laboratory of the International Space Station

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Cosmic radiation and its secondaries created in interactions with spacecraft shielding structures constitute one of the most important hazards associated with human spaceflight. Crewmembers are facing exposures to radiation qualities that are known to produce distinct biological damage compared with radiation on ground, and dose levels that may easily exceed those routinely received by terrestrial radiation workers. DOSIS is a comprehensive and overarching international dosimetry programme coordinated by the German Aerospace Centre (DLR), which supports assessment of potential biological implications on the health of space crew. It is dedicated to determine the nature and map the distribution of the radiation environment in the European Columbus laboratory of the International Space Station (ISS) using a comprehensive set of active and passive instrumentation to account for the cosmic-ray charge and energy spectrum. Within two stages, passive detector packages (PDP) accommodating luminescence and plastic nuclear track detectors (PNTD) measured absorbed dose and linear energy transfer (LET) spectra at eleven sites throughout Columbus for mission durations of 135 days (July to November 2009) and 191 days (November 2009 to May 2010). Discussion focuses on thermoluminescence dosimetry (TLD) results but strives exemplarily the convolution of TLD and PNTD data to derive dose equivalent and evaluate the significance of the high-LET ($\geq$ 10 keV/µm) contribution to the TLD dose. The absorbed dose distribution determined by different luminescence phosphors (CaF_2:Tm, ^{6}LiF:Mg,Ti and ^{7}LiF:Mg,Ti) showed a high degree of consistency and a distinct spatial pattern with variations of up to 22% between the measuring sites within Columbus. The highest dose rate of 301± 7 µGy/d was found on the Human Research Facility Rack 2 (HRF-2), while the lowest dose rate of 235π 6 µGy/d was recorded on the European Drawer Rack (EDR). A ~14% decrease in absorbed dose rate was observed between the first and the second stage of the DOSIS measurements, which is attributed to increasing solar activity and ISS altitude changes.

The DOSIS experiment was realized under the European Programme for Life and Physical Sciences and Applications Utilizing the ISS (ELIPS) of the European Space Agency (ESA) under contract no. ILSRA-2004-167. Austrian participation was supported by the Austrian Space Applications Programme (ASAP) of the Federal Ministry for Transport, Innovation and Technology under contract no. 819643.

P10.08
Assessing Public Exposure on Commercial Flights in Brazil

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The exposure to cosmic radiation during aircraft travel is higher than that at ground level and may vary with the route due to the effect of latitude, with the flight altitude, the flight length, and the year due to the cyclic variation observed in earth's flux of cosmic rays. The computer program CARI-6, developed by the U.S. Federal Aviation Administration Civil Aerospace Medical Institute, estimates the effective dose of galactic cosmic radiation received by an individual (based on an anthropomorphic phantom) in an aircraft flying the shortest route between two airports the world. Although originally developed to quantify the radiation exposure of flight crews, the code performs the dose calculation for a particular flight, depending on data provided by the user. The predicted results show good consistency with the available measurement data in the literature. Although, in relation to the general public, this exposure is not subject to regulation, because it is a voluntary activity, commercial flights represent a technological increased exposure of people to natural radiation. This component of the exposure of public is little studied, and few surveys are found in literature. The aim of this research is to estimate the contribution of cosmic radiation exposure on commercial flights to the Brazilian population. The research should serve as a baseline for future comparisons of the growth of civil aviation in the country. It shall also open perspectives for discussions on the concept of risk and its public acceptance, relevant to the establishment of radiological protection guidelines. At this first stage, a preliminary study was performed to verify the relevance of the information needed to perform the simulations using CARI-6 code. It was verified that most relevant parameters are the time of flight, the average flight altitude (CV ~ 25%) and latitude (CV up to 8 %) during domestic flights within the Brazil.

P10.09
Assessment of Natural Radiation Doses in Akure, Southwestern Nigeria.

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The worldwide average annual effective dose of 2.4 mSv from natural background radiation is made up of various components. This paper presents an estimate of the contributions of terrestrial γ-rays (external exposure) and ingestion (internal exposure) components from different sources. The activity concentration of natural radionuclides in surface soil and rock samples, which were collected from selected locations, were measured using gamma spectrometry system consisting of a 7.6 cm x 7.6 cm NaI(Tl) scintillation detector. Activity concentrations of natural radionuclides in dug well drinking water samples were determined using co-axial type high-purity germanium (HPGe) detector. Environmental gamma radiation in family dwellings was assessed in dwellings by means of short-term measurement using LiF thermoluminescent dosimeters (TLDs). The annual effective doses were calculated using determined activity concentrations of the radionuclides and their dose conversion factors.

P10.10
Naturally Ocurring Radionuclides in World Historical Sites Samples

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During past tree years, samples taken from the historical sites in Iran, China, India, Siria and Jordan were brought in the Environmental Protection Department of Institute for nuclear sciences Vinèa. Samples contained different natural materials used in masonery, for making artefacts for personal use as well as water, sand and mud from the Dead sea. This paper presents the results of measurement of the content of naturally ocurring radionuclides, calculation of hazard indeces and their comparison to the values recommended and obtained in modern days materials.

P10.11
Natural Alpha Emitting Radionuclides In Bottled Drinking Waters In Croatia And Their Dose Contribution

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Natural radionuclides from uranium and thorium decay chains are presented in Earth's crust and are leached by surface and groundwater, respectively. The geological setting strongly influences the occurrence of natural radionuclides in drinking water. Their quantitative determination is interesting from radio-ecological aspect because of their relatively high radiotoxicity and their importance in the study of cumulative radiation effects on human health.

In most countries there is an increasing tendency to replace tap water by consumption of commercial bottled natural and mineral waters. Due to the importance of bottled water in human diet, a monitoring of natural radioactivity in bottled waters produced in Croatia was performed. Alpha emitters (^{234}U, ^{238}U, ^{226}Ra and ^{210}Po) were analysed from all Croatian commercially available drinking and mineral water products (originating from various geological regions of Croatia), in order to assess the radiation doses from alpha emitting radionuclides.

Uranium was preconcentrated from water samples by coprecipitation with $Fe(OH)^3$ at pH 9-10 using an ammonia solution. The radiochemical separation was performed using an UTEVA column. The source for alpha counting was prepared by micro-coprecipitation with NdF^3. For determination of ^{226}Ra in water a coprecipitation procedure with $Pb(Ra)(Ba)SO_4$ was used and sources for alpha-particle spectrometry using $BaSO_4$ as carrier were prepared. Polonium was preconcentrated from large volume of water by MnO_2 and its separation from interfering elements by extraction chromatographic Sr resin was done. Source for alpha-particle spectrometry using selfdeposition on silver disk was prepared.

The obtained results show that activity concentrations of investigated alpha emitters in all examined waters are in levels a few percent of the values according to the recommendation and guidance levels issued by European Union and World Health Organization, respectively. Based on the radionuclide activity concentrations the internal radiation doses to adults as well as contribution of each particular radionuclide to the dose were assessed and discussed.

Poster sessions A-B: Area 10

P10.12
Study of Radionuclides in Cochiti Reservoir Sediments

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This paper summarizes a 2010-2011 environmental study of radionuclides in sediment deposited in the Cochiti Reservoir by the Rio Grande and its tributaries. The study was performed by Trinitek Services, Inc. of Albuquerque, New Mexico USA. Possible radionuclide sources examined were naturally occurring isotopes in the earth's crust, nuclear weapons fallout, and possible discharges from Los Alamos National Laboratory, municipalities, and the La Bajada uranium mine.

The study included evaluations of sediment and radionuclide-specific deposition patterns, exposures to nonhuman biota, and forensics. However, the most significant evaluation was potential risks to humans should the sediments be exposed due to lowered reservoir levels. Human risk scenarios used were farming, residential, and recreational activities on hypothetically exposed sediments. RESRAD was the principal computer code utilized for evaluating potential dose and risk to both human and nonhuman biota.

Numerous difficulties were encountered with validating data from the primary laboratory and the quality assurance laboratory, and with reconciling conflicting results between the two laboratories. In addition, the primary laboratory consistently returned errantly low alpha spectroscopy results for uranium, thorium, plutonium, and americium. The study identified the sources of the errant results, which are related to analyzing environmental concentrations using alpha spectroscopy. Alternative methods used to evaluate these alpha emitters included kinetic phosphorimetry analysis, ultra-low background Compton suppressed gamma spectroscopy, and neutron activation analysis.

P10.13
An Interactive Map Of Natural Uranium Content In Tap Drinking Water In Dwellings Surrounding The Joint Research Centre Of Ispra

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

The Radiation Protection Sector and the Medical Service

started, in 2009, a joint initiative for mapping natural uranium content in tap water publicly available in dwellings around the Joint Research Centre Site.

It was well known, since many years, that some public tap waters show significant levels of natural uranium (up to 11.000 ngUnat/l).

While the committed dose due to the ordinary daily consumption of tap waters showing high levels of natural uranium content is not significant, even for general public ingestion, this circumstance may significantly impact the interpretation and the evaluation of radio-toxicology analyses on urine samples, which may show unusual high levels of uranium content.

It must be noticed that the majority of JRC-ISPRA radiological facilities in which uranium was present, made use of depleted or enriched

uranium, hence easing the Qualified Expert's task to highlight and separate possible work contamination cases from natural uranium ingestion due to water consumption.

However, internal contamination due to work activities in other facilities outside the JRC-ISPRA cannot *a priori* be excluded.

A campaign aimed at assessing natural uranium content in tap water was then organised in 2009, with the spontaneous help of some JRC-ISPRA workers, either professionally exposed to radiation risks or not.

Tap water samples have been collected and analysed *via* ICP/MS methodology. Uranium concentration results, expressed in ng/l, have been collected and plotted in GOOGLE-style interactive maps, making it possible to localise uranium concentration distribution in a specific area surrounding the JRC-ISPRA. This paper shows the methodology and results of this first two years' monitoring campaign.

P10.14
Monitoring of Radioactivity in Fertilizers in Austria

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This paper reports results of a monitoring project regarding natural radionuclides in fertilizers which are commonly used in Austria.

Due to adaption of the Austrian Radiation protection rules to European legislative, fertilizers became part of products which have to be monitored by governmental authorities on their activity concentrations of natural radionuclides. In addition, the Austrian NORM ordinance lists processing of raw phosphate in chemical industry as well as in fertilizer industry as workplaces with possible elevated exposure to Uran and Thorium and their decay products and as industries, where residues could accumulate elevated concentrations of natural radionuclides.

Therefore about 500 fertilizer samples were investigated by gamma spectroscopy. The fertilizers were provided by the governmental fertilizer inspection staff and preselected regarding usage in Austria and types of fertilizers with possible elevated activity concentrations (e.g. Tripelphosphate). A further distinction was made in order to compare fertilizers regarding their major components (organic-, nitrogen-, phosphate-, potassium-, multi plant nutrient- fertilizers …).

The results are focused on U-238, Ra-226 and Pb-210. Using these results, input of Uranium in agricultural fields was calculated and three scenarios were discussed. These three scenarios include the total translocation of NORM nuclides into drinking water, the transfer of NORM nuclides into plants and the accumulation of Uranium in agricultural fields.

The relation between Radium-226 and Uranium-238 is also discussed with focus on fertilizer processing and the probability to accumulate NORM residues in processing components.

KEYWORDS: NORM, fertilizer

P10.15
Natural Radioactivity of Volcanic Tuff Stones with Different Colors Used as Commonly Building Materials

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The activity concentrations of uranium, thorium and potassium can vary from material to material and it should be measured as the radiation is hazardous for human health. Thus first study have been planned to obtain radioactivity of building material used in Cappadocia region of Turkey. The concentrations of natural radionuclides in 6 different colors of volcanic tuff stones which commonly use as building material around Cappadocia region,Turkey were determined using gamma ray spectroscopy with an HPGe detector. Absorbed dose rate in air (D), radium equivalent activities (Ra_{eq}), external hazard index (H_{ex}),internal hazard index (H_{in}), alpha and gamma index associated with the natural radionuclide are calculated to assess the radiation hazard of the natural radioactivity in the different colors of volcanic tuff stones. The average activity concentration of ^{238}U, ^{232}Th and ^{40}K were found to be 50.68 ,58.63, 6365.4 Bq kg^{-1}, respectively. Average annual effective dose equivalent is 0.45 mSv y^{-1}. The calculated Ra^{eq} are values vary from 60.31 Bq kg^{-1} to 281.32 Bq kg^{-1} with a mean of 189.78 Bq kg^{-1}.

P10.16
Second Assessment (2008-2009) – Radiological Quality Of Drinking Water In France

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The french nuclear safety authority (ASN), the french Ministry of health (DGS) and the french Institute for Radiological Protection and Nuclear Safety (IRSN) presented the results of the radiological quality of drinking water in France. This work is based on the results of the official controls of drinking water quality. The results show that the monitoring for radiological drinking water quality is operational all over the French country and radiological drinking water quality is satisfying. The drinking water complied with the guideline for Total indicative Dose (TID) for 99,83% of the French population. Uranium was measured by IRSN in 360 water samples with gross alpha activity higher than 0,1 Bq/L. For 6,39% of them, the uranium concentration was higher than 15µg/L which is the OMS guideline for toxicological assessment. An historical survey, produced by IRSN, on radon in sources designed for the production of drinking water set up that only 4% of the measurements were above 1000 Bq/L. European commission recommends that for concentrations in excess of 1 000 Bq/L, remedial action is deemed to be justified on radiological protection grounds. Monitoring in France is in accordance with the recent project of European directive on radiological quality of drinking water

P10.17
Mapping the Terrestrial Air-Absorbed Gamma Dose Rate Based on the Data of Airborne Gamma-ray Spectrometry in Southern Cities of China

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An environmental radioactivity survey by Airborne Gamma-ray Spectrometer (AGS) on a large scale was undertaken in Zhuhai Zone (ZZ) and Shenzhen Zone (SZ), the cities in southern China, covering areas of 3800 km^2 and 4660 km^2. Comparisons of AGS and different ground measurements are presented and they fit very well. Maps of the terrestrial dose rate at 1m above the ground level have been calculated based on the data of AGS. The mean of dose rates are 84.37±51.69 and 82.10±32.98 nGy/h in ZZ and SZ, and the maximum are 343.11 and 368.36 nGy/h respectively. Dose rates in some places are above 180 nGy/h, covered the areas of 149 km^2 in ZZ and 43 km^2 in SZ, respectively. The dominant geological conditions that evidently contribute to the radioactive anomalies are outcrops of middle and late Jurassic and Cretaceous biotitic-granite. The development of industrialization and urbanization has dramatically changed radiation background. Stone mining results in the increasing of radiation level and the maximum of dose rate reaches 368.36 nGy/h in an open pit. The investigation results provide valuable background data and give a good example to mapping nation-wide natural radiation terrestrial dose rate in China by AGS.

Keywords: Airborne gamma-ray spectrometry, full spectrum, dose rate, ionization radiation

P10.18
High Radioactive Materials In Building Industry

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All building materials contain various amounts of natural radioactive nuclides. The purpose of setting controls on the radioactivity of building materials is to limit the radiation exposure due to materials with enhanced or elevated levels of natural radionuclides. The doses to the members of the public should be kept as low as reasonably achievable. However, since small exposures from building materials are ubiquitous, controls should be based on exposure levels which are above typical levels of exposures and their normal variations. Fifty high active samples of building material used in Serbian building industry were surveyed for natural radioactivity by gamma-ray spectrometry. From the measured gamma ray spectra, activity concentrations are determined for ^{232}Th, ^{226}Ra and ^{40}K. The total effective dose and the activity concentration index are calculated applying the dose criteria recommended by the European Union for building materials.

P10.19
Radioactivity of Soil from Niksic ¡V Montenegro and Assessment of the Corresponding Radiological and Cancer Risk

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Soil samples from Niksic - the second largest town in Montenegro and candidate for a status of radon prone area, were analyzed by standard gamma spectrometry for radioactivity due to ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs. The obtained radionuclide activity concentrations are relevant from the aspect of environmental monitoring, and they were found to be with average values of 63, 60.1, 54.6, 491.5 and 172.2 Bq kg^{-1}, respectively. The corresponding radiological risk (relevant from the aspect of human health protection) was evaluated through the radium equivalent activity, gamma-absorbed dose rate, annual effective dose, external and internal hazard index, representative level index, annual gonadal dose equivalent and excess cancer risk, which showed average values of 172.6 Bq kg^{-1}, 102.6 nGy h^{-1}, 125.9 μSv y^{-1}, 0.45, 0.63, 1.27, 568.3 μSv y^{-1} and 4.4.10^{-4}, respectively. Outdoor gamma absorbed dose rates have been also measured by the Inspector 1000, Canberra. Ratios of absorbed dose rates in air – inferred from radionuclide concentrations in soil and from direct measurements, are found to be in the range from 1.3 to 2.0. Some information about the region geology, as well as chemical composition of each sampled soil type are also given in the paper.

P10.20
Assessment of Radioactivity Contents and Associated Risks in Some Soil Used for Agriculture and Building Materials in Cameroun

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A survey of radioactivity content and associated radiological risks was carried out in various soils used for agriculture and building materials in Cameroon by means of a well-calibrated high-purity germanium detector. Soil samples were collected directly from the agricultural farms and the brick's factories, air-dried at room temperature to a constant mass, crushed, sieved and sealed for at least one month before analysis. The specific activity of ^{238}U ranged from 8.00 ± 0.67 to 51.28 ± 9.67 Bq Kg^{-1} with an average of 33.72 ± 7.12 Bq Kg^{-1}; ^{232}Th from 5.09 ± 1.27 to 24.74 ± 3.10 Bq Kg^{-1} with an average of 16.31 ± 4.06 Bq Kg^{-1}; ^{40}K ranged from 19.23 ± 2.14 to 467.40 ± 50.80 Bq Kg^{-1} with an average of 202.03 ± 16.69 Bq Kg,startsup>-1; while that of the fallout ^{137}Cs ranged from 1.32 ± 0.62 to 4.79 ± 1.75 Bq Kg^{-1} with an average of 2.73 ± 1.04 Bq Kg^{-1}; The mean result obtained for the Representative levels index (Iγ), the radium equivalent (Raeq), the total absorbed dose rate (ADR) were 0.52, 72.60 Bq Kg^{-1} and 33.78 nGy h^{-1} respectively. The discrepancies of our data can be attributed to several factors such as past nuclear disasters, geological formation, transport process, etc. Although our results are just some fractions of the international standard limit, but still within the same ranges when compared with those obtained elsewhere. This results also will serve as a baseline data for future investigations.

Keywords: Radionuclides, radiological hazards, soil, Gamma spectroscopy, Cameroon

P10.21
Iran's Comprehensive Plan for Radiological Assessment on High Level Natural Radiation in Ramsar

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The highest level of background radiation reported so far in the world is from Ramsar. Ramsar is a town in north of Iran. Its area is 729.8 km2 and the city is located at 36° 21´ N to 36° 58´ N latitude and 50° 21´ E to 50° 46´ E longitude. It borders the Caspian Sea to the north. The effective dose equivalent of its inhabitants is several times in excess of ICRP-recommended radiation dose limits for occupational exposure and its natural background is up to 200 times greater than normal background levels. Most of the radiation in the area is due to dissolved radium-226 in the water of hot springs along with the existence of small amounts of uranium and thorium in travertine deposits. 52 years ago Ramsar was recognized as a high level background area. Many researches have been done by scientists in past years. Since the researches have been performed by outspread organizations without mutual cooperation and national coordination, it caused some despondencies and pessimism in peoples and city managers. In order to harmonize activities in Ramsar area, Iran Nuclear Regulatory Authority (INRA) has established a comprehensive national plan with cooperation of all relevant authorities. This plan contains four major phases:

i. Preparing detailed radioactivity map of Ramsar including gamma dose rate, radioactivity in soil and food stuff, radon in springs and soil and outdoor;

ii. Assessment of exposure of residents in high level natural radiation areas from all pathways including external exposure from soil and building materials and also internal exposure;

iii. Health surveillance of residents including biodosimetry and epidemiological study and

iv. Arranging for simple and easy remedial action to decrease exposure.

The plan was started in 2011 benefiting from financial support of AEOI. First phase of plan has been implemented and new hot spaces have been discovered during preliminary surveys.

P10.22
Occupational Radiation Doses of United Kingdom High Altitude Mountain Guides as a Result of Cosmic Ray Exposures.

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UK based mountain guides often lead multiple expeditions throughout the course of a year. They will receive radiation doses from ultraviolet radiation (UVR) and cosmic rays during air travel and their time spent at elevated altitudes in the mountains of the world. These radiation doses are received as part of their employment.

This paper illustrates that high altitude mountain guides from the United Kingdom can potentially receive greater than 1 milliSv per year of cosmic radiation dose in excess of what they would have received at UK ground level. These individuals are “occupationally exposed” to cosmic radiation as a result of their profession.

The European Community Basic Safety Standards Directive 96/29/EURATOM does not apply to exposure to cosmic radiation prevailing at ground level. The highest “ground level” that a UK mountain guide may be working at is 8848m (29,028’). The maximum flying altitude of some internal flights in the UK is 7925m (26,000’). 96/29/EUATOM does apply to cosmic radiations being received by aircrews therefore there is an anomaly in radiation protection where the cosmic radiation exposures of aircrew operating for short durations at altitudes lower than mountain guides operating at high altitudes for prolonged times have to be taken into account. UK based high altitude mountain guides are essentially undergoing planned occupational exposures to cosmic radiation whilst still on the ground.

Consideration should be given by the legislative authorities to include the control and assessment of cosmic radiation exposures of professionals likely to receive greater than 1 milliSv per year of cosmic radiation in excess of what would have been received in their home country at ground level.

In their next set of recommendations, the ICRP should consider whether the occupational cosmic radiation exposure of high altitude mountain guides should be included as a specialised group for whom some control and assessment of cosmic radiation exposures may be justified.

P10.23
Measurement of Gamma Radioactivity Level in Rock and Soil of Saunder Quarry Site, Abeokuta North, South-Western, Nigeria.

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Crystalline rocks have been observed to be rich in Naturally Occurring Radionuclides (NOR) which are the primary terrestrial sources of radiation in the environment. This study determined the activity concentrations of NOR in rock and soil from Saunder quarry site, Abeokuta North, South-Western, Nigeria using NaI(Ti) gamma spectrometer. The average activity concentrations of ^{40}K, ^{238}U and ^{232}Th in rock samples where 605.62±83.29, 39.69±12.57 and 62.64±22.47 Bq kg^{-1}, respectively. The calculated average Absorbed dose rate(ADR), Annual effective dose (AED), Radium equivalent dose rate (Ra_{eq}) and External hazard index (H_{ex}) where 84.00 nGy h^{-1}, 103.03 µSv y^{-1},175.61 Bq kg^{-1}and 0.47. The mean activity concentration of the sampled soils were ^{40}K (145.10±12.64 and 236.08±17.34 Bq kg-1), ^{238}U (13.36±3.53 and 23.99±6.80 Bq kg^{-1}) and ^{232}Th (15.09±5.48 and 19.74±7.22 Bq kg^{-1}). Similarly, the corresponding average ADR, AED ,Ra_{eq} and H_{ex} were 28.99 nGy h^{-1}, 35.56 µSv y^{-1}, 60.87 Bq kg^{-1}, 0.19 and 33,32 nGy h^{-1}, 40.87 µSv y^{-1}, 70.39 Bq kg^{-1} and 0.19, respectively at the two depths of soil sampling. The Ra_{eq} of the samples were lower than Organization for Economic Cooperation and Development (OECD) recommended limit of 370 Bq kg^{-1} and the average values of the sampled rock were higher than 70 µSv y^{-1} UNSCEAR recommended dose value. Hence, the granite rock used for building and construction purpose from the study area will be rich in NOR. There will be need for routine assessment of radionuclide contents of the rocks of the quarry site before supply for commercial purposes.

P10.24
Uranium and Heavy Metals in Narghile (Shisha, Hookah) Moassel

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Data on natural radionuclides and heavy metals content in narghile's (hookah, shisha, water-pipe) moassel are scarce. So, the objective of the present study was to investigate the contents of the main and widely used smoking product in the Middle East region; moassel. 10 representative samples of 3 different moassel brands were collected from the local market of Cairo city-Egypt and Riyadh City- Saudi Arabia. Uranium and heavy metals (e.g., Cd, Cu, Pb and Zn) were assessed using ICP-MS. Among the 10 representative samples of the 3 different moassel brands, the results indicate the existence of a wide range of variations in uranium and other element concentrations that could be because of non standard manufacture processes. The concentration levels were compared to the results of other studies and that of cigarette tobacco. Our study shows that, as far as trace elements are concerned, harm can be reduced. Public health officials could include in the national prevention plans the use of smokeless tobacco, particularly when addressing heavy narghile smokers. However, it must be clear that there are important differences between smokeless products. Both elemental inhalation via narghile smoking and harm reducts ion via using suitable filter should be studied in more intensive and more detail.

Keywords: uranium; trace elements; narghile; moassel; ICP-MS

P10.25
On the Population Dose 2010 and 2011 at Volincy Municipality in Belarus

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Large parts of Belarus suffered from Chernobyl fall-out. In several studies our group has been investigating the long-term development of population dose at the municipality of Volincy in Korma County (Belarus) (e.g. [1]). We report on the most recent results, which were obtained during the 2010 and 2011 field missions.

Korma County is situated approx. 70 km north of the city of Gomel/Belarus and about 200 km from the Chernobyl NNP. The municipality of Volincy is more forestial in nature. Strongly elevated body burdens had been found in the past [1].

Environmental monitoring included in-situ measurements and measuring soil samples. A van type mobile in-vivo monitoring laboratory has been used to assess body burdens of Cs-137. The calculation of dose is based on dose factors directly related to body burdens since more or less a chronic incorporation can be assumed.

In 1999 body burdens of Cs-137 were still quite high [2]. Individual advice provided by the measuring team led to a changed attitude towards the consumption of contaminated food. Over the time body burdens dropped significantly. In 2010 and 2011 a total of 104 and 1156 body burdens were measured, respectively. Presently the internal dose is only slightly enhanced over background values and of no special relevance to health. The mean value did decrease to less than 0.2 mSv/a in 2011 and is expected to drop below 0.1 mSv/a by the year 2020, as been indicated by model calculations.

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http://www.irpa2010europe.com (last accessed September 13, 2011)

P10.26
Display or Dispose - The Dilemma of Radium in Historical Military Aircraft

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The Battle of Britain Memorial Flight (BBMF) maintains aircraft that originate from the time of the Second World War, so that they may continue to fly at various locations throughout Europe. Original equipment is often luminised using radioactive material, i.e. radium-226 (Ra-226). Therefore, serviceable and non-serviceable equipment containing Ra-226 is stored on site and engineers, ground crew and pilots may come into close contact with such equipment. This poster highlights the difficulties in ensuring that these workers and members of public are receiving radiation exposures which are ALARP, but in doing so not affecting the flightworthiness or historic value of the aircraft.

The problems of accurately accounting for these items and methods in determining potential doses are discussed, with consideration of the complexity in implementing ALARP where the benefit of the 'cost benefit' element is subjective. Other difficulties discussed include the legacy of equipment 'donated' by well meaning members of the public and the problems this caused with waste arisings, contaminated facilities and elevated radon gas levels.

P10.27
A Coordinated International Effort to Remediate Uranium Mining Sites in Central Asia

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Much of the former Soviet Union uranium mining and processing was carried out in the Central Asian region and over seventy different uranium deposits were exploited. These activities continued throughout the second half of the twentieth century, but following the collapse of the Soviet Union considerable disruption occurred. Mining and processing activities in Tajikistan and Kyrgyzstan practically ceased but in Uzbekistan and Kazakhstan uranium ore mining and processing continue to the present day and Kazakhstan is currently ranks third in uranium producing countries. During the period 1961 to 1995 mining at many uranium mines in the region was stopped, but limited remediation measures were put in place. Due to the loss of economic activity associated with mining many of the communities around the mines had to resort to subsistence level farming and a considerable amount of scavenging took place on the former mine sites. These circumstances have led to a significant legacy of radioactive contamination, which has been addressed to some degree by various national and international organizations. In view of the scale of the problem a number of United Nations and other multinational organizations launched a coordinated effort within the ENVSEC framework. The initiative is developing remediation project proposals with a view to attracting international donors to support their implementation. This paper describes the work undertaken to date and future prospects.

P10.28
Environmental Risk Assessment at a Legacy Site with Enhanced Levels of NORM

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The Søve site in Telemark County, Norway was the location of extensive niobium mining up until the early 1960s, where after the complex was closed and partially remediated. Studies in the years following closure have shown that ambient dose equivalents are elevated and have led to identification of material exhibiting enhanced levels of radionuclides from ^{238}U and ^{232}Th natural decay series. The radiological risk from the site has been an issue of some concern as evidenced by the consideration that the exposure situation may be in contravention of several, pertinent regulations. Nonetheless, a rigorous radiological risk assessment at the site had not been performed in the several decades after the cessation of activities and this initiated the work presented here. Some progress has been made on this issue in recent years. The General Assessment Methodology Process, as of 2011, was being developed under the auspices of the IAEA and provides a system with which to perform a radiological risk assessment at legacy sites for both humans and the environment. The methodology in its application at Søve has proven both robust and insightful allowing the assessment procedure to be conducted in a structured and uncomplicated manner.

The initial use of screening criteria immediately introduced the requirement to undertake a more involved intermediate assessment wherein established assessment codes were run and bespoke models developed in order to determine the behaviour of radionuclides and establish the radiological doses to humans now and in the future. With these more detailed analyses, the screening criteria remained unsatisfied and there was thus a requirement to explore cleanup criteria and the application of remedial action. This last stage in the human radiological assessment was achieved via the consideration of various practicable remediation options at the Søve site and further extended applications of the various models applied at the intermediate stage of the assessment. Although it was clearly possible to identify options that would result in significant reductions in concentrations and dose-rates at the site, it was not always clearly apparent that dose-rates would automatically fall below the (dose-based) cleanup criteria. In this light, it seemed imperative to define the post-remediation use of the land so that appropriate exposure pathways can be scrutinized and secondary checks made on predicted prospective dose against established dose criteria.

P10.29
Russian Experience In The Regulatory Supervision Of The Uranium Legacy Sites

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Russia has many uranium legacy sites, which are decommissed now. Also, there are operating uranium mines and uranium ore milling facilities. After termination of the operating cycle of such units, decommissioning of the sites active life of which is terminated will be carried out. Today, the Russian list of the entrails areas of the federal significance includes 135 uranium depositions.

In case of the uranium legacy, the public exposure is induced by the radon presence in the air of dwellings, because the uranium mines are located in obviously radon hazardous uranium bearing areas. Unsatisfactory situation is in Octybrsky village and in Lermontov city. In Octyabrsky, located on the site of the largest Russian Priargunsky uranium combine, the established Russian radon regulation is exceeded in 39 % of dwellings (EEC above 200 Bq/m3). There is some aggravation: dumps and ore waste were used for additional covering of the urban roads and as a building material for the house foundations. On the basis of the findings of inspections and according to the directives of FMBA of Russia, the decision has been made on resettlement of the residents from the village to Krasnokamensk city. The situation in Lermontov city relates to operation of the mining and milling facility “Almaz”. About 1000 dwellings have been found in Lermontov where radon concentration is excessive. This problem is not solved yet, and the problem of contamination of the surface ponds with the mine waters either.

FMBA of Russia addresses the issues of the public radiation safety with respect to the former Soviet legacy in the uranium mining industry. Solving of some regulatory problems assumes to be implemented with the inter-state target program EurAsES “Reclamation of the territories of the EurAsES member states affected by exposure of the uranium mining and milling facilities”. The uranium legacy sites in Kyrgyzstan and Tajikistan, which might lead to the transboundary disasters and need reclamation in the first turn, can provide some experience to be used in other states as well. Harmonization of the national legislations and regulatory documents on radiation safety assurance is envisaged.

Perspectives of the further regulation we see, firstly, in the necessity to introduce the concept of the existing exposure situation in the national regulation and to put it in compliance with the international radiological protection system. Then, the criteria for the site remediation and return into the economic activity are to be developed along with the documents on control of such criteria observance.

P10.30
Managing Radiation Risks from Point Sources

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Discrete radioactive items have been detected on Dalgety Bay since at least 1990. Many surveys have been undertaken on the beach to determine the potential numbers of items present and possible implications for public health. In 2008, SEPA conducted a monitoring and recovery exercise to consider whether some areas of Dalgety Bay should be classified as Radioactive Contaminated Land (RCL) as defined by the Statutory Guidance.

In-situ and laboratory techniques were used to detect contamination and subsequently to characterise the potential hazard. Discrete items of radioactive contamination (particles) together with widespread low level contamination of radium on the inter-tidal area have been detected. An assessment was also made on the potential of encountering a particle. Following reporting of the hazard and potential for public encounter with a particle (Dale 2009, SEPA 2006), further direct laboratory measurements using radiochromic dye have been made on the particle to determine potential skin dose rates from alpha radiation emitted from the particle.

For the high activity particles recovered from Dalgety Bay which could have been ingested an assessment of the potential committed effective doses to a one-year-old infant could be around 66 millisieverts (mSv). For the skin doses initial estimates of doses had to be modelled, however subsequent work indicated that the dose rates were less than 1 Gray per hour (to 1 cm^2) to the skin thickness's recommended by ICRP[3] (ICRP, 89).

The work undertaken by the regulator has resulted in proportionate management arrangements being brought into place to reduce the potential risks these include signs and further recovery programmes.

P10.31
Health Risks from Radioactive Objects on Beaches in the Vicinity of the Sellafield Site

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A programme of monitoring carried out since 2006 has found radioactive objects on beaches near the Sellafield site in West Cumbria. These objects comprised particles with sizes smaller than or similar to grains of sand and contaminated pebbles and stones. The Environment Agency (EA) asked the Health Protection Agency (HPA) to undertake an assessment of the health risks to people using the beaches from these contaminated objects.

The assessment addressed two key aspects. Firstly, estimates have been made of the likelihood that people using the beaches for various activities could come into contact with a radioactive object. Secondly, in the unlikely event that an individual does come into contact with such an object, the resulting radiation doses and associated health risks were assessed.

The conclusion, based on currently available information, is that the overall health risks for beach users are very low, and significantly lower than other risks that people accept when using the beaches. The highest calculated lifetime risks of radiation-induced cancer are of the order of one hundred thousand times smaller than the level of risk that the Health and Safety Executive regard as being acceptable (below 10-6 per year). It is also very unlikely that deterministic effects, such as localised skin ulceration, could occur from encountering an object.

HPA has updated its formal advice to EA taking into account the findings of this study and continues to advise that “no special precautionary actions are required at this time to limit access to or use of the beaches”. HPA has recommended three criteria which would prompt an urgent review of health risks to beach users and has also made recommendations about continued regular monitoring of beaches in the area.

P10.32
Withdrawal of Radioactive Lightning Rods in France

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Radioactive lightning rods were manufactured and installed in France between 1932 and 1986. Those lightning rods are fitted in with sources of radium-226 or americium-241 with an activity from a few to tens of megabecquerels.

Manufacturing, marketing and import have been prohibited since January 1st 1987. According to The National Radioactive Waste Management Agency (ANDRA), which is responsible for the treatment of those lightning rods, there would be 40,000 radioactive lightning rods still installed on the French territory.

Except for certain facilities, their withdrawal has not been required by the French regulation until now Those lightning rods are then dismantled on the moment of the maintenance or the demolition of buildings (about 500 per year)

Because of their direct exposure to the elements for several years, the materials used in lightning rods containing radioactive sources are susceptible to be damaged, that's why the containment of the radioactivity can not be guaranteed.

For several years, the French Nuclear Safety Authority (ASN) has increased the professionals' awareness of the radiation protection issue during the removal of those radioactive lightning rods. The ASN has pursued this action in 2011 by launching a major campaign to remind the professionals of the regulation. The ASN also launched a measurement campaign conducted by the Institute for Radiological Protection and Nuclear Safety (IRSN) in collaboration with all the licensed professionals to evaluate the necessary means of protection during the removal of those radioactive lightning rods. That measurement campaign will lead to the publication of a removal guide.

From now on, as several European countries, the ASN wants to provide a new regulatory instrument which imposes the removal of all the radioactive lightning rods.

P10.33
Norwegian Support in Development of Standards and Regulations on Radioactive Waste Management and Long-Term Monitoring in Uzbekistan

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The main factors determining the state policy in the field of radiation safety and radioactive waste in Uzbekistan are -presence of radioactive waste including the waste from uranium mining and milling industry and other sources, and need for rehabilitation of the contaminated territories. Former uranium production facilities were often simply abandoned, without taking any security measures or left unattended after the insufficient measures for their closure. Currently in Uzbekistan there are no sufficient national regulations for the protection of personnel, population and environment during the work with radioactive waste from uranium production.

In September 2010, Norwegian Radiation Protection Authority (NRPA) has signed a new contract with State Inspectorate on Safety in Industry and Mining of Republic of Uzbekistan (SISIM) -regulatory body of Uzbekistan on the "Support in Development of Standards and Regulations on Radioactive Waste Management and Long-Term Monitoring in Uzbekistan.

The purpose is to provide assistance to the SISIM in: development of the regulatory requirements and rules on protection of personnel, the public and the environment in planning and performance of operations with radioactive wastes; consolidation of the infrastructure of the regulatory body of Uzbekistan for radiological protection of personnel, the public and the environment in radioactive waste management at the tailing dumps of the uranium industry.The work within the Project framework will cover both the contaminated territories of Uzbekistan and the boundary regions, which play an important role in safety of radioactive waste, radiological material and equipment of high risk in all the regions of Central Asia.

P10.34
Investigation and Remediation of NORM Legacy Sites in Merseyside

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Sefton, on the north side of Liverpool, holds a radioactive legacy from its industrial past. This legacy is in the form of tin slag buried in sub-surface seams. Located near the docks and adjacent to the rich Lancashire coal seams, Sefton became one of the main production centres of tin plate in Britain. A consequence of this industrial process is the production of low-level radioactive waste slag.

Tin rich ores are heated under reducing conditions to produce a molten metal stream, which is then separated into the component metal streams. Solid wastes produced by this process are known as slag and were usually stored on site in spoil heaps. U-238 and Th-232 and their associated decay chains, are the major contributors to the radionuclide inventory of the slags, with levels of these radionuclides being in the range 1-10 Bq/g. The main area of radiological concern is with the potential inhalation or ingestion of contaminated dusts. There is also a potential for Ra-226 to leach out into groundwater.

Because this slag is a very hard, glassy material it has been historically used as aggregate in underlying roads and rail way sleepers. Many of these sites pre-date the introduction of the regulation of radioactive substances in the UK and have never been under legislative control. There is a risk that the existence of some of the sites may not be known.

By bringing together expertise in sensitive gamma surveying, radiochemical analysis, hands-on remediation and a detailed understanding of the regulatory framework, AMEC is able to support the borough of Sefton in its redevelopment programme ensuring safe compliant development of an area with a historic radiological legacy.

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P10.35
Estimating the Radiological Impacts in a Natural High Background Radiation Area: the Case of Horta da Vilariça (Northeastern Portugal)

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From uranium mining prospecting works, carried out a few years ago, the occurrence of a high background radiation in the area surrounding the Horta da Vilariça village (Northeastern Portugal) was recognized. The source of radiation is the geological bedrock composed by uranium-enriched pre-Ordovician metasedimentary rocks occurring in the metamorphic aureole of a hercynian granite.

With the purpose of estimating the radiological impacts, several data were obtained in the uranium-enriched area: gamma-ray rate in air (177 points), surface radon fluxes (12 samples), soil-radon concentrations (13 samples) and ^{222}Rn, ^{226}Ra, ^{234}U and ^{238}U activities in groundwater samples (11 samples). Gamma-ray rate in air values varies between 0,25 and 2,78 uGy.h-^{1}, radon fluxes between 0,07 and 66,9 Bq.m-^{2}.s-^{1} and soil-radon concentrations between 297 and 78442 kBq.m-^{3}. Uranium activities in water vary from lower than the detection limit (^{1}, ^{226}Ra from ^{1} and ^{222}Rn from 64 to 9784 Bq.l-^{1}. Radon concentrations in the outdoor and indoor air were estimated from a deterministic approach methodology based in realistic scenarios; median of the measured parameters was used in all calculations. Thus, radon progeny values of 268 nJ.m-^{3} in outdoor air and 4136 nJ.m-^{3} in indoor air were estimated. The effective dose from the exposure of the human population to ionizing radiation was calculated for the following sources: external, radon progeny inhalation and water consumption. The preliminary calculated value, 36,8 mSv. year-^{1}, is 7 to 15 times higher than the mean annual average of the Portuguese and world population, respectively.

P10.36
Action Procedure in Norm Industries: Coal-Fired Power Plants

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The presented procedure was prepared as a consequence of the implementation of the R & D project "Study of the radiological impact of coal-fired power plants on their environment," funded by the Spanish Regulatory Authority (CSN - Nuclear Safety Council). The procedure was developed as a tool intended to provide guidance in radiological assessments on any other coal fired-power plant considering their own peculiarities. This tool allows to determine, in normal operation conditions, whether a significant increase in the exposure to ionizing radiation is produced or not on their workers, the members of the public around the installation or on the environment, as required by Title VII of Spanish Royal Decree 783/2001 on "Protection against Ionising Radiations".

The radionuclides of interest in this type of studies (i.e. industries which process Naturally Occurring Radioactive Materials (NORM)) are the ^{40}K and those belonging to the natural decay series of ^{238}U, ^{235}U and ^{232}Th. Effective doses to members of the public and workers, as a result of this industrial activity, need to be considered as the sum of the contribution of each radioisotope, included in each pathway, and must be assessed as an increase on the natural background of the area.

The procedure was structured in two levels of action. A basic assessment which allows to establish whether an increase above the allowed levels in terms of concentration or effective doses, in a new installation or an old installation in which modifications were introduced, is produced or not. If any of those levels is surpassed, a second level of action is proposed addressed to conduct more detailed studies to quantify the increase in a more realistic way.

P02.151
Patient Dose Measurements in Digital Mammography, Using Computed Radiography (CR) Versus Dose in Analog Mammography

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Protocols have now been published that give guidance on the commissioning and routine testing of full field digital mammography systems. These documents include remedial levels for the mean glandular dose to equivalent breasts for thicknesses of polymethylmethacrylate (PMMA) from 20 -70 mm and acceptable and achievable levels of image quality. For most film/screen mammography systems the automatic exposure control (AEC) is based on the use of a radiation detector placed behind the cassette which terminates the exposure when a certain level of dose is reached, corresponding to the level needed to achieve the required film density. With the introduction of digital mammography with solid state detectors, manufacturers no longer use a single radiation detector to control the AEC exposure; rather each manufacturer may use the signal from the image detector in a different manner in order to determine when to halt the exposure. The aim of this work is double: 1- to assess the image quality in clinical practice using the subjective rating scales of the European Guidelines on Quality Criteria for Diagnostic Radiographic Images, and 2- to estimate patient doses for the digital mammography and analog mammography for auditing compliance with the European Diagnostic Reference Levels (DRL). The study sample was constituted by 96 patients randomly chosen, providing a total of 384 images, i.e. 192 images for the cranio-caudal (CC) projection and 192 images for the medium lateral oblique (MLO) projection. In this work, image quality and average glandular dose (AGD) was evaluated in computed radiography systems and from the screen-film system. For estimating each patient glandular dose the radiographic technique parameters (kV and mA.s) and the thickness of the compressed breast were recorded. European image quality criteria were adopted by the radiologist doctor to accept the image for diagnostic purpose. For breast densities of 50% adipose and 50% glandular tissues the incident air-kerma was measured and the glandular dose calculated considering the x-ray output during the exam. In the study of 96 patients the mean glandular dose varied from 0.62 to 3.20 mGy with a mean value of 1.79 mGy for CC incidences. For MLO incidences the mean glandular doses ranged from 0.62 to 3.98 mGy and a mean value of 2.40 mGy.

P02.154
Computer Simulations and Image Reconstruction for a Proton Computed Tomography System

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This article presents the results of computer simulations for proton computed tomography (pCT) for a prototype installed at the Loma Linda University Medical Center, USA, which works with proton beam with energy ranging from 200 to 250 MeV [1]. Monte Carlo simulations with codes SRIM and Geant4 are a powerful tool to estimate the proton energy loss and the straggling in typical objects used in medical applications [2][3]. For the high energy region of protons only a few experimental data are available for the pCT case. The simulations were done using the code Geant4 based on a real phantom constituted of an acrylic tube with about 20 cm diameter, a little polyethylene bar located at the center, and water [4]. The polyethylene bar can be changed for different sizes and materials. The simulations were performed in order to adjust the parameters of a previous simulation used for an experiment done at the proton accelerator at IEN/CNEN and to understand some specific physics effects that affect the form of the final proton low energy spectra [4][5]. CT images were reconstructed with Fast Fourier Transform (FFT) algorithms using the simulated data. C++ Builder was used for the algorithm that makes the conversion of equivalent thickness of water density to reconstruct the image.

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P02.155
Mass Attenuation Coefficients of X-rays in ISO Quality Concrete in Barite of Different Regions of Brazil

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The mass attenuation coefficients of barite concrete have Been Measured using x-ray attenuation for different thicknesses of barite concrete qualities of the ISO. The attenuator material is used from different regions of Brazil. Part of these attenuators in the laboratory was made with materials from various regions of northeastern Brazil (Bahia, Piaui, Pernambuco, etc.). Measures of coefficients obtained from these materials were compared with measurements made with commercial samples of barite concrete of southeastern Brazil. Plates of different thickness were fabricated by the manufacturer to test this research in the laboratory. The plates were X-ray irradiated with potential constants of 60, 80, 110, 150 kV and gamma radiation of ^{60}Co and ^{137}Cs. The experimental procedure in this research was validated by comparison between the experimental measurements of mass attenuation coefficients and coefficients determined by the same atomic composition, using as a tool to XCOM. Values of μ / p ranged from 1.05 to 1.60 cm^2/g for barite concrete, made in the laboratory and the commercial. The difference of this magnitude was 50% as W60's ISO. This is explained by the wide variation in the density of these materials ranging from 2 to 3 g/cm^3

P02.156
Comparison of Different Methods for Measuring CT Dose Profiles with a New Dosimetry Phantom

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Computed tomography (CT) has become one of the largest contributors to medical radiation dose in radiology. Therefore, attention should be paid to optimize patient dose estimation. The most common dose quantity in computed tomography is the computed tomography dose index 100 ($CTDI_{100}$) which is measured with an ionization pencil chamber and a standardized acrylic phantom. However, for large beam collimations of multi slice CT scanners the $CTDI_{100}$ value underestimates the equilibrium dose. Therefore, the precise measurement of the (single axial slice) dose profile or dose profile integral (DPI) using different measurement techniques becomes more important in CT dosimetry.

The aim of this work was to evaluate different ionization chambers (semiflexible thimble ionization chambers, PinPoint ionization chamber, PTW Freiburg) and the Gafchromic XR-CT2 radiochromic film for the determination of (relative) dose profiles and DPIs from a modern multi slice computed tomography scanner. For this purpose a polymethylmethacrylate phantom for multi-detector use was developed.

The phantom is 32 cm in diameter and up to 50 cm long which allows a more appropriate consideration of radiation scattering than the rather short standard CTDI phantom, especially for large beam collimations. The design of the phantom enables measurements with different ionization chambers, thermoluminescence detectors or radiographic films. Using these detectors, dose profiles for different beam collimations and tube voltage values were determined for a Siemens SOMATOM Sensation 64 scanner.

The acquired dose profiles were compared to measurements using thermoluminescence detectors (TLD GR-200) as well as Monte Carlo calculated dose profiles. The accuracy of the Monte Carlo simulations was verified by comparing the results with CTDI values which were measured with a calibrated CTDI ionization chamber (PTW Freiburg) in a standard CTDI body and head phantom. The deviation between measurements and calculations were within an accuracy of 5.9 %.

In conclusion, the described phantom and proposed methods for measuring dose profiles and dose profile integrals can be of great value to evaluate the effectiveness of dose reduction methods in computed tomography.

P02.157
Using MCA DigiDART for Neutron Detection

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For neutron detection experiences, an ORTEC DigiDART Multi Channel Analyser (MCA) was connected to a CENTRONIC SP3 proportional counter, using an ORTEC 142PC preamplifier and a DIM-POSNAI voltage supply. Since the DigiDART MCA is designed for use with sodium iodide detectors, built-in functions that search for optimal detection parameters are not intended for use with those pulses coming from the interaction of neutrons with a proportional counter He-3 gas. The parameters needed to be reset for this new configuration with a proportional counter, in order to obtain reliable measurements. The criteria used to find new values for the parameters were counting repeatability and minimum dead time. After a series of experiments, the parameters were obtained. The response obtained with the detection system using the DigiDART was then compared to that using a Nomad Plus analogue MCA, showing consistent results. Finally, the SP3 was installed on a set of Bonner spheres, exposed to AmBe source and the counts in the DigiDART were measured. After that, the response as nuclear reactions by neutron/cm2 incident from an AmBe source was calculated with MCNPX. A linear relationship was found between the calculated and the measured values.

P02.158
First Argentinean Intercomparison of Neutron Detectors

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The Neutron Laboratory of the ARN has organized an intercomparison exercise on Neutron Detection in order to get knowledge about the present situation of the instrumental applied in this field, by the different nuclear installations in Argentina. Ten facilities have participated, included investigation reactors, power reactors, cyclotrons, an accelerator and a bureau of safety.

In the exercise, the ARN laboratory has acted as a reference laboratory to compare data obtained from the participant laboratories to that obtained by using the Neutron Irradiator N40-BG-M-2 (Hopewell Designs Inc.) and the sources ISO Cf-252, Cf-252 + D2O and AmBe.

In this paper an assessment of the measurement variables affecting the uncertainty was carried out as a criterion to compare the differences between detectors.

The intercomparison results showed that the neutron detectors currently used in Argentina, are mostly acceptable within the dose rate range of the ARN neutron laboratory.

P02.159
Thin Wall Recombination Chamber Filled with Nitrogen

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Parallel plate recombination ionization chambers made with different materials are known as the detectors which can be used in mixed radiation fields for determination of total absorbed dose, gamma and high-LET dose components and for characterization of radiation quality of mixed radiation fields. Specially designed chambers can operate correctly in broad range of neutron and gamma radiation energies. They can be used e.g. in the vicinity of accelerators and nuclear reactors.

In this work the investigations were extended to applications of a thin wall, high pressure, recombination chamber filled with nitrogen. The specially designed chamber, denoted as F5, has five thin electrodes with diameter of 80 mm, made with mylar foil and attached to titanium rings. The distance between electrodes is 5 mm and total sensitive volume is of about 100 cm^3. The housing of the chamber is made with titanium, commercially marked as GRADE 5. The material contains also Al 5.50–6.75 %; V 3.50–4.50 %; Fe<0.40 %; O<0.20 %; C<0.08 %; N<0.05 %; H<0,015 %. The main reason for using such material was its relatively low activation in thermal neutron beams. The thickness of the front wall of the chamber is 1 mm.

The chamber can be filled with different gases up to the pressure of 10 MPa. Because of low thickness of the electrodes and relatively high mass of the gas, the dosimetric properties of the chamber are determined mainly by the atomic composition of the gas.

In this study, the chamber was filled with nitrogen (with purity of 99.99%) up to the pressure of 0.6 MPa. Ionisation chambers filled with nitrogen are often used in radiation dosimetry because of their high sensitivity to gamma radiation and low recombination of ions, even at high pressures of the gas. In neutron dosimetry, the chambers filled with nitrogen were rarely used, because of several disadvantages, including strong dependence of the neutron sensitivity on neutron energy.

The chamber presented here is designed mainly for the measurements in thermal and epithermal neutron beams or stray radiation fields with moderate gamma component to the absorbed dose. The doses due to gammas and thermal neutrons are separated by recombination microdosimetric method (RMM). The signal of the chamber can be modified by use of polyethylene cups. The dependence of the signal and the shape of the saturation curve on the polyethylene thickness, combined with RMM makes it possible to determine the dose due to neutron capture on 14N in epithermal neutron beams, at different depths in tissue.

The dosimetric properties of the chamber were investigated in radiation fields of radiation sources of ^{137}Cs, ^{252}Cf and ^{239}Pu-Be as well as in the thermal neutron beam from a horizontal channel of nuclear reactor MARIA in NCNR in Swierk.

P02.160
Radioactive Source Detection by Vehicle Radiation Portal Monitors Considering the Background Suppression

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The radiation portal monitors (RPM) are now widely used for detection of nuclear and other radioactive materials in cargoes transported through state borders, sea ports, etc. Main causes considerably complicating the detection of gamma sources by the vehicle (and train) radiation portal monitors under field operation conditions are as follow:

· Gamma radiation shielding by materials transported in a vehicle and by the vehicle itself. This shielding can be so significant that even the most sensitive monitors cannot detect high activity sources.

· Radioactive source masking by materials containing naturally occurring radionuclides, or other declared radioactive isotopes (medical or industrial) transported in cargo.

· Suppression of the natural gamma background measured by the monitor during the vehicle passage between pillars. The value of this suppression can be rather high, reaching as much as 50% of the initial background level.

First two reasons can be casual or inadvertent, but can also be a result of deliberate actions of smugglers, or even terrorists. However, some suppression of the natural gamma background always occurs when RPM are used for detection of sources transported in vehicles.

In the present paper the authors consider the effects of the natural gamma background suppression for vehicle radiation portal monitors installed at sites having different heights above the sea level. As known, the traditional algorithm used in RPM is based on the comparison of the gross signal (i.e. a sum of the net signal caused by a gamma source and the background) measured during the vehicle passage through the monitor with the initial background level measured before the vehicle is appeared in the control zone (i.e., when the occupancy signal is OFF). However, the background level is decreased (background is suppressed) during the vehicle passage. The picture is complicated by the fact that the suppression value is time dependent. As a result, the gross signal is dependent on the source place in the vehicle. It is shown that in some cases the background suppression reached up to 10-12 “sigma”, and for this reason even strong radioactive sources could not be detected using the traditional algorithm. A new advanced algorithm which allows RPM to detect gamma sources even under such complicated conditions has been elaborated, and the results of its work are presented.

P02.161
Strontium-90 in the Teeth of Residents of Techa Riverside Settlements

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The study devoted to the evaluation of ^{90}Sr in the teeth of residents of settlements located upon the Techa River, which was contaminated by radioactive wastes in the 50s. Measurements of ^{90}Sr concentration in various dental tissues (enamel, crown and root dentin) using TL passive beta detection were analyzed. The dependencies of tissue contamination on the age and average intake typical for specific settlement are evaluated. A model described the expected levels of ^{90}Sr in the dental tissues depending on age and residence is elaborated. The individual and tooth-to-tooth variability of ^{90}Sr content in tooth tissues are assessed. Obtained results will be used for interpretation of EPR dosimety in Techa River region.

P02.162
Study of the Triage Method for Radiological Mass Casualty Event Using Plastic Scintillator

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Increasing use of radiation or radioisotopes in the field of industry, medical purpose, research such as non-destructive examination, computed tomography and x-ray, etc. constantly. With use of nuclear or radiation has incidence possibility for example the Fukushima NPP incident, the Goiania accident and the Chernobyl Nuclear accident. Also the risk of terror by radioactive material such as Radiological Dispersal Device(RDD) and so on. Especially, type of radiological/nuclear accident would be contaminated (internal or external) by gamma-emission radioactive materials. Rapid screening of contaminated people and provide radiological information to medical staff should be primary importance at the radiological incident scene.

In this study is to measure effective detection zone and effective detection activity of plastic scintillator detector. The plastic scintillator properties are fast response and easy to formation. So we use the plastic scintillator detector to determine contamination or not. Spatial response of a plastic scintillator detector was measured using a Cs-137 check source for various activities (4.44μCi ~ 31.08μCi). For measure the effective detection distance that position of the check source was changed by 0~2 meters high and 0~0.8 meters of side position. It was founded that the optimal position of plastic scintillator detector is 1 meter high and 0.4 meter from side. Changing the distance 0~1 meter from detector, we could obtain the effective detection zone. Based on these results, the effective detection activity was decided by changing activities of check source.

From these experimental results, it was conclude that the response of plastic scintillator detector is influenced by background level, so we should control the standard deviation (-value) at high background region. Therefore it will be applicable to rapid screening the contaminated people at radiological incident scene.

P02.163
Mathematical Calibrations for Measurements of Radionuclides in People following a Radiological Incident

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It is important to be prepared in advance for a radiological incident should one occur in the UK. Such incidents could occur as a result of the deliberate release of radioactive material from a Radiological Dispersal Device (RDD). Assessment of radiation doses to exposed people would in most circumstances include making measurements of the amount of the radionuclide in the body. Usually, body monitoring calibrations for such measurements are made using a physical model of the body (a "phantom") containing a known amount of radioactive material. Such phantoms are almost always constructed for measurements on adult males. However, in an RDD incident, men, women and children of different ages and different body sizes could be exposed. Using a calibration phantom with different physical attributes to the person being measured gives rise to errors in the measured activity. Furthermore, calibrations with physical phantoms may not have been performed for the radionuclides that might be encountered. Radionuclides that are inhaled may be distributed non-uniformly in the respiratory tract, which will affect the detector efficiency for lung calibrations. Commercially available phantoms typically use a uniform radionuclide distribution. Phantoms designed to be used in a supine position do not always provide reliable calibrations for measurements on people made in a seated geometry, which presents problems for emergency monitoring applications. Mathematical phantoms can be applied to overcome all of these limitations. A research project (VOXPOP) is under way to develop mathematical phantoms and mathematical detector systems for use with particle transport codes such as MCNPX. Research is currently being carried out to produce more realistic phantoms that represent the range of subject sizes and used for calibration of body monitoring measurements occurring hours or days after the incident. The research is applicable to both hand-held and portal monitors that can be used for screening measurements, and for dedicated static and mobile body monitoring systems. To facilitate research into this field, a number of software applications have been developed to simplify the building and validation of mathematical detector and phantom models. This software will allow mathematical calibrations to be carried out for detector systems for a wide range of incident scenarios. This presentation will provide a summary of progress on this topic.

P02.164
Mobile Unit for Site Characterization in Environmental Remediation Projects

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As part of an environmental remediation plan to be applied to areas affected by past activities and accidents, characterization of the site is a mandatory step. This activity will determine the extent of the contamination, contaminants' distribution, etc. Traditionally, this activity involves the collection of different environmental samples and laboratory analysis of the relevant radionuclides (and eventually other contaminants like heavy metals). When the results are available they are interpreted and then a decision is made. This process is normally very expensive and time consuming. In recent years many techniques have been made available for in-situ measurement that can provide reliable information on the contamination profile in radiologically contaminated land. Such measurements tend to be less expensive, faster and with the aid of GPS/GIS systems decisions can be made on-site in real time. Mobile units may also be useful to states who do have laboratory analysis facilities, but are faced with large, unforeseen characterization challenge, such as following and accident or radiation emergency. To overcome this situation we developed the DACM (Data Acquisition and Control Module) technology. Instruments based on this technology can be modified anytime by the user without special knowledge and the claiming of the manufacturer.

The DACM based offers a set of components which can be configured, parameterized and controlled with respect to the requirements on site. Typical components are Radon/Thoron modules (soil gas, water, air, exhalation), signal inputs for sensors like Co2, Methane, So2.., control outputs for instance for pumps, magnetic valves for exhalation measurements but also complex functional blocks like spectrometers, GPS receiver, PID regulators etc. A complex sampling schedule can be created within few minutes by a graphical software interface.

Definition of a local dose, detection of radioactive sources:

The handy and robust NaJ(TI) detector is connected to the unit via a 10m long cable, so that it can be positioned flexibly in relation to the source. Thanks to the big detector volume, even small sources can be detected.

Net activity of free definable nuclides in food and material probes:

The NaJ(TI) detector is also used to analyze food and material probes regarding specific nuclides (e.g. Iodine, Caesium, Americium). By means of the gamma spectrum, the net activity of two user definable nuclides is automatically calculated.

Measurement of radioactive aerosols in inhaled air:

The aerosol sampling head with its spectroscopy filter and its silicon detector samples continuously and detects even small quantities of aerosol carried radioactivity. Both alpha and beta radiation are measured. The spectrometric analysis allows e.g. detecting Plutonium aerosols which cannot be detected by measuring gamma radiation.

Mop tests, surface contamination (clothes), electrochemical probes:

Optionally, the DACM can be connected to a portable vacuum chamber, to allow on-site analysis of mop tests and other samples under circumstances similar to those prevailing in a laboratory. The employed vacuum pumps can be connected to a 12V source (car battery).

All detectors can be operated simultaneously. The concept of the system allows an easy handling and a standardized data basis. The device offers predefined measurement procedures that can be easily modified by the user. Additional measurement programs can be created without any problem.

The Data transmission and device control can be done by GPRS or GSM modems, as well as via ZigBee adapter (Wi-Fi), if the device is operated in inaccessible or contaminated areas.

P02.165
Analysis of the Life Time of Quartz TL peaks: Comparison of the Deconvolution Using the First Order Kinetic to the Initial Rise

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Thermoluminescent materials like quartz are used as passive dosimeters in a wide range of radiological applications. Quartz has been used since the 60s for dosimetry and/or dating but the method is still subject to some improvement. One of the problems is the estimation of the lifetime of the "used peak".

The application of the glow-curve deconvolution (GCD) technique for the analyses of a composite thermoluminescence glow curve into its individual glow peaks has been applied widely since the 80s. Many functions describing a single glow peak have been proposed.

For analysing quartz behaviour, we compared thermoluminescence glow-curve deconvolution (GCD) functions for first order of kinetic. The free parameters of the GCD functions are the maximum peak intensity (I_m) and the maximum peak temperature (T_m), which can be obtained experimentally. The activation energy (E) is the additional free parameter. The lifetime (t) of each glow peak, which is an important factor for dose reconstruction, is calculated from these three parameters.

For "used peak" lifetime analysis, we compared GCD results to those from initial rise method (IRM). Results vary fairly from method to method.

KEYWORDS: quartz, thermoluminescence, lifetime, GCD, IRM.

P02.166
Which Levels of Alpha- and Beta Contamination on Surfaces are Possible to Detect with Manual Search?

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Measurement of alpha-beta activity on surfaces can be a cumbersome task. Results of a measurement vary depending on the velocity with which the probe is conducted over the surface, distance to the surface and characteristics and flatness of the surface.

Contamination limits are given in levels of Bq/cm^2 while the instrumental response are given in counts per second (cps), therefore a relationship between contamination and instrumental response needs to be developed. This relationship will be different for each type of instrument.

Measurements will be made with custom made equipment and computer program created for this purpose. All parameters are monitored and modified. The first instrument tested is Intensimeter 28 used by Swedish Armed Forces. It will be followed by other types of instruments. All are used with hand-held alpha/beta probes.

Sources used are Am-241, Ni-63, Tc-99 and P-32, i.e. alpha, beta and gamma sources of low, medium and high energies. Activity between 0.4 Bq/cm2 and 400 Bq/cm^2 is placed on glass surfaces. The active area is 200 cm2 (10 cm „e 20 cm). The results show the relationship between distance, velocity of the probe and degree of contamination. This work will during 2012 continue with fabric-covered, painted and arched surfaces.

P02.168
Fiber Optic Interferometric Sensor for Registration of X-Ray Radiation

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We present a fiber optic sensor based on Mach-Zehnder interferometer scheme for registration of x-ray radiation. The interferometer consists of two segments of standard single-mode fiber, where the sensitive arm is exposed to a high-flux x-ray beam. A He-Ne laser is used as a light source. The output of the Mach-Zehnder interferometer is projected on the matrix of the CCD detector connected to a PC. Absorption of the x-ray radiation produces an increase of the local temperature in the single mode fiber that induces a shift in the phase of the propagating beam of a He-Ne laser. X-ray irradiation of the fiber gives rise to the local temperature increase of the exposed segment of the fiber and then a change of its optical path length in the Mach-Zehnder scheme. By processing of the fringe pattern one can determine the intensity of the x-ray irradiation directed to the fiber.

The x-ray tube used in this experiment has a Cu anode whose K wavelengths is Kα=1.5418 Å (30 kV and 30 mA anode current). The fringe pattern in the far field is registered with a HDCS-1020 CMOS image sensor with the pixel size 7.4×7.4 µm and image array sizes VGA 640×480. The full frame video rate at 8-bit resolution was 30 fps. The program for processing of the interferometric fringe pattern has been developed on the basis of C++ language and run on the *Linux* platform. The PC technical profile is characterized by *AMD Sempron Processor 3000+ 1.61GHz, 1GB RAM.* A possible application of this technique to registration of x-ray radiation for radiation protections or physical protection of nuclear or radioactive materials purposes are discussed.

Key words: X ray radiation, fiber-optic sensor, Mach-Zehnder interferometer, CCD detector, radiation protection, physical protection.

P02.169
Angular Response of Polymer Films Irradiated with Accelerated Electron Beam

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Electron accelerators have been used in the industrial (petrochemical, chemical, pharmaceutical, food and sewage treatment), medical (sterilization of clothing and equipment, and diseases treatment), and in scientific research areas. Incident electrons on the material or on the patient are characterized by its different parameters of energy, incidence angle and particles average range in a specific medium. The dose distribution determination for a given beam configuration is performed to optimize processes; it must ensure that the delivered dose is uniform throughout the irradiated volume. When radiation is applied in a large area, as in the skin diseases treatment in which the whole body must be irradiated, or in the industry which large and irregular volumes should be irradiated, obliquely incident particles must be considered, since, can result in different doses from those obtained in irradiated material in normal direction exposure. In this work the obtained results of polymer detectors irradiated in an electron accelerator with energies of 0.732 and 1.25 MeV, doses of 10 and 30 kGy and, in the normal direction exposure (horizontal) and incidence angles of 30, 60 e 90° were analyzed. The results were analyzed using spectrophotometry based on the absorbance values change, comparing irradiated and non-irradiated detectors. The accelerator model JOB 188 – Radiation Dynamics Inc. (RDI) used belongs to the Radiation Technology Centre – IPEN. Under the analysis conditions was observed that the dose decrease linearly with the incidence angle, the highest dose was received by the detector positioned in the normal direction and the lowest dose in the detectors positioned at 90°. Different volumes were irradiated and analyzed, the irradiation response of detectors positioned in different geometries allow the dose distribution determination in the processes simulation; this knowledge is important for dosimetry, treatment planning, quality assurance and design of an accelerator.

Keywords: electron beam, oblique incident angle, polymer detector, spectrophotometric analysis

P02.171
Studying the Variation of Radon Level Among Covering Materials in Some Houses in Major Cities of the Southwestern Nigeria

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Next to smoking, inhalation of indoor radon has been recognized as a major health hazard responsible for increasing cases of lung cancer. In the present work a set of indoor radon measurements was carried out, in buildings of the same building materials having different covering materials in major cities of the Southwestern Nigeria. The measurements were carried out from February 2011 to August 2011, using an active electronic radon gas detector (safety siren Pro 3 model HS71512). The commonest combinations of covering materials in the respective order of walls, ceilings and floors are: (A) – paint, paint, carpet; (B) – paint, asbestos, plastic tiles; (C) – paint, asbestos, ceramic tiles; (D) – ceramic tiles, asbestos, ceramic tiles. The mean values of the indoor radon concentrations for combinations B, C and D were found to be greater than the world average of 40 Bqm^{-3}. However, the risk assessment from the results of this work showed that the exposure to indoor radon in houses in the cities considered is of low risk of fatal cancer occurrence due to indoor radon inhalation.

Keywords: covering materials, indoor radon, walls, ceilings, floors, paints, carpet, asbestos, plastic tiles, ceramic tiles, southwestern Nigeria.

P02.175
Evaluation and Analytical Comparison of Different 2D and 3D Radiotherapeutic Treatment Planning Systems using Dosimetry with Anthropomorphic Phantom

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Introduction: One of the priorities of quality assurance programs in a radiotherapy department is the entrance of new Treatment Planning Systems (TPS) along with discussion and evaluation of calculation algorithms. As dose calculation algorithm is one of the main sources of uncertainty in the radiotherapy sequences, like the other elements, such as treatment unit parameters and uncertainties related to patient. Because of these reasons, it is necessary to evaluate the dose calculation accuracy of different methods in variant body regions. The aim of this study was to evaluation and analytical comparison of different calculation algorithms applied in our country radiotherapy centers base on the methodology developed by IAEA for treatment planning systems commissioning (IAEA TEC-DOC 1583).

Material & Methods: The methodology was based on an anthropomorphic phantom representing the human thorax, and 7 tests that simulate the whole chain of external beam radiotherapy treatment planning activities. The phantom was scanned in every center, using computed tomography and seven test cases were planned on 2D and 3D treatment planning systems witch imitate different irradiation geometry found in conformal radiotherapy. The dose were measured with ion chambers and the deviation between measured and TPS calculated dose was reported. This methodology, which employs the same phantom and the same setup test cases, was tested in 4 different hospitals which were using 5 different algorithms/inhomogeneity correction methods implemented in different treatment planning systems. The algorithms in this study were divided into two group algorithms inclusive correction based algorithms and model based algorithms. Correction based algorithms was ETAR, EPL and Modified Batho. Model based algorithms was CCC, CS and FSC.

Results: A total of 84 clinical test cases dataset for different energy and calculation algorithms were produced, which amount of differences in inhomogeneity points with low density (lung) and high density (bone), decrease meaningful with advanced algorithms. Most the systems with advanced algorithm that use lateral inhomogeneity correction in calculation modeling, compiled with predicted agreement criteria. The number of deviations outside agreement criteria increases with the beam energy and decreases with advancement of the TPS calculation algorithm.

Conclusion: Large deviation exist in some simple dose calculation algorithms as ETAR, Modified Batho and EPL, in some points, therefore more advanced algorithm specially Mont Carlo based algorithms, would be preferable and therefore should be implanted in clinical practice, specially for calculation in inhomogeneous medias like lung and bone. Use of model based algorithms with lateral transport calculation, is recommend. The systematic errors that observed in this study, show necessity of performed periodic tests like this in reasonable time, for radiotherapy centers, to appreciate the possibilities of their systems and understand its limitation.

P02.177
Development of a Protocol for Radiation Survey Meter Calibration

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In nuclear medicine, brachytherapy and radiation oncology, radiation survey meters are an integral part of radiation safety. Radioactive fluids present a high risk for surface contamination while small size brachytherapy seeds are difficult to spot if dropped. Radiation survey meters are used to ensure patient and staff safety. To enable the optimal functionality and reliability of these detectors, the Canadian laws require the annual calibration of all detectors by an accredited organism. In this context, we have developed a calibration protocol for radiation survey meters that meets the criteria cited in the R-117 protocol (primarily produced by the Atomic Energy Control Board of Canada; archived on January 14th by Canadian Nuclear Safety Commission) and the ANSI N323A-1997 standard. Model 773 calibrator from Sentinel, containing a Cesium-137 source with a certified activity of 164.9 mCi on 29 January 2003 was used as calibration source. The Geiger detector to be calibrated and the calibrator were elevated 1 m above the ground on two low Z support platform (made of wood) and placed far from any obstacles to minimize scatter radiation. Transmission filters and distances between the calibrator and the detector were adjusted to deliver a known dose rate corresponding to 80% and 20% for every scale. It takes approximately 2 hours to calibrate four Inspector Alert detectors and the mean error for a complete calibration procedure is around ±4.4%, well below the recommended ±20% error criteria. A standard protocol document was generated and an Excel file has been developed to ease the parameter calculations and data analysis.

P02.179
Characterization of OSL response of LiF:Mg,Ti and microLiF:Mg, Ti in 60Co gamma source

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OSL dosimetry has been investigated for medical dosimetry applications due to its characteristics for applications in external beam radiation therapy. The ability to register the absorbed dose accumulated in the detector over extended periods of time, the high sensitivity, small detector size and real time measures of the OSL detectors make this technique suitable to be used as personal dosimetry technique. In the OSL technique no heating is required to the dose measurement, so there are no changes in the physical characteristics of the material and non-destructive readout, in other words, repetitive measures for the same material can be carried out. In this work the gamma dose assessment using LiF:Mg,Ti and microLiF:Mg,Ti dosimeters from Harshaw was evaluated using OSL technique. The dosimeters were previously selected according to its TL sensitivity to ^{60}Co gamma radiation using a TL reader Harshaw model 3500. The dosimeters were divided in two groups: before irradiation one group of dosimeters was heat-treated using a furnace Vulcan model 3-550 PD and the other group was optically-treated using two fluorescent lamps (20W) Sylvania, model F 16 W/78. The dosimeters were irradiated in air at electronic equilibrium conditions using a ^{60}Co gamma source with doses ranging from 0.1 up to 5 Gy. The OSL and TL measures were performed using an OSL reader Risø. The studied parameters were reproducibility, dose response and optical and thermal fading.

P02.180
Long Distance Radiation Monitoring System using Optical Fiber Scintillator and Silicon Photomultiplier

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The amount of an annual radiation usage have been increased in the medical application and the environmental radiation measurement. With the consequence that real time radiation monitoring system have been needed for a safe radiation detection. In this study, we have developed a new radiation detection system that composed of an Optical Fiber Scintillator(OFS) and Silicon photomultiplier(SiPM). Nearly 400nm light is transferred from the OFS sensor to detector by the optical fiber. The results of sensitivity for scintillation fiber sensor are reported in this work. We also show a β-ray detection from ^{32}P. We compared the experimental results with MCNPX Code simulation results at the same condition. For the future applications the optical fiber scintillator will be studied and compared a 2D real time radiation imaging system and other considerations such as cost and geometry.

P02.181
Phenomenon of Self-Absorption of Calcium Sulfate - Dysprosium Dosimeter, Made With Iranian Natural Calcium Sulfate

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Introduction: Detection and tracing different types of ionizing radiations is scientifically important. One of its main advantages is dosimeter thermo luminance(calcium sulfate - dysprosium dosimeter) peak of this phosphor is 220oC. Linearity area of this dosimeter is large enough (10-6 -10 Gy). The sensitivity of this dosimeter is 30-50 times higher than TLD-100.

Keyword: Dosimeter, thermo luminescence, self-absorbed

Materials and Methods

Iranian natural calcium sulfate CaSO4.2H2O ,dysprosium oxide (Dy2O3) and H2SO4 are the main materials. basic materials (CaSO4 & DyO3) should be weighted, Dy2O3 should be solved in some diluted acid.then added to thick and warm sulfuric acid.

Table1

Irradiation with cobalt-60 source, output 25 mGy / min

Dose (Gy)	Time	Field dimensions	Distance from the source
0.05	12 Sec	10 * 10	80 Cm
0.25	59.14 Sec	10 * 10	80 Cm
1	3 min, 82 Sec	10 * 10	80 Cm
5	19min, 43Sec	10 * 10	80 Cm

The reading were performed in room temperature in TLD reader device, and with heating trend of 3^{o}C/s and maximum temperature of 300^{o}C using aluminum basins, the results of this step are presented in Table 1. Radiation of sample was conducted with cobalt - 60 and cesium - 137 with one cure radiation in order to investigate the impact of activator concentration.The results are given in fig.3 and fig.4 .

Poster sessions C-D: Area 2

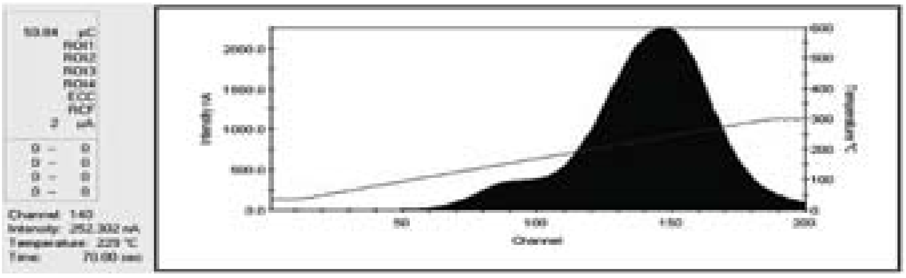


Fig.3 CaSo4:Dy CaSo$_4$ brightness curves 15%mol made by Iranian natural

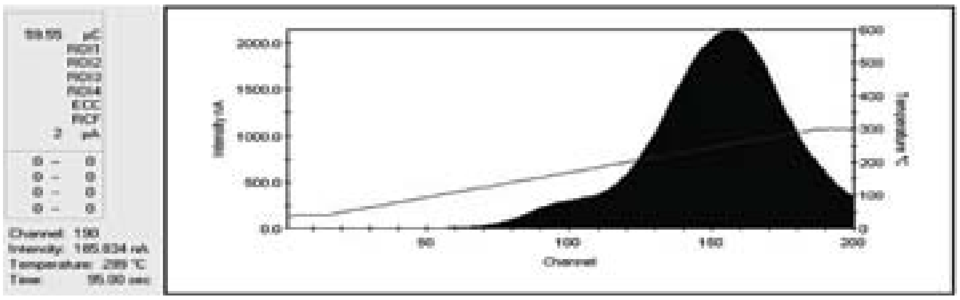


Fig.4

brightness curves 15%mol CaSo4:Dy made by fluka CaSo4

Impact of heating rate

CaSO4:Dy phosphor with 0.15 mol% concentration from dysprosium was radiated after pre heating in 400^{o}C for one hour with 0.25 dose and5 Gy from cobalt -60 and then they were read with heating rate of 5 and 3^{o}C/s and maximum temperature of 300^{o}C.

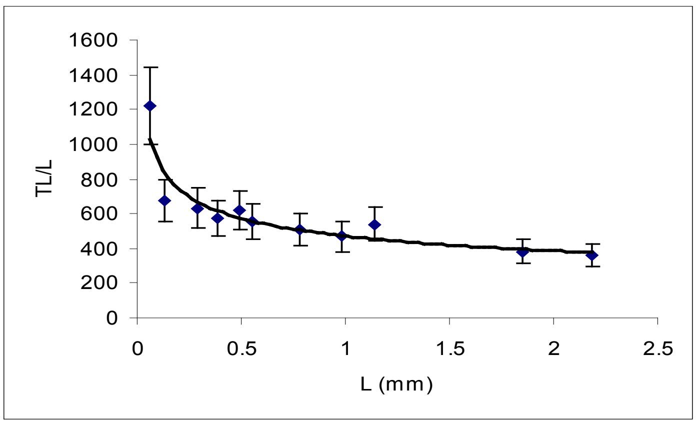
Investigating self absorption In order to study self absorption phenomenon, For this purpose, we treated CaSO4:Dy sample having 0.15mol% concentration from Dy, after heating in 400oC for 1 hour, under 5 dose radiation from cobalt-60 spring.

Conclusion

The present study indicated that optimum concentration of dysprosium in calcium sulfate dosimeter is 0.15 mol% wich is shown in Fig.1.Also, regarding maximum response of TL in exchange for heating rate of 3^{o}C/s, this rate was selected as optimum heating rate for next readings.According to Fig.2, 17 milligram powder for each reading, is an optimum thickness for achieving required goals.Having high sensitivity in beams dosimetry in general, and also in individual dosimetry in particular, this phosphor is useful and efficient and it can be used in dosimetry and also clinical fields .

Fig.2

self absorption, radiation with 5 Gy dose from cobalt-60



P02.182
A Comprehensive Study Of The Glandular Dose To Women Participating In The National Mammography Program For Early Detection Of Cancer Of The Breast, In Israel.

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The dose to a Standard Breast phantom was measured and the glandular doses to women attending for mammographic screening are evaluated for 60 screening centers in Israel. This is the first time in more than 20 years that a systematic evaluation of the average glandular dose in mammography screening procedures was carried out in Israel. Especially data is lacking related to the glandular dose (GD) involved in mammography carried out using the CR and DR mammography systems.

The method used for the measurements and the details related to the average mean glandular dose (MGD) will be presented.

Initial results of the measurements and dose evaluation related to most of the 36 mammography machines operating in 31 mammography clinics in Israel will be presented and discussed.

About 15% of the systems six are conventional (film screen), 25% are DR and the rest are CR.

Partial results of this project were recently published in RPD1.

The results of the measurements and epidemiological data collected by the Israeli Center for Cancer registration will be used to perform risk-benefit ratio evaluation of the Israeli national program for early detection of cancer of the breast by mammography.

References:

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P02.183
Different Methods for Tritium Determination in Surface Water by LSC

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The main aim of this paper was to compare different methods of preparing water samples for tritium analysis by ultra-low-level background liquid scintillation counter, Quantulus 1220. Three methods of sample preparation for low-level tritium measurement have been developed in the Nuclear Physics Laboratory in Novi Sad: electrolytic enrichment, direct method without electrolytic enrichment and sample Oxidizer 307 method. The examined fresh water samples were rainfall collected during 6 months and water from a stream in the Vinèa nuclear research center collected during 3 months. The obtained results with these three methods showed satisfying agreement. The appropriate measuring time by LSC for each sample prepared according to different methods has been determined.

P02.184
Full-range isotopic calibration of an RMS detector by F-18 decaying source method

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Vendor-supplied environmental radiation monitoring system (RMS) has been calibrated for an energy-compensated G-M detector by using a high specific ^{18}FDG point source in our shielded iodine therapy ward. During high pulse rate operations, most of the RMS detectors would suffer nonlinearity response due to detector dead-time, signal pulse pile-up and others. With the modern digital RMS design in progress, the detector nonlinearity behaviour can be “straighten-out” by using software programming technique, for examples, such as the dead-time correction or the look-up table methods, etc. The purpose of this study is to calibrate the installed G-M dosimeter to be used in our whole body clearance rate research project involved with high dose rate operations. Normally in the past, an ambient RMS detector full-range calibration would be done either by using multiple standard sources set or by varying detector-to-source distances and attenuators to achieve per-decade calibration ranges needed. In our Nuclear Medicine PET/CT Center, we are routinely receiving high specific F-18 sources (in ^{18}FDG format) in early morning for diagnostic imaging use. This F-18 source, with a half-live value of 109.74 min, can be adopted for the RMS detector linearity calibration purpose of convenience. The isotope impurities are the major concern when a decaying method is in use that has to span across three decades range or more. No impurity gamma peaks have found in the source spectrum for up to 24-hour decay (more than 10 times of F-18 half-lives) that has done by a 2”x2” NaI(Tl) gamma spectroscopy system. The activity of the prepared F-18 source also has to be calibrated and dated before each use by using a certified ionization chamber dose calibrator. For our first experimental tryout, the RMS counting is set-up for one minute dwell-time and a 1-min averaging data is recorded at every 20-minute interval in sequential order. An initial dose activity of 6.57 mCi (0.243 MBq) in 1 mL-volume of the F-18 source was placed in a fixed distance of about 12 cm away from the detector with dose-rate starting readout of 2472 µSv/h. Only upper three decades have been checked for our current interest. As a preliminary result, after normalizing for the source decay-corrected activities, the average linearity response is then calculated to be 386.2 +/- 5.2 µSv/h (+/- 1 α), per mCi of F-18 point source in this specific geometry. The RMS detector under investigation has shown a very good linearity check in upper three decades of better than 2% by this calibration run.

P02.185
Criteria For Reporting Radiological Data: Two Different Approaches

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The data obtained from field measurements or samples analysis are frequently used to decide whether or not radioactivity is present. The specific activity or the surface activity concentration have to be calculated when the "critical threshold" tests have concluded that the radioactive material is present above the counting background level. In both cases, the obtained results have to include acceptable limits of uncertainty.

For many years, Currie criteria (Detection Limit and Critical Level, L_D and L_c) and Minimum Detectable Activity (MDA) have been used to decide about radioactive detection, and very often these concepts have been misapplied. The international standard ISO-11929, published in 2010, clarifies these two concepts and provides a useful guide on how to calculate the decision threshold and detection limit in radiological environmental measurements.

Multi-Agency Radiological Laboratory Analitical protocols Manual (MARLAP) recommends to compare the measured amount to its critical value to make decisions about detection capabilities. Any response above this level is considered greater than background. In the case of spectrometric measurements (gamma spectrometry), the use of commercial softwares provides results that need to be reviewed. In fact, some of them supply negative results with no uncertainties associated, since their calculation implies the square-roots of negative counts. These negative values must not be reported and the detection limits should be registered instead. The negative results and their associated uncertainties should be applied just for statistic approaches in environmental measurements, but should not be considered in dismantling operations.

The *person-in-charge* of the measurements has to establish adequate criteria to report radiological results according to his professional judgment. This paper describes the criteria of two CIEMAT labs (environmental and characterization of contaminated sites) for reporting their radiological data.

P02.186
Thermal Neutron Fluence Measurements Arround a Cyclotron for PET producion

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The complete dosimetric characterization around a cyclotron (Cyclone 18/9, IBA) is one of the aims of an investigation project in which the Ionizing Radiations Metrology Laboratory (LMRI) and Medical Applications Unit belonging to CIEMAT are involved. Considering that the most of the contribution to the dose comes from the neutron production in the target materials is necessary to determine the fluence rate and the spectral distribution in several points inside the cyclotron vault. But, because of the presence of strong electromagnetic fields and the pulsed radiation is not possible to use active detectors and thermoluminiecence dosimeters, TLD600 and TLD700 pairs, and gold activation foils have been used instead.

The measurements were made in several points close to targets during the ^{18}F and ^{11}C production.with a set of TLD600 – TLD700 inside PMMA phantoms and gold activation discs with a NaI:Tl (3” x 3”) scintillator detector.

In addition a system of 12 Bonner Spheres Spectrometer (CIEMAT-BSS) where the original 3He proportional counter (SP9 type) was replaced by passive gold foils has been used in four points. The GRAVEL and MAXED unfolding codes have been employed in order to determine the full spectra but a high uncertainty value is asociated with the thermal component with this method. For this reason the use of thermal neutron complementary measurements may be very suitable. A suitable agreement has been found for the results obtained with every technique and with previous results obtained by other authors.

P02.187
Identification of a Low-Energy Beta-Emitter by High-Resolution Gamma Spectrometry

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Introduction: AMEC has successfully identified an unknown beta source by undertaking a non-intrusive measurement using High Resolution Gamma Spectroscopy (HRGS) to look at Bremsstrahlung emissions from the source. Bremsstrahlung x-rays have a continuous energy spectrum up to a maximum energy equal to the maximum kinetic energy of the beta particle emitted. It was thus expected that the Bremsstrahlung emission spectrum for the unknown source would be similar to its beta spectrum. The Bremsstrahlung energy spectrum would however be modified by absorption within the HRGS detector's aluminium outer-can (and within other materials associated with the construction of the detector) before interacting within the detector's sensitive volume.

Initial screening of the source with a range of conventional Health Physics instrumentation only detected the presence of low-energy photon radiation, with no beta counts being recorded. This suggested that the source was a low-energy beta-emitter, with potential candidates being identified as Nickel-63, Lead-210, Zirconium-93 and Tin-125.

The Monte Carlo N-Particle Transport Code (MCNP) was used to predict the anticipated Bremsstrahlung energy spectrum from Nickel-63 using appropriate emission data. MCNP was also used to generate an efficiency calibration for the detector to enable an activity estimation to be made. The unknown source was then placed on a High Resolution Gamma Spectrometer, and the measured spectrum compared to that from Americium-241.

This work allowed AMEC to establish the radionuclide present and also to make a reasonable assessment of the total activity, enabling the source to be disposed in accordance with regulatory requirements.

Topic: Measurements and Dosimetry – instrumentation and measurement

P02.188
The use of a TrueBeam System for the Characterisation of Optical Fibre Based Dosimeters

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Significant improvements occurred in radiation therapy technology during the recent years as effect of the availability on the market of new generations of linear accelerators. The modern machines are indeed able to deliver the planned dose to the tumour target in shorter time with respect to conventional systems thanks to the higher dose rates. TrueBeam (Varian Medical System, Palo Alto, USA) is a new accelerator designed for delivering both in flattened filter (FF) and flattering filter free (FFF) modality. Removal of the flattening filter implies the possibility of delivering treatments with higher dose rates, up to a factor 4 at 10 MV, and with a much higher dose per pulse, opening new possibilities for stereotactic body radiation therapy (SBRT) delivery technique. SBRT routinely uses small fields and beamlets of less than 10 mm in diameter in order to achieve the desired, highly focused and precisely modulated dose distribution. Measurement of small photon beams is a well-known problem that requires very small detectors to guarantee a correct measurement of the various parameters used for the beam physical characterisation.

In this work radioluminescent dosimeters based on doped silica optical fibres (diameter 200 µm) are tested using the radiation beams produced by a TrueBeam accelerator. After first measurements aimed to verify the reproducibility of the radioluminescence signal, the linearity with dose and the dose rate dependence, the capability of the detectors to correctly assess Output Factors and profiles of the smallest radiation fields is tested and discussed

P02.189
Neutron Dosimetry Device Using PADC Nuclear Track Detectors

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The principle of producing and observing neutron induced tracks in organic detectors exhibits most attractive properties and is the basis of one of the main methods used in neutron personal dosimetry.

A device consisting of Poly Allyl Diglycol Carbonate (PADC) foils with a polyethylene and Polyvinyl chloride (PVC) radiator was calibrated in order to perform the dosimetry of neutron sources covering a wide range of doses. Working conditions were established for a good visualization and counting of tracks: chemical attack was made in two steps with different solutions and etching times. A good fit was obtained for the dose as a function of the number of tracks per unit surface area.

P02.190
Review on Adequacy of Skin Exposure Dose Evaluation Using Harshaw Algorithm

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TLD reader systems used in nuclear power plants at home are either Panasonic or Harshaw, and among these, Harshaw reader systems use DOELAP (operating system: DOS) for its dose evaluation algorithm except for those at Kori Unit 2 and Shin-Kori Unit 1 that use Win-Algorithm (operating system: Windows). It came to our attention that the algorithm for skin dose evaluation based on beta energy was missing in Win Algorithm (ALGM-W05-0908-001) provided initially by Harshaw. Upon our request for supplementation, Harshaw provided another algorithm (ALGM-W05-U-0908-003), and this study was launched to examine the adequacy of the new algorithm. Consequently, a completely new algorithm had to be developed as the one provided by Harshaw resulted in over-evaluation to a degree when it involved mixed beta field. We are planning to request to Harshaw to reflect the new algorithm, and we hope that such an effort will help enhance reliability of dose evaluation for workers at nuclear power plants while serving as a foundation to set a proper course in the develop

ment of a domestic algorithm. KEYWORDS: TLD; Harshaw; nuclear power plant; algorithm.

P02.191
Enhancement of Exposure Dose Prediction Reliability for Radiation Workers by Using Represented TLD/ADR Ratio

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Exposure dose of workers of nuclear power plants in Korea is managed with TLD, a legal personal dosimeter. However, because TLDs are collected and read once a month due to its measurement principle, radiation workers are equipped with a supplementary dosimeter, ADR, to manage exposure dose on a real-time basis until TLD readings are provided. Dose readings may vary due to each dosimeter's specific characteristics, and these are overcome by using the previous year's TLD/ADR dose ratio in order to manage radiation-tasks that are performed actively. However, simple quoting of ADR/TLD ratio alone has its limitations fundamentally to effective exposure dose management for workers. Therefore, this study aims to obtain a more advanced represented ratio to address the aforementioned problem.

KEYWORDS: TLD; ADR; EPD; dose ratio; photon energy

P02.192
Can GATE Be Used For Monte Carlo Calibrations Of Whole Body Counters?

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The aim of the presented work is to determine if GATE can be used for Monte Carlo calibration of a whole body counter scintillation spectrometer system consisting of large plastic detectors.

GATE is an open source software, on a GEANT4 platform, dedicated to medical use such as PET and SPECT. Even though whole body counting scintillator spectrometer systems and PET/SPECT systems have different purposes and complexity, there are a few fundamental similarities: the use of scintillation detectors, moveable detectors, source inside a patient and the amplification method of the detector signal. Compared to whole body counting, the PET/SPECT medical field is large, which affects the development of system specific software such as GATE in a positive direction. However, if it is possible to use GATE for whole body counting specific problems as well, then a rather small field of research could benefit from the already extensive work done in a larger. If so GATE can be used instead of in-house codes, or general-purpose codes that may not be specific enough for whole body counting purposes.

In this work, GATE will be used to investigate the optical transport in large plastic scintillators and its effect on intrinsic spectrum resolution. Further, since the signal from a plastic scintillator needs to be amplified, it will be investigated if it is possible to simulate a broadened spectrum produced by a photomultiplier tube.

If these two problems are possible to simulate using GATE, then GATE would be a promising software to be used for a Monte Carlo calibration of whole body counters. The results of these finding will be presented at the conference together with the conclusion whether GATE can be used also for whole body counting.

P02.193
Easy Determination of the State of Contamination with a GM Counter

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Generally the GM counter has been used as radioactive contaminants monitor in the radiation control area. In most cases, a GM counter represents the value to the counter per second (cps). Permissible surface contamination level for alpha emitting radionuclides and beta/gamma emitting radionuclides are defined as 4 kBq/m^2, 40 kBq/m^2 under the Atomic Energy Act in Korea respectively. It is not easy to know whether the measured value of cps properly indicates the level of contamination in the control area. So the measures should be calculated to kBq/m^2. The aim of this paper is to study on easy determination of the state of contamination with a GM counter. Taking into consideration the factor of calibration and detector area, the equivalent value can be made. The radiation workers in the site easily use the created conversion chart on the wall in the radiation control area. This effort can provide the way of radiation safety control.

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P02.194
Building a Modular γ-Radiation Monitoring System from off the Shelf Components

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The currently used environmental γ-radiation monitoring systems used in Sweden are based on a specialized system produced with limited extensibility. Recent events have highlighted the need for a more versatile radiation monitoring system which can be deployed on short notice and in a wide range of situations. The main goals of the project was to build a small, modular, spectrometric system which can run independently from battery power supply for a few days or from mains power indefinitely.

The resulting system uses the ORTEC DigiBASE MCA as a PMT base to a 2" x 2" NaI(Tl) crystal. The MCA is connected to a Gumstix Overo computer running Linux. The hardware is mounted in a carbon fiber tube with a diameter of 1 dm and a length of 5 dm.

The software running on the computer performs gain stabilisation of the detector as well as data collection, analysis and promotion. It also has support for connection of additional sensors for monitoring ambient parameters such as temperature, humidity and precipitation. It is furthermore possible to connect a dose rate instrument to the computer through a serial port.

The computer runs a web server which allows remote configuration of the system as well as remote access to the data.

P02.195
Stability of a Berthold LB6411 Neutron Probe for Use as a Secondary Standard

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At the PSI calibration laboratory neutron reference fields are provided for the calibration of ambient and personal dose equivalent (rate) meters and passive dosimeters. To ensure traceability to the national standards of the Physikalisch-Technische Bundesanstalt (PTB) in Germany the neutron fields are characterized by means of a Berthold LB6411 neutron probe which is used as a secondary standard. It is known that the LB6411 detector suffers from an unstable, increasing dose rate reading in the order of up to 5% (according to the manufacturer due to a charging effect in the ^{3}He proportional counter). This instability is usually corrected for based on the reading obtained with a test source.

In this work the instability was investigated by means of long term measurements up to ten hours under irradiation with ambient dose equivalent rates up to 24 mSv/h. It was identified that the reading of the instrument reaches a plateau, e.g. it becomes stable after 90 min in an irradiation with 10 mSv/h ^{252}Cf. The plateau is reached faster for higher dose rates, This supports the correlation of the effect with a charging effect in the proportional counter. The effect could also be duplicated in an irradiation with photons (^{137}Cs). The decay time of the accumulated charge was found to be very long, i.e. the instrument showed a stable reproducible reading for up to six hours after the plateau was reached. From these observations a conditioning procedure was derived which ensures a stable operation of the instrument after an irradiation of the instrument preceding its use in reference measurements.

P02.196
Uncertainty of Fragment Yield Ratios from Heavy Ion Fragmentation Measured with Track-Etched Detectors

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A risk assessment related to transport of heavy ions in a shielding or in a tissue is very important especially in hadron therapy, or space dosimetry. The primary ions may be affected by reactions of projectile and target nuclei resulting in a production of nuclear fragments. The risk prediction can be performed using a several existing calculation models. Their validation with a measurement is difficult due to the range of the fragments, which is typically very short.

Track-etched detectors (TED) have been used to investigate fragmentation processes for several years. These passive detectors are available for detection of particles with linear energy transfer (LET) over approximately 5 keV.µm^{-1}. A measurement with TED is a multistage process with different sources of uncertainty at each stage. The uncertainties can be divided into three basic independent categories: i) uncertainty associated with randomness of particle detection, ii) calibration uncertainty, and iii) uncertainty associated with detector response. In our previous work, we developed a method for determination of uncertainties associated with individual bin counts of an LET spectrum and applied it for the LET spectra measured with TED on board the International Space Station.

The aim of our contribution is to present an extended method that can be used for the purpose of fragmentation studies. The method was used to determine fragment yield ratios and their uncertainties for carbon and neon beams with nominal energy 400 MeV/u impinging on a PMMA shielding. Measured values were compared to values calculated using Monte Carlo simulations. It was found that the differences between measured and simulated fragment yield ratios were not statistically significant mainly due to relatively large measurement uncertainties.

P02.197
Performance Evaluation of Silicon Photomultiplier Sensor for Thickness Gauge

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The objectives of this study were to assess characteristics of silicon photomultiplier sensor for a radiation detector module and applicability of the sensor as a thickness gauge. Electrical, optical and radiographic properties of the silicon photomultiplier sensor were characterized. A detector module was set with optimal scintillator combination and tested as a thickness gauge. Noise equivalence charge displayed values of 10,000 or higher and was matched to a large-area sensor of 100 pF or higher in internal electrostatic capacity. Signal to noise ratio indicated an increase in noise level at 27 V or higher. Dynamic area did not display a significant drop in performance. Measurement of dark current of the silicon sensor showed a typical current-voltage characteristic curve. Dark current increased due to the effect of optical adhesive. Silicon photomultiplier sensor produced the maximum current output at the section of 550 - 600 nm, and thus well matching with a CsI(Tl) scintillator. Counting rate in dark was proportional to the voltage applied to silicon photomultiplier sensor. To assess radiographic characteristics, a scintillator with optically treated surface and signal processing board were combined with silicon photomultiplier sensor. Energy resolution of CsI(Tl) and LYSO scintillators with the silicon photomultiplier sensors were ± 3% on an average, indicating no difference of in energy resolution. However, in terms of counting rate, CsI(Tl) was higher by about 50%. A commercial level conventional NaI(Tl) scintillator combined with photomultiplier and CsI(Tl) scintillator combined with silicon photomultiplier sensor was prepared and thicknesses of four different types of metal plates were measured. The difference in pulse heights measured by the detector modules was within ± 5%. Both detection modules were capable of distinguishing four different types of metal plates. The detector modules showed similar levels of energy resolution and indicating applicability of the silicon photomultiplier sensor as a thickness gauge. In addition, it was found that silicon photomultiplier detector was more sensitive than general photomultiplier tube detector for a performance test.

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P02.198
Thermoluminescence Characteristics of High Gamma Dose Irradiated Natural Quartz

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The present investigation elaborates the thermoluminescence (TL) characteristics of colourless natural quartz irradiated with high dose (30 kGy to 280 kGy) of gamma radiations from ^{60}Co source. Two TL glow peaks in the temperature ranges of 491-499K and 634-666 K were observed in irradiated quartz. Colour transitions, dose response on the TL peak intensity, shift in peak temperature and defect production have been studied in the present paper. The kinetic parameters (activation energy, order of kinetics and frequency factor etc.) of natural quartz have also been determined.

Keywords:

Natural quartz

Gamma radiation

Thermoluminescence

Kinetic parameters

P02.199
Deconvoluting the Internal Contamination of the LaBr3:Ce Crystal

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The internal contamination of ^{227}Ac and ^{138}La with daughters is a problem with the Lanthanum Bromide crystal ($LaBr_3$:Ce). While the decay of ^{138}La to ^{138}Ba and ^{138}Ce generates some major beta continua and gamma lines, the ^{227}Ac decay series consists mainly of alpha-emitters and associated gamma lines. This effectively divides the pulse height distribution of the internal contamination into two distinct parts; the ^{138}La-part below 1.6 MeV and the ^{227}Ac-part above 1.6 MeV. This presentation deconvolute the observed pulse height distribution from a 3x3" crystal, breaking it down into its parts. Monte Carlo simulations using the GATE 6.0 interface for Geant4 was used to simulate the contributions from individual contaminants. Good agreement between the model and measurements were achieved with the alpha-region above 1.6 MeV presented the largest challenge.

P02.200
Interlaboratory Comparison of Tritium Electrolytic Enrichment Systems at RBI (Zagreb) and JSI (Ljubljana)

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Tritium (^3H) activity of natural waters (precipitation, groundwater, surface waters) has recently become too low to be directly measured by low-level liquid scintillation (LSC) techniques. It is therefore necessary to perform electrolytical enrichment of tritium in such waters prior to LSC measurements. Electrolytical enrichment procedure has been implemented in the Laboratory for liquid scintillation counting at the Department of Low and Medium Energy Physics of the Jožef Stefan Institute (JSI) in Ljubljana, Slovenia, in 2007 and in the Radiocarbon and Tritium Laboratory at the Department of Experimental Physics of the Ruđer Boškoviæ Institute (RBI) in Zagreb, Croatia, in 2008. Both electrolysis systems were obtained from the same producer (AGH University of Science and Technology, Krakow, Poland). Since establishment 21 electrolyses have been completed at RBI and more than 100 at JSI, where last66 were carried out under identical conditions. The mean enrichment factor E (a ratio between the final and initial ^3H activities) after stabilisation of the system is $ERBI = 22.8 \pm 0.8$, and the mean enrichment parameter (which describes the process of water mass reduction during electrolysis) is $PRBI = 0.947 \pm 0.003$. The corresponding values at JSI (after 66 electrolyses) are $EJSI = 18.9 \pm 1.5$, and $PJSI = 0.896 \pm 0.021$.

Both RBI and JSI laboratories have Ultra-low-level LSC Quantulus 1220 (Wallac, PerkinElmer) for measurement of ^3H activity. A set of water samples having ^3H activities in the range from 0 TU ("dead-water" samples) to 18 000 TU (1 TU = 0.118 Bq/L) were measured at both laboratories. Samples having ^3H activity <200 TU were electrolytically enriched, while the others were measured directly in LSC. A very good agreement was obtained (correlation coefficient 0.991).

Both laboratories participated in the IAEA TRIC2008 international intercomparison exercise. The analyses of reported ^3H activity results in terms of z and u parameters showed that all results in both laboratories were acceptable.

P02.201
The "Electronic Instrumentation Laboratory" (Label) of the Radiation Protection Sector at the Joint Research Centre of ISPRA

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The Joint Research Centre located in Ispra, is one of the research sites belonging to the European Commission, Directorate General JRC. It was created in the late '50s, in order to steer European research on nuclear industry. Within the Nuclear Decommissioning Unit, the Electronics Laboratory "LabEl", as part of the Radiation Protection Sector, is committed to the procurement, preparation, assignment, analysis, electronic calibration, performance check and repair of hundred of fixed and portable nuclear instruments in use at the Site.

The LabEl manages a fleet of radiation protection instruments (radiation detectors and monitoring systems) composed of around 200 portable instruments and almost 100 fixed monitoring stations, plus some 300 electronic dosemeters.

Instruments include portable dose and contamination monitors for direct measurements, personal dose rate monitors, electronic dosemeters, pedestrian and vehicles portal monitors, neutron monitors, hand and foot monitors, air samplers, scintillation detectors and more.

The LabEl mission is to ensure the correct functioning of all radiation protection instruments, via electronic calibration and daily performance checks; tracking of instruments' assignment for daily radiation protection surveillance tasks, including follow-up of malfunctioning instruments, is also included.

LabEl activities also include Radiation Protection Technicians continuous training, drafting of instruments' operating procedures, and the complete life dossier follow-up for every single radiation detection instrument.

Specific softwares have been developed throughout the years, in order to accomplish those tasks according to the Quality Assurance regime in force at the Nuclear Decommissioning Unit.

Specific procedures, mock-up systems and practices have been developed and put in place.

This work will present the mission, functions and procedures in place at the LabEl, in order to deal with a large fleet of radiation protection instruments used in daily radiation protection tasks by a large team of operators.

P02.202
Reducing Personnel Doses and Ensuring Radiation Protection: Electronics Calibration and Performance Checks in the Joint Research Centre Of ISPRA

Saracho Tortajada, I[1]; Migneco, A[2]; Riganti, A[2]; Patron Palomo, JE[2]; Zarza Perez, I[2]; Graboleda Castells, F[3]; Minchillo, G[1]; Giuffrida, D*[1]; Osimani, C[1]

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Starting from the main standard guidelines, UNI-9102:1988, UNI-8846:1987, UNI-08143:1980 and UNI-08300:1981 the LabEl developed specific operational procedures, in order to perform electronics calibration and needed instruments' checks to ensure correct functionality and quality of some operational Radiation Protection instruments.

This work describes some of type tests for the Sirius Alfa Beta Hand Foot Monitors and Automess Teletector Ratemeter daily used in JRC-ISPRA Radiation Protection Sector.

These specifics tests provide an implementation of electronics calibration and electronics checks, permitting a deep verification of the detectors behaviour, and the study of its electronic response, in order to verify energy dependence and linearity.

Following basic Radiation Protection Principles, those checks are mainly implemented simulating electronic signals, therefore significantly reducing the use of radiation sources and exposure to radiation of the Laboratory's Personnel.

P02.203
Determination of the Effective Linear Attenuation Coefficient of Samples with Unknown Chemical Composition

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A linear attenuation coefficient can be required for the correction of self-attenuation effect in gamma spectrometry. It can be determined by using a collimating system in a non-destructive way. However, the method may require sophisticated measurement systems with a collimator as well as relatively high radioactive photon sources. For the system, adequate space and safety system may be additionally required. This study was conducted to determine effective linear attenuation coefficients without any chemical composition analysis or collimating systems. Point-like sources with approximately 1 μCi were used in this study. NaCl, $(NH_4)_2SO_4$, Na_2CO_3 and K_2CrO_4 were used as a reference material, in order to calibrate the correlations between the linear attenuation coefficient, photon energy and the ratio of the counts with and without materials of interest. The linear attenuation coefficients of the reference materials were calculated using the XCOM program (by Hubbell, J. H.). The gamma-ray from the point-like sources was measured using a BEGe (Broad Energy Germanium) detector with relative efficiency of 38%. The measurement was conducted with and without sample materials, in order to determine the attenuation rate of gamma-ray for the materials. Then, the linear attenuation coefficients with the varied gamma-ray energy and materials were plotted vs. the ratio of counts with and without the reference materials. The count ratios were plotted vs. gamma-ray energy and the plots were fitted to polynomial functions. Finally, a formula was derived from two fit-curves to calculate the effective linear attenuation coefficients with the count ratio and gamma-ray energy. This method was validated using a Monte Carlo simulation with the MCNP code. The effective linear attenuation coefficient of samples with unknown chemical composition can be determined in a more rapid and simple manner with this method.

P02.204
Application of Neutron Fields with Fractional Changes of Fast and Thermal Neutron to Test Neutron Measuring Devices

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Reference neutron calibration fields such as those recommended in the ISO8529 are always not enough to test neutron detectors used for workplace monitoring because neutron fluence spectra at working environment are different from those reference one and finally neutron measuring devices over or under respond to them. Simulated neutron calibration fields (SNCFs) were constructed by using a thermal neutron field and a 14 MeV neutron source produced from a DT neutron generator at the Korea Atomic Energy Research Institute (KAERI) and six kinds of commercial neutron survey meters were tested under the fractional changes of thermal and fast neutron fluence. Thermal neutron calibration fields were constructed using eight AmBe sources which were installed inside a graphite pile with the dimensions of 1.5 x 1.5 x 1.5 m^3. The ratio of fast neutron portion to total neutron fluence was provided by changing the distance of position of an additional AmBe source or the DT generator from the reference position. Six kinds of neutron fields were used for test including a pure thermal neutron and a 14 MeV neutron attenuated by a 10 cm thick SST plate. All dosimetric quantities of SNCFs were determined by using a KAERI Bonner Sphere system. The responses of neutron detectors which were calibrated by using a Cf-252 source before test were ranged from 0.12 to 1.34.

P02.205
Maintenance of the Buried Neutron Irradiator

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The Argentinean Nuclear Regulatory Authority (ARN) has developed a neutron irradiation facility at the Ezeiza Atomic Centre to provide support to regulatory activities. In order to perform a preventive maintenance of the N40-BG-M-2 neutron irradiator (Hopewell Designs Inc.), a bearing was changed by a new one. The first step was to take out the radioactive sources “housed in” and to install them in different shields. The radioactive sources were Cf-252 (41 μg to 10/2010) and AmBe of 5 Ci. The transport package that was originally sent by the manufacturer was used as a temporary storage. For the extraction operation, a special device was designed to avoid operators irradiation. This resulted in an operation that did not deliver dose to operators. However, little doses could not be avoided while manipulating packages. Problems arising from mechanical operation to select sources were solved after replacing the bearing. Previous attempts had been focused on the air pressure line as well as to the irradiator pipe which had been also purged by air blowing and a treatment to remove the rusty affecting the bearing. The irradiator was successfully reassembled and the sources installed again. Once the device was up to work, performance tests on sources motion were carried out. The collective dose of all operations was less than 66 μSv. In this paper a detailed description of every step achieved to get the best performance of the irradiator, is presented. Results of the tests showed that the reparation of the irradiator was successful.

P02.206
Evaluation of Radiation Exposure by Natural Radionuclides for Employees in Water Supplies

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Indoor Rn-222 exposure is a problem, especially in specific working areas such as water supplies. Due to the open water surfaces and the flow rates, Rn-222 can exhale in large amounts. A comprehensive study to evaluate the risks of radiation exposure for employees in water supplies is conducted in seven of nine federal states of Austria. On the basis of geografical, geological and hydrological aspects 21 water supplies (165 measuring sites) were selected. Rn-222 concentration in air is measured for one year. Several different active and passive measuring methodes come to use and are evaluated. Passive methods for Rn-220 detection are tested. Besides Rn-222 other natural radionuclides of the uranium and the thorium decay chains can be accumulated in water filtering systems. Raw water and residues of filters are analysed by gammaspectrometry. The influences of several parameters, i.e. Rn-222 in water and venilation, on the radon concentration in air are investigated. Preliminary results of this on-going study are dicussed in this paper.

P02.207
Setup and Characterization of X-ray Reference Calibration Fields in a Dosimetry Laboratory

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For testing, calibration and verification of radiation detectors a new X-ray irradiation facility was set-up in the dosimetry laboratory Seibersdorf (DEL) jointly operated by Seibersdorf Laboratories (SL) and the Federal Office of Metrology and Surveying (BEV). The X-ray assembly was installed in an acclimatized, shielded room of 6.2 m x 3.8 m x 2.8 m inner dimensions and consists of a 160 kV X-ray generator (ISOVOLT HS160, Pantak Seifert, GE Inspection Technologies, Germany), a voltage divider, and three water-cooled x-ray tubes of tungsten, molybdenum and rhodium target material, respectively.

The objective of this work was to establish geometrical conditions of the X-ray unit for the introduction of various photon reference radiation qualities according to international standards, e.g. IEC 61267 for medical diagnostic x-ray equipment. The precise positioning and orientation of the selected x-ray tube, diaphragms, filter wheel, and transmission ionization monitor chamber along the central beam axis were carried out to finally provide accurate and traceable calibrations according to requirements of a primary and secondary standards dosimetry laboratory.

Simplified mathematical simulations (Microsoft Excel, Wolfram Mathematica) of geometrical arrangements were tested for choosing the appropriate distances and diameters of the diaphragms. The components of the X-ray irradiation facility were installed and adjusted in a stepwise procedure using a laser alignment system and a digital amorphous silicon X-ray imaging detector XRD 0822 (PerkinElmer Technologies, Germany). Setup and characterization of the X-ray field parameters, e.g. field-size, homogeneity and width of penumbra, were based on measured 1024 x 1024 pixel maps of the lateral X-ray intensity distributions at two application distances from the X-ray focus. Finally, field sizes of about 100 mm diameter and 167 mm diameter were verified at application distances of 600 mm and 1000 mm, respectively.

Determination of the focal spot sizes and shapes of the three x-ray tubes was achieved by applying the pin-hole imaging technique. Results of the air kerma profile and half-value layer measurements and practical peak voltage measurements may be included in a future paper. Measurements of photon fluence spectra are currently planned as well as the implementation of Monte Carlo simulations for verification purposes and for determining influence quantities such as scattering contributions.

P02.208
Towards a Tool for an Automatic Evaluation of Mammographic Image Quality

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In order to promote the assessment of the quality of the images of mammographic services provided in the state of Minas Gerais, the Sanitary Surveillance of the State of Minas Gerais (VISA – MG) together with the Centro de Desenvolvimento da Tecnologia Nuclear (CDTN) foment the Program for Quality Control in Mammography. This joint resulted in an image database of phantom images which are used in this study in order to develop a protocol for automatic evaluation of mammographic image quality, specifically aiming the image resolution and the detection of microcalcifications.

The strategy to achieve this goal is multi-level:

1. Fourier transform is the technique used to determine the limits of the spatial resolution. The existence of very specific frequencies in the image is shown by the luminous points visualized in the transformed images, and the location of the highest frequency level, the mean, and variance of the distance of the others frequencies to this highest one may show, computationally, the difference between the resolutions.

2. For the detection of microcalcifications, it is selected a region of interest (ROI) performing a subtraction of the background, and then a thresholding technique together with morphological operations is applied in order to determine the structures.

These algorithms were developed in the MatLab environment. The phantom images were obtained of the phantom Brazilian College of Radiology (CBR) and evaluations of test objects were made following the parameters of the Ministry of Health of Brazil.

Preliminary results show that, for the four spatial resolutions available in the images and using 28 phantom images with the ground truth settled, distance limits varying from 18.66 to 11.46 were established, allowing that for a new image, its resolution is evaluated as approved or reproved. The results are compared with evaluations done by visual analyzers and by a computational method using the program Image J.

The subjectivity inherent in the methods of visual assessment of mammographic images may be eliminated using these techniques with the computer as an aid, and also an efficient tool for image analysis can be provided, so that the improvement of public health is obtained in relation to early detection of breast cancer.

P02.209
Development of High Performance Automated Digital Imaging Microscope and Counting System Applied For Etched Track Detectors

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Solid state nuclear track detectors (SSNTD) are being widely used in variety of application through the field of radiation dosimetry. In large scale radon and neutron dosimetry, counting of particle tracks is feasible by an automatic track counting system.

The automated system consists of a professional Nikon® LABOPHOT-2 microscope coupled to AM7023 digital eyepiece CCD camera which is an USB 2.0 powered device with resolution of five megapixels and picture sizes up to 259 x 1944. The total magnification can be changed in the rage of 10X-2000X.

The detectors are placed in special frame mounted on a 100 x 300 mm^2 wide glass sheet installed on a monotypic high precision XY stage. The motion of the axis is controlled by a microcontroller system interfaced to a PC. The readout time is 40-60 seconds per detector or about 30 minutes for a tray (30 pcs).

The MATLAB-based software manages XY motions and adjusts best focus using Z axis motion.

The software is also capable to set for various chemical or electrochemical etching conditions and different polymeric detectors. The system applies for both passive radon dosimetry and personal neutron dosimetry based on nuclear track detectors in our laboratory and provides a commercially high accuracy of tracks counting system in comparing with manual operations. For the better recognition of the etched tracks and separation of overlapping tracks in a high track density, some of image processing techniques have been established. The program and image processing algorithm have been developed in MATLAB environment. The image processing criteria can be changed for specific works such as the filter threshold and image intensity level. The magnification and other specifications must be determined for evaluation and calculation of track density and mean track diameter.

Using this system can be avoided the disadvantages of manually counting such as observer subjectivity during the track field determination, improving counting statistic, measurement of the various track parameters (surface track density and mean tracks diameter) and obtaining the fast and reliable results.

P02.211
Evaluation of Novel Formulations of PADC Using the TASLImage Analysis System

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Nuclear track detectors (PADCs) have been used for many decades in the detection of ionising radiation, but by changing the formulations of these materials there is the potential to improve the performance of these detectors, particularly in the areas of long-term dosimetry and spectroscopy. This work presents a study of a number of important features, which affects the dose determination from such materials.

New formulations of PADC were tested to investigate the difference in aging, sensitivity, reproducibility and inter and intra batch variations. The TASLImage analysis system was used to compare a standard PADC, TASTRAK, to these of newly developed PADC's and investigate their response to neutron and alpha radiations

P02.212
Study of Agate Using the OSL Technique and Application in High Dose Dosimetry

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In the last decade, at the radiation metrology group of IPEN different stones have been studied as new materials for application in high-dose dosimetry. Amethyst, quartz, topaz, jasper, citrine and onyx have already shown their usefulness for gamma dosimetry, using the thermoluminescent technique (TL). McLaughlin et al described several kinds of high-dose dosimeters, showing their advantages and disadvantages. A study of the optically stimulated luminescence (OSL) of the samples is reported in this work. Agate is a variety of chalcedony, a form of quartz, in which the color appears in bands or concentric zones. The bands may be of different colors or also of a uniform tone. The samples for this study were prepared from four different types of agate stones: yellow, moss green, gray and purple. The samples were powdered and selected to be mixed with Teflon in a proportion of 2(Teflon):1(agate) in open atmosphere of nitrogen. The mixture was pressed, and pellets of agate-Teflon of 50 mg with 6 mm of diameter and 2 mm of thickness were produced. The irradiations were performed in air (room temperature) using a Gamma-Cell 220 system (^{60}Co). In this work, the agate samples were characterized for gamma radiation using the OSL technique. The minimum detection limits, dose-response curves and reproducibility of the OSL response were obtained. The results indicate the possibility of use of these agate samples as radiation detectors for gamma high-doses, using the OSL technique. These dosimeters can be used in the radiation processing areas of disinfection, water treatment and sprouting of seeds.

Keywords: High-dose dosimetry/OSL/agate

P02.213
Development and Implementation of the NDS Next Generation Thermoluminescence Dosimetry Service

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Health Canada's National Dosimetry Services (NDS) provides thermoluminescence dosimetry (TLD) services for the monitoring of occupational personal exposure to x-ray, gamma, and beta radiation. The NDS TLD uses two TLD-100 elements, namely a thick chip behind an aluminum filter and a thin chip behind an aluminized mylar filter, to directly measure $H_p(10)$ and $H_p(0.07)$ doses. The dosimeter card can be loaded into a plastic badge for whole body dosimetry, or a flexible strap for extremity dosimetry. The current service was launched in 1978 and has operated continuously since then with only minor changes to the dosimeter design.

NDS is now preparing to launch the Next Generation of its TLD service. This service will eliminate client handling of sensitive dosimeter components, which is a weak point of the current service. All dosimeter cards will be shipped pre-loaded into sealed holders to avoid contamination and UV exposure at the client site. The Next Generation TLD holder is small and aesthetically pleasing, and can be used for whole-body or extremity monitoring. Most significantly, the holder is designed for mechanical handling. To create an efficient and cost-effective pre-loaded dosimetry service, NDS and its engineering partners have developed a full automations suite for dosimeter loading, labelling, and unloading.

The Next Generation TLD service builds on the well-established performance of the previous design. The dosimeter uses the same TLD-100 elements and filters as its predecessor, and in fact, the old TLD cards can be converted to the new design by a simple machining process. Several enhancements have been made to dosimeter processing, including a refined time temperature program for readout, an automated glow curve deconvolution step that dramatically reduces the need for operator intervention during data analysis, and an advanced dose algorithm that provides significantly better energy response characteristics than would be expected for a two-element dosimeter.

This poster presents an overview of the new NDS Next Generation TLD service and an exploration of the development work behind it.

P02.214
Characteristics of Teflon Powder for Thermoluminescent Dosimetry

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In the production of pellets for use in TL dosimetry, it is common to see in several papers the report of the mixture of crystals and politetrafluoetileno (Teflon), a type of polymer, in a ratio of 1(crystals):1(Teflon) or 1(crystals):2(Teflon). Polymers depending on their physical, mechanical, electrical, optical properties are suitable for one or more applications. The most widely used type of the material in the Brazilian market is the Teflon (DuPont); it is a branched polymer which chemical formula has carbon and fluorine. It is inert, stable and non-corrosive, has a very low attrition rate and does not react with other chemicals; it is widely used as a binder in the production of TL dosimeters of $CaSO_4$:Dy at IPEN. The Teflon causes an increased sensitivity of the TL pellet signal with respect to the crystalline powdered Teflon. The objective of this work is to study the physical and morphological characteristics of Teflon powder with a view for the applicability of this material as a radiation dosimeter. Initially, differential thermal analyses (DTA) and thermo gravimetric analyses (TGA) were made in order to assess the changes in physical or chemical properties as a function of temperature in Teflon samples. The analysis using the X-ray diffraction technique (XRD) of powder method was made to obtain structural information of the samples. The porosity and microstructure morphology of the TLD samples prepared using β-spodumene and lithium aluminum silicate ($LiAlSi_2O_6$), bonded with Teflon, were observed by using scanning electron microscopy (SEM). The preliminary results allow to conclude that Teflon acts as a binder, giving greater strength to the TLDs, but extreme care must be taken in handling them with metal clamps. Vacuum special clamps were utilized, since the utilization process of dosimeters is repetitive, and drastic changes should not occur on the surface of the pellets. The XRD analysis showed that this type of Teflon has a totally amorphous structure, and not totally crystalline clear. In the SEM analysis a cohesive surface was observed, as desired in preparation of the TLD dosimeters.

Keywords: High-dose dosimetry/DTA/TGA/Teflon

P02.215
An Innovative Electronic Detector for Computed Tomography Dosimetry

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Computed Tomography (CT) dosimetry is normally reported in function of the quantity named computed tomography dose index (CTDI). To perform the CTDI measurement one can take a single slice at the middle of a 100 mm pencil ionization chamber. However, in general, clinical CT examinations involve exposures from multiple rotations of the X-ray tube and consequently the dose to the irradiated human volume is the accumulated dose from the adjacent scans, and another quantity was defined: the multiple scan average dose (MSAD). Actually, the MSAD value is a calculus based on the CTDI value which is obtained at the center and the periphery holes of a head phantom, for instance. However, the MSAD value can be estimated using a film or thermoluminescent dosimeters (TLDs). Generally, these methods require a considerable time interval due to the nature of calibration, handling, and reading. Nowadays electronic components have been used as radiation detector because of the fact that semiconductors have some advantages for dosimetry (e.g. high sensitivity, small size, and real time measurements). In this work an innovative detector is proposed based on an array of high sensitivity miniature photodetectors plus its electronic circuit embedded in an encapsulation like a 160 mm pencil. 64 photodetectors can be arranged to have their signals multiplexed in time to be measured at once. This property makes possible to obtain the dose profile with at least 5 mm spatial resolution and with only one shot.

Furthermore, such a method allows that one can directly measure the MSAD in a single scan without any formulae. The experimental arrangement is based on a CT scanner and it was used for all irradiation assessments. The proposed detector was evaluated free in air and in a head phantom undergoing CT examination in axial mode. For measuring the CTDI, the detector was positioned at the middle of its longitudinal axis to take a single slice dose profile. On the other hand, to obtain the MSAD, the measurement was taken by scanning all the detector length. The results showed that the developed detector could be an alternative for CT dosimetry. It allows to obtain the CT dose profile in details and also to estimate the CTDI in longer length than the 100 mm pencil chamber. Then, consequently, both CTDI and MSAD can be measured in real time and in a more accurate, simple and fast way.

P02.216
Mass Attenuation Coefficients of X-rays in Calcium Phosphate Biomaterials

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The advances of the diagnosis methods in dentistry, mostly due to new radiograph techniques, provide a more conclusive diagnosis; however they lead to extensive uses of X-rays. Given the evolution of the diagnosis processes, the enhancement of the sensitivity of the radiographic methods alongside a simple and efficient quality control, represents the greatest achievement and efficiency enhancement in the area.

In modern dentistry and medicine, synthetic carbonated apatite ceramics are considered as promising to allograft materials for bone substitutes. Various investigations were carried out in organic and inorganic materials in order to make it useful in radiological diagnostic and dosimetry whose characteristics are based on the interaction between the radiation and the matter in low energies presenting specific medical and technological applications. However, there are no reports in literature concerning the use of dental biomaterials as attenuation materials.

The mass attenuation coefficient (μ/ρ) was investigated in four dental biomaterials (BoneCeramic, BioOss, CeraSorb e Osteogen) at the interval between 10 and 200 keV. The inorganic and organic composition analysis in the four biomaterials was performed by Instrumental Neutron Activation Analysis (INAA), X-rays Fluorescence (XRF) and Elemental Analysis (EA) at the laboratories of the Centre of Development of Nuclear Technology (CDTN/CNEN). The weight fractions of each element present in the biomaterials were determined by analytical means mentioned above. In this research, the values of the mass attenuation coefficient (μ/ρ) of biomaterials samples were calculated by the WinXCOM software. The mass attenuation coefficient (μ/ρ) of the all samples was inversely proportional to the energy of the photon. It was observed that the mass attenuation coefficient (μ/ρ) depends on the photon energy.

The data presented on the photon interaction parameters are believed to be helpful in the dosimetry, diagnostic and other radiation physics-based applications. Further investigation on the photon interaction parameters in different compounds and/or composite materials are still needed in order to confirm the validity of both interpolation method and mixture rule at different incident photon energies.

P02.217
Establishment of Radiation Measurement Instrument Calibration Facility Capable of Lowering Scattered Radiation and Shielding Background Radiation

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The principle for radiation measurement instrument calibration facility is producing a radiation field used by a standard radioactive source to irradiate the to-be-calibrated radiation measurement instrument. The readout values of the instrument are interfered with the background radiation and the scattered radiation. Without proper and detailed corrections, the employment of the calibrated instrument would affect the measurement accuracy. To solve the above problems, The Institute of Nuclear Energy Research (INER, Taiwan) fabricated a radiation measurement instrument calibration facility which is capable of lowering scattered radiation and shielding background radiation. The facility comprised of a self-made 137Cs irradiator, a collimator, a shielding device, an electric door unit, a remote control unit and a radiation baffle. The INER's facility does have the following characteristics and functions: (i) Addition of shielding device effectively reduces the interference coming from the background radiation and scattered radiation in the laboratory during the calibration; (ii) Using the collimator to control the radiation field size of the primary radiation beam to reduce the scattering coming from the radiation's interaction with the shielding device and using the radiation baffle to reduce the background radiation; (iii) With the design of the attenuators within the irradiator, the instrument calibration and testing can be done in low-, medium- and high-dose radiation fields, respectively. This calibration facility had been completed and installed. The testing results showed that the background radiation decreased to 0.065 $\mu Sv\ h^{-1}$; the scattered radiation decreased to 1% of the primary radiation beam which was much lower than the limit of ISO 4037-1 Standard. With the self-made 137Cs irradiator and attenuators, the measurement deviation stayed within 0.1% for the 25 $\mu Gy\ h^{-1}$ air kerma rate range. And the measurement deviation stayed within 2.5% even for the environment-level field of 0.8 $\mu Gy\ h^{-1}$.

Keywords: Radiation measurement instrument; Calibration facility; Background radiation; Scattered radiation; Irradiator

P02.218
Mean glandular dose behavior using different glandularity phantoms

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Abstract. The three quantities used for mammography are the incident air kerma (Ki), the entrance surface air kerma (Ke) and the mean dose to the glandular tissues within the breast, known as the mean glandular dose (DG). For phantoms, the Ki is measured with a diagnostic dosimeter in the absence of the phantom, using the tube loading required for exposure of the phantom. DG is derived from measurements of the Ki and the half-value layer (HVL), using tabulated conversion coefficients (Dance et.al. 2000). The aim of this work is to present preliminary results of the DG behavior adopting protocols with different values of tube voltage, target/filter combinations and using different glandularity phantoms. Irradiations were done using a 3000 Nova model Siemens MAMMOMAT mammographic unit in a cranio-caudal view, with the compression plate in position and a load cassette in the bucky. Protocols with 26, 28, 30 and 32 kV were used for Mo/Mo and Mo/Rh combinations. The mean tube loading were calculated from three exposures using a solid state detector FLUKE. Phantoms used for the determination of DG had 45 mm thick, which approximately simulates a standard breast of thickness 53 mm, and glandularity of 0, 30, 50, 70 and 100%.The DG ranged from 1 to 6 mGy and 1 to 4 mGy, for Mo/Mo and Mo/Rh combinations, respectively. The preliminary results are in according to the reference level of 3 mGy established by the International Basic Safety Standards (BSS115) to breast of thickness 45 mm and glandularity 50%. The results showed that the DG increases with the glandularity. With increasing voltage decreases mean glandular dose for dense breast. This feature is more pronounced for phantoms of glandularity 100%. Considering that the most radiosensitive tissue is the glandular, this work contributes to disseminate in clinical practice the optimization of procedure and establish reference levels depending of breast glandularity.

P02.220
Simultaneous Determination of U and Pu Isotopes by Alpha Spectrometry

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Determination of actinides by alpha spectrometry is usually carried out after full separation of each of the components of the sample. The procedure presented in this paper permits U and Pu isotopes to be measured together allowing faster sample processing and measurement. The method consists in the extraction with tributyl phosphate of U and Pu isotopes from the rest of the matrix, followed by a cathodic electrodeposition to obtain suitable pieces for alpha spectrometry. It can be applied to various environmental samples, such as water, filters and soil (about 0.5 g of solid sample for the described conditions). High-quality electroplated discs are essential for simultaneous processing, so a technique to achieve this requirement is also explained.

P02.221
Study of the Response of a SP9 Neutron Detector to an Am-Be Source

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The CIEMAT-BSS-3He is a Bonner sphere neutron spectrometer that consists of a set of twelve polyethylene spheres (from 3" to 12") with a thermal neutron detector located in its center. A spherical 3He proportional counter (SP9 type) is used in this system that was calibrated at PTB.

The response of this proportional counter has been characterized through several measurements and Monte Carlo simulations. These measurements were made in the Howitzer device that provides a thermalized spectrum and on the calibration bench where the neutron spectrum is essentially fast. Both installations belong to the Neutron Measurements Laboratory of the DIN-UPM.

From a detailed MCNP model of the laboratory and the SP9 detector, the developed experiences were simulated. The results of the simulations agree with the measurements showing the validity of the model. Then, several parameters that affect the detector response, such as 3He atomic density (filling pressure), diameter of the detector sphere and its wall thickness, have been studied for the ISO Am-Be spectrum and the resulting from an Am-Be source inside the Howitzer device.

P02.222
New image analysis system for nuclear track detector Radon dosimeter, developed in the Central Laboratory of the Italian Red Cross (SMRA/LC/CRI).

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The Environmental Radioactivity Measurement Service of the Central Laboratory of the Italian Red Cross (SMRA/LC/CRI) has performed radon dosimetry in indoor environments for about 8 years, employing CR-39 nuclear track detectors, also thanks to participation in national (INMRI-ENEA) and international intercomparisons (Health Protection Agency). The National Institute of Ionizing Radiation Metrology (INMRI-ENEA), in addition to its task of development and maintenance of the primary standard for airborne radon, conducts radon exposures at controlled values in order to calibrate the dosimetric systems of these laboratories. In pursuit of further improvement in the accuracy of this calibration service, a collaboration with the SMRA laboratory was established, which involved the exposure, development, and reading of a considerable number of CR-39 nuclear track dosimeters. On the basis of eight radon exposures at the INMRI-ENEA laboratories, the measurement procedures of SMRA/LC/CRI laboratory have been further refined. In particular, a new semi-automatic track reading system has been developed and refined experimentally at SMRA laboratory, utilizing the modular software platform "Leica QWin Plus" for the analysis and processing of microscope-acquired images. This system, together with a preatching of the detectors, allows the discrimination between nuclear tracks and track due to defects of the detector. Furthermore, at high exposure levels the microscope images are acquired at higher magnification (10 x) and superimposed tracks are discriminated and not counted as a single track. This procedure allows to extend the linearity range of the dosimeter beyond 6000 kBqhm-3 as shown from the experiment. In this study, the results of the experimental tests confirm the accuracy and reliability of the internal procedures utilized by the laboratory of SMRA/LC/CRI. Furthermore, the study confirms the precision, and repeatability of the new Leica QWin Plus semi-automatic reading system, developed at the Central Laboratory CRI. Finally, the sensitivity of the dosimeters was calculated, and the experimental results confirm measurement accuracy with a 1% mean deviation from the linear regression even at the higher exposure values.

P02.223
NaI spectrometers for indirect detection of neutrons

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In-field gamma spectrometry for nuclear security often relies on NaI detectors. Most of the decay gamma-rays have energies below 3 MeV. A background above 3 MeV is low at the sea level. The spectrometers are normally set to cover only the energy region 0 to 3 MeV. This range is also influenced by the commercially available hardware, i.e., Multi Channel Analyzers processing the signals from the NaI detectors often only produce spectra with 1024 channels (resolution about 3 keV/channel). Recently, however, integrated systems with 2048 channels have become commercially available. This development enables the extension of energy range up to about 8 MeV without significantly worsening the resolution (4 keV/channel). This extension is important since now the high-energy gamma-rays, >3MeV, produced in (n,γ)-reactions or directly in the neutron sources can also be detected. These high-energy gamma-rays are very penetrating and therefore can be used even for the detection of shielded neutron sources. Conventionally the detection of neutrons is based on the use of He-3 counters. These detectors are now expensive due to the worldwide shortage of He-3. Therefore, intensive search of alternative neutron detection solutions is widely carried out.

Detection efficiency for neutrons using the NaI spectrometers can be enhanced by surrounding the detector with a moderator-converter system [1]. We have a programme based on 4” ×4” ×16” and a cylindrical (diameter 4” and thickness 5”) NaI detector. Different detector-moderator-converter combinations were experimentally tested in our work. They have also been simulated using a GEANT 4 code. Results of these measurements and simulations will be presented. Also a comparison between the NaI detector (4” ×4” ×16”) and a state-of-the-art cylindrical (diameter 2” and length 32”) He-3 counter is made.

This work was supported by the Finnish Scientific Advisory Board for Defence.

[1] D. J. Mitchell et al., IEEE Transactions on Nuclear Science 57 (2010) 2215.

P02.224
Using the Image Pro Plus to Count Alpha Particles Tracks in Cr-39

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The presence of naturally occurring radioactive materials (NORM), which contaminate oil and gas facilities, is a common fact in the petroleum industry and may be severe enough to cause the exposure of workers at elevated levels of radiation. This investigation aimed to measure the emanation of radon present in the sample containing NORM, using diffusion chambers that contained a nuclear track detector (CR-39). Being used for automatic counting of these tracks the computer program Image Pro Plus. This paper aims to report the application of the software Image Pro Plus in nuclear tracks counting, from the emanations of radon present in samples from NORM. The images of α particles tracks emanated by ^{222}Rn registered on CR-39 were observed with a Nikon E400 optic microscope and captured by a Nikon Coolpix digital camera and then stored in a database, to later count the tracks using the computational program, Image Pro plus. Since the number of those tracks resulted proportional to the emanation rate of ^{222}Rn this methodology allowed the comparison of contamination levels in analyzed samples.

P02.225
International Intercomparison of Thoron Active Devices with NIRS Thoron Chamber

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1. Introduction: The measurement of the atmospheric thoron is difficult due to the short half life (55.6 s), short diffusion length as well as heterogeneity in the air. Therefore, from quality assurance point of view to obtain reliable and comparable data from around the world is necessary to provide intercomparison among laboratories. Thus, an international intercomparison for sampling and analysis of thoron gas measurement by active devices was held at NIRS, Chiba on May 2010.

2. Experimental Methods: Experiment was provided at the NIRS (National Institute of Radiological Sciences, Japan) thoron chamber with a 150 dm^3 inner volume and lantern mantle as a thoron source [1)]. Totally nine participants (consisting government laboratories, companies and universities) conducted exercises for thoron measurement (with eleven devices). Eight participants (Australia, China #1, China #2, France, Germany #2, Japan, Korea and USA) used RAD-7 Detector[(1)], one participant (Germany #1) used RTM-1688-2[(2)] and RTM-2200[(3)] devices and one (Japan) used ERS-2-S Rn/Tn Sampler[(4)].

All of instruments consists decay chamber and silicon detector for registering the α-decay of thoron, radon and their progeny in an air stream flowing through the chamber. Basically, the thoron concentration was estimated based on calibration provided by manufacturers. The exercise was carried out for two concentration levels (low – around 5 kBq m^{-3} and high – around 20 kBq m^{-3}).

3. Conclusion: Final results showed differences between instruments and may indicate that thoron measurement procedures are not well developed until now.

1) A. Sorimachi, S. K. Sahoo, S. Tokonami; Generation and control of thoron emanated from lantern mantles. Review of Scientific Instruments 2009, 80 (1)

[(1)]DURRIDGE Company, Inc., USA

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P02.226
Mercury Supplementary Inner Shield for Low-Background Gamma-Ray Spectrometry

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Gamma-ray spectroscopic measurements of low-level environmental samples require the reduction of the background as low as practicable. In the present work, we investigate the advantages of adding Hg passive shielding inside a low-background Pb-shield with a thickness of 10 cm to further reduce the background radiation. Four different arrangements for the Hg-shield were investigated. The background count rate achieved by the Pb-shield alone over the energy interval from 25 to 2700 keV, amounts to 8.4×10^{-4} counts/s.keV which is ~1.5% of the normal background. The introduction of Hg adds another 4—11% reduction depending on the design of the Hg-shield. On the average, the Hg-shield suppresses the net peak areas of X- and gamma-rays to <3 and 1% of the normal background, respectively. On the other hand, the reduction in the count rate of these peaks due to the addition of Hg-shield varies according to the design of the Hg-shield and/or the energy. The measurements showed no evidence of the presence of cosmogenically produced ^{194}Hg in the measured spectra. An additional 2% reduction was achieved by using active cosmic ray veto detector and neutron moderators.

Keywords: low-background gamma-ray spectrometer; Mercury; HPGe detector; passive shielding; active shielding.

P02.227
Introducing Monte Carlo based calibrations at the whole body counter of the Swedish Radiation Safety Authority

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The whole body counting laboratory at the Swedish Radiation Safety Authority (SSM) should provide fast and reliable measurements in the context of preparedness and response to nuclear and radiological emergencies. The flexibility that Monte Carlo simulations offer regarding the distribution of radionuclides in the body, the choice of radionuclides, the size of the simulated mathematical phantom and, in general, the measurement geometry makes this method advantageous in emergency response.

In vivo determination of internal radioactivity is performed at SSM using phantom based calibrations in different sizes of the phantom for homogenously distributed activity and the gamma emitters Cs^{137}, Co^{60} and K^{40} in corresponding sets of single radioactivity. The phantom used for calibrations is the so-called Irina phantom made of blocks of tissue-equivalent material. Up to six different sizes of the phantom (P1 – P6) can be built by combining the blocks in different configurations.

The purpose with this work has been to introduce Monte Carlo (MC) based calibrations for the measurements conditions at SSM. The MC code used was MCNPX. The study reports on the modelling parameters simulating a verification experiment and the results for this verification by means of comparison between the measurement and simulation efficiencies. The detection system including the stretcher, three NaI detectors 5'' x 4'' and the phantom built in the adult size P5 were implemented in MCNPX for the three calibration set of sources. Additional verifications for point sources of Na^{22} and Cs^{137} were run. Efficiency factors in cps/Bq are the results of the simulations in good agreement with the experimental efficiency factors. The simulation tool will allow the quantification of internal radioactivity in the cases for which the necessary set of phantom based calibrations is not available making possible a reliable and speedy response.

P02.228
Development of a New Iodine Monitor

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The Nuclear Research & consultancy Group (NRG) offers a wide range of products and services to energy utilities, governmental organizations and various branches of industry - including the nuclear, financial services and medical sectors. NRG is a major producer of medical isotopes in Europe.

When existing products on the market do not fulfil the required specifications NRG sometimes starts a development project for a new types of instrument. In former years NRG already developed an instrument with which we were able to measure the inside of tubings from the oil and gas industry which were contaminated with scale with NORM radionuclides.

In a similar way NRG developed a new type of iodine monitor, which was composed out of mostly standard components available on the market. The difficulty in this type of equipment is not only measuring the several components of the possible iodine emissions, but also the right discrimination between the iodine particles and the noble gases often being present in the emissions of nuclear power plants and cyclotrons.

First a prototype has being made, in which a smart filtering method of the iodine particles and aerosols from the has been applied. After this a special software algorithm has been developed to select the iodine contribution in the spectra. After this the prototype has been tested under laboratory circumstances in which iodine gas has been led in different activity concentrations through the prototype. Tests were also performed with noble gases. Results showed that the monitor is very well able to discriminate between the iodine and noble gas concentrations. As a result of this the iodine monitor can also be used for alarming on predefined action levels of I-131.

The new iodine monitor can be a very helpful instrument for nuclear power plants to alarm on increasing amounts of iodine concentrations. At the moment the monitor is tested at the cyclotron facility in Petten, where possible I-123 emissions can be expected.

In the near future the possibility of expanding the registration possibilities to an accurate registration of the noble gas concentrations will be realised.

P02.229
On The Counting Parameters In The Alpha/Beta Gas Flow Proportional Counters

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Gas flow proportional counters are widely used in most radiological surveillance laboratories to measure not only gross alpha and beta activities but also some radionuclide activities after their radiochemical isolation. i.e. $^{90+89}Sr$, ^{210}Pb, ^{129}I, ^{226}Ra, ^{14}C.

However, to take full advantage of the equipment, values chosen for parameters like operating voltage and alpha - beta pulse discriminator should be optimized.

Efficiency, measurement stability and cross-talk depend on these parameters. But most of the equipment, in the market today, have more than one detector and do not allow the independent selection of these parameters. And in some equipment not even the pulse discriminator can be chosen. Consequently, after an initial set-up, the same detector parameters are usually selected for all the determination methods and detectors, although, they are not the most suitable ones. In these cases, the required correction factors should be determined and used or, alternatively, the correct parameters should be used as the best option.

For example, the change in the counting parameters for the 129I determinations with respect to the ones used for gross alpha and beta activities can improve the detection efficiency in around 50%.

In this work, the values of operating voltage and alpha beta pulse discriminator for different alpha and beta energy emissions are analyzed and its implications, in some specific determination methods, are presented.

P02.230
The Response of Radiophotoluminescent Glass Dosimeter for Charged Particles and Its Microscopic Consideration

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Radiophotoluminescent glass dosimeter (RGD) is widely used as a dosimetric QA tool in conventional photon radiotherapy; however, its response for charged particles is poorly investigated nevertheless the interest toward the radiotherapy with light ions such as carbon is glowing for its superior dose conformity and high biological effectiveness even against radioresistant tumors. In this study, the response of the RGDs for the therapeutic carbon ions was studied for the application of the RGDs.

Experiment was carried out at the Heavy Ion Medical Accelerator in Chiba (HIMAC) of National Institute of Radiological Sciences in Chiba, Japan. The RGDs GD-302M-W manufactured by Asahi Glass Co., Ltd. were irradiated there by the therapeutic carbon beams as well as other species such as proton, helium, oxygen and iron beams for comparison.

The RGDs showed superior linear dose response for carbon ions in the dose range of 0.5 – 3.0 Gy; however, also showed strong decrease in response as LET (Linear Energy Transfer) of the beam increased. The extent of the drop relative to ^{60}Co γ rays exceeded 90 % near the Bragg peak where the LET was 160 keV/μm approximately. The similar LET dependency was found for the other particle species and the extent of the drop was more significant for lighter particles at the same LET.

In order to understand the observed LET and particle species dependency of the RGD response, Local Effect Model (LEM) was used for the analysis. In the LEM the particle species dependency is considered to be evoked by the microscopic heterogeneity in energy deposition (track structure). The analysis of the response with the LEM, based on the radiation quality of the beam in the experimental conditions simulated by GEANT4, succeeded in reproducing the experimental results. The derived experimental as well as modeled response of the RGDs is useful for the application of the RGDs as a dosimeter for the therapeutic light ion beams.

P02.231
Environmental Dosimetry with the Pille TL Space Dosimetry System During the BEXUS-12 Stratospheric Balloon Flight

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Due to significant spatial and temporal changes in the cosmic radiation field, radiation measurements with advanced dosimetric instruments on board spacecrafts, aircrafts and balloons are very important. The Hungarian CoCoRAD Team was selected to take part in the BEXUS (Balloon Experiment for University Students) project. In the frame of the BEXUS programme Hungarian students from the Budapest University of Technology and Economics carried out a radiation experiment on a research balloon, which was launched from Northern Sweden in September 2011.

The objective of the CoCoRAD experiment is to measure the effects of the cosmic radiation at lower altitudes where measurements with orbiting spacecrafts are not possible due to the strong atmospheric drag. The experiment included measurements with the Pille thermoluminescent (TL) space dosimetry system to measure the absorbed dose during the BEXUS-12 stratospheric balloon flight with the Pille TL dosimeters. One of the main goals of the experiment was to prove the usability of the Pille passive TL dosimeter system during stratospheric balloon flights for environmental dosimetry monitoring purposes.

The BEXUS-12 balloon flew at an altitude of 27.6 km and a latitude of N68° for more than 2 hours. Ten Pille dosimeters were on-board to measure the absorbed dose during the BEXUS-12 mission. This paper presents the scientific background of the cosmic particles for the altitude range of the stratospheric balloons, the expected doses in case of the minimum and the maximum of the solar activity, the results of the Pille measurements during the BEXUS-12 stratospheric balloon flight and conclusions about the usability of the Pille TL system on-board stratospheric balloons.

P02.232
Stability Study of Ionization Chambers in Standard Mammography Radiation Beams

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The ionization chambers are widely utilized in diagnostic radiology quality control and dosimetry. They are simple to use, and can be found in various types depending on their applications. They are the recommended devices for the determination of the beam qualities in mammographic range. To assure the reliability of the measurements, the stability of the response of the ionization chamber should be within international limits. In this work, the stability of two ionization chambers of the Calibration Laboratory of IPEN was evaluated. The ionization chambers utilized in this work were a homemade tandem ionization chamber and a reference class ionization chamber. They were irradiated in standard mammography beams at the Calibration Laboratory of IPEN. For the short-term stability the chambers presented a maximum value for the coefficient of variation of 2.9%, within ± 3% as stated in the IEC 61674 standard. The long-term stability test results for the ionization chambers were within ± 2%, as recommended by the international standard.

P02.233
Application of Monte Carlo efficiency transfer method to calibration of coplanar-grid large volume CZT detector

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Monte Carlo efficiency transfer method has been developed and used to calibrate several type HPGe detectors. It is much more convenient for full energy peak efficiency calibration than the direct Monte Carlo method. In this paper, the efficiency transfer method was introduced to determine full energy peak efficiency of the coplanar-grid CZT detector. The crystal dimension is 10mm×10mm×10mm. The comparison between calculations and point-source experiments showed that the relative deviations was mostly within ±10% for CZT detector with and without a lead collimator. And the result of the application of the efficiency transfer method and the coplanar-grid CZT detector system in the field of radiological characterization was also presented in this paper.

Key words: CZT detector, Monte Carlo, full energy peak efficiency, efficiency transfer

P02.234
A Sample Assay Geometry for a Wide Range of Sample Types and Volumes with a Single Efficiency Calibration, and Still Achieve Reasonable Accuracy

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There are many situations where very high accuracies are not needed, and where a wide range of sample types and shapes must be assayed. One example is for D&D projects. Many different sample types are encountered [soil, water, vegetation, building materials, …]. Another example is for response to radiological emergencies [soil, vegetation, food, personal objects, …]. Operational nuclear sites frequently encounter items of unusual shapes that are of interest to quantify the radioactivity [items being shipped off site for repair, accidentally contaminated items for release, …]. These situations typically have modest size samples [grapefruit size to watermelon size]. These situations have samples in a wide range of shapes. These situations have samples with a wide range of matrices. Any one of these sample conditions makes efficiency calibrations very difficult when using radioactive standards. Mathematical techniques like ISOCS can create approximate efficiency calibrations for these, when the appropriate assumptions are made, and are far faster and easier, but still take some time to do.

There is a perceived need, in the author's mind at least, of a simple geometry that can easily and reasonably accurately assay a very wide range of sample types and sizes, over a wide range of energies, but using a single efficiency calibration curve.

The starting point was to assume that the item to be assayed must fit within a 40cm diameter cylinder that is 40cm tall [the size of a modest watermelon]. Three sample detector geometries were evaluated for this cylinder – detector on the top, side, or bottom. Two types of calibration methods were evaluated – normal efficiency and massimetric efficiency calibrations. Energies ranging from 60 keV to 2500 keV were evaluated.

The tool that was used was the ISOCS Uncertainty Evaluator [IUE]. IUE is a standard part of the ISOCS efficiency software. It performs a probabilistic uncertainty evaluation of a sample efficiency using the operator inputs describing the range of possibilities for parameters affecting the efficiency that are not well known. The uncertainty analysis considered the following not-well-known variables.

• All sample fill heights from 5 to 40cm were equally likely

• All densities from 0.5 g/cc to 2.0 g/cc were equally likely

• All the following materials were equally likely: soil, cellulose, sand, concrete, mineralized soil, aluminum, plastic, a mixture of 75% soil and 25% iron.

The 3 detector geometries were evaluated and the two efficiency methods. The best one was where the detector was at the bottom and the massimetric calibration was used. Under these wide ranging sample conditions, the standard deviation of the activity due to inaccuracies in efficiency was only 25% at energies from 60 keV to 2500 keV. And since the massimetric calibration is used, the results are automatically presented in Activity/gram with no weighing of the sample needed.

P02.235
Investigation of the Dosimetric Parameters of the PorTL Thermoluminescent Dosimetry System

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The PorTL System, a portable, lightweight thermoluminescent (TL) dosimeter system developed by the Hungarian Academy of Sciences Centre for Energy Research consisting of a relatively small size reader device and a set of special dosimeters. The development was based on the Pille thermoluminescent space dosimetry system, which has been on board all space stations orbiting the Earth since 1980. The latest version of the Pille system, that has been the service dosimeter system of the Russian expeditions of the International Space Station since 2003, provided more than 30 000 valuable read-outs on board the station including personal dose data of extravehicular activities and high resolution dose monitoring.

The main goal of the development was to combine the reliability and robustness of the Pille system with the expectations for a common-use dosimeter system. Therefore, the main structure of the reader device was preserved, and several user friendly features were added.

The PorTL dosimeters consist of a suitably positioned TL material fixed to a heating plate, a thermometer and a memory chip storing the unique calibration parameters of the corresponding dosimeter. The PorTL system is currently available with Al_2O_3:C as well as ^{6}LiF, ^{7}LiF, and ^{nat}LiF TL materials. During the read-outs, the reader device heats the dosimeters and registers the TL glow curve. The reader also performs preliminary evaluation of the data. The glow curve and the derived data are saved in the memory of the device and can be downloaded via serial connection to a personal computer. Software for managing data downloads and dosimeter calibration, performing glow curve visualization and detailed data evaluation is also available.

The main dosimetric parameters of the PorTL system were measured during the past years according to the IEC 61066 International Standard for Thermoluminescence dosimetry systems for personal and environmental monitoring. The linearity, the reusability as well as the radiation energy and angle of incidence dependence were measured.

The results of the investigations of the main dosimetric parameters of the PorTL system are presented in this paper.

P02.236
Luminescence Technique and Research on OSL Measurement Instrument

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Thermally stimulated luminescence (TL) and optically stimulated luminescence (OSL) have been used in geological dating and radiation dose assessment after nuclear accidents. The radiation energy is stored in the crystal lattice of mineral such as quartz and feldspar which exist in bricks, tiles or pottery collected in nuclear accident areas. When the sample is stimulated, it releases the energy in the form of light photons. Photons captured by photomultiplier (PM) tubes, and the optical signals are converted to electric signals. The electric signals sent to a pulse amplifier, then feed to a pulse counting circuit. The counts accumulated during measurement can be converted into light intensity and get a dose of radiation. An OSL measurement instrument was developed and an apparatus for automatism carry sample and stimulation source was developed later. Recently an improved design based on pseudo random theory presented for the instrument. An advantage of this design is to avoid possible pulses loss caused by count carry for high radiation sample and to gain more accurate radiation dose.

P02.237
Investigation of Metrological Characteristics of Whole Body Spectrometer

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At the ionizing radiation department of the D.I. Mendeleyev Institute for Metrology (VNIIM) a metrological characteristics of Whole Body Spectrometer (STC "RADEK") were investigated with help of phantom of human body. The MKGB-01 spectrometer-radiometer with two NaI(Tl) crystals of 80 x 80 mm are used for photon radiation detection.

The ^{137}Cs and ^{134}Cs efficiency of registration were experimentally determined for three tissue-equivalent phantoms (an adult, a teenager and a child). The results obtained are in good coincidence within ranges of uncertainty with the computation results made by Monte Carlo method. The ^{131}I efficiencies of registrations were determined by a Monte Carlo method. Influence of background protection was investigated and optimal distance from human body to detector was found.

As a result of investigations method of calibration of Whole Body Spectrometer with Monte Carlo method without ionizing radiation sources was developed. Requirements for operating conditions of Whole Body Spectrometer were settled, achievable uncertainty of the results were evaluated.

P02.238
Automation of the Calibration of Dosimeters for Radiotherapy

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Traceability, accuracy and consistency of radiation measurements are essential in radiation dosimetry, particularly in radiotherapy, where the outcome of treatments is highly dependent on the radiation dose delivered to patients. The role of Secondary Standard Dosimetry Laboratories (SSDLs) is crucial in providing traceable calibrations to hospitals, since these laboratories disseminate calibrations at specific radiation qualities appropriate to the use of radiation measuring instruments. A common objective for SSDLs is continuous maintenance and improving of calibration competences. SSDLs follow OIEA/WHO guidelines for calibration procedures, often being current and charge measurements described in these guidelines a tedious task. However, these measurements are usually done using modern electrometers which are equipped with a RS-232 interface that allows instrument control from a PC.

This paper presents the design and employment of an automated system aimed to measurements of the radiotherapy dosimeters calibration process. A software was developed in order to achieve the acquisition of measured values, calculation of the calibration coefficient and issue of a calibration certificate. A primary data report file is filled and stored in the PC's hard disk. The used electrometer was a PTW UNIDOS E, although UNIDOS 10001, UNIDOS 10002, and UNIDOS WEBLINE models are also supported. The used calibration method was calibration by substitution, described in Technical Report Series No. 374. The automated system is currently in use and has improved the measurements of the calibration for radiotherapy at Cuban Secondary Standard Dosimetry Laboratory at CPHR. A 24% reduction in the calibration process time is appreciated. By using the software, the process tediousness and human level error probability are also reduced.

KEYWORDS: calibration; dosimeters; data acquisition; laboratories; computer calculations.

P02.239
Performance and type testing of selected dosimeter used for individual monitoring

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This study describes calibration and performance testing carried out for a set of 14 electronic personal dosimeters (EPDs) and thermoluminescence dosimeters (TLDs) at the Secondary Standard Dosimetry Laboratory of Sudan. Also the conversion coefficients from air kerma have been determined. Dosimeters tested are belonging to three manufactures representing most commonly used types in Sudan. Calibrations were carried out at three X- ray qualities: 80, 120 and 150 kV, ISO 'narrow' spectra and for ^{137}Cs, ^{60} Co gamma rays.

The experiments were carried out using ICRU Slab phantom with dimention 30x30x15 cm. Secondary standard ionization chamber was used to measure the personal dose equivalent, Hp(10) as standard dosimetric quantity of interest. Parameters tested include: The variation of response with radiation energy and angle of incident in addition to dose rate dependence.
The angular dependence factors have been experimentally determined for the same qualities and for different angles (0, ±20, ±40, ±60°). + were performed in accordance to the relevant international standards. Excellent energy, angular and dose rate response was demonstrated for 662 137Cs, 1250 ^{60} Co beam and (118, 100, 65 keV) X-ray beam qualities, exception the EPD at PM1203M are slightly larger but still with the acceptable range.

The responses of electronic dosimeters were found to in limits of acceptable performance. For the mean response of all energies is range of EPDs type RADOS 60, Greatz ED 150, Polimaster PM1203M, TLD were (0.75 ±0.08 - 1.13±0.13), (0.83±0.29 - 1.06±0.07), (1.08±0.14 -1.27±0.09), (0.99±0.05 - 1.14±0.13) respectively. The majority of the dosimeters tested showed good energy and angular response.

P02.240
Conversion Factors of Modern Devices Which Can Be Used to Measure Radioactivity in Human Thyroids after Radiation Accident

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As a rule, after radiation accidents concerned with release of iodine isotopes in environment, measurements of radioactivity in human thyroids are made by specialized or unspecialized devices. Such "direct" thyroid measurements were done after the Chernobyl accident as well as after the Fukushima one. Monte-Carlo models of two modern unspecialized radiometric devices - organic scintillator based-on dosimeter DKS-96 (SPE "Dose", Russia) and NaI scintillator based-on radiation monitor AT1117M (probe BDKG-05, SPE "ATOMTEX", Belarus) have been developed and verified. Both devices were used for measurements of radioactivity in human thyroids of Japanese people after Fukushima accident. The quantity of interest in analysis of such measurements is a so-called conversion factor (CF), i.e. activity of 131I in thyroid per unit exposure rate. MCNP-based model of measurements of radioactivity in human thyroid with these devices has been developed using family of Oak Ridge National Laboratory (ORNL) phantoms (newborn, children aged 1, 5, 10, 15 years and adults). ORNL phantoms include a rather complicated mathematical model of thyroid in the form of two ellipsoids cut by trachea and connected by isthmus. For calculation of CF quantities of the devices it is necessary to know their sensitivities in terms of deposited in detector energy per unit dose rate. These characteristics of the devices were determined by combining the experimental and theoretical results of measurements of the gamma radiation reference sources at fixed distance between source and detector. Conversion factors were calculated for reasonable scenario of thyroid measurements when lower point (LP) of the detector coincides with the lower point of the neck. Their age dependence is described by the square-law function which parameters are found for all iodine isotopes of interest. The CF quantities and their uncertainties caused by errors in the position and orientation of the detectors relative to the thyroid have been analyzed. It has been shown that dependence of conversion factors versus take-off of the device away from the neck or displacement of the device from its LP position along the neck is described by the square-law function which parameters have been determined for both devices. Conversion factors obtained can be used in analysis of thyroid measurements with these devices.

P02.241
New Electronic Personal Dosimeter

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Nuclear industry and medical professionals have constantly provided constructive feedback on Mirion Technologies electronic personal dosimeters (EPDs). This feedback includes the need for more accurate dose measurements and robust alarm capabilities in order to better guarantee user safety

In order that today's EPDs more accurately measure personal dose equivalent and personal dose equivalent rate in real time for nuclear, medical, and security professionals, it is essential that the main detection characteristics as energy response, angular response and dose rate linearity are perfectly characterized.

Although all the EPD's comply with international standards, a joint IAEA/EURADOS international intercomparison of EPDs on the market noted significant differences in the performances of different models. More recently, medical publications also demonstrated that EPD's did not give accurately assess of doses encountered during Interventional Radiology and Cardiology (IR/IC).

To better respond to those needs, Mirion Technologies has developed the DMC 3000 personal electronic dosimeter, providing better dose assessment and enhanced alarming features.

P02.242
Determination of the I-131 Activities in Thyroids from Measurements of Exposure Rates after the Chernobyl Accident: Devices Response and Uncertainties

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The reconstruction of individual thyroid doses from iodine-131 (^{131}I) intakes in an epidemiologic study of thyroid cancer and other thyroid diseases in a cohort of Belarusian persons exposed as a result of the Chernobyl accident is based on measurements of exposure rates (called "direct thyroid measurements") against the neck of the study subjects, who varied in age from newborn to 18 years. The measurements were made within a few weeks after the accident, at a time when ^{131}I was present in substantial amounts in the thyroids of the subjects. The devices used for the direct thyroid measurements were SRP-68-01 scintillation survey meters, DP-5 Geiger-Mueller dose-rate meters and, to a smaller extent, DRG3-02 survey meters with organic scintillators. Because the direct thyroid measurements were performed by means of devices that were not designed to measure radioactivity in humans, a calibration factor, defined as the activity of ^{131}I present in the thyroid per unit exposure rate measured against the neck, needed to be estimated for each of the three devices. A Monte Carlo method of numerical simulation of radiation transport was used to calculate the calibration factors. To perform the Monte Carlo simulations the mathematical models of the three radiation devices were developed. To verify the validity of the model, the known activities of reference point gamma radiation sources were compared with the activities of those sources calculated from the measured exposure rates and the results of simulations of the measurements. To simulate radiation transport during measurement of the exposure rate near the thyroid gland, a family of Oak Ridge National Laboratory (ORNL) phantoms representing newborn, children aged 1, 5, 10, 15 years and adults was used. Calibration factors were calculated for the appropriate positions of the detectors against the necks of the subjects. Uncertainties in the device calibration factors due to variability of the device characteristics, variability in the thyroid mass and statistical uncertainty of the Monte Carlo method were estimated. The influence of deviations of the device position from the proper geometry of the direct thyroid measurements was also evaluated. The results of this study are being used to improve the estimates of ^{131}I thyroidal content and, consequently, thyroid dose estimates (and their uncertainties) that are derived from direct thyroid measurements performed in Belarus shortly after the Chernobyl accident.

P02.243
Neutron Spectrometry and Dosimetry Results at McMaster KN Accelerator Using Three Different Instruments

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Neutron spectrometry measurements took place at the McMaster KN Van de Graaff Accelerator. Protons were accelerated onto a thin (1 µm) ^{7}LiF target, inducing the ^{7}Li(p,n)^{7}Be threshold reaction. Depending on proton incoming energy, different mono-energetic neutrons are produced. Four different effective proton incoming energies were considered: 2.15, 2.24, 2.34 and 2.44 MeV. These protons produce mono-energetic neutrons with energies of 401, 511, 620 and 720 keV, respectively. Measurements were performed one meter from the target with three different instruments: Bonner Sphere Spectrometer (BSS), Nested Neutron Spectrometer (NNS) and Rotational Spectrometer (ROSPEC).

The main purpose of these measurements was to evaluate the AECL neutron spectrometry and dosimetry systems in various neutron fields and under different operational conditions, and to evaluate these fields and compare them to theoretical predictions. All the results were normalized to time-integrated proton current (proton charge) deposited on the LiF target. Every instrument yielded neutron fluence rate. These values were then converted to several dosimetric quantities, by folding with appropriate dose conversion coefficients: ambient dose equivalent, personal dose equivalent and neutron kerma to soft tissue. Very good agreement was seen among the three instruments, with a slight over-estimate for the BSS. This issue has been resolved by calibrating BSS at the standard neutron metrology laboratory at NPL, Teddington, UK, and by correcting the BSS response function matrix for the appropriate polyethylene density of the spheres, as well as for the appropriate number density of He-3 atoms inside the central proportional counter.

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P02.245
Application of the OSL Technique for Determination of the Useful Calibration Distance Ranges for Beta Radiation Detectors

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The Calibration Laboratory at Instituto de Pesquisas Energéticas e Nucleares (IPEN) offers calibration services of detectors with different radiations: X, alpha, beta and gamma. The laboratory presents two secondary standard systems of beta radiation: BSS1, Buchler GmbH and Co, Germany ($^{90}Sr+^{90}Y$, ^{204}Tl, ^{147}Pm), and BSS2, Isotrak, Germany ($^{90}Sr+^{90}Y$, ^{85}Kr, ^{147}Pm). When beta-gamma radiation detectors are calibrated, they are initially exposed to standard gamma beams and then to standard beta beams at the calibration distances of these sources (provided in their calibration certificates). However, not always are the recommended calibration distances the ideal ones for all detectors. Therefore, in this work the useful distance ranges of the beta radiation sources were determined in order to allow the calibration of different kinds of instruments. The optically stimulated luminescence technique was applied in this study. For this purpose, single Nanodot detectors of Al_2O_3:C, Landauer, were utilized. Initially, the dosimeters were characterized in standard beams of beta radiation through tests (reproducibility, linearity of response and lower detection limit), and measurements were taken varying the source-detector distance mainly in small distances around the calibration distances, using the different sources from BSS1 and BSS2 systems. Furthermore, results for an energy dependence study were also obtained for these detectors using the beta radiation sources. The useful source-detector distance ranges were determined for the calibration of radiation detectors.

KEYWORDS: Beta radiation sources, calibration, optically stimulated luminescence, radiation detectors

P02.246
Calibration of 90Sr+90Y Sources used for Betatherapy, using a Postal Kit of Thermoluminescent Dosimeters

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The $^{90}Sr+^{90}Y$ sources utilized in betatherapy, called clinical applicators, are used in treatments of superficial lesions, like those from skin and eyes. According to international recommendations, the sources used in procedures of brachytherapy have to be calibrated in order to confirm the absorbed dose rates. In the case of clinical applicators, the importance of their calibration takes into account the fact that most of these sources are very old (some are from the 60's). The thermoluminescent technique has been applied in the calibration of the clinical applicators, and these results have been showed in some published works. In Brazil, many hospitals and radiotherapy clinics still use these sources for treatment of dermatological or ophthalmic lesions. In order to follow the recommendations and to collaborate for the continuous use of these sources, a dosimetric system for their calibration was developed at the Calibration Laboratory at IPEN. This system is composed by 16 thermoluminescent dosimeters, an aluminium support for their storage, a PMMA support to fix the pellets, a chronometer, a pair of gloves, a clamp, a form to be filled with the information about the sources and the calibration procedure. Initially, the system was tested in some hospitals at the São Paulo city to train the users of clinical applicators, and to answer the possible questions that may appear in relation to the calibration procedure. These situations were necessary to verify the possibility of this dosimetric system to be used as a mail system, because there are hospitals and clinics in almost all Brazilian states that still use clinical applicators. To send these sources to the Calibration Laboratory is difficult, and requires authorization from the governmental authorities. The thermoluminescent dosimeters of the system were already characterized. The objective of this work was to verify the usefulness of this system as a postal kit, using the usual mail system.

KEYWORDS: $^{90}Sr+^{90}Y$ clinical applicators, calibration, CaSO4:Dy pellets, thermoluminescent dosimeters

P02.247
Extensions to the Beta Secondary Standard BSS 2

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For several years, the irradiation facility for beta radiation, the Beta Secondary Standard BSS 2 developed at PTB, has been in worldwide use to perform irradiations with calibrated beta sources [1].

In this work, the following extensions to the BSS 2 are described:

1) Possibility of using a ^{106}Ru/^{106}Rh beta source;

2) Inclusion of the (small) contribution due to photon radiation;

3) Implementation of the quantity personal dose equivalent at a depth of 3 mm, $H_p(3)$;

4) Improvement of the correction for ambient conditions (air temperature, pressure, and relative humidity);

5) Checksum test to secure the calibration data;

6) Connection of the PC and the BSS 2 via network interface (TCP/IP);

7) Distribution of the BSS 2 with a rod phantom.

All these extensions have been implemented at the PTB's BSS 2 example without any change to the hardware. The routine implementation of extension 1 is still under investigation by the manufacturer. The commercially available BSS 2 will contain extensions 2 to 6 approximately starting in 2012, while extension 7 has already been contained since 2011. Extensions 2 to 4 will also be available for old BSS 2 examples via a software update approximately starting at the end of 2011. This work was financially supported by the Bundesministerium für Wirtschaft und Technologie by the project „Innovation mit Normen und Standards – INS“ “Verbesserung der Überwachung der Dosis der Augenlinse ”.

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P02.248
Life Cycle Assessment of the Romanian Reference Standard for Dosimetric Quantities

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Introduction

The measuring instruments are an instrumentation class with some special features, which come from their main function-the measurement of different quantities, in any specific field of activity.

The measurement process of any quantity involves two main aspects:

- the indication of the numerical value of the measured quantity;

- the evaluation of the measurement uncertainty.

In order to assure the correct measurement of a quantity, any measuring instrument must have traceability; this traceability is accomplished by calibration. If the instrument is dedicated to the calibration of the other instruments measuring the same quantity that is it is a standard instrument, its traceability must be assured by calibration and intercomparison.

The life-cycle assessment of the measuring performances of the reference standard instrument of a standard for a specified quantity includes, besides the traceability, another specific operation; the monitoring of the operating mode and of the metrological characteristics of the instrument.

The reference standard of Romania for the dosimetric quantities is a PTW doserate/dose meters UNIDOS 10001 with the several ionization chamber.

This instrument is periodically calibrated at PTB, Germany. For the assessment of the operation of this instrument, between two successive calibration, a special programmed of monitoring of the instrument was developed.

The monitoring operation consists in the invadiation of each detector, connected to the UNIDOS, with the ionizing radiation produced by the same radioactive source, in a very reproducible geometry and the recording the instrument's indications.

This paper deals with the method used for the monitoring of this standard instrument and with the results obtained during these measurements. Tables with the results of the measurements, their uncertainties and representative graphics with these data are also included

P02.249
The Effect of the Radiation Background on the Accuracy of the Calibration Performed with Gamma Ray in the IFIN-HH

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In the Calibration Laboratory of the Horia Hulubei- National Institute for Physics and Nuclear Engineering, a calibration stand for dose and dose rate meters was set up. This stand uses a collimated gamma-ray beam produced by a radioactive source of Cs-127

. In order to assure a high accuracy of the calibration, some correction factors have to be established. One of the factors which can affect to accuracy of the measurements, during a calibration work is the value of the radiation background in the area of the calibration stand. This is why in our calibration laboratory we started a programme for the monitoring of the gamma-ray background.

The measurement of the dose equivalent rate was performed with an AUTOMESS 6150 AD 6/H instrument, having a large scintillation probe 6150 AD-b/H.

This instruments has a measuring range of 50 nSv/h to 99.99µSv/h this allows a accurate measurement of H at the background level.

The paper deals with the measurement of the natural background, and with the effect of the background on the accuracy of the calibrations performed on the gamma calibration stand of IFIN-HH.

Tabels with the results of the measurement, their graphic presentation are also included, as well as the calculation of the correction due to the background.

P02.250
Establishment of the Practical Peak Voltage for Tomography Standard Radiation Qualities at the Calibration Laboratory of IPEN

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At the Calibration Laboratory of IPEN/CNEN-SP (LCI) several radiation qualities were established, and they are in use for the calibration of radiation detectors for clinical and industry uses. In order to follow international recommendations [IEC, 1994], a new quantity is being established at LCI, the practical peak voltage (PPV). In this work, an analysis of this quantity was made for the tomography standard radiation qualities RQT8, RQT9 and RQT10 [IEC, 2005]. The PPV, the peak kilovoltage (kVp) and the air kerma were measured with both a noninvasive Radcal Accu-kV Diagnostic Sensor™, model 40X12-W meter, and a Physikalisch-Technische Werkstätten (PTW) meter, model Diavolt™. The tests were performed with an X-ray system Pantak/Seifert, tube model MXR-160/22 (constant potential). The measurements were taken varying the electric current and the distance between the focal spot and the meters. The uncertainties attributed to the quantity of air kerma, kVp and PPV for a noninvasive method did not exceed 5%, and therefore were within the IAEA recommendations [IAEA, 2007]. In the corresponding measurements, increasing the distance between the focal spot and the meter, the dose should decrease exponentially, while the PPV and the kVp should be constant. The results were within the predictions, and the PPV and the kVp presented a variation of less than 1.5%. This type of quality control procedure is very important to verify the good reliability of the X-ray system used at the LCI, because this system is used for routine calibration of dosimeters.

IAEA, 2007. INTERNATIONAL ATOMIC ENERGY AGENCY. Dosimetry in diagnostic radiology: an international code of practice. IAEA-TRS-457, Vienna.

IEC, 1994. INTERNATIONAL ELECTROTECHNICAL COMMISSION. Medical Diagnostic equipment – Radiation Conditions for use in the Determination of Characteristics. IEC 61674, Genève.

IEC, 2005. INTERNATIONAL ELECTROTECHNICAL COMMISSION. Medical diagnostic X-ray equipment – Radiation conditions for use in the determination of characteristics. IEC 61267, Genève.

Keywords: PPV, quality control, noninvasive kV meters.

P02.251
Evaluation of Gamma Dose Rate Probes Response in the Slovenian Early Warning System

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In years 2004-2006, the Slovenian Nuclear Safety Administration (SNSA) undertook the project renovation and expansion of the network for real-time measurements of external radiation in Slovenia. The Slovenian manufacturer AMES installed their product, model MFM-203, which made integration and administration of the network easier, since the majority of existing probes were also produced by AMES.

In 2006, the SNSA participated in the 3rd international intercomparison campaign for instruments for automatic measurements of external radiation, organised by WG EURADOS, at PTB, Braunschweig, Germany. In the report, published in Radiation Protection Dosimetry in June 2009, the SNSA found that the characteristics of the gauges in the Slovenian network early warning system are distinctly different from the instruments of other participating countries. Due to historical reasons, calibration of the MFM probes was performed with radionuclide ^{60}Co, unlike the others, calibrated with ^{137}Cs and the results are expressed with the physical quantity H_X (photon dose equivalent) rather than in units of H*(10) (ambient dose equivalent).

As a consequence, the SNSA, analysed the response of the probes, with special consideration to cosmic, terrestrial and inherent instrument contributions. With additional engagement of the probe manufacturer AMES and the National laboratory for dosimetry standards, steps needed to rectify the situation were undertaken. The National laboratory for dosimetry standards, with the help of the SNSA, developed a new procedure for the calibration of probes, using 137Cs and proper physical quantities. The probes then underwent field tests at different locations. The results of the newly evaluated response of the AMES probes MFM-203 showed that the existing network gives up to 35% lower response as regards a real radiation field. The new probe response showed – as expected – for about 15% higher values then the natural background. These newly obtained values are much more in agreement with the results of the other European countries and, more importantly, would be much more realistic and reliable in case of contamination from a nuclear accident.

P02.252
Establishment of the New IEC 61267 Mammography Qualities in a Clinical System

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The mammography is ±a clinical exam that allows the premature breast cancer, because it is capable to show a possible tumor in its initial stage. But, in order to obtain a reliable diagnosis is necessary that the mammography system be calibrated and working properly, otherwise it can cause a loss in the produced image, which can generate a false result, and a possible damage to the patient. Therefore it is important the quality control of these equipments, especially in terms of the radiation emitted by them. In this study were established the IEC 61267 mammography qualities in a clinical system. The objective here is to establish a calibration condition that is as close as possible to the hospitals and medical clinics situation, including the scattered radiation from the breast support, the anode effect, the system geometry etc. The qualities were established in a VMI mammograph, Graph Mammo AF model, which works in a range from 20 kV to 35 kV, has a molybdenum (Mo) target and filtration of Mo and rhodium (Rh). The half-value layers (HVL) used were those presented by the German Primary Dosimetry Laboratory Physikalisch-Technische Bundesanstalt (PTB). Although, the only established qualities were those that use Mo as additional filtration, because the reference ionizing chamber was calibrated only in this condition.

To determine if the Mo filtration is appropriate for each quality it is necessary to use the HVL, which must reduce the beam intensity in (50.0 1.5) %. If the reduction is within this range, the quality is established. If not, the quality cannot be established. In this case, it were expected that the additional filtration was already correct, because the mammograph, with the anode and filtration of Mo, according to the IEC 61267, should be the most adequate system to establish the mammography calibration qualities. Although, tests made using the HVL given by the IEC 61267 did not fit the expectation and all the intensity reduction were about 47.2 %. For the HVL given by the PTB, the only one that stayed out this range was the RQR-M 3 (voltage of 30 kV), with a reduction of about 48 %. Using the calibration factor, given by PTB in the reference ionizing chamber calibration certificate, the air kerma rate was determined for each quality.

P02.253
Results of a Dosimetric System for Personal Dose Equivalent Assessment.

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The Individual Monitoring Service of the Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP) monitors approximately 1500 workers on a monthly basis, from 14 facilities spread all over the country, using thermoluminesce dosemeters (TLD).

The TLD system used for Individual Monitoring at IPEN is based on thermoluminescent detectors and on a Harshaw 5500 Automatic TLD reader. The IPEN TL dosemeter is based on $CaSO^4$:Dy sintered discs with a diameter of 6mm and a thickness of 1,0mm. The TLD pellets are mounted in a plastic badge under plastic filters, lead filters and lead filters with hole.

This work compares the results obtained for the assessment of personnel dose equivalent Hp(10) according to national and international reccomendations, using the IPEN TL dosemeter with another dosemeter developed at IPEN that uses TLD discs of CaSO4:Dy placed mounted on a plastic badge under plastic filters, copper plus plastic filters and copper plus lead filters.

Calibration of the TL dosemeters were carried out using a ISO slab phantom of polymethyl methacrylate (PMMA), with dimensions of 30x30x15 cm^3.

The dosimeters were irradiated with ^{60}Co gamma radiation and X rays chosen from the International Standards Organization's (ISO) Narrow Series , using the irradiation facility from Radiation Metrology Department of IPEN.

The TL measurements were performed using a Harshaw 5500 Automatic TLD reader in a nitrogen atmosphere, with a linear heating rate of 10°C.s^{-1}. The reading cycle was performed within 23s. The maximum temperature of 250°C was reached in each readout cycle. Results on reproducibility, radiation dose response and energy dependence are presented.

P02.254
Conversion Coefficients from Air Kerma to Personal Dose Equivalent for Low Energy X-Ray Reference Radiations

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The International Organization for Standardization (ISO) defined sets of x-ray reference beams for calibrating and testing dosimeters used for ionizing radiation protection purposes; the ISO standards provide values for conversion coefficients from air kerma, K_a, to ambient dose equivalent, H*(d), and to personal dose equivalent, Hp(d), quantities in different depths d, that are used for area and individual monitoring, respectively.

For reproducing the reference radiations in metrology laboratories, the ISO 4037 standards establish that two beams shall be considered the same when the first and the second half value-layers (HVL) agreed within 5%. Some experiments have exhibited relevant energy spectrum differences between beams although they have the same HVL. For low energy photons, small differences in the spectral distributions can result in significant changes in the numerical values of the conversion coefficients. The ISO 4037-4 standard suggests that each metrology laboratory should measure the energy spectrum of each reference radiation in order to calculate the accurate conversion factors.

The aim of this work was to establish a spectrum based methodology to determine the conversion coefficients from K_a to H*(10) of ISO narrow spectrum series with mean energies in the range 20 – 24 keV.

In the Dosimeter Calibration Laboratory of the Development Center of Nuclear Technology (LCD/CDTN), Belo Horizonte, Brazil, ISO narrow series reference radiations were implemented. HVL values were determined from attenuation curves in terms of air kerma rate versus the thicknesses of high purity aluminum filters and beam energy spectrum was measured with a cadmium telluride detector. The discrete function of the photon energy distribution in the finite amount of channels was used for calculations.

Conversion coefficients from K_a to H*(10) were obtained from the weighted average of published monoenergetic conversion coefficients related to the correspondent energy of each channel. Results showed differences from the ISO recommended values for up to 20%. They emphasized that for low energy narrow spectrum series the conversion coefficients from K_a to H*(10) should be determined by beam spectrometry based method to avoid unacceptable errors during calibration and performance testing of radiation protection dosimeters.

P02.255
Application of advanced composite materials in the creation of reference volume sources of radionuclides activity.

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Modern measuring means, applied in the field of radioecological monitoring, use mostly a relative method of measurement. It seems actual to improve the accuracy of standard and reference activity sources manufacturing, used for calibration, since one of the main contributions in the uncertainty of radionuclides activity measurements is the uncertainty of calibration sources characteristics.

During the volume sources manufacturing it is necessary to provide a maximum possible concordance of geometric and physical-chemical characteristics, such as: shape, dimensions, density, mass absorption coefficient of X-radiation and gamma-radiation, law of activity allocation, to the measured sample.

STC "RADEK" together with SRI of Industrial and Sea Medicine have developed a technology of composite materials manufacturing, which have a density within the limits from 0.1 g/cm^3 to 3.0 g/cm^3, (with accuracy 1,5-3%), and also a given dependence of mass absorption coefficient from energy in operating range 10 – 3000 keV, with accuracy of approximation 2-5%. The obtained materials are homogeneous, chemically inert and stable in normal operating conditions, are not affected by oxidation and are not hygroscopic. Operating temperature range from -5°C to +35°C

The introduction of reference radionuclides solutions in the material, which is provided by manufacturing technology, allows to obtain a highly stable activity volume sources (AVS) with precisely specified metrological characteristics. Typical activity allocation – uniform over the volume.

A technology particularity is the possibility of manufacturing of stable and hygienic imitators of natural and technogenic objects, including biological tissues affected by decomposition.

A special place in the raw of AVS, manufactured from composite materials, occupy the phantoms of human body, its parts and separate organs, intended for calibration of human radiation spectrometers, and also for dosimetric researches.

At the present moment, in STC "RADEK", on the request of Radiation and Nuclear Safety Authority of Finland (STUK), a new radiodosimetric anthropomorphic organotropic phantom of human body is designed and manufactured, it is executed in the form of collapsible model of an adult man's body of 18-25 years old. The phantom is represented as a full set of skeleton bones models, models of internal organs and models of integumentary tissues, which are mounted at the place of use. The models are made of plastic-imitators of biological tissues, which are adequate to body tissues, relative to the interaction with ionizing radiation. A radiation-free background set of the phantom has in the set the replacement kits of organs models, containing radionuclides of known activity (^{239}Pu, Unat, ^{241}Am, ^{60}Co, ^{137}Cs, ^{133}Ba, ^{90}Sr, ^{210}Pb, etc.).

Anthropomorphic phantoms of human body allow to perform calibration of human radiation spectrometers (HRS) of expert level.

P02.256
Accreditation of Laboratories in the Field of Radiation Science in Croatia

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In the Republic of Croatia accreditation of laboratories that are providing official measurements and testing in some fields of radiation science (i.e. radiation and radioecological monitoring, radiation protection, dosimetry etc.) is, in order to assure objective evidence of their competence, mandatory by the law and by ordinance of the State Office for Radiological and Nuclear Safety.

In the paper are presented results and experiences of accreditation of laboratories working in the field of radiation science, according to the international norm EN ISO/IEC 17025, that are accredited by Croatian Accreditation Agency (HAA).

Accreditation provides an unbiased, third-party evaluation and recognition of competence and accreditation signifies that a laboratory has demonstrated that it operates in accordance with EN ISO/IEC 17025 management and technical requirements pertaining to quality systems, personnel, accommodation and environment, test and calibration methods, equipment, measurement traceability, sampling, handling of test and calibration items and test and calibration reports. Also, special attention is paid on mandatory participation in Measurement Quality Assurance (MQA) programmes like intercomparison runs and proficiency testing schemes.

Up to September 2011, in the Republic of Croatia HAA has issued accreditations to four different laboratories working in the field of radiation science. The accreditation process involved 2 lead assessors and 5 technical assessors.

About 40% of observed non-conformities were related to management system and 60% to technical requirements. However, when number of observed non-conformities is considered on the time-scale, it is evident that after initial assessment (i.e. first accreditation) it is significantly decreasing in subsequent surveillance assessments. In the paper is presented detailed structure of non-conformities related to respective requirements of the norm.

It can be concluded that accreditation significantly improved overall performance of laboratories, raising the confidence of customers in services they provide and their measurement and testing reports.

P02.257
Experience Of Introducing A Personal Dosimetry Website HPA Dosimetry On-Line

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The Health Protection Agency (HPA) Personal Dosimetry Service operates a number of Health & Safety Executive approved personal dosimetry services. In 2008, the HPA introduced a new database called DORIS (DOsimetry Records Information System) which replaced its ageing, inflexible predecessor. In 2010, to continue with its development of the service, HPA began a project to introduce on-line access to this information for its customers called HPA Dosimetry On-Line. As the use of the internet increases, HPA wanted to be able to offer its clients easy, constant and secure access to their dose data and to improve the speed at which this information was available.

Planning and Project Schedule: As this project was to supply an on-line service for our customers and their Radiation Protection Advisor's (RPA's), early contact was established with RPA's and customers to help with the design and user friendliness of the service. The project began with several meetings with the supplier to develop the User Requirements into detailed Software Requirements Document. This established the main structure of the on-line system and included plans for security, for access and the scope of information to be provided to the user. To test the potential screens and user friendliness of the system, HPA invited some customers in for sessions of paper prototyping. This enabled the supplier to make changes to the design before the software script had been written.

The supplier carried out System Testing on the completed software/website and HPA staff carried out User Testing to check specific tasks. HPA then asked selected customers to view and use the system prior to release to gain further feedback.

Conclusions: This project involved liaising with internal and external IT suppliers which required a very organised approach to the project management. HPA had to ensure that the suppliers were working together to achieve the end goal. HPA has just launched the website to its customers and plans to ask for feedback from customers in approximately three months time to assess the reaction to the new service.

P02.258
Progress in Neutron Metrology and Dosimetry at the National Physical Laboratory, London, UK

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The National Physical Laboratory (NPL) in Teddington, south west London, is the UK's national standards laboratory, and the NPL Neutron Metrology Group provides an extensive range of facilities for measurements on neutron sources and neutron-sensitive devices. These facilities include a manganese sulphate bath for measuring neutron output rates from radionuclide sources (one of very few such facilities in the world); a Van de Graaff accelerator for producing monoenergetic, broad-spectrum and thermal neutron fields; and a set of radionuclide sources of various types and strengths. All have been carefully characterised, and allow manufacturers to calibrate and type test survey meters and personal dosemeters to international standards. Device irradiations take place within a large experimental area measuring approximately 18 by 18 by 26 m, where scatter is low and large artefacts can usually be accommodated.

This paper describes recent improvements to the neutron facilities and to the detectors and spectrometers owned by the Group. Such improvements include a recently acquired high-output ^{252}Cf neutron source (approximately 3.3 x 10^8 neutrons per second into 4π) with a pneumatic transfer system to move it remotely; the development of an 8 keV monoenergetic neutron field via the ^{45}Sc(p,n)^{45}Ti reaction; and ongoing work to produce an additional Bonner sphere set for high energy neutron spectrometry.

P02.259
Photon Radiation from the 252Cf and 241Am-Be Neutron Sources of the PSI Calibration Laboratory

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At the accredited PSI calibration laboratory neutron reference fields traceable to the national standards of the Physikalisch-Technische Bundesanstalt (PTB) in Germany are available for the calibration of ambient and personal dose equivalent (rate) meters and passive dosimeters. The photon contribution to the neutron fields of the ^{252}Cf and ^{241}Am-Be sources was measured using various neutron-insensitive photon dose rate meters and active and passive dosimeters. Measuring photons from a neutron source usually involves considerable uncertainties due to the presence of neutron induced photons in the room, due to a non-zero neutron sensitivity of the photon detector, and last but not least due to the energy response of the photon detectors. Therefore six independent detectors and methods were used to obtain a reliable estimate for the photon contribution of the two sources as an average of the individual methods. For the ^{241}Am-Be source a photon contribution of approximately 5% was determined and for the ^{252}Cf source a contribution of 3.5%.

P02.260
Novel Reference Field for Pulsed Photon Radiation for Research and Type Testing

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The main application of pulsed photon radiation is to be found in the medical sector, which has increased remarkably in the past few years. Active personal dosemeters, which are used for measurements in such pulsed radiation fields, have only been tested in continuous fields. But Ankerhold et al. [1] have shown that the characteristics of dosemeters determined in continuous fields cannot be transferred to those in pulsed radiation fields. Therefore, a reference field for pulsed radiation is needed. Such novel X-ray equipment has been installed at PTB for research and the type testing of dosemeters.

The characteristics of this new reference field are oriented on the properties of actual medical X-ray equipment. But in contrast to medical X-ray equipment, all relevant field parameters, like pulse duration, tube voltage, and tube current can be adjusted independently with small uncertainty. This is the basic precondition for the determination of the dosemeters' properties under test. The grid-controlled X-ray tube has an electric pulse power of 80 kW for 300 ms. The pulse duration can be varied in the range from 0.2 ms to 10 s or can be switched to continuous radiation with a power of 3 kW. The tube voltage ranges from 40 kV to 125 kV. We have installed filters to generate the following radiation qualities: N series according to ISO 4037 and RQR series according to IEC 61267. We are able to apply single pulses, pulse repetition and even arbitrary pulse sequences. The dose of each pulse is measured by a monitor ionization chamber and the time-dependent behaviour of a pulse is measured by a monitor diode (Si PIN diode). The novel reference field has been characterized and we have investigated the influence of the Heel effect on the radiation field distribution using different detector types, e.g. ionisation chamber, image plates and flat panel detector. In addition, we are also active in the development of new measurement techniques for the characterisation of pulsed radiation fields. The set-up and the technical details will be presented in detail.

References:

1. Ankerhold, U., Hupe, O. and Ambrosi, P. Deficiencies of active electronic radiation protection dosemeters in pulsed fields. Radiat. Prot. Dosim. 135, No. 3, 149-153 (2009).

P02.261
The effect of PMMA Build-up Layer for a Calibration of Dosemeter for Gamma-ray Sources

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In the ISO-4037 part 3, that is for calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence, the irradiation field should have a charged particle equilibrium. It is written that 2 mm thick PMMA plate for Cs-137 or 4 mm thick plate for Co-60 are placed in front of dosemeter to make that condition. The correction factor k_{pmma} are introduced in that document and there values are 1.00 for Cs-137 and Co-60.

The PMMA plate is worked as a attenuator and also made scattered photons, but there are no data how is there effect. In this study, several chambers and dosemeters were irradiated with and without PMMA plate for Cs-137 and Co-60, and also irradiated with changing distances from detector to PMMA plate to evaluate the effect of scattered photons from PMMA plate.

P02.262
Calibration of the High and Low Resolution Gamma-Ray Spectrometers

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Many laboratories accredited according to the requirements of the standard EN ISO/IEC 17025:2005 "General requirements for the competence of testing and calibration laboratories" are implied in the measurement of the radioactive content of various materials, by analyzing samples collected from the environment and food chain or industrial products. The most used method is based on the gamma-ray spectrometry measurement, using high resolution HPGe and low resolution NaI(Tl) or equivalent detectors, with the advantage of being non destructive. In order to improve its sensitivity, one applies many technical and methodological means, such as: careful choice of detector material, passive or active detector shielding, measurement of high volume samples with various matrix content, positioned in close to detector geometries. This last aspect has direct influence on the measurement, by introducing large errors in the results when the influence of geometry, sample volume and content, and true coincidence summing effects (in the case of cascade gamma-ray emitters measurement) are neglected, such as it was demonstrated during many proficiency tests. The Radionuclide Metrology Laboratory (RML) from IFIN-HH, Primary Activity Standard Laboratory assures the continuity of the whole metrological traceability chain of measurement and is accredited by the national accreditation body RENAR as a Calibration and Testing Laboratory, according to the EN ISO/IEC 17025:2005, for the products and services for clients. RML elaborated two special working procedures for the calibration of the gamma-ray spectrometers and for the analysis of the low level radioactive samples measurement. This new activity of RML relies on the long metrological experience and the good results obtained in international comparisons or proficiency tests. The paper describes the calibration procedures and the types of radioactive standards to be used in this process, with emphasis on the corrections applicable by the measurement laboratories.

P02.263
Evaluation of Radiation Dose in Computed Tomography Standard Beams Using Simulators

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Computed tomography (CT) is a diagnostic imaging method widely used since its discovery. When CT is compared with conventional radiology, its radiation dose is higher almost always and the absorbed dose to the patient is also higher. The increasing use of CT in children has been verified mainly by reducing the time required to scan - now less than 1 second – eliminating, in most of the time, the use of anesthesia to prevent the child movement during image acquisition . The harmful effects of radiation are more likely to happen in children than in adults because they are in growth stage. Studies have shown that the absorbed doses in pediatric CT examinations ranged between 0.7 mSv and 3.5 mSv and the risk of developing cancer during their lives has been 0.16%. These measurements have been done in phantons which simulate 5 year-old children. In the present study it was used two acrylic simulators developed at the Laboratório de Calibração de Instrumentos (LCI) that belong to the Instituto de Pesquisas Energéticas e Nucleares (IPEN). Measurements were carried out using radiation standard beams for CT from 100 kV to 150 kV, to evaluate the quantities air kerma, incident air kerma and entrance surface air kerma. The results were compared with the literatures. Based on the findings of this study, it was proposed a specific simulator to apply in pediatric CT examinations.

P02.264
Impact Of IEC 61066:2006 Standard Testing To The Joint Research Centre Dosimetry System

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The Joint Research Centre of Ispra is a research site belonging to the European Commission, Directorate General JRC. It was created in the late '50s, in order to steer European research on nuclear industry. The Dosimetry Service belongs to the Radiation Protection Sector, Nuclear Decommissioning Unit, and is committed to the preparation, assignment, and reading of personal and ambient dosimeters.

The International Standard IEC 61066:2006 "Thermoluminescence dosimetry systems for personal and environmental monitoring" is a guideline for type testing thermoluminescence dosimetry (TLD) systems. It is used for measuring both the personal dose equivalents $H_p(10)$, $H_p(0,07)$ and the ambient dose equivalent $H^*(10)$ for external photon or beta radiation within the dose range from 0,01 mSv to 10 Sv. This Standard is a revision of the first edition published in 1991. The main technical changes include: (a) specify the use of operational quantities, (b) harmonise the reference radiation and calibration with ISO standards, (c) integrate the basic uncertainty analysis, and (d) align IEC uncertainty requirements on dosimetry system with those stated in ICRP Publication 75 "General Principles for the Radiation Protection of Workers".

The JRC-ISPRA personal thermoluminescence dosimetry system was tested according to this Standard. The JRC-ISPRA Dosimetry System is composed of: a transparent plastic outer casing with a Panasonic TLD badge (UD-802A series), a Panasonic UD-716 AGL automatic reader, a computer with appropriate software and algorithm to control, transmit, store, and calculate the evaluated doses respectively.

Three type tests' categories were performed, namely: (1) radiation performance requirements and tests on the dosimetry system, (2) additivity of the indicated value on the dosimetry system, and (3) environmental performance requirements and tests.

Moreover, range of type test (1) was extended, both in terms of linearity range (from 0,05 mSv to 1 Sv instead of 0,1 mSv to 1 Sv) and in terms of incidence angles (± 80 degrees instead of ± 60 degrees) as requested by the Standard.

This work confirmed the overall excellent quality of the JRC-ISPRA TLD system, which, now also implementing basic uncertainty analysis, is hence ensuring a strict metrological traceability to personal dose equivalents $H_p(10)$ and $H_p(0,07)$, according to international standards.

P02.265
Assessment of the Uncertainty of the Results of Control of an Individual Dose Equivalent

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Measurement of an individual equivalent of a dose ($H_p(d)$) is connected with necessity of the accounting of arising errors. In this connection processing of results of a radiation control is an important element providing reliability of the received information.

Uncertainty of results of radiation measurements is characterized by numerical values which can be attributed to measured $H_p(d)$. The basic quantitative expression of uncertainty of measurements is standard uncertainty.

Calculation of standard uncertainty is made in two ways. In the first case calculation is carried out by processing of results of repeated measurements. In the second case they use for uncertainty calculation:

- data of the previous measurements of $H_p(d)$;

- data of a kind of a distribution of measurement results;

- data of technical and metrological characteristics of applied dosimetric devices;

- data of checking, calibration, data of the device manufacturer, etc.

Application of the first method is limited by necessity of carrying out of repeated measurements that is impossible in the conditions of performance of real works.

In the second case it is possible to present uncertainty of results of a radiation control in the form of borders of a departure of value of $H_p(d)$ from its estimation.

The most widespread way of formalization of insufficient knowledge of value of size consists in application of the assumption of the uniform law of distribution of possible values of $H_p(d)$ in established (bottom and top) borders.

However, the analysis of the data of individual doses of the personnel shows that in certain cases laws of distribution of possible values of $H_p(d)$ differ from uniform law that essentially influences results of estimations.

The analysis of the data of individual doses of the personnel presented in the established reporting forms is carried out. It has allowed to establish typical laws of distribution of $H_p(d)$ for various types of performing works in the conditions of influence of ionizing radiation.

P02.266
Evaluation Methodology And Performance Tests Of Ionization Chambers Of The Air Kerma Area Product Using Mathematical Simulation

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The Monte Carlo method was used to study the dependence of the calibration coefficient on tube voltage, radiation beam size, additional filtration, energy and reference plane in simplified geometries modeling a KAP meter. The MCNP5 code was used to calculate the imparted energy in the air cavity of KAP meter and the spatial distribution of the air collision kerma in entrance and exit plans of the KAP meter and on a plane close to the patient. From these data, the air kerma-area product (PKA) and the calibration factor were calculated and its dependencies with the tube voltage, radiation beam size, additional filtration and energy were analyzed. There was a variation of the calibration factor as a function of the tube voltage when the additional filter was used. The additional filter placed next to KAP meter decreased the calibration coefficient for the patient's plane compared to the additional filtration in the output of the beam. The effect of the beam aperture was small in terms of patient and negligible to the exit plane.

P02.267
Upgrading of the National Radiation Standards at the Secondary Standards Dosimetry Laboratory (SSDL) in the Philippines

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The programs for establishing the national radiation standards for diagnostic & protection Level at the Secondary Standards Dosimetry Laboratory (SSDL-PNRI) of the Philippines is presented. Ongoing projects, training programs, new equipment & infrastructure are presented. Preliminary measurement results are also discussed. Results show that the X-ray tube output and the radiation quality are within the international recommendations. The SSDL-PNRI is therefore on track in establishing the national standards towards a strengthened capacity in radiation dosimetry, metrology and ultimately safety of the users of ionzing radiation.

P02.268
The Support Offered by the Romanian Primary Activity Standard Laboratory to the Nuclear Medicine Field

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The quality of a nuclear medicine procedure depends on the activity and quality of the radiopharmaceutical administrated, IAEA-TRS 454. Both aspects are connected with high precision activity (Becquerel) and derived units measurement. The technical support is offered by the Primary Activity Standard Laboratories, like the Radionuclide Metrology Laboratory (RML) from IFIN-HH, which assures the continuity of the whole metrological traceability chain of measurement. The RML's role is: to develop activity standards, to validate them in relation with the International System (SI) and to disseminate them as radioactive standards, or calibration services. The paper presents RML's actions and results. (i)Development of installations and methods for the primary/absolute standardization of radionuclides: a coincidence installation and the TDCR-LSC system. They were internationally validated, through key or supplementary BIPM comparisons, and their international equivalence was established. RML's results are part of *the Key Comparison Data Base (KCDB) Annex B of the CIPM - MRA.* The supplementary comparisons, within the IAEA-CRP E2.10.05, regarded ^{57}Co and ^{131}I. Implementation of the QMS, in accordance with the standard EN ISO/IEC 17025:2005 and its recognition by the EURAMET TC-Q, allowed the approval and publication of RML's 34 CMC files in the Annex C of the CIPM-MRA. (ii) Establishment of a secondary standard, reentrant ionization chamber CENTRONIC IG12/20A, calibrated and validated for 20 radionuclides. The determined calibration factors allow the measurement and certification of the radiopharmaceutical standards. (iii) The direct support of RML to the nuclear medicine units consists from: delivery of radioactive standards; calibration or metrological check of the Radionuclide Calibrators; organization of national comparisons and proficiency tests (PTs). These actions are deployed under the national RENAR (EA member) accreditation, as a Calibration and Testing Laboratory, for the products and services for clients. The description of the calibration services for radionuclide calibrators presents a 6-years work period, in the aspects: check of the measurement uncertainty and comparison with Pharmacopoeia requirements; recalibration and establishment of new calibration factors (dial settings); follow up of the calibrator's behavior in time; comparison of the activity values measured with the most used instruments: Curiementor 3 and ¾, Capintec CRC 15/25R, Romanian EMR 15G, Picker, with the reference value; results of calibration check versus the participation of nuclear medicine staff at PTs organized by the RML. Some conclusions and recommendations are formulated.

P02.269
Calibration and Energy Response Determination of Radiation Protection Area Survey Meters in ISO Narrow Spectrum Photon Beams

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Dosimetric measurements were made to study the energy response to a set of 8 radiation protection area survey meters to some ISO narrow spectrum photon beam qualities. Experimental measurements were carried out at the Secondary Standard Dosimetry laboratory in Sudan. Irradiations were carried out using ^{137}Cs and X-ray Narrow spectra beam described in ISO standard 4037[1]. X-ray beam qualities: 48, 80, and 100 keV and 662 KeV ^{137}Cs were used for irradiation. Standard ionization chambers were used to measure the air kerma rate. Appropriate, conversion factors were used to determine ambient dose equivalent H*(10) as standard dosimetric quantity of interest [2, 3]. Parameters tested include the variation of instrument response radiation energy and different dose rates. The response of the survey meter under study were within the limits of acceptable performance. Energy response of survey meters: tracerco, RDS and Radiagem ranged from 0.4 to 1.04, (0.77-1.3), (0.85-1.4) respectively. Most of the dosimeters tested showed acceptable energy response. Survey meters under stdy show stable response in Variation of the response for the beam energies.

Keywords—Ionizing radiation calibration, area survey meter, Energy response, ambient dose equivalent rate.

1. ISO 4037-1:1996. X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy d Part 1: Radiation characteristics and production methods. ISO, (1999).

2. ISO 4037-3:1999. X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy d Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence.

3. International Atomic Energy Agency. Calibration of radiation protection monitoring instrument .IAEA Safty Reports Series. No.16.IAEA Vienna (2000).

P02.270
Secondary Standard Dosimetry Laboratory in Central Laboratory for Radiological Protection in Poland

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To ensure appropriate quality of a dosimetry monitoring, taking into consideration Polish nuclear energy program, Central Laboratory for Radiological Protection (CLOR) has started measures for establish within its department a Secondary Standard Dosimetry Laboratory (SSDL). The planned SSDL will cover wide range of dosimetry calibration standards. It will remain in compliance with the methods already accredited by Polish Accreditation Centre. The accredited methods are operational in Laboratory for the Calibration of Dosimetry and Radon Instruments (LWPDiR). These methods refer to calibration with a use of standardized field of gamma and X-ray radiation as well as alfa and beta surface contamination sources. Additionally, Beta Secondary Standard (BSS-2) and Neutron Calibration stand with Am-Be source are planned to be adjust to SSDL's requirements.

Presented work shows a conception of the planned development and validation of existing and newly implemented methods including part of realized Monte Carlo (MC) simulations designed to adequate a relocation of the stands within laboratory to minimize their influence on the quality of calibration process. The planned SSDL will be established in two calibration labs: the first lab with a Gamma (Co-60, Cs-137, Am-241) and BSS2 (Sr-90, Kr-85) calibration stands whereas the second lab will include X-ray (N-40 ÷ N-300) and Neutron (Am-Be) stand.

Numerical simulations based upon MCNP/MCNPX code were commitment to cover two aspects of interest. The first case was to compare reference values of an air kerma measured by PTW ionization chamber type M23361 with UNIDOS electrometer with values given by MCNPX code. Obtained results show up high correlation between calculated and measured values. The second simulation was conducted to asses an influence on values of the ambient dose equivalent by attached to Neutron stand table. Results obtained for two configurations, with and without additional equipment, show only of difference range 3% in the ambient dose equivalent.

When SSDL is established, high quality of measurements performed at the unique in Polish laboratories equipment will improve the dosimetry monitoring in the current activities and future needs regarding nuclear energy program.

P02.271
Measurement of Single Scan Dose Profiles in Computed Tomography Dose Phantom Using a Micro Ionization Chamber

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Purpose We have measured the single scan dose profile (SSDP) in computed tomography (CT) dose phantom for several X-ray beam widths on 64-slice Multi-Detector-Row CT (MDCT) using micro ionization chamber.

Materials and Methods SSDP was measured using micro ionization chamber (10X5-0.18, Radcal, Monrovia, CA) which have an active length of 19 mm and a 0.18 cm^3 active area on 64-slice MDCT system (Aquilion CX, Toshiba Medical Systems, Tochigi, Japan). The 64-slice MDCT system was used with a tube voltage of 120 kV, tube current of 200 mA, rotation time of 1 second, and nominal X-ray beam widths of 4, 12, and 32 mm (4*1 mm, 4*3 mm, and 64*0.5 mm axial slice acquisitions, respectively). These options complicate the SSDP measurement and analysis procedures. Longer CT dose phantoms were evaluated. Other ionization chamber (100 mm pencil chamber) was utilized to perform the measurements and evaluated. We were installed several ionization chambers at the center of the CT dose phantoms and acquired several axial scans as 5 mm increments of phantom length and 0.5 mm increments around the peak.

Results An increment of SSDP from extended CT dose phantom length was within 10 % at range of 60 mm (-30 mm to 30 mm) from center of X-ray beam. However, it was greatly increased toward peripheral of the SSDP. As dose integral length at 100 mm, cumulate dose from single dose phantom was involved approximately 85% of SSDP, and two stacked dose phantom was involved approximately 67% of the SSDP. Both cumulate doses were not related to the X-ray beam width.

Conclusion □@Some investigators shown CT dose index (CTDI) measurements in recent MDCT systems were required to using longer CT dose phantoms. Generally, many institutes did not have longer CT dose phantoms in Japan. We thought our data was shown basically data for CTDI dosimetry in recent MDCT systems.

P02.272
Electronic Dosemeters in Pulsed Fields of Ionising Radiation: Determination of Relevant Parameters to Decide on Usability

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Active electronic dosemeters employing counting techniques are used in radiation fields for X-ray diagnostics in human and veterinary medicine and in accelerator-driven fields for therapy or science. Nowadays, these fields are more and more pulsed fields of ionising radiation. Besides the many advantages of such direct reading dosemeters, the disadvantage of the limited maximum measurable dose rate becomes significant in these pulsed radiation fields and leads to some negative effects. In case of a pulse dose rate above the limit of the dosemeter, the indicated value for the acquired dose may be considerably wrong.

Since the specifications and requirements for dosemeters in pulsed radiation fields have been excluded from all standards for direct reading dosemeters so far, a set of relevant parameters of a dosemeter is described, which can be used to decide whether it is applicable in a given radiation field or not. The determination of these relevant parameters – maximum measurable dose rate in the radiation pulse, dead time of the dosemeter, indication per counting event, and measurement cycle time – is specified. The test methods are introduced in the IEC Technical Specification 62743 TS Ed. 1, which is currently under development.

The Technical Specification will be designed in such a way that the user of the dosemeter can decide - on the basis of the given parameters of the dosemeter and the known parameters of the radiation field - if the dosemeter is suitable for his specific workplace. There will be no type test for a specific radiation field or workplace but rather for the general parameters of the dosemeter. Typical field parameters will be given in an informative annex in the Technical Specification.

The results of the first measurements on the determination using the test procedure given in the draft of the Technical Specification for a direct reading electronic personal dosemeter are shown.

P02.273
Calculation of dose distribution in PET/CT units using MCNPX monte Carlo code

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The number of PET/CT units in Saudi Arabia is limited to large cities compared to the UK and the USA. There are four units in the kingdom located in two cities, Riyadh and Dammam covering the central and eastern part of the country but there is no unit in the western area. The design of PET/CT unit is very important for reaching the maximum number of scanned patients per day. It also plays a role in maintaining smooth workflow while keeping occupational background and the staff doses within the limits of acceptable levels recommended by NCRP. However, this is not an easy goal in a culture where two sections for males and females are required. A proposed design for dedicated PET/CT is in the western area at the city of Jeddah is tested in this study allowing maximum patients flow while accounting for patients privacy during the procedure. Both MCNPX and hand calculations are used to calculate the dose distribution and to estimate the staff absorbed doses. The same methods are used to calculate the required lead and concert for shielding of 0.511MeV.

P02.274
Determination of the Radiation Field in an Interim Storage Facility

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Since currently there are no final disposal places available, casks for storage and transport of radioactive material (CASTORs) are used to store spent nuclear fuel in interim storage facilities. For radiation protection purpose, we have performed simulations for CASTORs V/19 with MCNP5. Due to the strong radiation shielding characteristics of the CASTORs, simulating the radiation emitted from sources inside a CASTOR presents a challenge. Usually a large number of particles are required to obtain statistically significant results. In order to deal with such complex simulations, variance reduction techniques were applied to increase the performance of the simulations. In particular, the weight window method was combined with the ability of MCNP5 to record a surface source. In this way the simulation time could be decreased. Moreover, the use of a computer cluster allowed simulating geometries with 64 CASTOR-casks in acceptable times. The simulations yield new insights into dose rate distributions and notably into the composition of the mixed radiation field, taking into account that an overall spectrum of the field is difficult to measure. Hence the simulation results provide the possibility for more detailed investigations of e.g. the response of dosimeters in such fields.

P02.275
Construction and use of a Library of 25 Full-Body Male Numerical Models: Rationale and Results

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Purpose of the study: A library of 25 full-body adult male voxel models covering the following extent:

- 162 – 200 cm in height,

- 51 – 147 kg in weight,

- 16.5 – 45 kg/m² in body mass index,

has been achieved. Monte Carlo computations in radiation protection, radiotherapy, nuclear medicine use numeric 3D models of the human body in the voxel format. In the male adult case, even if several voxel models of the full human body have been constructed, their body type is relatively limited if one simply considers the extent of height and weight in the human population. A set of voxel models representing a large extent of these two parameters could be helpful for the study of the accuracy, relevance, morphological dependence of calculated dosimetric quantities wherever anthropomorphic models are used.

Materials and methods Representative body shapes have been selected from the European edition of the CAESAR database. Internal organs and skeleton have been adapted to these body shapes using commercially available 3D models. The 3D modeling work was performed with the Rhino3D software using mesh and NURBS formats. The construction process requires the definition of target masses for the skin, internal organs, skeleton and the definition of an average tissue composition for the remainder tissue. These target masses and composition have been made as simple as possible but are based on a detailed study of the literature. As compared with other work the main advantages of the construction process is the definition of *prior* target values for internal organs and tissues and the use of individual body shapes.

Results: Depending on the model, the full body is defined by 6.2-20 millions of voxels, which requires 46-102 Mb for storing the full body and an air-filled bounding box. The volume resolution is 6-12 mm^3/voxel. Currently 109 organs are included in each model. The agreement between target and obtained masses is most of time better than 5%. These models and Monte Carlo calculations enable to quantify the variation of relevant quantities used in radiation protection with body type. Such calculations have been undertaken for specific absorbed fractions, fluence to dose conversion factors and numerical calibration of in vivo counting systems.

P02.276
Use of Computer Vision Algorithms for Fast Evaluation of the Dose Caused by Scattered Radiation in Industrial Environment

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We have developed a program that allows you to make a rapid assessment of the dose due to computer vision algorithms. Our algorithms are based on ray tracing from the source, reflection from the surface, and ray visibility from detector. The program is written in R-language and for visualization we use the capabilities of OpenGL.

In calculations for scattered radiation we take into account the effect of a single-scattering albedo from walls, floors, ceilings and objects inside the room. Scattering in the air is ignored. Accuracy and computation time are depending on the number of rays emerging from the source. The user can vary these parameters.

3D models of the environment and internal objects are imported into the program as wrl-files that can be created in 3d-editors. They are converted to the 3d mesh structure for calculation on them.

P02.277
Monte Carlo Analysis of Spectrum Produced by Transmission-type X-ray Target

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The special design of transmission-type X-ray target that generates X-rays with micrometer focal spots renders extremely good quality images. The transmission-type X-ray target consists of a thicker metal which is coated on beryllium (Be) window in the tube. Different target materials and thicknesses will influence the spectrum and affect the image quality. The Monte Carlo simulation MCNP5 code was used for the calculation of X-ray spectrum. The optimum design was derived through simulation with different factors to reduce unwanted radiation dose and improve the image. For the present study, we considered various calculated spectra corresponding to accelerating voltages of 60, 80, 100, 150 kV. The target materials chosen were Ta, W, Rh targets which are most widely used as X-ray target materials. The target thicknesses of simulation are from 2 μm to 20 μm . We investigated in detail the dependence of target material with electron range. If the target thickness is smaller than the electron range and the probability of interaction of electrons with the target atoms is smaller compared to thick targets. The optimum thickness of x-ray intensity induced is 70-80% of electron range (Katz-Penfold equation) without considering the possibility of low energy photo being attenuated by additional filter. However, it is necessary to filter low energy photo since the patient would receive extra dose otherwise. The simulation result showed that the optimum thickness is 90% of electron range with additional filter. In fact, target thickness plays an important role in enhancement of X-ray intensity. The attenuation rate was evident in low energy photo range if we continuously added target thickness.
In higher electron energy range, characteristic radiation x-ray spectrum was more evident by adding target thickness. From the analysis, the results we simulated would be applied in the design and fabrication of transmission-type x-ray target.

P02.278
Monte Carlo Modeling of Photon Dose Rate Field in the Chernobyl New Safe Confinement

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The design solutions and radiation safety regime of the Chernobyl New Safe Confinement which is under construction now critically depend on the parameters of radiation fields in the potential workplaces. Since existing photon field will be substantially modified by metal structures of the arch to be built, Monte Carlo simulation of photon transport and resulting dose rate fields was performed. It was necessary to estimate dose rate fields under the arch in the locations of the main cranes which are intended to provide safe remote deconstruction of unstable structures such as the roof of the existing Shelter Object (SO). It is particularly important to estimate dose rates at this stage in order to avoid possible negative consequences like necessity to implement additional biological protection or to revise and strengthen the power frame arches later at the irreversible stage of construction.

Two scenarios of exposure were considered:

• Scenario 1. The phase after the arch completion (existing Shelter Object structure after the removal of ventilating stack plus the arch including its western and eastern walls);

• Scenario 2. The phase of the deconstruction start (the same as Scenario 1, but with the Unit 4 reactor hall roof removed).

Although detailed reproduction of all components of the arch and SO constructions was not plausible, all significant structural elements were modeled in accordance with technical drawings with some simplifications and assumption about their material composition.

To model the sources we use the data on dose rate measurements performed in 2000 and 2007 over the SO buildings and structures roofs and adjusted to October 1, 2010. Verification was achieved by comparing the calculated and measured values of the air kerma to some benchmark pount in the airspace. Then all the horisontal surfaces were presented as secondary sources of a given photon energy (50, 100, 150, 300, 400, and 662 keV) and isotropic distribution of the direction of emission of gamma rays within a half-space (2π) above each surface.

The partial contributions to the air kerma as formed by individual sources were calculated by MCNP-4B code and then superimposed taking into account available data on the strength of the sources for given locations: for the whole cathcing area at hook level (+77m) as well as for both service and storage garages.

Scenario 2 was implemented by increasing the intensity of the source corresponding to the plane of the reactor hall roof in proportion to the calculated attenuation of the primary sources located inside the reactor hall.

Parameters of secondary sources were specified *a priori* and need further verification resulting in possible correction of model assumptions. Such verification can be achieved by comparing the calculated and measured values of the air kerma for the 3-D grid within the airspace over the SO.

P02.279
Analysis of Dose and Risk Associated with the use of Transmission X-Rays Body Scanner Using Monte Carlo Simulation

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In recent years, X-ray body scanners have been introduced at airports, penitentiaries and other places with considerable movement of people to combat drug trafficking, the entry of illegal materials and terrorism. However, although the application of this equipment in the national security area is indeed relevant, its use has caused a great deal of controversy, especially with regard to the doses absorbed and to the cancer induction risk associated with these exposures. The aim of this study is to use the Monte Carlo MCNPX code and the male adult voxel (MAX) and female adult voxel (FAX) phantoms, to evaluate the absorbed dose, effective dose and cancer mortality and induction risk values associated with the exposures of individuals submitted to transmission X-rays body scanners model BI2002 manufactured by Nuctech Company Limited. The effective dose values were calculated as recommended by the new ICRP 103 and the cancer mortality and induction risk values were estimated through the BEIR VII document.

P02.280
Selection of an Appropriate Air Kerma Rate Constant for Volumetric Se-75 Sources

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Industrial gamma radiography is an effective method of using gamma-emitting radioisotopes to test for cracks, defects and occlusions in pipes and welds without the need for conventional power sources. The process was established more than 50 years ago and has proven to be an important tool for non-destructive testing in remote locations. Historically, ^{192}Iridium, ^{60}Cobalt, ^{169}Ytterbium and ^{170}Thulium have been used in gamma radiography, with ^{192}Iridium and ^{60}Cobalt being the most common isotopes. Recently the isotope ^{75}Selenium has become available for industrial gamma radiography, and its use has been increasing significantly for examining metals ranging from 5mm to 30mm in thickness. The increased use of ^{75}Selenium is due to a lower photon energy range which improves operator safety and produces higher image quality for metals of thicknesses between 5 and 30mm. The purpose of this research was to determine an appropriate Air Kerma rate constant factoring in source encapsulation and to analyze transmission of photons from an encapsulated ^{75}Selenium source through a variety of shielding materials.

The photon spectrum of ^{75}Selenium contains a significant number of low energy photons, less than 12 KeV. Typical source encapsulations, such as ~0.1 mm of titanium or stainless steel, will greatly attenuate these low energy photons. Consequently, the Air Kerma rate from an encapsulated unit-activity source of ^{75}Selenium will be significantly different than for unencapsulated ^{75}Selenium .

Within this study, a Monte Carlo code (MCNP5) was used to determine the Air Kerma constant for a massless 0.64mm diameter spherical source of ^{75}Selenium encapsulated in 0.1mm thick stainless steel. It was determined that an Air Kerma rate constant of 17.7 Gy-cm^2/hr-Ci (0.203 R-m^2/hr-Ci) should be used when estimating exposure rates for an encapsulated ^{75}Selenium gamma radiography source.

The Monte Carlo code (MCNP5) was also used to determine the transmission of photons from a 0.64mm diameter source of elemental ^{75}Selenium (p = 4.0mg/mm^3) encapsulated in 0.1mm thick stainless steel. For computational efficiency, photon emission in this study was confined to a 30 degree cone in the direction of the shielding and the detector (tally cell). Transmission was calculated using an energy deposition tally at 250mm from the source. Transmission through varying thicknesses of iron, lead, tungsten and uranium, ranging from 0mm to 50mm, were calculated.

P02.281
Radiological Dose Exposure comparison study between Monte Carlo codes MCNP and SCALE

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for a Criticality Accident in a Low Enriched Uranium Facility Vault This is a comparison study of the radiological dose exposure and dose contours, as a result of a criticality accident in a Low Enriched Uranium Facility Vault, to the workers within the facility and the public 1km away from the facility. The report summarises the investigation of hypothetical criticality excursions producing 10^{15}; 10^{16}; 10^{17} and 10^{18} fissions.

The concrete facility and vault was modelled using the Monte Carlo neutronics transport code MCNP and SCALE, assuming a supercritical water moderated U(20) system. In the case of the calculations performed with MCNP, a spherical fissile material was placed at the centre of the facility within the vault, 75cm above the concrete floor. However, in SCALE the fissile material was modelled as a rectangular parallelepiped at the same position. In order to investigate the radiological dose consequence to the worker and member of the public, detector phantoms filled with tissue equivalent material were placed over a range of distances from the vault in the MCNP models. In the SCALE models four point detectors were placed at four positions 1km away from the facility walls and dose contours where produced over the entire facility to determine the dose to the work.

The results show that in the event of a criticality accident within the LEU Facility Vault, the retention by the vault walls is minimal and the total equivalent radiological dose during such an event could potentially lead to severe deterministic effects and possible death to the worker. However, the calculated dose to the public was found to be insignificant when compared to the 1mSv regulatory limit.

Both codes show good agreement for the calculated radiological dose exposure the worker and member of the public. It is therefore recommended that further consideration be taken into account for the materials of construction of the vault to minimise the potential radiological dose to the worker in the event of a criticality accident and consideration be taking to mitigate against exposure to personnel in close proximity of the vault and facility.

P02.282
Simulation of the Influence of the ISO Water Slab Phantom on the Neutron Field of a Calibration Source

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At the accredited PSI calibration laboratory neutron reference fields traceable to the national standards of the Physikalisch-Technische Bundesanstalt (PTB) in Germany are available for the calibration of ambient and personal dose equivalent (rate) meters and passive dosimeters. Personal dosimeters are irradiated under reference conditions on the ISO water slab phantom. Detailed MCNPX models of the irradiation facilities are used as simulation tools for the characterization of the radiation fields. In this work the Monte Carlo models were used to determine the influence of the presence of the ISO water slab phantom on the neutron field of a ^{252}Cf and a ^{241}Am-Be source. In particular the dose build-up at the phantom surface due to backscattered neutrons was investigated as well as the homogeneity of the dose at the phantom surface and the modification of energy spectrum due to the presence of the phantom. Furthermore the influence of backscattered radiation from the room on these effects was quantified. In one meter distance from the ^{252}Cf source a dose build up of 10% in the room was obtained. The useful area for dosimeter irradiations in that case was determined to be a 22 x 22 cm^2 square in which the dose rate varies by less than 2%.

P02.283
Monte Carlo Simulation of Radiation Leakage and Design Optimisation for Doors and Doorframes of X-Ray Facilities

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Purpose: The objective of this study was to evaluate the radiation leakage behind the shielded doors of x-ray facilities and to optimise the design within the practical construction considerations.

Materials and Method: Monte Carlo simulations were used to obtain radiation leakage visualisation maps and also to evaluate radiation dose rates at different positions behind various shielded door and doorframe designs. The design alterations in the iterative optimisation process were made taking into account the relevant construction standards.

Results: The inter-comparisons yielded designs with significantly reduced radiation leakages. Dose rate reductions to as low as about 50% were achieved. The results showed that leakage contribution may dominate the radiation transmission through the core door lead thickness. Once radiation leakage was minimised, radiation leakage from the gap between the door and the floor persisted as the dominating contribution. The Monte Carlo leakage visualisation maps illustrated the anisotropic nature of the radiation leakage behind the shielded door.

Conclusions: Careful shielding design improvements could result in significant dose rate reductions. The results relating to leakage visualisation maps indicated that when evaluating the practical significance of the door / floor gap, the higher dose limits for the feet and ankles may form an important consideration.

P02.284
Comparison of Radiation Shielding Requirements for Ir-192, Co-60 and Yb-169 HDR Brachytherapy Sources Using Monte Carlo Simulations

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Purpose: To compare the radiation shielding requirements for ^{192}Ir, ^{60}Co and ^{169}Yb HDR brachytherapy applications.

Materials and Methods: Monte Carlo simulation was used to obtain ^{60}Co, ^{169}Yb and ^{192}Ir broad-beam transmission data through lead. Furthermore, the expected dose rates behind the concrete primary barriers and the shielded door (with a short maze) for a typical ^{192}Ir HDR Brachytherapy treatment room facility were compared to facilities where the source was replaced by equivalent ^{60}Co and ^{169}Yb sources.

Results: The primary barrier lead thickness required for the ^{60}Co source was found to be about five HVLs higher than that required for the ^{192}Ir source whilst for the ^{169}Yb the thickness reduction was found to be about three HVLs. For a typical lead door at the end of a short maze, the dose rates were found to about 4.5 times higher for the ^{60}Co source and 10% lower for the 169Yb source in comparison with an equivalent ^{192}Ir source.

Conclusions: Selection of ^{169}Yb source over ^{192}Ir and ^{60}Co sources would afford significantly less massive direct shielded doors. For facilities with a typical maze, the ^{169}Yb source does not afford a significant saving on the shielding thickness requirement for the door.

P02.285
Calculation of Calibration Factors and Minimum Detectable Activities in the Lung of Radionuclides Released in the Case of a Nuclear Power Plant Accident

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Assessing the intake of radionuclides inhaled after an accident in a nuclear power plant or after the intentional release of radionuclides in public places is necessary for the dose calculations for members of the public and for emergency response teams. High energy gamma emitters in the lung may be readily detected and quantified by methods of in vivo counting. However, the physical lung phantoms developed for calibration purposes are mostly for low energy gamma emitters, such as members of the ^{238}U, ^{232}Th and ^{235}U series and ^{241}Am. Whole body phantoms such as the BOMAB phantom are available for the higher energy radionuclides, but physical lung phantoms containing these radionuclides are not widely available. In this paper, the Monte Carlo program Visual Monte Carlo was used to simulate the photon emission of a number of high energy photon emitters in the lung so as to calculate the calibration factor for the lung geometry, and to calculate the minimum detectable activity (MDA) of the radionuclide in the lung for a broad energy germanium detector in a low level counting room such as a whole body counter. It turns out that most of the radionuclides evaluated including ^{95}Zr, ^{95}Nb, ^{124}Sb, ^{134}Cs, ^{137}Cs and ^{192}Ir have a MDA of around 10 Bq in the lung, with ^{106}Ru having an MDA of around 40 Bq for this geometry.

P02.286
Thyroid Screening Of Members Of The Public With Portable NaI Detectors After A Radionuclide Release From A Nuclear Power Plant

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After an accident in a nuclear power plant or spent fuel pond with releases to the environment, members of the public with possible internal contamination with radioactive isotopes of iodine should be screened so that those cases where a more detailed evaluation and medical follow-up is necessary may be identified. In the case of the screening of large numbers of the public, this may be performed with a quick measuring protocol using hand held NaI based detectors giving results in cps. The screening geometry was simulated using the Monte Carlo code Visual Monte Carlo, and the results showed that for a geometry with the NaI detector in contact with the skin in front of the thyroid, the interference of the gamma radiation coming from the associated radionuclides such as ^{137}Cs and ^{134}Cs deposited in the lung and other organs is sufficiently low to allow screening criteria to be established. The screening criteria were developed for adults based on the ICRP reference phantoms and also on a 8-year female, a 11-year male and a 14-year male phantom.

P02.287
Transformation of the Normal Distribution for Monte Carlo modeling of regions of Adult trabecular bones for use in Computational Models of Exposure

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One of the biggest challenges in numerical dosimetry is to estimate the absorbed dose by the radiosensitive soft tissue of the skeletal inside the cavities of trabecular bone. These tissues are formed by hematopoietic cells of RBM (Red Bone Marrow) and osteogenic cells located on the endosteal surfaces of trabecular bone, called BSC (Bone Surface Cells). The greatest difficulty in evaluating of the absorbed dose in RBM and BSC is to represent realistically the structure of trabecular bone. Since 2006, members of the Research Group on Numerical Dosimetry (GDN/CNPq) publish papers on this subject. The bone dosimetry presented so far is based on the transport of radiation through voxels of trabecular bone obtained from real micro-CT images of five parts of the adult skeleton: skull, spine, rib/sternum, pelvis and femur. One of the difficulties it has observed is the obtaining of these real images, which involves appropriate acquisition machines and ethical questions that could be avoided if the images were virtual. Another difficulty is of computational nature: the *trabeculae* of human bones have linear dimensions of about 0.1 mm while the finest anthropomorphic simulators used in dosimetric evaluations are typically made up of cubic voxels with edge of about 1 mm. Thus, a voxel of these phantoms corresponds to a cube of 1000 voxels in the micro-CT images! This work presents a Monte Carlo method to obtain synthetic images of regions of trabecular bone in adults. The method is based on the standard Gaussian probability density function (pdf), modified by a transformation that moves its maximum over its domain, it changes its intensity and the width of the curve. Using a programming language that provides a good uniform random number generator, it can implement a transformation method of uniform pdf in normal pdf (for example, the Box-Muller method) and then transform normal samples as normal translated. In this work, these steps were implemented to obtain and analyze curves of the count of clusters (set of bone voxels) along the three dimensions of a volume generated on the computer as function of the size of these. Adjusting these charts served as the basis for obtaining the virtual bone samples in appropriate dimensions. So, when the program ends, the sample for a given bone is ready to be transformed into text file that is used as input in the exposure computer models used by the GDN. This was done for the EGSnrc/MSTA model where MSTA is the acronym for the adult male voxel phantom in the standing position of the Department of Nuclear Energy, Federal University of Pernambuco. The results for internal sources are presented and discussed in this paper. Adjustments in the method are in progress, but the dosimetric results are already promising.

P02.288
Measurements of Air Kerma as function of potential in X-ray tubes for estimates standard quantities used for dosimetric evaluation

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Computational Models of Exposure (CMEs) are tools that simulate situations in which irradiation occurs in a given volume. Some of these CMEs have already been produced by the authors both in internal and external dosimetry. From 2008, were published versions of CALDose_X, computational tool developed to organize and present simulations performed with the phantoms of the adult voxels developed at Nuclear Energy Department of Federal University of Pernambuco (DEN-UFPE). The software has been a useful tool for researchers' worldwide due to be a friendly user, contain estimated data with great accuracy and be produced in C #, a modern programming language object-oriented. The CALDose_X presents results to the user who requests information about the dose distribution in a given region of a radiological examination in the format of conversion factors between absorbed dose and a standardization quantity. Information about distribution of absorbed dose need more input from the user: he must inform the software a measured value of the standard quantity to be used. In this work it is raised a curve K x V (K = INAK/mAs; INAK: INcident Air Kerma; KERMA: Kinetic Energy Released per unit Mass, mAs: Work load of the X-ray tube, V: Potential of the tube) to be inserted in CALDose_X in order to obtain the absorbed dose distributions for various examinations. The collection of points obtained is called *yield curve* of the X-ray machine used. These types of data should be collected whenever a machine is installed or undergoes maintenance. The curve was obtained in the X-ray laboratory of the Regional Center of Nuclear Sciences of the National Commission of Nuclear Energy (CRCN-NE/CNEN) using an X-ray equipment (HF320 of Pantak) and a measurement system consisting of a chamber ionization RC6 of Radcal, calibrated in terms of INAK to the radiodiagnostic qualities (IEC61267), and a Keithley 6517A electrometer. The focus-camera distance used was equal to 1 m. The points (V, K) were obtained for potentials ranging from 50 to 120 kV. It was applied the statistical technique of linear regression for the potential function $K=B.V^A$, transformed to $\log(K)=\log(B)+A.\log(V)$, so that the user can enter the potential and the work load of physical examination required to then the CALDose_X calculate the INAK using the *yield curve*. Thus, values of absorbed dose in the region of the examination can be saved to a text file. As CALDose_X has a theoretical *yield curve*, the results of the curve measured in this article were comparatively analyzed. It could say that the experimental arrangement used for the measurements was appropriate, because the yield curve measured for the type of designed X-ray machine, results in a dose distribution in the region of the simulated exam in accordance with the theoretical distribution the software.

P02.289
Review of Dosimetric Models of the Extrathoracic Airways for Internal Photon Emitters

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In the human respiratory tract model of ICRP Publication 66, for incorporation by inhalation of radioactive ma-terials emitting photons, the values of specific absorbed fractions (SAF) have been calculated using the stylized phantom for dosimetric estimation in extrathoracic tissue, assuming surrogate tissue source and target that can give an estimate of the SAF. In this study, we found the SAF values for photons using the computa-tional phan-tom reference male of the ICRP 110, and the Monte Carlo transport code MCNPX. The source regions consid-ered are ET1, ET2 and LN_{ET} with a total of 30 target organs. The results were compared with approximations of ICRP 66 and other calculations available in literature. The use of surrogate regions shows good behavior for the combination of SAF (←ET1 ET1) and SAF (← ET2 ET2), but other combinations are only an approximation, where the differences of SAF values are significant.

Keywords: Monte Carlo method, SAF, Reference Computational Phantoms.

P02.290
Experimental Verification of TPS Software and Tabulated Data for Blocked Fields

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Objective: To experimentally verify the accuracy of the Eclipse® treatment planning system (TPS) and the Tabulated commissioning dosimetric data for blocked fields.

Method: In-phantom measurements were made using Semiflex® ion chamber in the isocentric setup at 10cm depth with varying blocking for each of the chosen field sizes. The blocking was achieved by means of multileaf collimators (MLCs). The readings obtained were compared with those from Eclipse® calculation and Tabulated dosimetric data calculation.

Results: The experimental values agree well with Eclipse® calculation and Tabulated data calculation. However, the deviation was found to increase with increased blocking, with the greatest being 3.4% and 4.2% for Eclipse® and Tabulated data respectively.

Conclusions: Head scatter reaching the ion chamber decrease with increased blocking. The Varian's Eclipse TPS and the Tabulated data are accurate in their calculation within acceptable limits of error, except for increasing smaller apertures for large field sizes where the deviation for experimental values from the Eclipse® and Tabulated values increase.

P02.291
The Interaction of Natural Background Gamma Radiation with Depleted Uranium Micro-Particles Located Deep in the Human Body

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The biological effects of ionising radiations are mainly produced by the interaction between secondary electrons and the genetic components of living cells. An interesting radiological situation arises in the case of the absorption of relatively low energy x-rays and gamma rays, of energies below about 250 keV, by high atomic number particles since the absorption of the photon energy is proportional to the third to fourth power of atomic number. In this situation highly ionising short-range photoelectrons are produced, which will cause a dose enhancement in the immediate vicinity of the particles. Some protagonists have asserted that the dose enhancement that uranium particles in the body would produce upon exposure to naturally occurring background gamma radiation would be a factor of 500 to 1000, and that this would then contribute a significant radiation dose in addition to the dose received from the radioactivity of the uranium (Tickell, New Scientist, 195:8-9, 2008). The present study was a continuation of a recently reported study (Pattison et al, J. Roy. Soc. Interface 7:603-11, 2010) whose aim was to obtain an accurate estimate of the dose enhancement due to uranium micro-particles in the human body using the Monte Carlo code EGSnrc. A cylindrical body, 32 cm diameter and 60 cm long, made from ICRU four-element tissue was exposed to isotropic natural background gamma radiation. The dose enhancements in the immediate vicinity of micron-sized cylindrical uranium particles at three different positions in the body were calculated, and found to be generally less than 10. In the present study, enhancement factors were calculated as a function of distance from the micro-particles over an extended distance and the energy fluence spectra for the photoelectrons was determined both inside and outside of the micro-particles, again using the code EGSnrc. Only a 10 micron sized uranium particle located in the centre of the body was examined in this study since this was found to produce the largest dose enhancement in the earlier study. The range of the photoelectrons in the tissue, as estimated from the dose enhancement against distance curve, was about 40 microns. This curve was roughly exponential as expected for poly-energetic electrons. The mean energies of the photoelectrons in the uranium particle and in the immediately surrounding tissue were found to be 38 keV and 50 keV, respectively, while the total photoelectric energy fluence in the immediately surrounding tissue was only 14% of that in the uranium particle itself. These mean electron energies correspond to ranges of the photoelectrons in the uranium particle and tissue of 13 micron and 39 micron, respectively.

P02.292
Shielding Evaluation for a Radiotherapy Bunker by NCRP 151 and Portuguese Regulation on Radiation Safety

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NCRP Report No. 151 (2005) concerned with radiation safety is one of the most suitable documents for structural shielding design and evaluation in contemporary radiotherapy facilities. For radiation safety purposes, the barriers thicknesses must be designed to attenuate the primary, leakage and scatter photon radiations. The purpose of this work was to establish a comparison between the primary and secondary barriers thicknesses calculated according to NCRP 151 recommendation and the current Portuguese regulation (DL 180/2002), which recommends the German Standard DIN-6847 (1977) for a radiotherapy bunker with a linear accelerator.

The calculation methods performed are based on the tenth-value layer (TVL) concept, and in this study were used the TVL values recommended in each norm for the same shielding material, the ordinary concrete. For both standards, the calculation was carried out for a treatment room with a Elekta-Synergy linear accelerator, with maximum nominal energy of 15 MV, and for three-dimensional conformal radiation therapy treatment technique.

The results obtained by both standards show that the maximum deviations for the primary and secondary barriers were up to 16% and 19%, respectively. When using the same occupancy and use factors, the deviations between both norms for the primary and secondary barriers were up to 5% and 29%, respectively.

Some reasons for the discrepancies between both methods are the TVL values. Differently from DIN-6847, the NCRP´s TVL is a function of the energy and radiation scatter angle. Another source of discrepancy is that DIN methodology takes into account the neutron contribution for the secondary barriers.

P02.293
Quantification of the Effect of Respiratory Motion on Efficiency Calibration for Internal Dosimetry

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Introduction: Partial body counting is applied for the detection of low energy photons of incorporated radionuclides localized to certain organs. To exactly quantify incorporated activity calibration measurements are performed using computational anthropomorphic phantoms. Many phantoms, such as the current ICRP reference phantoms, are based on single, segmented CT datasets which are generally assessed at full lung capacity. This ignores normal respiratory motion due to tidal breathing during measurements and introduces a systematic error to efficiency calibration.

Methods: A series of voxel phantoms was created based on a 4D-CT dataset of a human male thorax with tidal breathing motion. The dataset contains eight equidistant time steps and has a resolution of about 0.7x0.7x2.0 mm^3. In consideration of reproducibility and efficiency in segmentation, the phantoms were subdivided into seven segments: air, lungs, liver, fatty tissue, muscle tissue, cortical bone and soft tissue. Based on these phantoms lung counting scenarios were created using validated models of two HPGe detectors of the partial body counter at Karlsruhe Institute of Technology (KIT). The detector positions for all phantoms were adjusted to the reference position at full inspiration. Radiation transport simulations were performed with MCNPX 2.7 covering 16 photon energies from 22 keV to 1.4 MeV.

Results: To evaluate the simulation results, computed efficiencies at full inspiration were related to the efficiencies integrated over all time steps. This leads to an underestimation over a whole respiratory cycle of 0.5-1.5% depending on photon energy. It was also shown that the reduction to seven segments introduces an insignificant error of less than 1.0%. However, the uncertainty of the actual segmentation, presumably caused by interactive segmentation of liver and lungs, was estimated to be 2.6%.

Conclusion: These results suggest an insignificant overestimation of incorporated activity for lung measurements. Therefore, the variation of efficiency due to respiratory motion can be neglected when using a calibration phantom at full inspiration of tidal breathing. However, when using single CT datasets (which are assessed at full lung capacity) the effect is expected to be larger.

P02.294
Comparison Between Simulation and Measurement of Activation Products in High-Energy Medical Linear Accelerators

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The generation of activation products has been simulated using Geant4 Monte Carlo (GMC) code at the isocenter of a medical linear accelerator during irradiation of a high energy photon beam with 20 x 20 cm^2 field size. Important isotopes, as expected from the geometry used in the simulation, were ^{28}Al, ^{56}Mn, ^{54}Mn, ^{62}Cu, ^{64}Cu, ^{187}W, and ^{24}Na. Calculated dose rates from isotopes using GMC code will be compared with published measured isotope-specific dose rates.

Air activation products will be identified using gas-tight Marinelli beakers and a portable gamma spectrometer at the isocenter of a medical linear accelerators shortly after termination of a high energy photon beam irradiation with 10 x 10 cm^2 field size. Measurements of air activation products will also be compared with calculated results using the GMC code.

The components of the linac simulated with Geant4 in the present work did not include the head shielding, the bending magnet and steel structure. Accordingly, the expected results, the measured values will be higher.

Keywords: Activation, Geant4, spectroscopy, medical accelerator

P02.295
Proton Beam Characterization Using Monte Carlo Simulation Technique

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The Monte Carlo (MC) technique for the simulation of radiation transport is an essential tool in proton radiation therapy. For example, the method has been used from improving dose calculation models for clinical treatment planning to building a comprehensive program for beam commissioning and routine quality assurance [Paganetti 2004]. Despite of many advantages it offers, due to the passive scattering beam delivery system of proton therapy, secondary neutron energy spectra are found inside the treatment unit leading to neutron absorbed dose in patients. The objective of this study is to study characteristics of proton beam particularly beam scattering and production of secondary neutron using Monte Carlo code MCNPX. We will present data from MCNPX for proton interactions with scattering components and estimate neutron energy fluence. Furthermore, we will calculate proton and neutron absorbed dose and dose equivalent specifically in tissue equivalent materials and present the comparisons of calculated proton dose with measured data from gel dosimetry and ion chamber systems. The results of our study are of relevance to proton beam commissioning, quality assurance of proton beams and further designing of proton treatment facilities.

P02.296
Modeling of Spontaneous Particle Sputtering from Plutonium Dioxide Material

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From the very beginning of the first radioactivity studies investigators have observed spontaneous displacement of some radionuclides. The subject of this work is focused on ejection of plutonium particles from the radioactive source material (plutonium dioxide) due to alpha-decay of the material. This process, termed as internal sputtering, is of great importance for radiation safety because such materials turn out to be a constant source of air contamination with nanodispersed alpha-emitting particles. Besides that fact, due to the same processes inhaled radioactive aerosols can transform in new forms with radical change of its transport patterns in the body and dose coefficients as well. From the very beginning of the first radioactivity studies investigators have observed spontaneous displacement of some radionuclides. The subject of this work is focused on ejection of plutonium particles from the radioactive source material (plutonium dioxide) due to alpha-decay of the material. This process, termed as internal sputtering, is of great importance for radiation safety because such materials turn out to be a constant source of air contamination with nanodispersed alpha-emitting particles. Besides that fact, due to the same processes inhaled radioactive aerosols can transform in new forms with radical change of its transport patterns in the body and dose coefficients as well.

At present work the particle sputtering has been studied numerically by Monte Carlo calculation. Processes of transport of ions in matter were calculated using SRIM 2010 software. Resulting sputtering yield amounted to 0.98 plutonium and 3.23 oxygen particles per decay. For real bulk plutonium dioxide with density of 11.5 g/cm^3 and specific activity of 2 GBq/g this will correspond to $3.40.10^5$ cm^{-2}.s^{-1} for plutonium particles and $1.11.10^6$ cm^{-2}.s^{-1} for oxygen particles. Mean energy of sputtered particles amounted to 366 eV for plutonium and 120 eV for oxygen, some particles appeared to have high enough energy (60 keV for plutonium particles maximum energy and 20 keV for oxygen).

The main uncertainty in sputtering yield was formed by values of surface binding energy for compound elements. Thus, deviation of these parameters in the range from –50% to +50% of its most likely values resulted in changes of sputtering yields within the limits from +50% to –25%, respectively. Other parameters, such as displacement energy and lattice binding energy, showed no significant influence on resulting values. Alpha particles formation also has no essential impact on surface sputtering and the effect is entirely determined by heavy uranium recoil nuclei.

P02.297
Dose Rate Distribution from a Standard Waste Drum Arrangement

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The evaluation of the dose rate distributions from radioactive sources, together with the specific detector locations with respect to those sources, in many cases presents a significant analytical challenge. With the exception of a few, simple source-detector geometries, it is not possible to find an analytical expression for these dose rate distributions as functions of detector location.

In this paper, the dose rate distributions due to the arrangement of radiological waste drums on a standard wooden transport and storage pallet are investigated. The dose rates at various distances, ranging from 5 cm to 20 m, from the waste drum assembly have been evaluated by Monte Carlo calculations. The simulation data are fitted by smooth analytical functions in two independent regions, the waste drum near zone, where a logarithmic function best described the data, and the far zone, where the functional dependence closely approximates the $1/r^2$-law for point sources.

P03.60
IRIS: A Comprehensive Approach for Information Management and Automated Administration

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Several databases had been gradually developed for information management in different practices by Iranian Nuclear regulatory Authority (INRA) in late 90s. INRA then launched a project for developing a unique and comprehensive information management system, i.e., Iranian Regulatory Information System (IRIS) in 2002, about two years before introducing the Regulatory Authority Information System (RAIS) by IAEA. While RAIS were experiencing its pilot stage collecting feedbacks from using countries, IRIS went under serious commissioning and operation getting slightly matured and optimized according to the national requirements. Moreover, RAIS as the IAEA's minimum expectations of a regulatory information system inspired INRA.

IRIS is more than a simple database today. It provides several features as follows.

1- A comprehensive database for sources, licensees, registries, notifications, workers, doses, accidents, equipment, etc.

2- Web access for applicants and users not only as an informative media but also as a root for application and reporting to the regulatory authority. Users and public can access to the latest regulations, procedures, and news in ionizing and nonionizing radiation context.

3- It also benefits of an office automation that greatly facilitates and expedites the paper processing within INRA. It allows a faster and more precise investigation of applications, identification of noncompliances, and enforcements.

4- In contrast to the traditional version of RAIS, there is direct links between licenses and resources in IRIS. In other words, there is a direct and quick access to sources, radiation workers, equipment, etc. of a licensee through the registered license of an applicant.

5- The fifth and exclusive feature of IRIS is an evaluation system for one of the most high-risk practices, i.e., industrial radiography. This feature enables INRA to quantitatively evaluate the safety performance of industrial radiography companies and to more efficiently enforce the law.

INRA believes that the convenient communication between users and the regulatory authority provided by IRIS plus its informative nature have been improved the effectiveness of the regulatory control over radiation sources and users. Furthermore, the features such as embedded evaluating machine (item 5 above) into IRIS have made it more powerful for analytical and enforcing purposes. Currently, it includes the data of about 8,000 users and facilities, 24,000 radiation workers, 4,400 sealed and 550 unsealed sources, 8,800 radiation generators, and 1,100 associated equipment. This paper describes the structure of IRIS which has been developed according to the INRA's structure and duties and also IAEA's recommendations. It also presents the supplementary features of IRIS and explains their advantageous features in administration of radiation sources and practices in the country.

P03.61
Some Aspects on the Nuclear Regulatory Issues in the Republic of Moldova

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The following main normative forms the domestic legal environment for nuclear and radiological activities regulation:

• Law No 1163-XIV from 26.07.2000 On export-import-re-export and transit of strategic goods;

• Law No. 111-XVI from 11.05.2006 On safe deployment of nuclear and radiological activities;

• Law No. 10-XVI from 03.02.2009 On supervision of public health;

• Contravention Code of the Republic of Moldova;

• Criminal Code of the Republic of Moldova.

For implementation of the above mentioned laws, by the Government Decisions were approved or updates a number of regulations and norms about: structure and staff limit of the National Agency for regulation of nuclear and radiological activities (further Agency); national system of control of export, re-export, import and transit of strategic goods in the Republic of Moldova; national network on observation and laboratory control of environment pollution with radioactive, poisonous, high toxic substances and bacteriological means; radiation protection basic norms; hygienic rules and requirements; national register of radiation ionizing sources and of authorized physical and juridical persons; authorization of nuclear and radiological activity; control and state supervision of nuclear and radiological activities; on management of radioactive waste etc.

According to the law "On safe deployment of nuclear and radiological activities" the Agency is established under the Ministry of Environment with necessary financial and decision independence in the matter. In general terms the Agency is responsible for the authorization, review on legal aspects, inspection and enforcement subjects. A specialized inspection is subordinate direct to the Director, which is the Main State Inspector from the office and appointed or withdraws by the Government Decision.

Very important area as radioactive waste management has been improved in the last years through upgrading the radioactive waste repository (RADON facility type). In present the facility pre-treatment (segregation), treatment and conditioning of solid and liquid waste. The environmental monitoring surrounding the repository has been established too. A new waste storage for the low level waste was constructed and the physical protection system was putting in to operation recently.

In 2008 was initiated the new National Register of ionizing sources, which reflect also the categorization of sources in compliance with the IAEA Code of Conduct on the Safety and Security of Radioactive Sources and IAEA Safety Guide # RS-G-1.9. The Agency manages this Register of radiation sources which involves information regarding sources, authorization, licensees and operated controls. Finally, it is necessary to mention, that development of activities of the Agency were possible effective by many side sustaining technical assistance from the IAEA Department of Technical Cooperation, USA NRC, USA DOE and Sweden STRALSAKERHETSMYNDIGHETEN (SSM) and Romanian CNCAN.

Keywords: Republic of Moldova, regulatory framework, authorization of radiological and nuclear activities.

P03.62
Proposed Methodology for Standardization on Evaluating Radiological Protection System Implementation in Regulatory Inspections: One Researching Agenda

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This paper's main goal is to establish a researching agenda in the Area of Evolution and Implementation of the System of Radiological Protection, proposing the introduction of a standardization methodology that produces, to the regulatory inspections, a numerical-accurate score.

Regulatory inspections in radioactive installations are developed worldwide, based on IAEA safety standards, to check if the radiation protection system is implemented. Although the regulating safety is a national responsibility, each country has to fulfil its national and international undertakings and obligations, as to guarantee that the radiation risks to workers, to the public and to the environment have to be assessed and, if necessary, controlled.

The proposed methodology is supported in a bibliographical and documental researching, such as: IAEA Safety Standards, books, guides, recognized authors on radioprotection safety area, Brazilian rules, guidelines and inspection forms of safety and radiation protection, developed by CNEN (Brazilian Nuclear Energy Commission) etc.

To achieve its goal, the proposed methodology has been developed in steps, as follows: (1) Analyse existent bibliographical sources, to guarantee the state of the art evaluation, in terms of radiation protection requirements; (2) Define main topics to be evaluated in a regulatory inspection; (3) Split each main topic, producing a tree modelling: this permits reproducing as many levels as the detailing of the main topic requires; (4) Identify single-statements, which must have one straight question format, that will be argued during the regulatory inspection; (5) Produce one numerical-accurate score, calculated by one math modelling, that considers the weight established for each of those radiological protection requirements, based on the risks and criticality; and (6) Define clear distinctions between recommendations and non-conformities identified. The main results, to be achieved by this proposal methodology of standardization on evaluation of the radiological protection system implementation, are: (1) Produce a score for each radioactive installation inspected in Brazilian Industry, (2) Establish a national ranking for each area of radioactivity applications, (3) Develop ranges of acceptance to classify each installation based on its inspection score, (4) Permit the Regulatory Agency to proceed the: (4.1) Review of the inspections frequency based on follow-up of previous results , (4.2) Produce automatically the action plan for each inspection, based on a data-base of the Brazilian Safety Rules (4.3) Evaluate the improvement of each installation's radiological protection system, based on its comparison with a chronological sequence of the previous inspections' scores, (4.4) Penalize those installations that were scored into a non-acceptable band of the pre-defined range.

P03.63
Implications of ICRPS Evaluation of Tissue and Non-Cancer Effects

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The concept of tissue reaction was introduced in ICRP 103 and subsequently developed in the ICRPs January 2011 evaluation of epidemiological data on early and late effects on tissues and other non-cancer effects. Particular attention is given to effects on the lens of the eye and cardiovascular (CV) effects. For these tissues, the ICRP has proposed a threshold dose of 0.5 Gy and that that no credit should be given for fractionated or protracted doses The ICRP interpret a “threshold dose” of “around” 0.5Gy (irrespective of the rate of dose delivery) as equivalent to an annual dose of 12 my/year for a working life of 40 years. This raises a question of whether or not the ICRP will move toward a reduction in the annual dose limit. Irrespective, the lower threshold dose may well lead to new requirements to manage doses in the case of radiation incidents and medical exposures such as those from interventional radiology. This paper examines selected aspects of the ICRPs review and discusses the possible implications for concepts such as trivial dose , threshold, LNT and possible practical implications for the ICRPs system of radiation protection

P03.64
Recent Experience Gained in Radiation Protection Activities in Egypt

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The radiation protection and consultation and services project (RPCSP) of Atomic energy Authority (AEA) of Egypt was initiated 20 years ago to offer and consultations and services to non AEA workers . For the last two years, the following Radiation Protection Services were counted such as :-

1- Transport of radioactive sources not only from Airport to working storage sites but also from storage sites to Airport.

2-External dosimetry using Film badges and TLD to radiation workers at Hospitals, companies , hotel and others.

3- Internal dosimetry using Whole Body counters to radiation workers at nuclear medicine laboratories and companies in abnormal situations

4- Radiation monitoring around radiation facilities such as X-ray rooms, nuclear engineering laboratory, mounted sources at companies,

5- Testing and calibration of radiation measuring devices . Furthermore, assist in upgrading TLD system and radiation consultations was offered upon request.

P03.65
Medical Physics in Guatemala, Central America (History)

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A brief description of the medical physics profession in Guatemala is presented herein. As this profession constitutes a support to medicine, the historical development of radiology and radiotherapy in Guatemala and the most important events in the world that had a repercussion on this country such as the establishment of the International Commission on Radiation Protection (ICRP) and the International Atomic Energy Agency (IAEA), among others are briefly described.

The legal instrument that recognizes the profession of medical physics is also presented up to the approval of the Radiation Safety Bylaws and the guide that establishes the requirements for the recognition of such profession by the Energy General Directorate.

P03.67
Comparison of Individual Doses from Risk Assessments to Doses from National Registry

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Relevant available data obtained through licensing process were compared to data from national dose registry. In Slovenia, a risk assessment document for each practice has to be elaborated as a part of a licensing procedure. Risk assessment document is drawn up by licensee in cooperation with an approved radiation protection expert. Document has to describe the radiation practice and radiation work condition, and anticipated individual annual dose has to be assessed, taking into account the data on dose rates, work load and other relevant information.

Anticipated annual individual doses for each practice were analysed and compared with dosimetry data. Results show that in general individual doses are kept below the maximal anticipated value; only in some work sectors few percentages of workers has exceeded it. Dental radiology was identified as a work sector with the largest fraction of workers exceeding anticipated values.

It is considered that in most cases maximal anticipated values for individual dose is a good estimation of an upper point of optimisation process.

Such approach is “practice related” rather than “source related”. In simple radiation practices where a single source of radiation is prevailing or where many identical sources are involved in radiation practice the distinction is not relevant. In complicated cases where multiple sources are contributing to a workers dose (e. g. nurse is taking care of brachytherapy patients as well as patient receiving iodine thyroid treatment) dosimetry data can not be compared to source related dose constraints.

Analysis indicates that certain aspects of licensing procedure and dosimetry data management could be improved. Categorisation of workers to work sectors could be improved to match categorisation of radiation practices in licensing procedure. Intention of ESOREX and UNSCEAR to propose international agreed categorisation of work sectors could be beneficial also for comparison of other relevant radiation protection data like dose constraints, action values, etc. at international level.

P03.68
Radiation Protection in Using the Mobile Hot Cell for the Conditioning of High Activity Sealed Radioactive Sources

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The mobile hot cell for the conditioning of high activity radioactive sources was designed, manufactured and commissioned by the South African Nuclear Energy Corporation (Necsa). The primary objective of the hot cell is to assist in the recovery and conditioning of disused and orphaned high activity sealed radioactive sources. The mobile hot cell is used in countries with no infrastructure to handle high activity sources such as available hot cells, etc.

Most of the disused high activity sealed radioactive sources in these countries; originate from teletherapy machines, gamma irradiators, brachytherapy units, and agricultural research units. The hot cell was designed to handle a maximum activity of 3.7E+13Bq (1000Ci) Co-60. However, recent conditioning operations undertaken have demonstrated that the mobile hot cell can handle much higher activities with ease. The higher activity of course requires adaption of the radiation protection control requirements.

The hot cell consists of a biological shield filled with river sand sandwiched between metal plates and a viewing window filled with 50% zinc bromide solution. The mobile hot cell was designed to provide optimal shielding to ensure that doses are kept ALARA (As low As Reasonably Achieved) during operations.

This paper discusses the Radiation Protection (RP) measures put in place during the conditioning of high activity sealed radioactive sources. This includes the personnel dosimetry requirements as well as the specific radiation protection controls before and during the handling of the high activity sealed radioactive sources which have activities that range from a few GBq up to TBq and higher activities.It also examines the challenges and lessons learned during completed conditioning missions. A conclusion is drawn and recommendations are made on how to implement experience feedback from past missions into future operations.

Poster sessions C-D: Area 3

P03.69
HERCA Statements on the Justification of X-Ray Body Scanners and on the Regulatory Status of Small Amount of Radioactive Substances added to Lamps

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HERCA is a voluntary association in which the Radiation Protection Authorities work together in order to identify common issues and propose practical solutions for these issues. The HERCA working group on non medical sources and practices (WG2) covers all radiation protection issues concerning the justification and optimization of non-medical applications of ionizing radiation. Two major works for HERCA have been achieved since 2010 following the work of WG2, the first one concerning the justification of full body-scanners using X-Ray for security purposes, the second one concerning the regulatory status of small amount of radioactive substances added to lamps.

During the past months, following some failed terrorist attempts, there has been a significant increasing interest in body screening technologies, particularly for use in airports. On the basis of a report provided by its WG2, HERCA agreed on the very strong need of a common approach for decision making on the use of X-rays body-scanners in Europe, and decided to produce a Statement on this issue. After an intense process of consultation, a final consensus has been reached and the Statement was approved and published in December 2010. HERCA agrees that regardless of the level of dose of ionizing radiation per scan to the concerned individuals, the three principles of justification, optimization and dose limitation must fully apply to the use of all human imaging technologies using ionizing radiation. Other recommendations are addressed in the Statement.

In June 2011, HERCA approved an interim Statement promoting a consistent European approach to the processes of national assessment and regulatory decisions on the use of lamps containing small amounts of radioactive substances. With this aim, the results of national assessments and regulatory decisions on this issue will be shared in Europe through HERCA. As consumer goods are introduced in open markets in Europe, HERCA recognises more generally the need for harmonization of the radiation safety regulation of goods containing small quantities of radioactive material. HERCA WG2 works further on this topic and a complementary Statement is foreseen for the end of 2011.

The purpose of the presentation is to report on these two topics and to present the working methodologies inside HERCA to strive for consensus between the 46 radiological protection competent authorities from 28 European countries represented at its Board.

P03.70
Optimization versus Dose Constraints: a Concept Loses its Way

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The basic message of ICRP 103 was "continuity and stability". Today after extensive redrafting the IAEA Basic Safety Standards on Radiation Protection and the Safety of Radiation Sources and the distribution of a preliminary version of the new European Basic Safety Standards Directive (EU-BSS) the situation looks somewhat different.

Those who want to see "continuity and stability" may find a lot of prove for it. But those who look for a new challenge in radiation protection will find it e.g. in the overemphasis on dose constraints.

According to ICRP the dose constraints serve three purposes:

- exclusion of a solution of the optimization task above a certain dose level,

- avoiding that workers receive high doses just below the dose limit,

- prevention of an exposure above the limits when several sources cause exposures to the same individual.

Dose constraints may be – under certain conditions – a tool in the optimization process. But history of radiation protection practice shows that in most circumstances optimisation without this tool works as well. The above mentioned objectives are also achievable by using other optimization tools or by following ALARA in everyday practice.

However, the revision process of the IAEA BSS, the EU-BSS and the Users' Manual of the International Nuclear and Radiological Event Scale (INES) has shown that the ICRP emphasis on dose constraints as a tool of optimization has deteriorated. The 2008 edition of the INES User's Manual e.g. points out that the exposure of a worker above a dose constraint is a Level 1 event.

The paper will discuss possible negative consequences of this development, warns against a growing bureaucracy in radiation protection and gives hints where to reasonably use the optimisation tool of dose constraints.

P03.71
Implementation of the system of public exposure assessment in Lithuania

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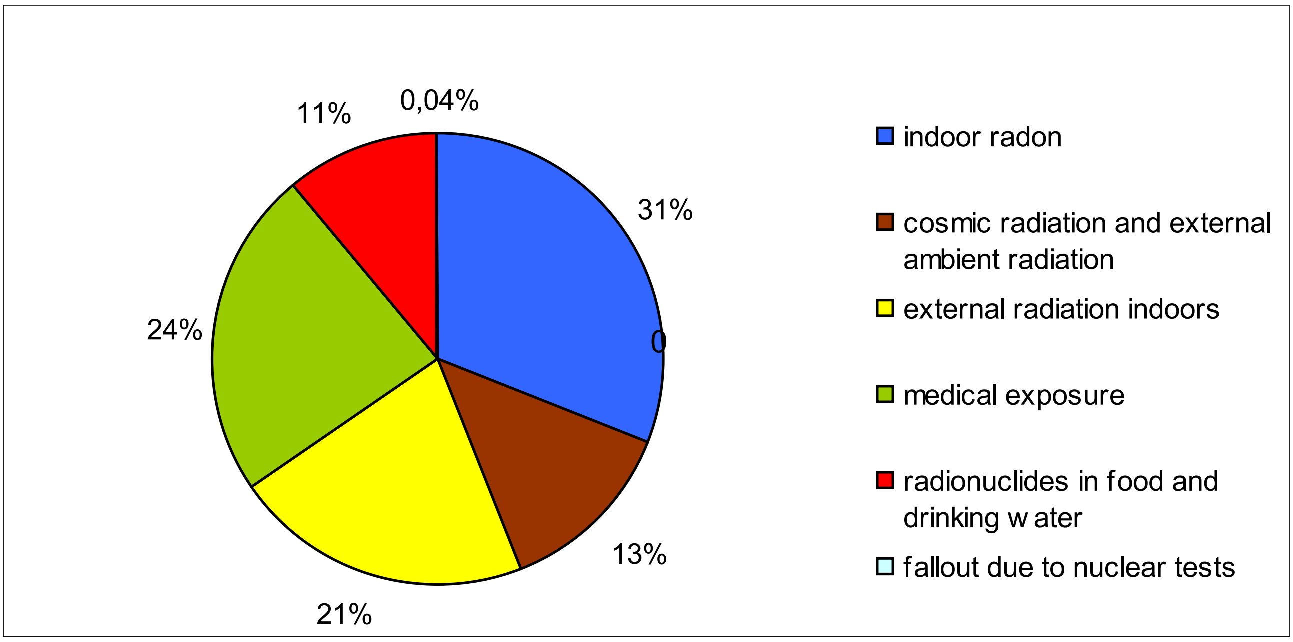
Regarding international regulation doses to public should be estimated due to all possible sources of exposure. Lithuania created a system which includes dose assessment to public from various sources, including natural and man–made radiation.

Radiation Protection Centre (RPC) of the Ministry of Health of the Republic of Lithuania is regulatory body in radiation protection. RPC has experience at least of twenty years in the estimation of doses to public. Public exposure is controlled using infrastructure of radiation protection – starting from State Register of Sources of Ionizing Radiation and Dose, including authorization and inspections at ionizing radiation sources installation sites and by evaluation of doses. Dose evaluation based on the results of radiological investigations of own laboratory of RPC is combined with evaluation of public exposure based on the results from other state institutions – State Food and Veterinary Service, Environmental Protection Agency and on the monitoring results performed at vicinity of Ignalina NPP by operator. At that moment public doses are periodically estimated due sources of natural radiation – indoor radon, radon in drinking water, natural radioactivity in drinking water and food, external ambient radiation. Due to man–made radionuclides food and drinking water monitoring is performed and doses due to those radionuclides are estimated annually. Monitoring of soil, building materials, radionuclides in aerosols, surface water leads to the estimation of public exposure due to radioactivity in that environmental components. Doses for air crew are monitored and reported as well. Doses due to discharges from industry nad medical installations are monitored and dose assessment using general models are performed.

Main source of public exposure in Lithuania is indoor radon which leads up to 1 mSv average annual dose. The next main component is medical exposure, and average annual exposure to member of public due to medical diagnostics using X–ray machines is 0,65 mSv. Other components are much smaller to compare with that indicated earlier. Total average dose to member of public in Lithuania is 2.6 mSv per year. Some of components are indicated in the Picture, by percentage.



P03.72
Evolution of Radiation Protection Trends – the Malaysian Experience

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Radiation Protection has quickly become a radiation industry performance measure, and the emphasis on its reliability has always been part of a strategic commitment. The approach is on better protection of workers and source security, thus emphasising on human factor rather than on technology, and addressing the common missteps of the management. In Malaysia, there are continuous efforts and challenges in further promoting radiation protection and safety. This paper presents an approach taken by Malaysian Nuclear Agency (Nuclear Malaysia) and authority to develop and implement Radiation Protection culture in the growing application of radiation sources in medicine, industry, agriculture and research. Maintaining and improving radiation protection culture is a continuous process. Emphasis is placed on the human factors of performance rather than technology, and addresses the common missteps taken by the management, while suggesting strategies for implementing and strengthening the radiation protection cultures. There is a need to establish a program to measure, review and audit radiation protection performance against predetermined standards. Proper assessment will help to identify the non-compliance of safety culture as well as the deviation of management, individual and policy level commitment, the audit and review of radiation protection program and activities should be preceded.

KEYWORDS: safety culture, safety audit, continuous process

P03.73
Optimization of the Radiation Protection at Operation of Nuclear Objects of the Marine Technology

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The solution of the estimation of the system of radiation protection (SRP) condition at nuclear objects of marine technology (NÎÌÒ) possible through the application of optimization systems. That is why the structural-functional model of SRP has been developed.

In a basis the following generalized structure of SRP is applied:

• organizational subsystem;

• engineering –technical subsystem;

• medical –sanitary subsystem.

The objective function of SRP is characterized by the presence of two components. The first component is determined by the presence of elements that reduce the intensity of the radiation exposure to the personnel. It expands the area of the safe state of source of ionizing radiation (SIR). To increase the limits of safe operation of the IRS the passive elements of SRP are applied, the function of which consists in the absorption of radiation, clearing of the polluted environments and creating insurmountable distance barriers.

These elements of SRP are technical level of the system, basis of which are limits of safe operation. An important role at this level of security is control of radiation parameters, reflecting the effectiveness of passive elements of SRP and allowing to identify transition SIR in area of inadmissible conditions.

The second component includes functions of the elements reducing negative consequences of influence of ionizing radiation on the person.

To reduce the unfavorable impact of IRS on the person active elements of SRH are used, their function consists in limitation of the working time in conditions of influence of ionizing radiation, on the use of individual protective equipment, on the sanitary zoning, on the sanitary-epidemiological supervision and monitoring of the health status of the personnel and the population.

These elements of SRP are considered to be medico-sanitary level of the system, the basis of this system is hygienic norms. On this level of radiation protection the leading role is played by the control of the individual equivalent of the dose of an internal and external irradiation.

The increase of efficiency of SRP considered levels interaction is the basis of its optimization. The substantiation and the choice of the concrete method of optimization can be made on the basis of model's system. It allows to estimate efficiency of functioning SRP that is an important practical task in the field of sanitary-and-epidemiologic supervision for NÎÌÒ

P03.74
The Way Forward for Implementation of new Recommendations

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Turkish Atomic Energy Authority (TAEA) is the regulatory body in Turkey under the direct supervision of the Prime Minister and authorized for drawing up regulations concerning radiation protection, licensing and safety of nuclear installations and radiation sources. The Department of Radiological Health and Safety (DRHS) has regulatory responsibilities in respect of safe use of sources of ionizing radiation, radiation protection, safe management of radioactive waste and safe transport of radioactive material. Legislation is in place and up-to-date in the field of regulations and principles of radiation protection, transportation and storage of the radioactive materials, licensing and inspection of radiation sources; and to perform other related tasks.

The information about principal radiation safety and protection legislation in Turkey will be summarized in detail. .

The new recommendations of the International Commission on Radiological Protection were adopted on 21 March 2007. As a possible member country of European Union, Turkey has accepted the recommendations of the ICRP as presented in the ICRP Publication 103. TAEA is empowered for the regulatory activities and as a regulatory body, takes the main part of implementation of new recommendations and revised BSS of the IAEA in Turkey. In parallel with this mission, TAEA takes in consideration the new dose constraints and reference levels which are introduced in new recommendations in order to tailor them in national regulatory system.

There is a general view that stakeholder involvement will be central to the implementation of radition protection with a national perspective. In parallel with this opinion the understanding of the Turkish professionals in following the international recommendations and guidance is discussed in this paper. In order to give more specified view of this point, a quick survey is conducted to the relevant parties and stakeholders with the participation of a regulatory body representative, representatives from other relevant governmental organizations and NGOs and operators/licensees from the medical and industrial applications.

P03.75
REVIEW OF SAFETY AND SECURITY OF RADIOACTIVE SOURCES IN AFRICA

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Radioactive materials are used worldwide for peaceful applications in medicine, industry, agriculture, environmental science, education and research and military applications. Most of these radioactive sources used are imported therefore trans-boundary movement is a significant factor in consideration of safety and security measures during movement of these sources. The purpose of this paper was therefore, to analyze, review, address and share knowledge and experience with regard to safety and security measures of radioactive materials in Africa. The approaches used included; Off-site source recovery project, Global Threat Reduction Initiative program (GTRI); Mobile unit for Spent High Activity Radioactive Sources (SHARS); the Model Project on upgrading radiation protection infrastructure and the establishment of African nuclear free zone treaty. Approximately 550 people have been trained, and many orphan sources recovered. Networking and sharing of knowledge and experience has been considerably achieved in Africa with the model project The projects have managed to secure and recover more than 69 radioactive sources in Africa. This project will benefit IAEA's African member states in creating nuclear safety and security networking in the region.

Keywords: Africa, safety, security, source, radioactive.

P03.76
Development and Implementation of the New Radiological Protection System in Russia

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Today, intensive work on adaptation of the principal provisions of the ICRP Publication 103 to the national system of radiological protection and safety began. When improving the national regulatory documents, the accumulated experience and up-to-date social and economic circumstances of Russia are collated. The following new provisions of the radiological protection system are important for Russia:

· Refuse of the concepts “practice and intervention” and their replacement by three types of the exposure situation: planned, existing and emergency;

· Introduction of dose constraints and reference levels for each exposure situation depending upon the category of individuals exposed;

· Replacement of the “critical group” concept by “conditional man”;

· Establishing of the environmental central principle in radiological protection of biota and environment.

Some new provisions of the radiological protection system have already found their reflection in the most significant regulatory documents including:

· Up-to-date radiation risk coefficients of the stochastic effect arising are given;

· Limitation of the building raw materials, chemical fertilizers and agrochemicals is enhanced;

· When regulating medical exposure, the criterion for discharge from the hospital after treatment using the sources of ionizing radiation.

Despite the mentioned changes and new provisions of the radiological protection system, no radical revision of the current national Radiation Safety Standards is assumed. These standards will mainly undergo some evolutionary changes relating to the “reconstruction” of the conceptual basis of the radiological protection system.

Thus, the further work will aimed at putting the basic norms and rules of the sanitary regulation on radiation safety and protection of workers and public and environmental protection (NRB-99/2009, OSPORB-99/2010, SPORO-2002, SP AES-2003, SP PUAP-2009 and other national regulatory and methodical documents) in compliance with recommendations and standards provided by the international organizations (ICRP, IAEA etc).

P03.78
Context effects on the Willingness to Pay for Mortality Risk Reductions from a Nuclear Accident: An analysis before the Fukushima Daiichi NPP Accident

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The monetary valuation of reducing risks caused by radiation exposures in nuclear accidents is a key issue of the optimization process of emergency protective strategies. Willingness-to-pay (WTP) approach yields values that the individuals would be willing to pay to reduce the risks and the valuation is believed to reflect individual preferences. However, the WTP approach is criticized because of the uncertainties in derived values. For example, it is known that the monetary values based on the WTP approach for reducing risks of public transport modes are subject to people's perceptions related to the controllability, the extent of voluntary acceptance and the level of own responsibility. Such effects resulting in the uncertainties in the monetary values derived from the WTP approach are called "context effects." The objective of the present study is to clarify the context effects on the WTP-based monetary values for reducing risks of radiation exposures in nuclear accidents. To accomplish the objective, a contingent valuation survey was conducted in vicinity areas of Japanese nuclear power sites before the Fukushima Daiichi Nuclear Power Plant accident. In the survey were evaluated the WTPs for the reduction of mortality risks caused by (i) fatal cancer, (ii) fatal cancer induced by radiation exposures from naturally occurring radioactive materials and (iii) fatal cancer induced by radiation exposures in a nuclear accident. The validity of the construction of the questionnaire used in the present study was confirmed by the internal scope test. From the results of comparisons among the WTPs for the reduction of the three type risks, it was confirmed the mean value of the WTP for reducing risks due to a nuclear accident was lower than that for the reduction of the other two risks. In addition, the number of respondents who protest to pay for reducing risks from nuclear accidents is significantly higher than that for the reduction of the other two risks. These respondents believe that the responsibilities for reducing risks from nuclear accidents should be attributed to electrical companies and national authorities. Consequently, the WTP for the reduction of the mortality risks due to nuclear accidents was found to be subject to the context effects in terms of the responsibility for reducing risks.

This research project has been conducted under the research contract with the Japan Nuclear Energy Safety Organization (JNES).

Keywords: Emergency protective strategy, optimization, Willingness-to-pay, context effects

P03.79
National Program of Radiation Protection of Patients (Argentina)

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Introduction:

The medical radiation are undoubtedly the most important contribution to human exposure to ionizing radiation. Statistics indicate a growing trend in the number of practices as well as the amount of services particularly for Intervention cardiology. The quality of practice, justification and optimization are now an important issue for the scientific and regulatory bodies. Since the adoption of Directive 97/43/EURATOM, and the realization of the Malaga Conference most European countries have implemented action plans for radiation protection of patients, including the seeking of consensus regarding the optimization dose and the criteria for justification.

In this context, and convened by the Nuclear Regulatory Authority was held in our country, December 10, 2004, the first Conference on Patient Radiation Protection (PRP) in order to install in the medical community an active discussion on this topic. Then came a series of activities that today constitute the National PRP is sustained and driven by medical societies in the country and in particular the Argentine Society of Radiology and the Society of Radiation Protection.

Basic objectives of the PRP program:

1) Justification: The study is performed only when imaging studies are needed. (Refferal Guide)

2) Optimization of practice: That studies be carried to the doses received by the patient are the minimum necessary.

3) Prevention of risks: To avoid the occurrence of accidents and serious injuries in interventional procedures establishing quality systems and standards for the practice.

4) Training and Education: Including the prescribing physician and the whole team of interventional cardiology. (Recertification)

5) Dissemination of PRP criteria to the entire medical community

Results:

PRP program has reached a reasonable maturity and this year marks the 6th Day of PRP at the National Academy of Medicine and 4 Regional Symposia one of which is dedicated to intervention in all specialties.

Conclusion:

The establishment of national PRP is an appropriate measure that can systematically improve the quality of care in all specialties that used ionizing radiation. The active participation of medical and technicians societies is essential for program success.

Strategies to cope with different interests within society are described. Main problems, failures and difficulties are also described.

KEYWORDS:

Radiation Protection of Patients; Procedures; Quality System; certification.

P03.80
The Binational Nuclear Energy Commission between Argentina and Brazil: its activities in the area of regulation and standards

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The Binational Nuclear Energy Commission (COBEN) was established on 3 March 2008, in accordance with the terms of the Declaration signed on 22 February 2008 by the President of the Republic of Argentina and the President of the Federative Republic of Brazil. The nuclear agencies of both countries integrate COBEN, whose objective is to implement specific co-operative projects in the field of peaceful use of nuclear energy. The twenty-nine existing projects are coordinated by five executive groups in the areas of reactors and waste, nuclear energy applications, fuel cycle, uranium enrichment and regulatory issues.

The Nuclear Regulatory Authority of Argentina (ARN) is an autonomous body reporting to the President of Argentina, empowered to regulate and control the nuclear activity with regard to radiation and nuclear safety, non proliferation issues and physical protection and security. Its objective is to establish, develop and enforce a regulatory system applicable to all nuclear activities carried out in Argentina.

As the competent body in regulatory matters, the ARN, together with its Brazilian counterpart –the National Commission of Nuclear Energy, CNEN- implements the regulatory projects under the framework of COBEN.

The above-mentioned projects are aimed at harmonizing the norms and standards of both countries, i.e. on the methods and procedures of licensing radioactive facilities, the notification procedures on the import and export of radioactive sources, radiological and nuclear emergencies, physical protection, illicit trafficking, licensing fuel cycle facilities and safeguards.

This paper is focused on describing COBEN´s activities with a special emphasis on the development of the regulatory projects.

P03.81
HERCA Working Group on Medical Applications For Harmonizing the Implementation of Radiation Protection Regulation in Europe

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HERCA (Heads of the European Radiological protection Competent Authorities) is a voluntary association in which the Heads of Radiation Protection Authorities work together in order to identify common issues and propose practical solutions for these issues. HERCA is working on topics generally covered by provisions of the EURATOM Treaty. The HERCA Working Group on Medical Applications (later called WG MA) will cover all radiation protection issues concerning medical applications of ionizing radiation for diagnosis and therapy. The focus of the WG MA is on the harmonizing the implementation of radiation protection regulation in Europe especially concerning new medical applications.

The WG MA conducts its work through sub working groups on *patient release criteria and stakeholder involvement with CT-manufacturers, justification, optimization and screening (exposure of asymptomatic individuals in health care).* Further consideration will be given to the formation of a sub working group on radiation therapy.

The HERCA WG MA enhances harmonizing the implementation of the radiation protection regulation on medical applications, focusing on justification and optimization by

• Sharing the information among regulatory bodies of good practices on implementing the radiation protection regulation on medical applications. Examples of that are the statement of the patient release criteria and surveyed good practices for controlling exposure of asymptomatic individuals in health care.

• Enhancing the exchange of knowledge on technical and scientific aspects of the radiation protection of new medical applications. Competence of the radiation protection authorities to control optimization of new medical techniques has been surveyed and discussed. Examples will be given.

• Preparing guidance for implementing radiation protection regulation on medical applications. Examples are given of the collaborative work for harmonizing suspension levels for imaging equipment in Europe.

• Highlighting and reporting through HERCA of needs for developing European guidance and providing advice on implementing and modifying existing directives from the perspective of regulators. For example justification of health assessment will be discussed.

The HERCA WG MA engages in stakeholder involvement on radiation protection issues by

• Enhancing the exchange of information on best available radiation protection practices between regulatory bodies and other relevant competent authorities, professionals, manufacturers and patients.

• Enhancing the exchange of scientific knowledge between the experts and regulatory bodies.

• Co-coordinating national efforts under the umbrella of HERCA to maximize impact in stakeholder involvement.

Example of that is the stakeholder involvement with the CT manufacturers. In the presentation more examples will be given of the achieved results.

P03.82
Radiation Protection Research at the U S Nuclear Regulatory Commission

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The United States Nuclear Regulatory Commission (NRC) radiation protection research program provides technical support to the NRC in the areas of dose assessment and assessment of human health effects for reactor and non-reactor licensing, emergency preparedness, and nuclear security activities. The program's scope includes development of: technical basis for radiation protection regulations, external exposure computer codes, occupational exposure and effluence databases, and public health studies research. Current work in the radiation protection regulation arena is the development of a regulatory basis for possible revisions of 10 CFR 20 for greater alignment with the recommendations in the International Commission on Radiological Protection (ICRP) Publication 103. The NRC is sponsoring research in biokinetic and dosimetric models and dose coefficient factors for occupational and public exposure to radionuclides that are based on ICRP Publication 103.
In the area of external exposure computer codes, the NRC funds VARSKIN and PIMAL. VARSKIN is used to facilitate skin-dose calculations. PIMAL is a computational "phantom" with moving arms and legs used to assess the radiation dose for realistic exposure geometries. The NRC maintains several radiation protection databases. The NRC collects and reports the annual occupational radiation exposures to workers from certain NRC-licensed activities into the Radiation Exposure Information and Reporting System (REIRS) database. The NRC collects, reports, and maintains a database for both the gas and liquid radioactive effluents discharged from NRC-licensed facilities. As part of the effluence work, NRC is modeling the exposure pathways of gaseous releases of organic forms of carbon-14. The NRC has also developed the Radiological Toolbox: an electronic handbook is used to quickly access databases needed for radiation protection, shielding, and dosimetry calculations. In the area of public health studies, the NRC has requested the U.S. National Academy of Sciences to conduct a feasibility study on the analysis of cancer risk of populations living near NRC-licensed facilities. All NRC-sponsored radiation protection research seeks to implement tools for state-of-the-art techniques and to provide recommendations on policy.

P03.83
Safety Regulation for the Design Approval of Radiation Devices

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Various radiation devices are commonly used in industry and medicine in Korea and they should meet strict safety requirements specified in the domestic and international safety regulations. According to their design and safety performance, radiation devices can be categorized in several types such as perfect protection type, self-protection type, cabinet type, remote handling type and portable type. The design of radiation devices should be certified by the regulatory authority, the Ministry of Education, Science and Technology (MEST) and the regulatory expert body, the Korea Institute of Nuclear Safety (KINS). Applicant who wants to get design approval for a radiation device should submit the required documents for the safety review of the device design. Necessary documents for the safety reviews include the design data including drawings, safety analysis report, quality assurance manual and procedures. The safety features of radiation devices are being checked by multiple steps of regulation such as careful reviews in the design and safety inspections for the safety features of the radiation devices. Main safety features to be inspected include radiation shielding, safety interlock system, safety features that prevent any unauthorized use of the devices, emergency stop function, radiation generation control, warning sign and signals, etc. If the results of the safety review and inspection comply with the safety requirements, the MEST issues the certificate of design approval for the radiation device. More than 950 designs of radiation devices have been certified since 2003 when the safety regulation for the design approval of radiation devices was introduced. This paper provides Korea's regulatory procedures for the design approval of radiation devices and brief summary of approved designs of radiation devices.

KEYWORDS: Design approval, Radiation device, Safety regulation

P03.84
HASS Financial Provision – Lessons Learned And Shared

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The European Council Directive 2003/122/Euratom (the “HASS Directive”) on the control of high-activity sealed radioactive sources (HASS) and orphan sources requires holders to make adequate provision, by way of financial security or equivalent means, for the safe management of HASS when they become disused sources; including the case where the holder goes out of business. This “Financial Provision (FP)” is seen by the UK regulators as a key measure to enhance both environmental radiation protection and the security of radioactive sources.

Implementation of the HASS Directive via UK regulations falls in the jurisdiction of the three UK environment agencies.

In England and Wales, the Environment Agency’s multi-disciplinary “HASS Financial Provision Panel” was created to assist regulators in the assessment of submissions from applicants about the financial provisions they make for end-of-life disposal of High Activity Sealed Sources.

In assessing some 340 applications, many insights have been gained. In addition, the first “call in” of a financial guarantee has occurred. The guarantee was successfully called in and it covered the costs of disposal of the HASS; but some other costs were not covered. Lessons learned from the entire experience of the HASS FP Panel are reported here.

P03.85
Radiological Principles of Israeli Standard 5098 "Content of Natural Radioactive Elements in Building Products"

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Most building materials of terrestrial origin contain small amounts of Naturally Occurring Radioactive Materials (NORM), mainly radionuclides from the ^{238}U and ^{232}Th decay chains and the radioactive isotope of potassium, ^{40}K. The external radiation exposure is caused by the gamma emitting radionuclides, which in the uranium series mainly belong to the decay chain segment starting with ^{226}Ra. The internal (inhalation) radiation exposure is due to ^{222}Rn, and marginally to ^{220}Rn, and their short lived decay products, exhaled from building materials into the room air.

Restricting the use of certain building materials might have significant economical, environmental and social consequences at a local or national level. Such consequences, together with the existing national levels of radioactivity in building materials, were assessed and considered when establishing binding regulations.

This paper reviews the regulations on radioactivity in building materials and presents the radiological principles of the final edition of the Israeli Standard 5098 (IS 5098) "Content of natural radioactive elements in building products".

The IS 5098 was first published in 2002, issued and approved at the end of 2009. The radioactivity in building materials is treated as a planned exposure situation, limiting the excess dose above the typical exposure level to 0.3 mSv per year. This dose criterion refers to external exposure from gamma radiation as well as internal exposure from radon.

The typical exposure levels were classified according to the type and density of the building product.

Detailed procedures for pre-conditioning the building material and for the measurement method for the activity concentration and the radon emanation were defined.

The frequency of the control is determined according to the compliance of a building product after three consecutive annual tests

The IS5098 entered into force at the beginning of 2010.

P03.86
Radiation Exposure of Workers in Korea

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Objectives: Occupational radiation exposures are monitored and recorded by two national dose registries in Korea. One registry is for radiation workers in nuclear fuel cycle, industry, radiation therapy and miscellaneous uses and the other registry is for radiation workers in diagnostic radiology. The objective of this study is to provide systematic summary of occupational radiation exposures in other than diagnostic radiology in Korea.

Materials and Methods: Korea Information System on Occupational Exposure (KISOE) was established at Korea Institute of Nuclear Safety (KINS) to evaluate trends in occupational radiation exposure for assessment of the effectiveness of radiation protection program. Occupational dose data and occupational information maintained by KISOE were analyzed and summarized in this study. Using the occupational information, radiation workers were categorized into 5 groups, including nuclear fuel cycle, industrial uses, medical uses, military activities and miscellaneous uses.

Results: Total 23,500 radiation workers in 774 licensees were monitored in 2000. The numbers had increased annually by about 5%, resulting in 34,000 radiation workers in 1,139 licensees in 2009. Radiation workers in nuclear fuel cycle were about 39% of the radiation workers and followed by industrial uses (31%), miscellaneous uses (18%), medical uses (12%) and military activities (0.4%). Collective dose was 31 man.Sv in 2000 and slightly increased to 33 man-Sv in 2009. Radiation workers in nuclear power plant and industrial radiography were the highest contributors to the collective dose. They represented about 75% of the collective dose. Annual average dose has decreased over time from 1.33 mSv in 2000 to 0.97 mSv in 2009. In 2009, annual average doses per worker were 1.2 mSv for industrial uses, 1.0 mSv for nuclear fuel cycle, 0.8 mSv for medical uses, 0.5 mSv for miscellaneous uses and 0.12 mSv for military activities. Specific job categories with average dose higher than 1 mSv/year were industrial radiography (2.3 mSv/year), heavy water reactor (1.8 mSv/year), nuclear medicine (1.2 mSv/year) and radiotherapy (1.1 mSv/year).

Conclusion: Annual analysis of occupation exposure by KISOE has effectively contributed to occupational radiation protection in Korea.

Acknowledgement: This analysis was supported by a grant (KINS 11-33) from Korea Institute of Nuclear Safety in 2011.

P03.87
Informatization of Multi-Criteria Analysis Outranking: a Software to Improve Decision-making in Radiological Protection Optimization Programs

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This project aims the informatization of the decision technique known as Multi-Criteria Analysis Outranking, used in radiological protection optimization programs, in order to assist the decision maker to identify the optimal analytical solution. This technique is useful whenever options can not be placed in ascending or descending order when related to each factor. The system was developed according to the criteria and methodology established by the ICRP-55, and it comprises four distinct stages. In the first stage the decision maker defines factors, criteria and radiological protection options to be adopted, as well as build-up factors. The system allows up to ten options and ten factors, which should be entered with numeric data. Whether a factor is expressed in words it is necessary to establish their relative importance in numbers. Yet, at this stage, there should be given the exclusion criterion, as well as more discriminatory elimination criteria when options outrank others but are not themselves outranked. In the second stage, differently from ICRP, at first the system calculates all exclusion indexes, presenting graphics and data tables according to the results. The third step includes the advantage index calculated according to the results obtained in the previous step. Then the system compares and evaluates the outranking relations. In the fourth stage outranking options are checked and more discriminatory elimination criteria are applied whenever it is necessary. Besides the optimal analytical solution, the program provides spreadsheet calculation which can be saved or printed in order to be given to stakeholders and competent authorities. This software was developed in HTML and PHP (Web based languages) with aid of MySQL relational Database and jQuery Library (javascript). This system is full compatible with all major internet browsers and can be accessed from any computer with a conventional internet connection.

P03.88
Sixty Years Experience on Safe Transport of Radiactive Material in Argentina

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In 1950 the Argentine Atomic Energy Commission (CNEA) was established as the Competent Authority for the control of nuclear applications with regard to protection against the harmful effects of ionizing radiation and to the safety of installations in Argentina. A regulatory branch was then formed within the CNEA, Decree No. 1540 (1994) created the Nuclear Regulatory Agency (ENREN), an independent governmental body performing all the regulatory control activities in the areas of the nuclear activity with regards to radiation and nuclear safety, physical protection and nuclear non-proliferation issues. In 1997, the Nuclear Regulatory Authority (ARN) is created as an independent agency reporting to the Executive, as the successor to ENREN, with their same staff and technical resources.

It is important to mention that since the 50´s, it means before the IAEA´s first Regulations for the Safe Transport of Radioactive Material (1961), the transport of radioactive material (RAM) has been performed safely in this country.

The current paper aims to present an overview of the main activities related to the safe transport of RAM in Argentina over the last sixty years.

The review and analysis results will provide evidence of:

a) The implementation of national Argentine regulatory standards in line with Safety Requirements and related documents published by IAEA ensuring a high level of protection and safety in transport of radioactive material.

b) Compliance with all the regulatory requirements which leads to high performance regarding each of them. Argentina has a wide-ranging experience and capacity in the design and licensing of package for the transport of RAM. It counts with the staff and technical resources necessaries to perform calculation, analysis and full-scale or small-scale test on packages, and therefore it can be demonstrated that the designs are able to withstand extremely severe conditions of transport if it is required. Argentinean experience in the design of packages and special form radioactive material (SFRM) will be described in detail.

c) Implementation of a Quality Management System. The International Organization for Standardization (ISO) plays an important role in developing standards at the international level, including those that apply to the packaging and transport of radioactive material. In the frame of ARN's quality policy the process related to the control of transport of radioactive material has obtained ISO 9001 certification.

d) The projects currently being carried out related to both the development of new multipurpose package designs, as with the improvement by the ARN of the guide to prepare the Safety Report, in order to facilitate the work of designers and the National Authority.

e) The training in safety during the transport of RAM conducted by ARN since about 40 years and its participation in the international field.

f) Other future regulatory tasks intended to improve the activity.

P03.89
Regulatory Oversight - Challenges and Solutions

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The paper discusses the present challenges of developing and maintaining nuclear regulatory capacity and competence and lessons learned in recent years with new and existing programmes. Specific emphasis is placed on the need for maintenance of adequate competency in licensing and regulation in the long term for the purposes of public and environmental protection. Recent international mechanisms to support the regulators, licensees and their supporting organisations (such as the International Nuclear Regulatory Academy) are presented.

P03.90
Population Exposure to Radioactivity in Building Material: Comparison Between the EU Index I and Other Computational Methods

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In the last 30 years, building materials have been recognized to be an important issue from the research as well as the regulatory point of view. Indeed, they are the most important source of indoor gamma ray exposure for the population, due to their content of naturally occurring radionuclides. A wide database collected in the last 10 years recently allowed the authors to calculate the activity concentration index I - as defined in the EU guideline RP112 [1] - for several building materials in the European Union [2]. This index is a screening tool for limiting the use of building materials with enhanced or elevated levels of natural radionuclides and it was recently adopted in the draft Euratom Basic Safety Standards Directive [3] to harmonise the control by Member States and allow movement of building products within the European Union.

In the last decades many countries developed methods to evaluate and classify building materials based on natural radionuclide content. Some of them were elaborated to take into account also the radon contribution from building materials to the annual effective dose. In this work a short review of this "criteria family" is reported. Some of them, both with and without radon contribution, are applied to the database, so that a comparison between results obtained with these different methods can be carried out. Finally, the impact of the new EU draft Directive implementation in Countries with already existing building material regulations is evaluated.

[1] European Commission 1999 Radiation Protection 112. Radiological protection principles concerning the natural radioactivity of building materials Luxembourg ISBN 92-828-8376-0

[2] Trevisi R, D'Alessandro M, Nuccetelli C, Risica S 2008 Radioactivity in Building Materials: an Overview of the Current European Scenario. Proc. Int. Conf. "12th International Congress of the International Radiation Protection Association - IRPA 12" 2008 Buenos Aires Argentina (cd-rom). Published in IAEA Proceedings Series STI/PUB/1460 (COMPANION CD), ISBN 978-92-0-105410-4 (2010), ISSN 0074–1884. IAEA, Vienna, 2010

[3] European Commission 2010 Draft Euratom Basic Safety Standards Directive http://ec.europa.eu/energy/nuclear/radiation_protection/doc/art31/2010_02_24_draft_euratom_basic_safety_standards_directive.pdf

P03.91
Modern Trends and Problems in Radiation Protection System

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Linear Non-threshold Concept (LNC) of harmful stochastic radiation effects (carcinogenic and genetic) occurrence frequency as a function of dose being used unconditionally in radiological regulation resulted in unreasonable toughening of requirements and in creation of a complex multistage structure of radiation protection system. Systematic toughening of regulations during recent decades in Russia as elsewhere in the world, transfer of normalized values of human irradiation doses into the range outside the scope of practically confirmed harmful radiation impact effects on human, beings made the society a hostage of single-sided theoretical constructions, which are far away from real practice of nuclear energy use. At the same time recently numerous data based on extensive radio-biological, epidemiological and statistic research have been accumulated, and these data challenge the validity of the non-threshold concept. Further confusion was introduced by the concept of dose constraints suggested by ICRP for the situations of planned radiation exposure, according to which the dose constraints should be less than the dose limit, however practically everybody perceives those constraints as strict dose limits with values below 1 mSv per year (0.3, 0.1 or even 0.01 mSv per year). Unfortunately these values of annual doses are rashly suggested to be included into regulatory documents though these doses are substantially lower than even fluctuations of natural radiation background. These issues become especially vital in the completion phase of the preparation of a new version of IAEA safety standards (BSS). Several ways out of the described situation are suggested in the proposed presentation. A real situation in Russia and in advanced countries of the world demonstrates that at present irradiation doses of population living in the areas of radiation-hazardous plants are very low, do not endanger the health of the people and there is no need in toughening of the regulations.

KEYWORDS: Radiation protection, BSS, dose limits and dose constraints

P03.92
One Of The Implications Of Monetary Reference Value

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In the analysis involving cost-benefit there is a need to define the monetary value of the reference person-Sievert. The safety report number 21, suggests that this value can be obtained through the human capital approach, by which the monetary value of one life year lost is given by an aggregate economy, usually the gross domestic product per capita. Thus, through this approach the reference value of $ 20.000/Sv-pessoa has been the agreed value, widely used in many countries. In this paper we show that if we adhere to this publication 21 of the IAEA Safety Series, all options to protect the example of a small mine used in the publication of ICRP Nº 55, would be eliminated in advance and therefore the publication should be urgently reviewed. On the other hand is incorrect remove in advance all the protection options that have an alpha value greater than that agreed and we will justify our assertion.

P03.94
Technical Specification for a Safe use of the X-Ray Generators

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The European Union 96/29/EURATOM directive establishes that the Member States have to issue specific regulation for electrical equipments emitting ionizing radiations that are commonly used for several industrial, research and veterinary applications.

This presentation focuses on the X-ray generators. Those kind of devices used in France are mostly manufactured abroad (mainly in Germany or the United Stated of America) by multinational companies. Contrary to medical devices, no European or international standard has been identified by the French nuclear safety authority (ASN) to check that those equipments provide sufficient protection against the ionising radiations.

This lack of international standard has led the French nuclear safety authority to consider a new set of technical specifications to ensure that the holding and the use of an X-ray generator do not generate radiation protection problems for workers or the public.

This work is directed towards the identification of a specification for fixed or mobile X-ray generators to ensure the safe use of the device. This identification will take into account : the control of the source term (useful beam), to limit the risk associated with radiation leakages from the device and guarantee, the presence of securities, to limit the exposure risk when the beam is not expected.

Beyond that French initiative, such an expertise, developed at an international or, at least, at a European level, would lead to an harmonized treatment of the licence demands related to such devices by the different nuclear safety authorities and to a multilateral recognition of the device reliability in terms of radiation protection.

The existence of such a set of technical specifications would reduce the administrative and commercial burden for X-ray generator manufacturers and distributors, which would have then to comply with only one standard, internationally acknowledged by many authorities.

This presentation aims to present the preliminary guidelines projected for the future expertise of the X-ray generators that could form the basis of the future set of technical specification for those devices according to the French regulation.

P03.95
Withdrawal of Radioactive Sources Smoke Detectors used in France

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Since 2002, the French Health Code, transposed from the biding European Commission 96/29 directive, forbids the deliberate addition of radioactive substances in the production and manufacture of consumer goods and construction products. Smoke detectors belong to the last category.

In France, smoke detectors with radioactive sources, called ionization smoke detectors, were first used in the forties with radium sources or other sources.

Since 1966, the use of ionizing smoke detectors in personal lodging is forbidden. Nevertheless, due to a better technical effectiveness, its usage was still allowed in industrial or administrative buildings.

This justification has been progressively reassessed in France with the technical developments of the other types of detectors non ionization detectors now comply with the essential requirements of national standards and regulations for fire detection.

Since recently, fire detection systems in new buildings are not any more supplied with ionization smoke detectors.

Nevertheless, the amount of ionizing smoke detectors in use in existing fire detection systems is estimated by fire detection professionals to be about 7 millions assigned to 300 000 sites. Those sites require regular maintenance.

The application of the banning of deliberate addition of radioactive substances in construction products to smoke detectors is then very difficult without considering a period of transition. The French nuclear safety authority has been taking actions with stakeholders in order to set a gradual removal of ionization smoke detector from existing fire detection systems.

Consequently ASN has proposed to the competent Ministry to set by regulation a transition period.

A new regulatory framework has been proposed by the French nuclear safety authority to the French government. It sets a transition period of 10 years that enables a gradual removal matching with technical and financial stakeholders constraints and in order to prevent illegal dumping.

This presentation outlines context, aims and guidelines set for regulation plan for removal of ionizing smoke detectors in France.

P03.96
Some Inconsistencies in the IAEA Publication Entitled: "Optimization of Radiation Protection in the Control of Occupational Exposure"

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The aim of this paper is to show some inconsistencies that we consider severe inserted in the IAEA Publication no21 of "Safety Series Report". In the first place in the section III-1 is informed that all radiation protection options with alpha reference values bigger than the alpha reference value should be excluded from the ALARA process because their costs are more than the amount that is been agreed to spend to avoid one unity of the collective dose. In the paper we show that this is not correct and produces many consequences appreciably expansive because will be necessary to modify all the ICRP and IAEA publication that deal with the ALARA process. In second place we return to show that the option given in the example III-2:"A model to determine a set of monetary value of a man-sievert according to the level of individual doses", presented in the section III-2.3 pages 59 and 60 are wrong. To consider that the alpha value decreases with the individual doses decrease is a sophism. By the own basic nature establishment the alpha value increase when the individual dose decrease.

P03.97
Regulating Radiological Protection Aspects Of Great Britain's Nuclear Industry

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The adequacy of radiological protection (RP) arrangements at Great Britain's nuclear sites is overseen by specialist inspectors in the Office for Nuclear Regulation (ONR). This new organisation has evolved from its predecessor, HM Nuclear Installations Inspectorate, to incorporate regulation of civil nuclear security, safeguards and transport of radioactive materials. It aims to protect people and society from the hazards of the nuclear industry. Environmental matters are regulated by separate agencies.

The evolution of ONR has been based on the principles of transparency and accountability for disciplined delivery of managed programmes of work. A culture of continuous improvement is fundamental and ONR continues to learn from IAEA peer reviews and experience such as that arising from the nuclear accident at Fukushima.

ONR regulates a wide range of nuclear licensed sites from 'cradle to grave' – through new nuclear plant design, construction, commissioning, operation, decommissioning and, in some cases, delicensing. Nuclear sites include reactors, chemical plant, defence sites, some waste handling / disposal sites and fuel manufacturing, enrichment and reprocessing plant,

This breadth of responsibility and range of hazards present fascinating challenges to the regulator, including the RP specialist, in openly explaining the basis of legislative requirements, standards and judgements to stakeholders in clear language in written reports, websites and stakeholder meetings local to the nuclear sites themselves.

This paper will provide a broad overview of several areas of radiological protection regulation which present specific challenges for stakeholder engagement in Great Britain. These include generic design assessment for reactor new build, learning lessons from the nuclear accident at Fukushima, assessing the adequacy of licensees' safety cases, emergency arrangements, decommissioning, delicensing and the impact on members of the public from direct radiation shine and other exposure pathways from licensed nuclear sites. These areas are addressed in detail in other papers and presentations submitted by ONR to IRPA 13.

P03.98
Argentine Regulatory Experience Related to the Application of Specific Standards in the use of Radioactive Material in Industries.

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The Argentine Nuclear Regulatory Authority (ARN) bases its regulatory actions on Standards to authorize the use of radioactive materials as well as to supervise the activities in which those materials are used and the compliance of the conditions established by means of the license issued. The set of standards and regulatory guides developed by ARN and, in particular, the implementation of specific standards for industrial uses since 2006, Standards AR 7.9.2 “Operation of Radioactive Sources in Industrial Applications” and AR 7.11.2 “Individual Permits to Use Radioactive Sources in Industrial Applications”, allowed the ARN to increase and standardize measures and control mechanisms in this type of applications with regulatory purposes. This implementation of specific standards in industrial uses resulted in a series of modifications not only on the part of the licensee but on the regulator’s as well. Therefore the regulated institutions and their responsible for the radiological safety, were required to introduce certain improvements to apply optimization criteria in all radiological practices and technological upgrading to improve radiological safety and security associated with the use of radioactive sources, defined the requisites and necessary education and training, depending on the kind of application, to request the permits as responsible for the radiological safety in a licensed facility. The obligatory training required by this specific standard as well as the implementation of refresher courses made the applicants gain actual consciousness about their responsibilities and enabled to obtain sensitive changes, in particular regarding those who already had their permits granted before the coming into force of the standards. Moreover, the implementation of such standards introduced modifications related to administrative, legal and operative requisites and it also brought great improvement regarding the qualification of the group of inspectors what resulted in an absolute growth in quality and performance of the regulatory control in industrial applications. In this piece of work the results and the experience obtained after 5 years of the applications of the standards are presented.

P03.99
Can, And Should, The Management of Radiological Materials And Hazardous Chemicals Be Harmonised?

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The regulation of releases into the environment of radioactive materials and of hazardous chemicals started in different scientific and regulatory communities and the approaches differ in several respects. Since the ultimate protection aims and many of the problems faced are similar, there may be scope for some harmonisation, or at least for learning from each other.

A survey of pertinent management trends, on behalf of the Committee on Radiation Protection and Public Health of the OECD Nuclear Energy Agency, yielded responses from one or more regulatory agencies in 12 member countries. Respondents in five countries observed no trend towards harmonisation of the regulatory approaches in their countries; a sixth country added that agencies collaborate to combine, but not align, different requirements. Four countries indicated various stages of development towards harmonisation of legislation and/or protection goals. In two countries, there was already a limited degree of harmonisation and this had resulted in some improvement of protection of the environment.

Thus, 6 out of 12 countries do not expect or plan for any harmonisation of their regulatory systems for radioactive or chemical releases. However, 6 countries anticipate, or have already initiated, such harmonisation. Separate information from two additional countries hints that one of them, but not the other one, begins to arrange for a degree of harmonisation.

Those countries that are considering some harmonisation mention anticipated advantages in terms of administration (and concomitant costs to operators) as well as sustainability: duplication of requirements avoided, conflicting requirements avoided, a more holistic approach leading to improved protection of the environment.

Conditions for different hazardous materials, and in various countries, differ vastly and it is unlikely that any ‘one-for-all’ solution is feasible or even desirable. However, judging from the survey results, it seems likely that in several countries, a closer integration of the management of releases of hazardous materials into the environment could be useful in selected cases. This seems to be an issue that is not yet being pursued by international organisations, and there may be scope for an initiative to encourage further development.

P03.100
Application of NEMA NU-3 for Intraoperative Gamma probes: A Cuban Experience

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With the increasing use of intraoperative gamma probe, the existence of quality assurance programs is highly important for guidelines and normative implementations. “Performance Measurement and Quality Control Guidelines for Non-Imaging Intraoperative Gamma Probes” NEMA NU 3-2004 standard, is the most complete document to carry out a performance and quality control tests to these equipments. Therefore, its application is complex to warrantee a reproducibility and geometry maintenance. This paper shows an implementation of this guideline as a proposal to warranty geometry and reproducibility, with phantom designs included. An organization of test order to improve radiation protection in that procedure is also analyzed. The results obtained in four gamma probes provide useful criteria to change the test order to avoid errors related to source activity decay and allows to use lower radionuclide activities.

P03.101
Current Status of the International Standards on Radiation Protection Instrumentation

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This paper will present the newly published IEC standards on radiation protection instrumentation as well as the most important projects in development. The following fields will be considered: detection of illicit trafficking of radioactive material, radiation systems for security screening, passive dosimetry systems, radiation meters and active personal dosemeters, warning equipment for criticality accidents, measurement of environmental radiation and radon. A new project concerning the environmental, electromagnetic and mechanical performance requirements for radiation protection instrumentation will be also discussed.

P03.102
A Cloud Approach To Environmental Radiation Protection Ethics

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Historically, ethics and philosophy were linked to natural sciences, and physicists and philosophers worked side by side. This was facilitated by a shared belief in logic, which allowed philosophical constructs describing philosophical systems and physical constructs describing the natural world.

Physics – particularly nuclear and radiation physics has moved away from logic with quantum theory, while Ethics seems to remain rooted in a traditionalist past. The "cloud" concept used in informatics may allow movement between these (to all outward purposes) opposed systems.

In computing, the "cloud" is used to describe a usually unknown location where individual data is stored collectively rather than remaining on an individual computer. The extent and consistency of this amorphous cloud is unknown, much as, I believe, is our knowledge about the environment and any radiation effects on biota.

All environmental knowledge has been garnered from an anthropocentric viewpoint. The reality may well be that we are effectively lost in cloud on environmental issues, and logic is useless to us in finding pathways and systems. Perhaps experience such as Alumbrados might be better suited for navigating the environmental radiation protection cloud.

P03.103
Has Protection Gone Too Far?

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The views expressed in this paper are the personal views of the author and do not reflect Dstl policy or practice. The topic has been included to prompt discussion of this important issue

Ever since the nature of injury from ionising radiation has been understood, radiation protection has employed a risk based approach to the control of the hazard involved. Ionising radiation is not unique in this respect, and in the UK the Courts have employed risk considerations to virtually all health and safety matters since 1949. The UK Courts, therefore, had a well developed appreciation of risk management in relation health and safety matters prior to this approach being adopted by the radiation protection community. This causes some difficulties as terms such as “reasonably practicable” are loosely used in radiation protection but have a clearly defined legal meaning that is not always understood by practitioners.

The fundamental of the approach to radiation protection advocated by ICRP and accepted by the industry is that risks from ionising radiation can be managed so they are acceptable, but they cannot be eliminated altogether. This brings with it the position for the radiation safety professional that there are many things that CAN be done to reduce the risks but that not all of them SHOULD be done. The limit placed on this by industry is that although risks can be reduced, the cost of doing so is so high that that it is not reasonable to reduce risks further.

Through examples from industry, this paper seeks to show that risks from ionising radiation have been reduced beyond the limits that were established by the ICRP. This is due to interpreting the ICRP regime in a very restrictive manner because regulators, safety professionals and industry find it easier to reduce doses where they CAN rather than where they SHOULD, and are effectively seeking to eliminate risk altogether. The situation is particularly difficult in the UK where a phrase can have both a technical and legal meaning.

P03.104
HSE's Enforcement Management Model for Ionising Radiation

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The Enforcement Management Model (EMM) is a logical system that helps inspectors to make enforcement decisions in line with the GB Health and Safety Executive's (HSE's) enforcement Policy Statement (EPS).

The EPS sets out the principles inspectors should apply when determining what enforcement action to take in response to breaches of health and safety legislation. Fundamental to this is the principle that enforcement action should be proportional to the health and safety risks and the seriousness of the breach. The EMM provides inspectors with a framework for making consistent enforcement decisions, helps managers monitor the fairness and consistency of inspectors' enforcement decisions in line with the enforcement policy; and assists less experienced inspectors in making enforcement decisions. It can also assist others (e.g. those directly affected) in their understanding of the principles inspectors follow when deciding on a particular course of action.

The paper details the operation of the enforcement management model in cases related to ionising radiations.

P03.105
The Compensation Culture

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Dstl, Gosport, United Kingdom

Has your organisation the information needed to evaluate and defend compensation claims for radiation linked diseases arising long after the claimant may have been exposed to the radiation or radioactive material?

This poster outlines the key information required to work out if a claim meets the requirements to receive compensation.

The content is based on experience from the United Kingdom Compensation Scheme for Radiation Linked Diseases where case outcome is determined by a calculation of the likelihood that the claimant's disease is caused by radiation exposure.

The focus is on the scientific aspects of the claims process, these are the underlying principles that would underpin any litigation. The poster is a simple guide to the areas that need to be considered when gathering and interpreting the evidence for claims.

P06.38
Implementation of International Guides and National Law for Gamma Radiography in Germany

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Non-destructive testing (NDT) is the determination of the structure integrity of material or components using non-destructive techniques as there is e. g. radiographic testing (RT). For radiographic testing x-ray and gamma devices are used. Gamma devices for NDT contain sealed radioactive sources with high activities with a activity of several TBq. Due to the potential risk working with high-activity radioactive sources many requirements on their safety and security are made. In matters of gamma devices this will mean training on radiation protection, technical safety, surveillance, safe transport and protection against theft (security).

In Germany these requirements are subject to the Atomic Law (AtG, 2010), Gesetz zur Kontrolle hochradioaktiver Strahlenquellen (HRQG, 2005, engl. Surveillance of High-Activity Radioactive Sources), Radiation Protection Ordinance (2011) and the German Standard DIN 54115 which correspond to the EURATOM Council Directive (96/29/EURATOM), the European HASS Directive (2003/122/EURATOM) and the international standard ISO 3999 (2004).

As a reaction of the growing awareness of the potential for accidents involving radioactive sources, the European HASS Directive was developed in 2003. Two years later the IAEA published the safety standard “Categorization of Radioactive Sources” (IAEA TECDOC-1344, 2005) in which radioactive sources are categorized to one of five categories according to their hazard potential. Following these papers in Germany the HRQG and the amendment of Radiation Protection Ordinance became final in 2005.

The poster gives an overview of the safety requirements on radioactive sources for NDT applications in Germany. It will illustrate how national and international acts and ordinances as well as technical standards are implemented.

P06.39
Food Control after a Major Nuclear Accident – the Need for Harmonisation

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According to the HASS directive the EU countries are obliged to conduct campaigns to identify orphans sources and to have in place emergency preparedness system. Actions mentioned are necessary in order to prevent the exposure of persons handling such sources not knowing characteristics of sources and to prevent contamination of the environment. Additional threat is caused by malevolent actions with orphan sources, because they can be easily acquired and used. Furthermore, economic impacts when sources are melted or found at scrap yards resulted in defence systems prepared by regulatory authorities and industry. The systems are established at state borders or within industrial objects. They are based on equipments specially designed for detection of orphan sources. Furthermore, international databases of incidents with such sources exist, e.g. IAEA database.

A necessary update of state database of sources is based on defence systems mentioned and on documentation related to sources in a state. However, the documentation available to a regulatory authority can have a systematic drawback. Namely, according to the experiences of the Slovenian Nuclear Safety Administration (SNSA), who conducted a systematic inspection campaign focused on non-registered sources, majority of sources found have never been under the regulatory control in the past. In general, owners of non-registered sources were not aware they are handling sources. The reasons for such uncontrolled use of sources can be different, e.g. military safety standards were different than civil ones or the staff at institutes often underestimated risks.

From 2004 when the SNSA prevention campaign started around thousand of sources were identified mainly through systematic inspection programme which included research and educational institutions and military objects. Till 2011 more than 100 inspections were conducted based on a special methodology. A whole spectrum of well known radioisotopes was identified starting with various uranium compounds. Physical states of sources were very different, some of them causing also the contamination of workplaces or the environment. Also unconventional sources were found. As a rule no documentation related to sources was available but owners were known. Risks associated with sources found are analyzed based on different criteria, e.g. radiotoxicity, potential contamination, radiation fields. Solutions regarding radiation safety are given. Lessons learnt from the SNSA campaign focused on non-registered sources which could become orphan sources in a near future, are systematically presented and can be used for establishing action plans in other states.

P06.40
Technical Specifications for Radiometric Screening Equipment at Border Controls

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Introduction: AMEC provided technical support to the Nuclear Safeguards Unit of the Joint Research Centre in the derivation of technical specifications for the purchase of a number of radiometric monitoring instruments required for use at screening points along the 2,302.6 km of borders that are shared between the Republic of Belarus and the EU. These instruments were defined in two lots: [1] static equipment which comprised vehicle radiation portal monitors and personal radiation detectors, and [2] mobile laboratories which are equipped with personal radiation detectors, radiation identification devices, portable radiation scanners and personal dosimeters. The purpose of the mobile laboratory is to characterise the nature of the radiation signal in the event that an alarm is generated by static equipment at a Border Control Point.

The marketplace offers a very wide range of different instrumentation suitable for the detection of radioactive materials, but the selection of the correct instrument for a specific application is not always straightforward. In addition to considering the prime radiations of interest (alpha, beta, gamma, x-rays, neutrons, or a combination of these), and the possible energy range, other factors must also be taken into account. For example, the amount of radioactive material that is likely to be present, the likely presence of any shielding materials (intentional or unintentional), the probable distances between the radioactive source and the detector, the potential size of the radiation field (uniform field or pencil beam) are just some of the aspects that must also be considered. In addition to considering the radiometric performance of instruments, the environmental performance must also be taken into account. Poor conditions will affect both the radiological performance, and the longevity of the instrumentation. System security and maintenance and serviceability are also vital considerations.

This poster highlights the numerous factors that must be taken into account and details how the technical specifications were derived to ensure that all of the requirements were met.

Topic:

• Planned Exposure Situations: Industry and Research – Management and Security of Sources

P06.41
Leakage Testing Of Sealed Radioactive Sources

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BAM is the competent authority in Germany for special form radioactive material approvals according to the IAEA regulations, for assessment of permissible recurrent leakage tests for sealed sources and for type testing of devices with inserted radioactive sources. BAM also performs tests according to the International Standard ISO 2919.

On that score, BAM has experience in leakage testing of various types of sealed sources for many years.

This poster will give an overview about the leakage test methods used by BAM based on examples for different source designs. Boundary conditions and limiting values for the application of the most common leak test methods by non –radioactive means (helium mass spectrometer leakage tests and bubble leakage tests) are demonstrated and special problems in testing of sources with a very small void by non-radioactive means or in testing of sources with very small leak capillaries are presented.

P06.42
The Security of Radioactive Sources in the UK - The Perspective of the Radiation Protection Profession

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As a signatory to the IAEA's Code of Conduct on the Safety and Security of Radioactive Sources, the UK has established a rigorous statutory regime for the protection of radioactive sealed sources. The scheme is regulated by the environmental regulators in partnership with specialist counter-terrorist police officers who are coordinated at the national level. The interface that the regulators choose to implement the scheme was the radiation protection profession, who were seen as key targets for stakeholder engagement.

Since 2006, the UK's Radiation Protection profession has learned how to implement and operate these requirements. This paper (which has been developed by the Security of Radioactive Sources Group of the SRP) will outline the arrangements and describe how the profession has learned to adapt to strict requirements in a variety of work places. It will also describe the security culture that has developed in the UK as a subset of the pre-existing safety culture.

Finally, it will describe what the UK profession is doing (via SRP) to provide mutual support and advice to stakeholders.

P06.43
The Removal and Transport of High Activity Cobalt Sources from the University of Adelaide and the Royal Adelaide Hospital in AUSTRALIA

Mayman, KA*

Australian Nuclear Science & Technology Organisation (ANSTO), Sydney, Australia

The University of Adelaide in South Australia owned an old teletherapy head stored in a lift well, and also an underwater “well type” irradiation facility, both containing high activity cobalt 60 sources that they wanted to dispose of. Similarly, the Royal Adelaide Hospital also owned a disused teletherapy head containing cobalt 60 that was stored in a basement.

These sources were originally supplied by the Australian Nuclear Science and Technology Organisation (ANSTO), and so as the original manufacturer, ANSTO agreed to take back the sources for long term safe storage.

In order to achieve this source return, ANSTO had to carry out significant historical research to obtain information on each source, develop methodologies and equipment to safely carry out the work, and meet regulatory transport and security requirements.

This paper discusses the planning, logistics, and execution carried out by ANSTO’s *High Activity Source Recovery Team* in removing these sources and transporting them to ANSTO’s Lucas Heights Facilities in Sydney, AUSTRALIA.

P06.44
All Is Not What It Seems!......Isotopes And Inventories

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Australian Nuclear Science & Technology Organisation (ANSTO), Sydney, Australia

Around Australia there are many radioactive sources stored at universities, hospitals, government agencies, and industry. While some organisations have appropriate dedicated storage facilities and extensive up to date inventories, others do not.

Some organisations have items stored in "out of the way places" and the sources and their control end up becoming a legacy that is handed down as responsibility moves from person to person over time. This phenomenon is particularly apparent in organisations that have a high degree of transient users where sources obtained for research or experimental use for example, when finished with, are simply left for "somebody else" to deal with. Often these sources decay to non-radioactive material, but they are still kept as no-one is able to decide their fate. Over time the knowledge of these legacy sources may be lost.

Sometimes, sources are re-housed into other containers for convenience and often as a result they may lose their correct identity, and under these conditions there is a potential increased risk for loss of control of the source, or for an inadvertent exposure to occur.

ANSTO has undertaken a number of projects assisting organisations with identifying and characterising their stored radioactive materials, and providing accurate and reliable inventories.

This paper describes ANSTO's experience in identifying and rectifying incorrectly identified and housed sources, and the procedures and techniques used in carrying out this type of source characterisation and inventory work in the field.

P06.45
Implementation of a Quality Assurance Program for Assembly and Production of Sealed Radioactive Sources used in Industrial Applications

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In order to manage radioactive facilities, the quality assurance programs have been strongly applied to minimize evolved risks and radiological accidents. Since 1983, the Sealed Sources Production Laboratory of the Nuclear and Energy Research Institute (IPEN/CNEN) has been the unique supplier of radioactive sources of cobalt-60, iridium-192 and selenium-75 to the Brazilian industry to gammagraphy and process control applications. Additional services related to surveys and inspections of critical parts such as shielded projectors and drive cable even as replacement and managing of spent sources are offered by this facility. Nowadays, more than twenty five companies such as private-sector, research institutes and universities are dependents of activities of this laboratory. Subsequently, the effective implementation of a Quality Assurance Program (QAP) in accordance with the nuclear regulatory authority depends on the efforts and compromise at all levels and participants verifying the achievement of the proposed targets. A QAP describing the organizational structure, functional responsibilities, levels of authority and the external and internal interfaces for those managing, performing and assessing the work was developed and implemented. The QAP also contains information about the management process including planning, scheduling, lines of communication and resource considerations, specifically local environmental laws of waste. Today, quality politics are ensuring the compliance for all stages of production of this facility and the implementation and maintenance have been verified by periodic surveillance and audits.

KEYWORDS: Quality Assurance Program, Radiactive Sealed Sources, gammagraphy

P06.46
Enhancing the Capability of Frontline Officers in Combating Illicit Trafficking of Radioactive Sources in Nigeria.

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All countries and international organizations are increasingly aware of the consequences that illicit trafficking of radioactive sources might generate due to the possibility the illicitly trafficked sources could be diverted for malevolent purposes, especially for Radiological Dispersal Devices (RDD) to cause harm to individual, society or the environment. The existence of competent regulatory authority in Nigeria that set up adequate control measures is an essential component to lower the probability of occurrence of illicit uses of radioactive sources. Moreover, the coordination by the nuclear regulatory authority of all relevant measures with other national organizations is seen as an important contribution to prevent illicit trafficking. However, experience has shown that having regulatory infrastructure systems intended to prevent inadvertent movement and illicit trafficking of radioactive are not sufficient. In this regard, the need to adopt a co-operative approach with Frontline officers and other law enforcement bodies to augment the traditional infrastructure is imperative; therefore, this paper describes the strategies to enhance the capability of Frontline Officers in combating illicit trafficking of radioactive sources in Nigeria in line with international best practice.

P06.47
Feedback of Experience in Industrial Radiography and Related French Regulation Projects on Justification and Accidents Response

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Some recent accidents with harmul exposures reported to the IAEA have reminded us that industrial radiography constitutes for workers as well as for the public, a major risk which should be prevented and limited. In France, about ten incidents are reported each years.. Therefore, this activity is a priority issue in terms of radiation protection for the French Nuclear Safety Authority (ASN), with about one hundred inspections each year focusing on industrial radiography. Since 2008, ASN evaluate the practices at national level. Some progress have been reported,concerning the appointment of person competent in radiation protection, the performance of controls required by the radiation safety regulation on sources and ionising radiation-emitting devices, the use of passive dosimetry, the improvement of the the design of sources devices and concerning the quality of dedicated trainings. Some improvement points are still reported from ASN inspectors, concerning the management of radiation safety, the quality of radiation safety measurements required by the regulation, the performance of risks analysis, the operational dosimetry or concerning the monitoring of radiation safety controlled zones around the source. Incident experience feedback has also showed a need for improvement of the response in case of emergency such as stuck source, which can require heavy equipments, trained staff and adapted transport solutions of recovered sources. Taking all these experience feedback into account, ASN is planning to strengthen the regulation to improve the safety of industrial radiography practices, to improve the effectiveness of national response in case of loss of control of an industrial radiography source and to integrate some recommendations of the French Society of Non-destructive Testing (COFREND) about the justification of industrial radiography.

P06.48
The UK Approach To Security Of Radioactive Sources

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This paper describes how the UK has implemented IAEA guidance documents in a blend of prescriptive and performance based approaches to establish a statutory regime for the security of radioactive sources.

The regime has been in place since 01 January 2006 and is considered to be proportionate to risk as well as fit-for-purpose. The approach is unusual in that the regulator draws on the advice of specialist police officers to provide expert assessment of the security measures needed on a premises, and the subsequent maintenance of standards.

Some lessons were learned in the early stages of its implementation and these will be shared in this paper. In particular, the "tuning" of the regime so that people can continue to work with radioactive sources despite the security climate, rather than being prevented from work because of it was a challenge, but it was overcome.

Further, the introduction of the regime created an effective and widespread security culture which as been an unintended addendum to the battery of means of protecting radioactive sources from the adversary. This was achieved by the regulators engaging closely with the Radiation Protection community, via regulator-mediated liaison groups and the professional societies.

The outcome is a robust regime which, although it has been challenging for operators to implement has been accepted as what is necessary in our current world.

P06.49
Improvement of the Buried Radioactive Source Situation at a Hospital in Cambodia

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This paper describes the successful outcome and completion of improvement works at the site of a high activity (a few TeraBecquerels) Cobalt-60 source buried in the grounds of a hospital in Phnom Penh, Cambodia, by the ANSTO Regional Security of Radioactive Sources (RSRS) Project. We describe the background of the situation and the efforts made since 2005 by the RSRS Project in collaboration with international partners: the New Zealand National Radiation Laboratory (NRL), as part of the New Zealand contribution to the Global Initiative to Combat Global Terrorism (GICNT); and the United States National Nuclear Security Administration represented by the Pacific North West National Laboratory (PNNL) who provided security upgrades as part of the Global Threat Reduction Initiative (GTRI). We describe the objectives related to characterising the buried source and improving the site's radiation safety, security and area amenity. The potential options available to meet these objectives, justification for the strategy chosen, and the preparation and conduct of the works involved are discussed. Shielding calculations, dose rate criteria, and occupational health and safety considerations from a radiation protection and construction perspective are presented. A comment on the nexus between safety and security for legacy radioactive sources is provided.

P06.50
UK Surplus Source Disposal Programme

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The UK Surplus Source Disposal Programme (SSDP), managed by the Environment Agency, was designed to remove redundant radioactive sources from the public domain. The UK Government Department for Environment, Food and Rural Affairs (Defra) was concerned that disused sources were being retained by hospitals, universities and businesses, posing a risk to public health and the environment.

AMEC provided a range of technical and administrative services to support the SSDP. A questionnaire was issued to registered source holders and the submitted returns compiled to assess the scale of the project. A member of AMEC staff was seconded to the Environment Agency to provide technical support and liaise directly with source holders during funding applications, which would cover disposal costs.

Funding for disposal of different sources was partially based on a sliding scale of risk as determined by the IAEA hazard categorization system. This funding was also sector dependent.

The SSDP was subsequently expanded to include the disposal of luminised aircraft instruments from aviation museums across the UK. These museums often hold significant radiological inventories, with many items being unused and in a poor state of repair. These instruments were fully characterised on site by assessing surface dose rate, dimensions, source integrity, and potential contamination issues. Calculations using the Microshield computer code allowed gamma radiation measurements to be converted into total activity estimates or each source.

More than 11,000 sources were disposed of under the programme from across the medical, industrial, museum and academic sectors. The total activity disposed of was more than 8.5E+14 Bq, and the project was delivered under budget.

P06.51
Absorbed Dose Simulation During Handling Radioactive Sources in Well Logging Temporary Jobsites

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The Brazilian nuclear Regulatory Body (CNEN), since 2010 expanded the regulatory inspection in well logging facilities to evaluate the operational and radioprotections procedures in temporary jobsites, has been observed in-loco different procedures for transfers of radioactive sources in the shields for the logging tools in explorations oil and gas wells.

These different protocols were modeled and subjected to various simulations with the GEANT4 simulator, using an anthropomorphic phantom to estimate the absorbed dose by workers and public in oil and gas sites during well logging operations.

P06.52
Dose Evaluation in Removal and Storage of Well Logging Sources Using an Anthropomorphic Phanton Simulator

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A human body modeling tool combined with Monte Carlo programs for simulation of radiation interaction can lead to obtain the distribution of the absorbed dose in different organs in the human body, with a great degree of accuracy, allowing the evaluation and modification of standard operating procedures from radiation protection point of view.

During the licensing of well logging radioactive facilities in Brazil, there is a need to submit the assessing the amount of radioactive sources to be stored in the field station. The Brazilian standard does not define a basic design for the storage location, existing in the country 5 (five) different design configurations.

This work presents the results of absorbed doses during the removal and storage of radioactive sources, using an anthropomorphic phantom implemented in GEANT4 simulator and the geometry and materials of different design radioactive source well logging storage sites in Brazil, in order to optimize procedures to minimize does in well logging team and define basic design more suitable for the source storage.

P06.53
Application of Phosphogypsum as a Material for Landfill Cover in Brazil

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Phosphogypsum refers to the gypsum formed as a by-product of processing phosphate ore into fertilizer with sulfuric acid. In Brazil, this material has been used, especially in agriculture as soil conditioner. However, the generation rate still much higher than the used one and, therefore this material is stored in piles close to the site production. Chemical analysis of air-dried phosphogypsum indicated that, in general, phosphogypsum is enriched with a sulfate compound ($CaSO_4$) at a level as high as 70%. The sulfate-enriched phosphogypsum can be used in the anaerobic (oxygen depleted) environment, such as landfills, to enhance microbiological processes to decompose municipal solid waste, and thus, extend the lifetime of landfill. This study aimed to assess, through laboratory studies, whether the application of phosphogypsum as a material for landfill cover in Brazil can contribute to an increment to human dose due to the exposure to natural radionuclides. The study was carried out in three stages: 1) sampling and analysis of phosphogypsum and urban waste, 2) assembly of an anaerobic biodegradation system, 3) analysis of natural radionuclides concentration present in leachate samples and 4) determination of the phosphogypsum solubility. The results indicated the use of phosphogypsum as a material for landfill cover must be done carefully.

P06.54
Occupational Exposure in Cleaning Tanks Containing Naturally Occurring Radioactive Material (NORM) in Offshore Oil Production.

Jesus, JMF*

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Historically, in offshore production units, in Brazil and worldwide, there is the occurrence of scales and deposits of inorganic nature derived from the reservoir rocks, consisting mostly of calcium carbonate and barium sulfate, sometimes radioactive.

The detection of radioactivity (gamma radiation) is due to the presence of NORM (Naturally Occurring Radioactive Materials), consisting primarily of barium sulfate (BaSO4), containing the chemical element Radium, which appears as natural radioactive isotopes Ra-226 and Ra-228, originating from radioactive decay, respectively, of the natural radioactive series of the Uranium-238 and of the Thorium-232.

The presence of NORM is still a myth that scares workers of the oil production area, who links the presence of radioactivity to historical accidents of great impact such as Chernobyl (1986) and Goiania (1987) and, more recently, the Fukushima nuclear accident (2011).

The quantification of occupational exposure to gamma radiation in the activity of cleaning tanks containing NORM is important since this activity is becoming more frequent and because it involves employees of third party companies that, invariably, having no qualification to secure proper radiological protection.

During the tasks of cleaning the tank, removal, handling, transport to the deck and storing the radioactive sludge in drums, the levels of dose rate were between 0.8 and 1.7 µSv/h on deck and between, 2.8 and 6.2 µSv/h inside the tank, both below the hourly limit derivative (10 µSv/h). The report of collection of doses of thermoluminescent dosimeters (TLD) pointed to individual doses of 0.3 mSv (four workers) and 0.4 mSv (two workers), for the period of twelve days of cleaning, with averages of 25,0 µSv/day and 33.3 µSv/day, respectively, both below the daily limit derivative (80 µSv/day).

The monitoring of occupational exposure to ionizing radiation of workers involved in the maintenance and cleaning of tanks and vessels containing NORM is important, both for the control of exposure to gamma radiation and as a part of the package of preventive measures to avoid the incorporation of this material by ingestion or inhalation, which would also expose the workers to radiations alpha and beta.

P06.55
Demobilization of Offshore Oil Production Unit (FPSO) Contaminated with Naturally Occurring Radioactive Materials to Revamp and Changing of Location.

Jesus, JMF*

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During the development of production of the Golfinho Field in the Espirito Santo Basin, Brazil, by offshore oil production unit FPSO in the period 2006 to 2009, there was the formation and accumulation of a large volume of sludge and scales inorganic over the entire plant process, from the turret to the slop tanks, through the separation plant, composed predominantly of calcium carbonate ($CaCO_3$) and barium sulfate ($BaSO_4$).

Measurements of radioactivity (gamma radiation) in the plant and the radiochemical analysis confirmed the radioactive properties of sludge and scales, due to the presence of Naturally Occurring Radioactive Materials (NORM) generated as a function mainly of non-use of anti-fouling in the early operation of the platform and the favorable feature of the produced water to the formation of sulfates such as Barium, Strontium, Radio (radioactive) and carbonates, previously unidentified.

NORM, in the form of scales and deposits of inorganic nature derived from the reservoir rocks, consists primarily of barium sulfate ($BaSO_4$), containing Radio, natural radioactive element, which appears as the isotopes ^{226}Ra and ^{228}Ra, originating from radioactive decay, respectively, of the natural radioactive series of Uranium (^{238}U) and of the Thorium (^{232}Th).

With the decline in production and the decision to change of location, the process of demobilization of the FPSO in 2009 had to include the removal of Naturally Occurring Radioactive Materials, with removal of oily sludge contaminated with NORM and cutting and removal of pipes, heat exchangers and valves, generating scrap metal encrusted with NORM. This removal was necessary to meet the laws of Singapore, where it would be done to adapt the unit to the new location. This material requires special packaging and storage in the appropriate place on land meeting the standards of the Brazilian regulatory agency, CNEN - National Nuclear Energy Commission.

This paper outlines the cleaning processes and procedures of removal of NORM to the demobilization of the FPSO, the types and volumes of waste generated, the allocation given to all the waste originated, as well as the final state of the unit.

P06.56
Dose Reconstruction for F-104 Strafighter Maintenance Personnel

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The F-104 Starfighter was in active duty and maintenance at the Dutch Royal Airforce in the period 1962-1983. Maintenance personnel that worked on the F-104 Starfighter J79 jet engine was occupationally exposed to ionizing radiation, as the compressor casing alloy contains between 2 to 4 percent thorium and inherent daughter isotopes. To quantify the external and internal effective dose received by the maintenance personnel, the following dose reconstruction methods have been used.

The quantification of the external effective dose is based on the combination of two main parameters: 1) the yearly duration of exposure per category maintenance personnel working in the vicinity of the compressor casing and 2) a 2-dimensional effective dose profile of the compressor casing. The information of the yearly duration of exposure was extracted from interviews with maintenance personnel and inspectors. The 2-dimensional dose profile was constructed by interpolating data from recently performed active and passive effective dose measurements. The quantification of the internal effective dose is based on the combination of the yearly duration of exposure and four parameters for internal exposure: 1) compressor casing wipe tests, 2) radon and thoron emanation estimates, 3) welding fumes, 4) machining dust particle distribution estimates.

The reconstructed internal effective dose is significantly lower than the external effective dose per year mainly due to removal by suction of welding fumes. The yearly duration of exposure is the most influential parameter in reconstructing the yearly effective dose but also the most sensitive to recall bias. The reconstructed worst case total effective dose for maintenance personnel is 17,5 mSv per year.

P06.57
Natural Radioactivity and Risks Associated with Mining of Rare Metal Pegmatite of Oke-Ogun Field, Sepeteri, Southwestern, Nigeria

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Within and around major cities of Southwestern Nigeria, there are scores of mining activities whose constitute menace into the immediate environments. In this study, a combined techniques using a portable survey meter (Gamma-Scout SN 038439) for in-situ investigation and a well-calibrated NaI(Tl) detector system were used for the measurement of the average radioactivity concentration in some rocks associated with mining of rare metal pegmatite of Oke-Ogun field, Sepeteri, Oyo state of Nigeria. The average dose rate obtained for gamma and beta exposure vary between 0.1 - 0.24 μSv/hr with a mean of 0.18 μSv/hr and between 0.01 - 0.08 μSv/hr with a mean of 0.03 μSv/hr respectively. With the exception of ^{40}K and the anthropogenic ^{137}Cs, all the radionuclides detected are traceable to the pre-medial series of ^{238}U and ^{232}Th. The specific activity value obtained for ^{238}U, ^{232}Th and ^{40}K varied from 26.06 to 97.10 Bq kg^{-1} with a mean value of 58.04 ±12.78 Bq kg^{-1}, 17.65 to 85.65 Bq kg^{-1} with an average of 29.04 ± 9.49 Bq kg^{-1} and 194.87 to 1035.56 Bq kg^{-1} with an average of 586.23 ± 88.56 Bq k^{g-1} respectively. The mean value obtained for the Representative levels index (I_γ), the radium equivalent (Ra_{eq}), the total absorbed dose rate (ADR) were 1.07; 144.71 Bq Kg^{-1} and 68.80 nGy h^{-1} respectively. The discrepancies of our data can be attributed to several factors such as geological formation, transport process, etc. Although our results are just some fractions of the international standard limit, but still within the same ranges when compared with those obtained elsewhere. This results also will serve as a baseline data for future investigations.

Keywords: Radioactivity, Mining, Hazards, Gamma Spectrometry

P06.58
Examination Of The Environmental Radioactivity Nearby The Uranium Mining And Milling Facility

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The examined media were: soil, grass covering and local foods (milk and potato). The specific activities of the natural ^{238}U, ^{232}Th, ^{40}K, ^{226} Ra, ^{210}Pb, ^{210}Po and global - ^{137}Cs and ^{90}Sr radionuclides have been determined in samples. Concentrations of the Natural Radionuclides (NR) in soil of the examined area vary over the wide range, and in some parts are much higher than the natural concentrations of these radionuclides in soils. This is especially true for ^{226}Ra and its progenies ^{210}Pb, ^{210}Po. The most high local soil contamination has been registered in the areas of the above-mine buildings (up to $2.6.10^4$ Bq/kg for ^{226}Ra, up to $1.5.10^4$ Bq/kg and $9.9.10^3$ Bq/kg for ^{210}Pb and ^{210}Po, respectively). The NR concentrations in the grass covering are also high there (up to 63. 37 and 11 Bq/kg for Ra^{226}, Pb^{210} and Po^{210}, respectively).

The NR concentrations in milk and potato are within the range of averaged Russian data (in potato - up to 0.65, 0.07 and 0.01 Bq/kg, in milk up to 0.43, 0.14 and 0.02 Bq/kg for Ra^{226}, Pb^{210} and Po^{210}, respectively). However, the difference is observed in the activity ratios of some radionuclides. So, the activity ratio of ^{210}Pb and ^{226}Ra in milk and potato is 2.5-2.3 over Russia on average, while for local foods this value is much lower than 1 (0.29 for milk and 0.13 for potato). This can be explained by higher concentration of man-made ^{226}Ra in soils, soil-weather conditions and physical-and-chemical properties of radionuclides.

The specific activities of ^{137}Cs and ^{90}Sr in local foods (milk, potato) are at the level of the global content and much lower than the radiation and hygienic regulation values established in Russia. Thus, the effective internal dose to the public due to the food intake is generated mainly by the NR intake.

P06.59
Radioactivity Assessment in Rare Earth Extraction and Steel Industry: A Study Case in Baiyun Obo, China

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Baiyun Obo mine is a typical deposit of multi-minerals that consists of iron, rare earth elements, thorium and niobium. Ores are mined in Baiyun Obo and transported to Baotou Iron and Steel Plant to produce Steel and rare earth elements. Ores in Baiyun Obo mine contain about 34% iron, 5% REO and 0.032% ThO_2.The ores are rich in thorium. Mining and processing ores cause a certain radiological impact on working places and environment. Radiation levels has been obtained by airborne and in-situ gamma spectrometry and dosimetry in Baiyun Obo and Baotou. Higher radiation levels were located mostly in mining area and their surroundings covering an area of about 55Km^2 in Baiyun Obo. The typical radiation levels range from 200 to 800nGy/h in most of the area and 600 to 2000nGy/h in mining sites. Another higher radiation areas covering about 7Km^2 in Baotou, are located mostly the sorting plant, RE plant, steel refining plant, as well as in the areas where NORM residues are stored. The radiation level mostly is 500 to 1,000nGy/h in most of the areas, 3000 to 6000nGy/h in some areas of RE slag, and 85 to 150nGy/h in contaminated soil.

Additional external exposure for workers in plants ranges from 0.29 to 0.41 mSv/a, while for those working in mining areas from 0.24 to 1.0 mSv/a. If inhalation of aerosol and dust containing thorium is considered, additional effective dose for many workers will exceed 1.0 mSv/a. Additional exposure received by members of the public is not significant. But their effective dose rises if they live in the buildings using slag materials.

P06.60
Analysis of Workers' Dosimetry of Industrial Gammagraphy in Argentina

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Industrial gammagraphy represents one of the activities using radioactive material with major radiological risk in the world for occupationally exposed personnel as well as for the public in general, these representing the main risk group in the radiological accidents reported so far.

The present normative that regulates this activity in Argentina establishes that the dose records of the staff linked to tasks of Industrial gammagraphy must be notified yearly.

The present work analyzes the statistics of annual dose records in the period 2003-2010 within the companies that operate with Industrial gammagraphy equipments, the deviations found in the values, the justifications presented by the users and the corrective actions taken by the "radiation safety officers" of gammagraphy companies. As a conclusion, the Nuclear Regulatory Authority (ARN) evaluates the data mentioned above so as to be able to require corrective measures that directly reduce the dose level of the operators.

P06.61
Assessment of the radiological impacts of Gypsum, Ferro-Manganese and Oil industries

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This study attempts to determine the concentrations of NORM in industries in Wadi-Nasieb, southwest Sinai. The area includes gypsum industry from quarries at Ras Malaab, Carbon ferro-manganese industry in Abu Zenima based on extracted Mn ore of Um Bogma and oil field on the Gulf of Suez shore of Abu-Rudeis. This investigation also included other raw materials; limestone, dolomite, carbon paste, coal, white sand, kaolin and locally produced petroleum products. The radionuclides present in all studied raw materials but the Egyptian Mn ore are neither a health hazard for the workers nor a threat to the general population. The associated wastes of these industries have been evaluated to guarantee the safety of the population and workers. Enhanced concentrations of NORM in the wastes was found only in the case of alloy production process, in such a way that the radiation exposure results in significant doses to the public.

P06.62
International initiatives addressing the safety and security of Disused Sealed Radioactive Sources (DSRS)

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High activity radioactive sources provide great benefit to humanity through their utilization in agriculture, industry, medicine, research and education, and the vast majority are used in well-controlled environments. None-the-less, control has been lost over a small fraction of those sources resulting in accidents of which some had serious – even fatal – consequences. Indeed, accidents and incidents involving radioactive sources indicate that the existing regime for the control of sources needs improvement. Additionally, today's global security environment requires more determined efforts to properly control radioactive sources. Consequently, the current regimes must be strengthened in order to ensure control over sources that are outside of regulatory control (orphan sources), as well as for sources that are vulnerable to loss, misuse, theft, or malicious use. Besides improving the existing situation, appropriate norms and standards at the national and international levels must continue to be developed to ensure the long-term sustainability of control over radioactive sources.

In order to improve the existing situation, concerted national and international efforts are needed and, to some degree, are being implemented to strengthen the safety and security of sources in use, as well as to improve the control of disused sources located at numerous facilities throughout the world. More efforts must also be made to identify, recover, and bring into control orphan sources. The IAEA works closely with Member States to improve the safety and security of radioactive sources worldwide. Besides the IAEA Technical Assistance Programme and Technical Cooperation Fund, donor States provide significant financial contributions to the Nuclear Security Fund and/or direct technical support to other States to recover condition and transfer disused sources into safe and secure storage facilities and to upgrade the physical protection of sources that are in use. Under the USA-Russian Federation-IAEA ("Tripartite") Initiative, for example, disused sources of a total activity of 2120 TBq (57251 Ci) were recovered and transported into safe and secure storage facilities in six countries of the former Soviet Union. Additionally, physical protection upgrades were performed in thirteen former Soviet Union republics at facilities using or storing high activity radioactive sources. Other donors have also provided funding for projects related to the safety and security of radioactive sources in the same region. Additionally, the EU and other countries are making regular and significant contributions to the IAEA for projects aimed at upgrading the safety and security of radioactive sources in South-Eastern Europe, the Middle East, Asia and Africa. Depending on the status of the radioactive source (in use, disused, or orphan) and the actual technical, safety and security situation, several options exist to ensure the source is properly brought or maintained under control. This paper will describe those options and the systematic approach followed by the IAEA in deciding on the most appropriate actions to take for the high activity sources that need to be recovered or removed from the countries under that request assistance.

Poster sessions C-D: Area 6

P06.63
Radiological Assessment of Black Powder in Sales Gas Pipelines

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Black powder is regenerative and is formed inside the sales gas pipelines as a result of internal corrosion due to condensed moisture and ingression of oxygen.

Naturally Occurring Radioactive Material (NORM), principally the radionuclides Lead-210 and Polonium-210 have been identified in Black Powder. A detailed investigation into the radiological components of Black Powder was carried to determine if waste produced during pipe line scraping operations presented a workers protection or environmental control problem due to the level of radioactivity present. The investigation looked at a sales gas pipeline network and spanned scraping operations over a two year period. This paper details the sampling, and analysis methods used to assess Black powder samples, the results of sample analysis and advice provided to ensure workers protection and environmental control of the waste produced during pipeline scraping activities.

P06.64
Decontamination of NORM Contaminated Facilities & Equipment, Case Study

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The contamination of oil and gas processing equipment with NORM bearing scales can present a radiological hazard in addition to restricted operability. Once NORM contaminated equipment cannot be released for sale or re-use as it has enhanced levels of radioactivity which can lead to exposure of workers, the general public and the environment if not managed appropriately.

Part of a successful NORM management strategy is the ability to decontaminate equipment which has become contaminated with NORM. The removal of relatively insoluble NORM scale which has become adhered to equipment surfaces requires aggressive agitation of the surface to remove the NORM contamination. The control of NORM contamination removed from contaminated equipment and the protection of workers during the decontamination process are achieved primarily by engineering controls, however these must be supported by administrative procedures and personal protective equipment.

This paper details the design, fabrication and operation of mobile NORM decontamination facilities, and insitu decontamination methods used to successfully decontaminate plant and equipment, together with lessons learnt during these operations.

P06.65
Radiological Characterization of Phosphate Rock and Soils of the Northern Region of Peru

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Radiological characterization was performed in soils and phosphate rock in the mining area of Sechura (Piura), where is located one of the largest phosphate deposits in South America, with a reserve of 238 MT of phosphate rock. To study the baseline levels of radioactive elements and distribution of radionuclides during the process of mineral extraction and treatment, characterization was performed using HpGe gamma spectrometry and proportional beta counting. The U-238 activity concentrations in phosphate rock were found in a range of 570 and 1350 Bq/kg and in soil samples, between 50 and 480 Bq/kg. Ra-226 values up to 830 Bq/kg were obtained in samples of surface soil and phosphate rock after reaching the secular equilibrium with its decay products. Th-232 values up to 95 Bq/kg were also found. Gross beta activity concentrations in phosphate rock was three times higher than in soil samples collected in areas adjacent to mining sites. This information is important to know the dose of the workers, public and environment due to the presence of NORM products during the mining process.

P06.66
Radiological Considerations of the BHP Billiton Olympic Dam Expansion

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BHP Billiton has recently received approval for the expansion of its Olympic Dam copper and uranium mining and production operation in South Australia. This follows an approval process of over 6 years duration which included an environmental impact statement (EIS), an extensive public consultation phase, a supplementary EIS followed by a bilateral state and federal government approval with conditions.

The expansion will make Olympic Dam the leading international producer of uranium oxide concentrate and includes the construction of one of the world's largest open pit mines, the construction of waste rock storage and tailings storage facilities, expansion of the metallurgical processing facilities and associated infrastructure.

In assessing the radiological impacts of such an expansion, the EIS considered;

- the unprecedented size of the pit and its impact on doses to mine workers,

- radon behaviour in the pit microclimate,

- increased emissions of radon, and the potential to increase public doses in the nearby township of Roxby Downs,

- containment of the low level radioactive tailings and reactive waste rock,

- the impacts of radioactive emissions on non human biota,

- long term impacts on the environment.

The EIS also considered systems for dose limitation by building on the existing radiological performance of the company including;

- enhancement of the existing radiation management plans,

- ensuring doses are as low as reasonably achievable, through design criteria and standards, targeted training and scheduled radiation optimisation studies on components of the project.

In addition, the public comments phase of the EIS provided an insight into radiation related issues that were of concern to sections of the local and national community. This information identified targets for future awareness and education programs.

This paper provides an overview of the radiation considerations in the early stages of the development of the world's largest uranium mine and production facility.

P06.67
Database on Naturally Occurring Radioactive Material

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The International Commission on Radiological Protection (ICRP) 1990 Recommendations recommend that the occupational exposure of NORMs should be controlled. However, the current extent of the industrial use of NORMs is not clearly perceived, because the activity concentration in NORMs has a wide distribution from very low level, and NORMs are used for a variety of purposes.

Because Japan has few natural resources, most ores used as industrial raw materials are imported. If these resources, containing radioactive nuclides in high concentration, are used, the workers handling them can be exposed to high levels of radiation without being aware of it. The activity concentration in many natural resources should be investigated to evaluate the radiation exposure of workers.

In this study, we collected imported natural resources, and measured the activity concentrations in these resources using ICP-MS (inductively-coupled plasma mass spectrometry) and gamma ray spectrometry. Furthermore, we developed a database of activity concentration in NORMs using their results as well as investigation in literatures, and published the database on the web.

(NORM database; http://www.nirs.go.jp/db/anzendb/NORMDB/ENG/index.php). The purpose of the database is to dispel anxieties among the general public and to provide extensive data regarding NORM to researchers and regulators. The database is providing the activity concentrations in more than 1000 NORMs at no fee. The database is freely available to the web.

KEYWORDS: NORM, natural radioactive nuclide, natural resource, activity concentration

P06.68
Radiation Safety Systems for the Linac Coherent Light Source (LCLS) at SLAC

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The Radiation Safety Systems for the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator laboratory is presented. LCLS is the world's first operating 4th-generation hard X-ray free electron laser (FEL) facility. LCLS facility consists on an injector, linac, Beam Transport Hall (BTH), Undulator Hall, Beam Dump, Front End Enclosure and two experimental halls housing 6 experimental stations. LCLS uses one-third of the existing 3-km-long SLAC accelerator to generate a 15 GeV, 2 kW electron beam. At the end of the linac electrons are transported through the shielded BTH, then through a 130-meter-long undulator generating FEL fundamentals ranging from 0.15 to 1.5 nanometers (0.83 to 8.3 keV). The electron beam is bent down to the main electron dump while the X-rays are transported to the experimental halls.

Some of the radiation safety issues for LCLS are similar to those that are present in high-energy electron accelerators and synchrotron radiation facilities. However, LCLS (and other single pass, linac based 4th generation FELs) pose new radiation safety challenges that need to be resolved. These issues include: 1) protection of personnel who need to access to experimental hutches that are located near zero-degree with respect to the electron beam and bremsstrahlung direction and 2) the high peak intensity (energy per pulse) of FEL that can damage beam line components including safety critical devices such as beam dumps and collimators.

To ensure radiations doses to worker and public are maintained below applicable limits and As Low As Reasonable Achievable, LCLS has deployed a Radiation Safety System that consists of passive, active and administrative sub-systems. It is comprise of a system that keeps personnel away from prompt radiation hazards in electron beam housing (e.g., access control system and shielding) and Beam Containment System (BCS) that keeps beam/radiation away from people. The BCS consists of a combination of mechanical devices (beam dump, collimators and apertures) and electronic devices with sensors ensuring that beam is contained within an approved operation envelope of beam parameters. BCS also detect and terminate unacceptable high beam losses via interlocked radiation detectors, thus preventing generation of excessive level of radiation in the occupiable areas. An overview of the Radiation Safety System at LCLS is presented.

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P06.69
Residual Gamma Dose Rate Evaluation at the Radioactive Ion Beam Facility SPES

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The SPES (Study for the Production of Exotic Species) project aims at the creation of Radioactive Ion Beams (RIBs) to be used in nuclear physics. The beams will be obtained by the fission of an uranium carbide target with a proton beam extracted from a cyclotron at the Legnaro National Laboratory of the INFN.

The access to the target hall and the cyclotron vault will be forbidden while the proton beam is sent on the target, due to the high dose rates in those areas. The gamma dose due to the fraction of the radioactive beam lost during the selection and the transport of the useful RIB must be evaluated in order to plan an adequate radiation safety system, including access permissions and local shielding where needed.

The selection devices where the beam losses will be non-negligible by design are the charge breeder, the beam cooler and the mass separator. The evaluation of the residual dose rate in the areas hosting those devices is object of this work. Calculations are done using a Monte Carlo method implemented with the FLUKA simulation program. The method will be explained and the results presented in the present paper.

P06.70
Radiation Safety of New X-ray Free Electron Laser Facility at SPring-8

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SPring-8 Angstrom Compact Laser facility (SACLA) is now under commissioning to obtain the full power of the X-ray laser with the shortest wavelength of less than 0.1nm. SACLA has been constructed at just close to the 1 km long beamline of the 8 GeV class synchrotron radiation facility, SPring-8. SACLA is based on three new technologies. One is the low emittance thermionic electron gun, one is the C-band accelerators of up to 30 nC/s with 8.5 GeV (255W), and the other is the in-vacuum type undulators. The length of this SACLA system is about 415m, 235m, and 66m for the accelerator section, the undulator section, and the experimental hall, respectively. Based on the ALARA principles, the shielding design of SACLA was performed under the design criteria of 8μSv/h, 2.5μSv/h, and 100μSv/y for the radiation controlled area, the boundary of the controlled area, and the site boundary, respectively. The interlock system which consists of radiation monitoring system, access control system and beam containment system was installed and these systems are linked organically to prevent the hazardous conditions. In addition to these systems, beam loss monitor and beam halo monitor were installed to prevent the unnecessary electron beam loss to increase leakage doses. These systems including the shielding conditions will be presented and we will describe the present status of the radiation fields of SACLA during the commissioning.

P06.71
Radiological Protection in Fusion Research at JET

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The radiological protection issues associated with the operation and maintenance of JET at Culham Centre for Fusion Research (CCFE) are reviewed. Particular emphasis is placed on the issues associated tritiated dusts and the implications for future fusion research machines.

The practical and managerial arrangements for keeping doses ALARP are summarised; the engineering protection techniques used and the experience gained from undertaking breaches of containment contaminated with tritiated gas and particulate are summarised. The techniques used to assess tritium off-gas from components are also presented.

The radiological hazard in terms of effective dose equivalent derived from size analysis and dissolution studies of the dusts generated by plasma operations have been assessed and the implications for future fusion machines (ITER) are presented.

P06.72
Neutron Fields Around the Joint Research Centre of Ispra Cyclotron's Beam Lines

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The Joint Research Centre of Ispra, one of the research Sites belonging to the European Commission, Directorate General JRC, was created in the late '50s, in order to steer European research on nuclear industry. It currently hosts numerous nuclear facilities, some of which are maintained in operation, while others were shutdown in past years or are currently being decommissioned.

The JRC Cyclotron is a Scanditronix MC-40, 40 MeV positive charge accelerator, able to accelerate protons, deuterons, He3 and He4 particles: it is mainly used for research on radio-isotope production, nanoparticles activation, and other studies on materials' properties. Since 8 years, the Cyclotron Laboratory hosts the first commercial FDG production facility in Italy, a joint initiative with General Electric.

A specific cyclotron beam line (BL5) has been dedicated to neutron activation analyses, via proton conversion on a berillium target: this dedicated beam line has been extensively used, in the past years, in a series of experiments, which also incidentally showed that existing room penetrations and shielding were not fully appropriate to those, originally not foreseen, higher intensity neutron fields.

This work reviews neutron fields around the Cyclotron's beam lines: it is composed of a set of simulations, mainly obtained by FLUKA modelling of the currently available cyclotron's beam lines and typical target irradiations; and a campaign of active and passive neutron measurements, which confirmed the effectiveness of the simulations performed.

This work has also contributed to a revision of existing shieldings and penetrations into irradiation rooms, and has led to some improvements in their original design.

P06.73
Preliminary Assessment of Radioactive Waste for the DEMO Fusion Reactor

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It is known that nuclear fusion reactor would not be produced the high-level radioactive spent fuel as like as fission reactors. However, medium or low level radioactive wastes which are produced when the fusion reactor was operated or decommissioned are expected to be non-negligible magnitude. Therefore, it is necessary to perform the quantitative assessments on of the fusion radioactive wastes. Furthermore, that process would be referred to make the regulation for the construction of DEMO fusion reactor which is planning for construction as a future work in Korea. In order to assess the fusion radioactive waste, activation characteristics have been analyzed for the main three modules of ITER model. By choosing irradiation and cooling scenarios, the activation calculations were performed by FISPACT 2007 code. Neutron flux distributions in the fusion reactor were provided by a MCNP calculation. The design of the DEMO fusion reactor is referred from ITER model. The calculated fluxes were employed to FISPACT for the activation calculation. As a result, the total activities and total decay heats for the three main modules of the fusion reactor (TBM, Vacuum Vessel, and Diverter) were calculated and analyzed. The module which gives the highest total activity right after shutdown of the reactor was the Diverter. However the total activity at the TBM after one year shows higher than that of the Diverter. The activation inventory and the main radioactive materials at every cooling time step were obtained for each one of the modules. Finally, the quantitative assessments of the fusion radioactive wastes were performed in comparison with the fission radioactive waste of Korean NPP.

P06.74
Parameter considerations of Accelerator-based Sub-Critical Nuclear Reactor

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After the East-Japan earthquake and the subsequent nuclear disaster, the safety issue of current nuclear reactor has been more important in the aspects of the energy generation facility and long-lived actinides. The accelerator-based sub-critical nuclear reactor or Accelerator Driven System (ADS) for solving the problem of nuclear fission energy was once proposed long time ago and recently the research facility such as EUROTRAN and MYRRHA have been proposed. In spite of long-story idea, the accelerator-based nuclear reactor has not been utilized yet by technical difficulty and economical reasons. It needs 1 GeV, 10 MW power proton accelerator. A conventional linear accelerator which can generate such huge power, would need several hundred meter length. It is highly costly and weak at long term stability. However, recent technologies make it possible to realize that scale accelerator by a reasonable size and to get the required stability. That is the fixed-field alternating gradient (FFAG) accelerator.

Another issue is sub-critical reactor which is based on heavy metallic target. Both of heat production from proton irradiation and heat delivery to power generator have to be considered coincidently. Special liquid metals like lead or lead-bismuth have been studied as a target.

In this study, the machine parameters to design sub-critical nuclear reactor, which is based on FFAG accelerator, and operational parameter to secure long-term stability and safety are investigated and discussed. Several concepts pre-proposed by others were reviewed and compared to make a idea of best condition. The neutron multiplicity of proton irradiation is also studied for reactor part basically. This study is first step to design optimized facility and the practical parameters and its basic idea will be presented.

KEYWORDS: sub-critical reactor; accelerator; ADS; FFAG; parameter optimization.

P06.75
ANSI N43.1 Standard "Radiation Safety for the Design and Operation of Particle Accelerators" (Final Draft Sept. 2011)

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An overview of the final draft of the ANSI N43.1 Standard "Radiation Safety for the Design and Operation of Particle Accelerators" is presented. The Standard sets forth the requirements and recommendations for accelerator facilities to provide adequate radiation protection for the workers, the public and the environment. The Standard applies to the design, installation, commissioning, operation, maintenance, upgrades and decommissioning of accelerator facilities. The Standard is applicable to most accelerator facilities. The N43.1 Standard specifies the requirements and recommendations for both the management and the technical aspects of the radiation safety program, with a graded approach that is commensurate with the radiological hazards and risk. The Standard has 9 chapters: 1) purpose and scope, 2) definitions, 3) radiation safety programs, 4) Radiation Safety Systems for the control prompt radiation hazards, which includes two complementary systems: the Access Control System (ACS) and Radiation Control System (RCS), 5) ACS details, 6) RCS details (shielding, active beam monitors and radiation monitors, etc), 7) accelerator operation, 8) operational radiation safety program, and 9) training. The Standard has five appendices to provide guidance and resources for a few key subjects.

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P06.76
Commissioning and Critical Examination of a new PET Imaging Centre

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CRIC, the Clinical Research Imaging Centre, is a partnership between the University of Edinburgh and the University Hospital's Division of Lothian NHS Board, jointly managed through the Clinical Research Facility. The state-of-the art equipment is located in the Queen's Medical Research Institute at Little France. CRIC incorporates a radiochemistry production facility within its overall site layout. This radiochemistry facility includes a dedicated PET, (Positron Emission Tomography), cyclotron operating in a concrete shielded vault, a GMP (Good Manufacturing Practice) manufacturing facility for the production of sterile, injectable PET radio-tracers and an R&D research laboratory, for the development of novel PET radio-tracers.

Protection of workers and members of the public from the potential risk from ionising radiation is regulated by the Health and Safety Executive (HSE) by means of enforcement of the Ionising Radiations Regulations 1999 (IRR99). In addition to the protection of individuals, the protection of the environment is achieved by adherence to the Radioactive Substances Act 1993, which is regulated by SEPA, The Scottish Environmental Protection Agency. As a consequence of the production of radiochemicals there will be the potential for off-site impact in the form of gaseous, liquid or solid wastes. These discharges and waste disposals are controlled by adherence to the prescribed limits stated in the Authorisation document.

The Commissioning Report provided an overview of the facility in terms of broad compliance against all aspects of IRR99 and RSA93, but it was specifically intended to meet the requirements of Regulation 31(2), of IRR99. This Regulation requires the erector or installer of an article which is for use at work which involves the potential exposure to ionising radiation to carry out a critical examination on that article.

Regulation 31(2) can be summarised as requiring the installer of an item of equipment to ensure that what they are providing meets the following:

i) The safety features and warning devices operate correctly; and

ii) There is sufficient protection for persons from exposure to ionising radiation.

Whilst the duties summarised above state the main aims of the Regulation in addition there is a requirement for the installer to consult with a Radiation Protection Adviser appointed by themselves or by the radiation employer of the facility into which it is being installed on the scope of the Critical Examination. In addition the manufacturer must also provide the radiation employer with adequate information to enable the proper use, testing and maintenance of the article.

P06.77
Survey of RF Test Facility During Cavity Conditioning

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Diamond Light Source is the UK's national synchrotron science facility, located at the Harwell Science and Innovation Campus in Oxfordshire. By accelerating electrons to near light-speed, Diamond generates brilliant beams of light from infra-red to X-rays which are used for academic and industrial research and development across a range of scientific disciplines including structural biology, physics, chemistry, materials science, engineering, earth and environmental sciences.

As the electrons emit the synchrotron radiation, they need to have their energy replenished to keep them in orbit around the synchrotron at 3 GeV. Diamond uses two superconducting Radio Frequency (RF) cavities to replace the lost energy. In order for the cavities to work in a stable mode, they need to be vacuum conditioned – this needs to be done when the cavities are first used, or after any vacuum intervention. The conditioning process involves raising the applied voltage on the cavity to the maximum sustainable level, then applying more power until the vacuum conditions to a level where a higher voltage can be tolerated, then the process repeats. While the cavity is conditioning, it may generate bremsstrahlung at MeV energies, at dose rates of a few Grays per hour at contact.

Cavity conditioning can take place with the synchrotron storage ring vault, which is already shielded for a higher radiation load than is produced by the adventitious radiation from the cavities. To provide more flexibility, and to allow cavities to be conditioned away from the storage ring, an RF test facility has been constructed. As a new facility being used to condition a new cavity, an extensive programme of radiation measurements was undertaken, both inside and outside the facility. This allowed not only the effectiveness of the shielding to be verified, but also allowed mapping of the field from the RF cavity as it conditioned.

This report details the radiation output of the RF cavity, the effectiveness of the shielding of the RF test facility and the safety systems that have been employed. The Conclusion includes some improvements to the shielding and safety systems of the RF test facility

P06.78
Survey on Occupational Exposure in Industrial Radiography Practice

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The aim of this study is to evaluate the occupational external exposure doses recorded in industrial radiography practice at fixed facilities and on site. The assessment was performed based on the doses recorded in a Romanian company from 1978 to July 2011 for 102 persons who have operated X-ray machines (max. 420 kV) and gamma installations (^{192} Ir and ^{60}Co; λ=3.7 TBq). Approximately 52% of the recorded doses are below the minimum detectable level of the dosimeter and 28% of the operators received less than 1mSv/year. The staff involved in the practice received whole body doses ranging from 0.1 to 8.9 mSv/year. It can be noted that the highest annual exposure received as a result of routine operations over the mentioned period is below the annual limit of 20 mSv. The state of the workers' health has been reviewed once a year. One of the main objectives of this paper is to provide information on doses in order to give an indication of whether the techniques are optimized in terms of doses and to discuss about the categorization of the industrial radiography workers.

P06.79
Dose Planning and Evaluation During Reactor Repair

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NRG is a major producer of medical isotopes in Europe. The isotopes are produced in the High Flux Reactor (HFR), which is present on our company area. As probably known this reactor showed some possible defects in the linings of the primary cooling system. With the Dutch government a repair project was defined, which was carried out in 2010.

In the preparation of this project a lot radiation safety issues were addressed: first the presence of radiation sources in the core shielding were explored. This was performed with use of model calculations and were confirmed by measurements. Then ALARA measures were planned, resulting in – amongst other measures – a design and placing of additional shielding measures for the radiological workers. Special interest was given to the registration of the doses of the radiological workers. Apart from the regular registration tools as on-line air dust and gamma monitoring inside and outside the reactor, an electronic APD-system was introduced before the actual work was carried out.

With this APD-system NRG was able to register daily the personal and collective dose of the several tasks which were defined in the project. Special interest could be given to the task which were expected to result in a significant contribution to the collective dose: placing the additional shielding and the welding of the linings of the primary cooling system. For all tasks so-called hold points were introduced. When the individual or collective dose reached the hold points, an obligatory evaluation of the working procedures should be held to discuss the progress of the project, and possible additional measures to keep the planned doses below the maximal expected doses.

With the new system, it could be concluded that all received doses of radiological workers stayed within the planned dose contributions of these tasks. For individual workers, the maximum received dose amount 89% of the maximal expected dose of 5 mSv. The collective dose amounted 56% of the total estimated dose of 85 man Sv.

After the project was ended the normal routine measures were taken for the areas and the personnel: the working areas were checked on the presence of remaining activity, and the personnel was checked on internal contamination.

From this project it could be concluded:

• that making a dose estimation of the several steps in your project gives provides good insight in the risks in the several phases of your project.

• that the installation of dose hold points encourages the right discussions at the right moment in your project.

Another additional interesting conclusion from this project is that the average difference between the regular dose meters (based on TLD-technology) and the active personal dose meters used in this project amounted less than 10% This difference should encourage the Dutch government taking the next step from regular TLD to APD based dosimetry.

P06.80
Occupational Exposure In Production Of Radiopharmaceuticals And Labeled Compounds

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The purpose of this paper is to assess the occupational exposure from radiopharmaceuticals production in the Center of Isotopes of the Cuban Republic. Data belong to the period 1996÷2010 are processed and a total of 668 workers are controlled. Percentage distributions of the annual effective dose (E), hand equivalent dose (Hp (0.07)) and lens equivalent dose (Hp(3)) are showed. Annual mean values of these dosimetric magnitudes are plotted. Bioassay results are processed. Handling annual activities for the radioisotopes which have the largest contribution and their relation with collective dose (S) distribution are evaluated. ALARA principle is implemented and maintained considering qualitative and quantitative analysis as it is required. There are 58-98% of the monitored workers for E, 80-100% for Hp(0.07) and 100% for Hp(3) that received lower than 10% of the annual exposure limits. The staff belonging to departments of Radiopharmacy and Quality Control is the most exposed. The maximum value registered for S is 98 man-mSv y^{-1} and this occurs in 2010. In spite of this, the maximum handling activity of ^{99}Mo was in 2009 and a year later for 131I. There are identified as the most useful tools from the point of view of the optimization of protection the use of electronic dosimeters, an additional shielding for the collection of radwastes and the internal shielding components in hot cells and glove boxes. It is obtained a dose reduction between 10-28%. It is demonstrated the exposure of workers related with radiopharmaceuticals production in Cuba is acceptable low.

P06.81
Performance Safety Indicators for a Radioactive Facility in Cuba

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The use of safety performance indicators is common in the nuclear industry. This paper illustrates indicators for the analysis of the effectiveness and efficiency of the safety management system in the Centre of Isotopes in Cuba. Current management practice demands that an organization inculcate culture of safety in preventing radiation hazard. The aforementioned objectives of radiation protection can only be met when it is implemented and evaluated continuously. Maintaining and improving safety culture is a continuous process. There is a need to establish a program to measure, review and audit health and safety performance against predetermined standards. All those areas of the radiation protection program are considered (e.g. licensing and training of the staff, occupational exposure, authorization of the practices, control of the radioactive material, radiological occurrences, monitoring equipment, radioactive waste management, public exposure due to airborne and liquids discharges, audits and safety costs). A set of indicators designed to monitor key aspects of operational safety performance are used. Their trends over a period of time are analyzed with the modern information technologies, because this can provide an early warning to plant management for searching causes behind the observed changes. In addition to analyze the changes and trends, these indicators are compared against identified targets and goals to evaluate performance strengths and weaknesses. A structured and proper radiation self-auditing system is seen as a basic requirement to meet the current and future needs in sustainability of radiation safety. These indicators are included in the periodic training of the workers.

P06.83
Assessment of the Radiological Safety of Exposure Devices For Industrial Gamma Radiography in Argentina

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The main objective of this work is to make an assessment of the factors taken into account to support the proposal which may allow the Nuclear Regulatory Authority of Argentina to decide about the withdrawal from circulation and service of great part of the inventory of equipment belonging to industrial gamma radiography facilities in the country. As the main elements of evaluation, the equipment which do not meet the terms of the international recommendations regarding the compliance to the main requirements of safety established in international standards as the ISO 3999 (Radiation protection – Apparatus for industrial gamma radiography – Specifications for performance, design and tests), the decision of some manufacturers to discontinue the production of certain equipment models and the provision of their replacement parts, as well as the validity of type B(U) package certificates for their transport, are considered.

A distribution of the types of equipment in the country at present classified by brand and model is presented, as well as the percentages of the total which are in process of being evaluated to be removed.

As a conclusion, it is highlighted the need of a regulatory decision complementary to the AR 7.9.1 standard concerning the operation of industrial gamma radiography equipment, based on the current international recommendations and the commitment of Argentina to the good practices and safety culture, which may lead to a positive impact on the radiological safety in a technique which, in view of its operating characteristics and taking into consideration the activities of the radioactive sources involved, is considered of a significant radiological risk, as it has been demonstrated by the magnitude and frequency of the radiological accidents occurred worldwide.

P06.84
Applications Of Ionizing Radiation. Irradiation Of Biological Materials And Small Animals In Research

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Events induced by ionizing radiation are used in diverse fields of scientific research, and the application of this technology has for many years offered advantages over alternative approaches.

Today, biological irradiators are established as one of the basic tools in diverse areas of biological research.

Most Spanish biological research institutes are equipped with X-ray or gamma ray irradiators, which are used for a number of research purposes. The risk associated with the use of this equipment is negligible, since radiation sources are effectively shielded and the equipment is fitted with multiple safety mechanisms. These safety mechanisms are verified by dosimetry reports for operators and researchers.

In addition, in type A gamma biological irradiators with a self-shielded source, the gamma emitter cannot be accessed by operators, increasing operational safety.

This type of gamma irradiator can be used for irradiation of experimental animals and various kinds of tissue sample, and is a standard methodology for biological research in fields such as cardiovascular research and cancer.

Considering these points, the aim of this paper is to review the use of industrial sources without radiological risk in cell and animal irradiators for biological research. The paper describes the technical characteristics of equipment, facility design and the techniques and applications of irradiation of biological samples used in research.

KEY WORDS: irradiator, biomedical research, self-shielded source.

P06.85
A Survey of Environmental Radioactivity Level in Laboratories of the Town Campus University, Uyo - Niger Delta Region

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The UNSCEAR (2000) observed that there could be some exposure at work which would require regulatory control but is not really considered. This study was, then, set up to evaluate the annual effective dose equivalent of 25 Laboratories in Town Campus of University of Uyo, Niger Delta Region and to determine if the evaluated dose levels could lead to any radiological health effect in the workers, and also determine if the laboratories require regulatory control. The radiation exposure at the laboratories measured using Inspector alert surveying meter were converted to effective dose and compared with the public and occupational values. From the result obtained the effective dose equivalent were moderately low ranging from *0.128±0.041mSv/yr* to *0.309±0.049mSv/yr* except in pharmaceutical/Medicinal Chemistry Laboratory store room (SA_{25}) where higher value of *1.015±0.09mS/yr* was recorded. The evaluated effective dose values in the laboratories were below public and occupational exposure safe limits and may not necessarily result in any radiological health hazard.

Keywords: effective dose, Occupational exposure, Laboratories, University of Uyo, health hazard.

P06.86
Technological Management Applied in Irradiation Foodstuff

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This paper presents a research focused on technology management applied to technical and economic viability for the installation of a multipurpose irradiator in Vale do Ribeira (Sao Paulo State). It presents the regional characteristics from the region and the emergent irradiation techniques applied to the food industry beside concepts of technology management. The methodology uses bibliographical, qualitative and quantitative research, and analysis supported by statistical and economic techniques. The research concludes that there is technical and economic viability of the venture analyzed, although it should be recommended more studies about banana irradiation and Brazilian consumer acceptance to irradiated food.

P06.87
Laser Research Centre Eli Beamlines - Radioprotection Issues and Shielding Design

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Recent development of laser systems resulted in their ability to focus ultra-short high-intensity pulses onto targets. As these intense lasers can generate ionizing radiation, radiation safety of workers at these facilities needs to be explored and ensured.

This paper is focused on newly built laser research centre ELI Beamlines, located in Dolni Brezany, Czech Republic. The facility will be the first one of planned four of the envisioned European ELI (Extreme Light Infrastructure) Project. The ELI Beamlines shall develop a new generation of secondary sources for interdisciplinary applications in physic, medicine, biology and material sciences.

The petawatt laser beams are about to generate pulsed mixed fields of high energy particles (up to several GeV), producing up to 6e11 particles of primary radiation per shot. Six experimental halls will host prompt sources of electrons, photons or protons. Depending on the source type, the length of pulses is expected to range from 20 to 30 fs and repeating frequency from 0.1Hz to 100Hz.

These projected specific source terms raise a number of radio-protection issues. In a first stage, the design of civil structure and local dumps were explored and analyzed. The targeted effective absorbed dose obtained by personnel as a direct result of lasers' operation shall not exceed 1mSv per year. Calculations were undertaken using Monte Carlo transport codes FLUKA and ATTILA.

P06.88
X-Ray Security Body Scanners – Dose Optimisation and Other Considerations in their Use

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X-ray backscatter body scanners have been used in various trials in the UK for over ten years. Dose constraints have been used to optimise potential exposures from this technology. In recent years, transmission x-ray body scanners have also been used but with a limited application. The justification issues around the use of both backscatter and transmission systems are discussed as well as suitable dose constraints to assist in optimising doses from this practice. The use of this technology has raised a number of concerns about exposure to ionising radiation and privacy issues. The paper sets out proposals to address some of these concerns through the provision of information and education.

P06.89
Optimization of a Bunker for Gamagraphy of Pipes with a Diameter of 2m

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The radioactive source is 192Ir with a maximum activity of $3,7x10^{12}$ Bq (100 Ci) and the material to be irradiated are steel pipes with a thickness of 1 cm until 4,4 cm and diameters until 2 m, with 6 m of length. For the bunker wall calculation was considered a supervised area until a distance of one meter and non designated area over that limit. The main protection options that we have for project the bunker are: a) that the pipes can enter into the bunker by from the front; b) by from behind by means of a rail road car; c) from ceiling using a Crane; d) by ceiling slipping over the rail road, in this case the pipe enter from the front or from behind of the bunker; e) the pipe enter by lateral with a removable slipping wall. Will be studied the best option by quantitative decision-aiding techniques used in the radiation protection optimization. Besides the two obliged factors that will be used in the calculation using the cost benefit analysis techniques will be introduced also the maximum individual dose by means of techniques more complex than the cost benefit analysis. For this calculation will be used two annual effective dose limit, i.e.: $20mSv.y^{-1}$ from national Brazilian regulation and 5 $mSv.y^{-1}$ from international recommendations. For the non classified area will be used the value of 1 $mSv.y^{-1}$ for the Representative Person, public annual limit. The bunker shielding material will be normal concrete but we will provide conversion factors for other usable materials..

P06.90
Optimisation of Radiation Protection of Mobile Security Scanning Systems for Vehicles and Cargo Containers Equiped with Gamma Radiation Sources

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In the process of implementing the 3rd generation of ROBOSCAN mobile security scanning systems, the optimization of radiation protection has been permanently pursued in order to reduce exposure for the operating staff, the population and the environment and, with special emphasis, for the maintenance and service staff.

The exposure monitoring and evaluation during over 5 years of operation of the first generations of ROBOSCAN equipments allowed the establishment of an ALARA plan with major system and radiation protection optimization measures that have been implemented starting with the ROBOSCAN 1MC design and manufacture phase. The previous generations of ROBOSCAN equipments have been also upgraded to be compliant with the above mentioned ALARA plan.

Design modifications that minimize the collimation angle of the radiation beam in the same time with the optimization of the detection system and the permanent shielding of the radiation transmitted through it are analyzed. The realized design changes have permanent attenuation effects on the exposure level and, implicitly, on the exclusion area established for the scanning process. They provide an optimum of radiation protection, a better radiological security and an efficient physical protection, improvement of technical performances through dual isotope technology, a superior productivity and lower production costs.

The modalities of revising the quality management system for the design, manufacture, operation, maintenance and service phases of the new ROBOSCAN 1MC generation and the way the revised quality management system ensures a very rigorous ALARA plan execution and implementation oversight are analyzed. The ALARA plan implementation provides a significant exposure reduction by completely eliminating the operator from the exclusion area and minimization of the radiation dose for the maintenance and service staff through the use of dedicated devices for temporary shielding. In the same time, specific procedures introducing additional training to the general training of the maintenance and service personnel involved in radiation sources changing and disused sources management are presented. The additional training combines exercises on "mock-up training models" with the practice of positioning and orienting the operator's body during interventions, in order to reduce the exposure of the entire body.

The achievements implemented starting with the ROBOSCAN 1MC make this one the most advanced mobile security scanning system for vehicles and cargo containers equipped with gamma radiation sources from the point of view of imaging and security performance, radiation protection of personnel, security of the sources and protection of the environment, even better then the 2nd generation of ROBOSCAN that won the great prize at the International Exhibition of Invention of Genève in 2009.

P06.91
Transport of Radiopharmaceuticals and Labelled Compounds in Cuba

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The Centre of Isotopes (CENTIS) is the main consignor and carrier of radioactive material in Cuba. The purpose of this paper is to describe the Radiation Protection Program (RPP) implemented inside a Quality Management System, to achieve and maintain an optimized standard of protection in the accomplishment of these functions. All those areas involving radiation exposures are considered (e.g. design of type A packages, packing, loading, handling, in-transit storage, road transport and inspection and maintenance of packaging). The quality assurance requirements for packaging components were established using a grading process. A material to absorb twice the volume of the liquid contents is tested and its water absorptivity, grammage and capillary rise were estimated. Categories and transport indexes for 67 packages of radiopharmaceuticals incorporating radioiodines, ^{32}P, ^{188}Re and ^{90}Y and technetium generators, are determined. Tests for demonstrating compliance with requirements for type A packages with liquid and solid radioactive content and for air transport are performed and documented. Safety and security of radioactive materials during storage in transit and transport are supervised. Individual Licensing of this staff is conducted by CENTIS and presented to the Cuban Regulatory Authority. The effective annual doses distributions are reported since 1996 to 2010. Occupational exposure is acceptably low and less than 6mSv, which is the dose constrain adopted. It has not been reported any incident in about two and half thousand road shipments carried out. CENTIS' RPP has been under review, detailed appraisals and audits.

P06.92
Actions To Reduce Denials And Delays Of Shipment Of Radioactive Material In Brazil

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In February 2010 the IAEA Director General proposed to ISC (the International Steering Committee) actions to reduce the occurrence of delays and denials to a level not worthy of reporting by the time of the IAEA General Conference in 2013. Such ambitious proposal and target require urgent actions and intensive work both at national and international level.

Responding to this challenge Brazil has created the first National Committee about denials and delays to study the problem in the country, address issues and to coordinate actions to minimize reported difficulties on the movement of radioactive material in all transport modes. One and a half year later the Brazilian networking was able to identify the so called bottlenecks and barriers for the sustainability of the transport as well as to outline, develop and implement a National Action Plan. The National Action Plan ranges from an educative approach, conversation with shippers, industry and carriers to review and revise domestic modal regulations and administrative rules, approach local environmental agencies and environmental NGO's.

The proposed paper will describe the educative approach, present the progress made and identify the next steps.

Natanael C. Bruno, Brazilian National Energy Commission

Tatiana F. Alvim, Brazilian Land Transport Authority

P06.93
Safe, Secure And Sustainable Transport Of Radioactive Material

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The transport of radioactive material is an expanding worldwide activity involving the movement of products that are essential and necessary for public health, manufacturing, science, and engineering. Since transport activities are inevitably in close proximity to public, the protection of public, environment and workers from radiation hazards during transport needs careful consideration by regulatory bodies, consignors and carriers.

The objective of this topic is to encourage discussion of the appropriate levels of safety and security during transport by:

-Promoting international discussion on safety and security during transport;

-Identifying and sharing best practices;

-Identifying issues and problems;

-Identifying opportunities, such as providing assistance, to support national adoption of comprehensive transport safety and security frameworks;

-Developing ideas for coordinating and enhancing transport safety and security. <P<

Although most of the States have national regulations addressing transport of RAM established according to IAEA Regulations, some States are in the process of developing the national regulatory framework essential to facilitate and ensure safe and secure transport.

2013 was set by the IAEA as the target for reducing denial to a level where it was no longer of note. This paper sets out the current status of the work of the IAEA in this area, and the changes taking place as a result.

P06.94
NECSA Waste to Vaalputs

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The Nuclear Energy Corporation of South Africa (Necsa) is in operation since the early 1960's and significant quantities of radioactive waste were generated over the past 45+ years.

Since the early to mid 1990's, the decommissioning of the Nuclear Fuel Cycle facilities commenced.

At this stage, all radioactive waste was still stored on Necsa's site in various forms and different facilities.

Although Vaalputs was owned and operated by Necsa, it was only licensed to dispose of Koeberg solid radioactive waste. Transporting radioactive waste from Koeberg to Vaalputs is taking place for 23+ years (1986 to 2011); Vaalputs however now falls under the National Radioactive Waste Management Institute.

In 2008 Necsa applied for nuclear authorization to the National Nuclear Regulator (NNR) to dispose of low and intermediate solid radioactive waste at Vaalputs.

Approval was finally granted in April 2011 and Necsa disposed their first batch of low level solid radioactive waste at Vaalputs, after years of extreme dedication and hard work. This historic moment in South Africa's nuclear history took place on 9 May 2011 and is regarded as one of the several milestones achieved by Necsa.

This momentous occasion was achieved through decades of planning, research, development, licensing, collaboration between Necsa and the NNR and compliance with legislation and standards.

The purpose of this presentation will cover the Transport Plan of Necsa waste to Vaalputs.

P06.95
Transportation of Nuclear Fuel Bundles - 15 Years of Experience in Nuclear Fuel Plant Pitesti Romania

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Nuclear Fuel Plant (FCN) is a facility that produces nuclear fuel bundles CANDU-6 type for CANDU nuclear power plant based on natural and depleted uranium. The transportation of nuclear fuel bundles from FCN to Cernavoda Nuclear Power Plant is performed by FCN authorised trucks (about 340 km between the two locations). FCN has the activity of transportation and the vehicles authorised by Romanian regulatory body National Commission for Nuclear Activities Control (CNCAN). In addition each transfer of nuclear material is authorised by CNCAN.

From 1996 to 2011, 150 nuclear fuel bundles transportations was performed by FCN Pitesti. In this moment about 15 nuclear fuel transportations were performed in each year. A transportation from Pitesti to Cernavoda consist regularly from 20 wooden crates with 720 nuclear fuel bundles, containing 15 tons of natural uranium dioxide corresponding with 14 tons of natural uranium. Each transport is escorted by qualified personnel from military troop. FCN has proper crew formed by responsible of transport, driver 1, driver 2, maintenance person, radioprotection technician. The persons involved have a strongly training on the domain. Randomly the transportation of nuclear fuel bundles is monitored by Romanian authority CNCAN. In this moment is intended to monitoring each transport of nuclear fuel bundles by satellite including this aspect in a large specific programme. All the activities regarding transportation is under quality assurance control and included in the integrated management system of FCN

KEYWORDS: CANDU nuclear fuel bundles, transport; radioactive material; management system; quality assurance

P06.96
Some Questions About Reference Levels. As an Example the Segregation Distance for Package Containing Radioactive Material Transported in an Aircraft

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The aim of the present paper is that many stakeholders forgot that the reference levels are not dose limitation as they assume. The reference levels are based on a scenery and if this scenery change the reference levels also change. In this case we take as an example the establishment of the minimum segregation distance in the radioactive materials transportation by aircraft. We present the IAEA scenery in these following situations: a) below main deck stowage of one group of packages in passenger aircraft; b) below main deck stowage of multiple groups of packages in passenger aircraft, and c) main deck storage on combi or cargo aircraft, and we will show the factors that we can vary to adapt an actual particular situation. In a table we show the distance calculated by the IAEA scenery and that adopted in the ICAO Technical Instruction and assumed by the IATA. The arguments presented in this paper are relevant in the case when the distance between the package containing the radioactive material and the individual that receive the dose is less than the distance presented in the table of the ICAO Technical Instruction and there is not any possibility to transport in a bigger aircraft.

P06.97
Practices and Regulations for the Safe Transport of Radioactive Materials in Sudan

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Transport of radioactive materials is internationally regulated to provide high degree of safety and have been in effect in many countries around the world. This paper describes regulations and practical issues concerning safety and security of transport of radioactive materials in Sudan. The aim of the study was to review national regulation and perform practical case studies in order to assure that transport of radioactive materials are carried out in accordance to the requirements and to advice national authorities on enhancing transport safety to minimize adverse effect of ionizing radiation. National regulations were reviewed for consistency with relevant international standards. For practical insight, Case studies were taken during transport of five radioactive sources from their port of first entry to the end user. Information concerning source type, physical characteristics and packaging type were reported on specially designed forms. Also included in the form are dosimetric parameters as required by relevant international standards. Source information and dosimetric parameters were recorded during the transport of ^{137}Cs (gamma source,1.7 Ci), ^{192}I (gamma source,107.8 Ci), ^{131}I (gamma source, 20 GBq), AmBe (neutron source, 10 Ci) , and ^{252}Cf (neutron source, 37.4 mCi). Radiation doses during transportation were measured using calibrated area survey meters. Measured dose rate from gamma sources were: 0.04 – 1 mSv/h at the container surface, 1 -150 µSv/h at1 m from the source. For ^{252}Cf neutron source, the measured dose rate was: 1 mSv/h and 150 µSv/h at the container surface and at1 m from the source, respectively. Our results showed that radiation doses during transport were within the recommended limits, however measure concerning emergency preparedness are lacking. Based on the current findings, general recommendations were made to the concerned authorities to achieve good practice and to enhance radiation safety measures in transport of radioactive materials.

P07.54
DAMEX – A Patient Dose Database For The Continuous Assessment Of The Medical Radiological Practice In Switzerland

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Technical audits in radiology departments represent an important part of the activities of the Federal Office of Public Health (FOPH) as responsible supervisory authority of the radiation protection in medicine. During these audits, however, not only the compliance with the legal requirements is checked but also patient doses are collected which serve as a basis for defining national diagnostic reference levels (DRLs). As the radiological practice is changing with time DRLs must be periodically adapted to the actual practice. This requires a quick and reliable access to patient doses. So far, this was difficult to achieve since patient doses were recorded on audit protocols written in Microsoft Word and spread over many folders in our digital network. With this project we aimed at developing a patient dose database that is intuitive, easy to handle and flexibly expandable. The database called DAMEX (Database of medical radiological examinations) was developed and implemented in-house using Microsoft Access. Currently, DAMEX is designed for the collection of data from Computed Tomography (CT), radiography, and fluoroscopy. In addition to patient doses, DAMEX contains also specific information on the radiology department, the X-ray unit, the audit, as well as technical parameters. The systematic data collection started in the year 2007. Since then, data of 256 CT scanners, 43 radiography and 23 fluoroscopy X-ray units have been recorded. These X-ray units are operated in 202 radiology departments in Switzerland. In total, the database contains around 3000 dose entries for CT (Computed Tomography Dose Index and Dose Length Product), 2300 dose entries for radiography (Entrance Surface Dose), and 1000 dose entries for fluoroscopy (Dose Area Product). Based on these doses national DRLs have been defined and published in official notices which are available for download from the FOPH website. In a next step, DAMEX will be expanded to cover also data for mammography X-ray units. Furthermore, DAMEX will be linked to another Database called RADDOSE (www.raddose.ch) which contains the frequency of diagnostic X-ray procedures performed in Switzerland as based on national surveys. This allows to estimate in a realistic way the collective effective dose of the Swiss population. Finally, in order to minimize error sources during data handling, the future data collection will be performed web-based or by means of electronic forms and then automatically imported in DAMEX.

P07.55
Calculation of Shielding for CT Rooms from Patient Dose Data

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The BIR/IPEM report describing methods for assessment of shielding requirements for medical X-ray facilities has been revised to take account of developments in X-ray equipment and techniques over the last ten years. Computed tomography (CT) makes up the largest proportion of the workload in radiology departments and so scanning rooms require the highest level of protection. Earlier methodologies for calculating scatter levels from CT scans required knowledge of the mAs workload, but as scanners now make adjustments for differences in body attenuation through automatic tube current modulation, the mAs is more difficult to determine. A method based on the patient dose parameter dose length product (DLP) has been developed related to the approach taken by the NCRP. Detailed measurements of scatter dose levels around CT scanners from four manufacturers have been made. Scatter factors linking scatter air kerma to the DLP have been established for head and body CT scans. Factors have also been derived to allow the shielding provided by the gantry to be taken into account. In addition an investigation has been undertaken to determine the importance of tertiary scatter from ceiling slabs to adjacent areas. The proposed methodology involves the initial calculation of scatter air kerma levels from scanner workload in terms of DLP and typical values for a range of CT rooms have been determined from surveys. Shielding requirements are then calculated based on an annual dose constraint of 300 µSv. The methodology will be described and things that the shielding designer should look out for in preparing the specification described.

P07.56
Radiation Protection in Dental X-Surgeries – Rooms for Improvement

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The UK Health & Safety Executive's 'Radiation Protection News' of June 2010 said that "HSE's Radiation Team is concerned about the poor standards of compliance with the IRR99 they have found during inspections at Dental Practices". We provide independent advisory and measurement services to general dental practitioners. A database of ~600 intra-oral and >60 OPTs has been created from direct measurements on x-ray sets. Maximum intra-oral patient entrance doses ranged from 0.28mGy to 6.53mGy for adults and from 0.33mGy to 3.02mGy for sets with child settings. All sets had measured beam filtration values on or above the minimum guideline values. 38% of sets exceeded the UK adult diagnostic reference level on at least one setting, as did 44% of those with child dose settings. Timer errors ranged from 0-400%, (mean 17%, median 6.25%). 55% of all timer measurements were <10% in error.

The data demonstrates the clear advantage of digital radiography and rectangular collimation in dose terms, with the mean dose from digital sets 57% that of film-based sets and a rectangular collimator 75% that of circular collimators. The data shows the unrealised potential for dose saving in digital sets and also marked differences in dose between manufacturers and model types of the same manufacturer.

Provision of radiation protection advice raised a number of issues on the design of surgeries with x-ray equipment and the positioning of the control panel/isolator switch (and hence the operator and other staff). There is also considerable variation in advice given on the need (or lack of need) for room shielding.

Many practices still do not have either an RPA or a Medical Physics Expert to advise on patient protection issues. This goes against direct HSE policy that "practices must consult and appoint a suitable radiation protection adviser about compliance with the IRR99". Where no RPA/MPE appointment has been made, there is often a very low level of compliance with legislative requirements.

P07.57
U.S. Radiation Protection Guidance for Diagnostic and Interventional X-Ray Procedures

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Since the 1970s, there has been a concerted movement away from film and toward digital imaging methods for the diagnostic and interventional use of x-rays in medicine. X-ray methods are being used to assess a range of situations from identifying cancer sites to a host of other potential anomalies. The shift from film to digital imaging has provided an opportunity for enhancing x-ray image quality while at the same time either increasing or decreasing radiation dose to the patient receptor. The current U.S. Federal guidance on medical x-rays was published in 1976 and addresses film imaging for radiographic and dental modalities. The Medical Workgroup of the Interagency Steering Committee on Radiation Standards (ISCORS) has modernized that document to address both diagnostic and interventional approaches, film and digital imaging, and the broad range of modalities by adding sections on computed tomography, interventional fluoroscopy, bone densitometry, and veterinary practice. The modalities are presented in terms of equipment, testing and quality assurance, personnel, and procedures, while endorsing procedure justification and dose/image optimization. Based on data published by the National Council on Radiation Protection and Measurements (NCRP), the medical use of x-rays is steadily increasing, and in 2006 was estimated to deliver 36% (2.23 mSv) of the 6.2 mSv radiation dose a member of the public receives each year from all sources. Extrapolation to 2011 based on understood growth places x-rays at 42% (3.3mSv) of a 7.2 mSv total. The draft Federal guidance document has been released by the US Environmental Protection Agency to the Office of Management and Budget for top level review, followed by a peer and public comment period. It provides guidance suitable to government and private medical facilities to help assure that the appropriate radiation dose is delivered to the patient in producing images of adequate diagnostic or interventional quality.

P07.58
Quality Control for the Mammography Screening Program in Serbia: Physical and Technical Aspects

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Breast cancer is the major cause of mortality among female population in Serbia. It is presumed that the introduction of screening programme will reduce mortality and therefore, 47 new mammography units were installed for the purpose of population-based screening program in 2011. In parallel, Quality assurance (QA) and Quality control (QC) in mammography has received increasing attention as an essential element of a successful breast cancer campaign that is for the first time initialed in Serbia.

The purpose of this study is to investigate the need for and the possible implementation of a comprehensive QC programme for the mammography screening in Serbia. The paper focuses on physical and technical aspect of mammography QC, which consisted of two phases. The aim of the first phase was development of QC protocols for all technologies of the mammography technologies that will be included in the breast screening, including medical physicists' and radiographers' tests. The protocols contain list of parameters, methodology, frequency of tests and reference values for screen-film (SF), computed radiography (CR) and full-filed digital mammography (FFDM) units, as all these are part of the seeing programme. The second phase is focused on the initial implementation of these protocols. The paper presents results of tests of the selected parameters in FFDM, CR and screen-film and SF units, with special emphasis on radiation protection considerations and patient dose and image quality descriptors. The aspect of image viewing environment and internal QC is particularly addressed, as these have been recognized as major problems in QC of clinical mammography units in Serbia in the past. The practical aspects and problems related to implementation of QC protocols were discussed, including importance for close cooperation between radiologist, radiographers, medical physicists and manufacturers.

The currently used QC protocol sufficiently ensures that the screening program is technically safe in its initial stage. After initial implementation at the beginning of the population-based breast cancer screening campaign, it is essential to establish system of regular and periodic QC equipment monitoring and to ensure high quality mammograms with minimal possible radiation dose to population included in the screening.

P07.59
Handling of Incidents within Medical Use of Radiation

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Incident reporting is an important tool for learning from incidents and errors, helping others to avoid similar incidents in the future.

Organisation of incident reporting within the medical field in Denmark: A central database for all incidents within the medical field has been established, the "Danish Patient Safety Database" (Dansk Patient-Sikkerheds-Database, www.dpsd.dk). Staff, patients and relatives can report incidents, which have been or could have been harmful. The reporting can be done anonymously, if desired, and reporting forms are available on the internet. The reports submitted are first handled locally, e.g. by a quality department in a hospital. The incident report is reviewed to find out what has happened, how it could happen, and how similar incidents can be prevented. When this review is finished, the report is forwarded to National Agency for Patients' Rights and Complaints (Patientombuddet, www.patientombuddet.dk), who gathers and disseminates knowledge based on incidents from all parts of Denmark.

Incidents involving radiation: The National Institute of Radiation Protection (NIRP) has access to the database of incidents. Previously, we have searched the database based on thirteen search terms, see Table below, which have resulted in approximately 1500 incident reports. Unfortunately, most of the reports found do not directly involve radiation (e.g. a patient falls out of bed, and is taken to x-ray). Thus, the reports have been reviewed to find the incidents where ionising radiation is directly involved in the incidents. In the future, incidents involving radiation will have a separate classification, enabling us to retrieve only relevant incident reports. This will also ensure that all cases relevant for NIRP are identified.

Results: Examples of types of incidents and distribution will be presented. In 2010, 270 incidents were found where radiation was directly involved. Common types of incidents are e.g. right-left mix-up and errors in registration of patient data.

Distribution of knowledge: News letters have been distributed 4 times a year to all interested parties and can also be found on the website. Anonymised examples are also used in teaching courses for staff, e.g. radiographers and doctors.

Table: Search terms used for identifying relevant incidents

Danish Term	To look for
Radiolog	Radiology
Rtg	X-Ray
Røntg	
Strål	Radiation
Radioak	Radioactivity/radioactive
Radioac	
Isotop	Isotope
Nuklear	Nuclear (medicine)
Ioniser	Ionising
Skintigrafi	Scintigraphy
Scintigraf	
Billeddiagnos	Imaging
IMRT	IMRT

P07.60
Estimation of the Effective Dose to the Personnel in Diagnostic Radiology from Under-Apron and Over-Apron Measurements

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In diagnostic radiology where the personnel usually is wearing lead aprons the individual monitoring of external exposure [personal dose equivalent Hp(10)] is frequently performed based on personal dosimeters worn on the body below the lead apron. Because this place normally represents the most protected area of the body the effective dose in most cases is underestimated. A simple solution would be a measurement in front of the apron, but in this way the effective dose would be considerably overestimated. Therefore a general approach with single dosimeter measurements assumes an algorithm with the reading either divided by (over-apron case) or multiplied (under-apron case) with a certain correction factor. The combination of one dosimeter worn below the apron and another one above the apron allows to determine the effective dose more accurately. In this "double dosimetry" concept the resulting effective dose can be validly estimated by a linear combination of both measurements.

Coefficients for the one-dosimeter and two-dosimeter situations are derived using organ dose conversion coefficients according to ICRP 60 and ICRP 103. The recent recommendations of the ICRP 103 emphasize the contribution of the head and neck region to the effective dose E. For the example of cardiac catheterization (apron 0.5 mm Pb, with thyroid protection; ICRP 103) for a single dosimeter reading in the anterior thoracic region ($H_{p,c,u}$) (chest underneath the protective apron) E = 2.0 x $H_{p,c,u}$ and with a dosimeter worn on the front area ($H_{p,n,o}$) of the neck over of the protective garment E = $H_{p,n,o}$/11.3. According to ICRP 103, a conservative general algorithm with thyroid protection is E = 0.84 $H_{p,c,}$u(10) + 0.051 $H_{p,n,o}$(10) and without thyroid protection E = 0.79 $H_{p,c,u}$(10) + 0.100 $_{Hp,n,o}$(10).

In a radiological department for one year over-apron personal dosimetry was performed instead of the usual under-apron measurement. The effective dose of the personnel was determined with the correction factors derived; the results are presented. Because of the lower detection limit the over-apron dosimetry provides a better measure of effective dose.

P07.61
Comparison of Local Radiation Protection of the Panoramic and the DVT mode of a Dental X-ray Device

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BACKGROUND: In Dental Radiography Digital Volume Tomography (DVT) gains more and more importance due to its possibilities of three-dimensional imaging of teeth, jaw and visercoranium and the reduced radiation dose in comparison to conventional Computer tomography (CT). Contrary to other well documented radiographic procedures like dental panorama x-ray imaging there are no national or international guidelines or recommendations relating to DVT which regulate the designation of areas and standardize risk assessment. This study aims to asses the parameters necessary for local radiation protection in dental practices and to compare the panoramic and the DVT mode of four dental X-ray device.

METHODS: This paper describes the results of measurements, which are carried out in dental practices in order to evaluate the local dose in varied distances by different modes (panoramic mode and DVT mode) of four different dental X-ray devices by using a special dental-phantom and to define the surveillance and control area by nominal voltage. The existing guidelines for dental panorama x-ray are analyzed and suggestions for future recommendations concerning the designation of areas and risk assessment for DVT are then deducted by comparing both sets of measurements. Special attention is given to radiation exposure of personnel.

RESULTS: The project outlined above aims to establish guidelines relating to local radiation protection in dental practices using DVT devices. These guidelines will complement the existing regulation framework for radiation protection in dental radiography.

P07.62
Estimation of Effective Dose in Common X-ray Diagnostic Examinations in India

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Skin entrance doses (SEDs) for the seven types of diagnostic examinations viz., chest (AP, PA, LAT), lumber spine (AP, LAT), thoracic spine (AP, LAT), abdomen (AP), pelvis (AP), skull (PA, LAT) and hip joints (AP) was measured for 1209 number of diagnostic projections by carrying out measurements of air kerma at 101 X-ray machines installed in 45 hospitals in the country. The measurements were carried out by using silicon detector based dose Test-O-Meter. Air kerma value was maximum in case of limber spine-LAT (13.795 mGy) and minimum in case of chest-AP (0.238 mGy). Effective Dose (E) was estimated from the SED values by using the conversion coefficients suggested by NRPB-R 212, UK and PCXMC software, Finland. The skull (LAT) and chest (PA) examinations contribute minimum while pelvis examination contributes maximum to effective dose. In general, the values of effective doses obtained in this study by using NRPB and PCXMC software are found to be comparable with those published in UNSCEAR (2000) report and HPS. The maximum equivalent dose H_T) to a body organ in each diagnostic projection was estimated by the PCXMC software. Value of H_T) for an organ adrenals is minimum (0.151 mSv) in case of Chest-LAT examination and maximum (5.2 mSv) for spleen in case of limber spine -LAT examination. Values of E in case of all the projections was found to be less than 0.1 mSv and the associated risk was therefore considered to be negligible and can be used as guide for the justification of medical X-ray diagnostic examinations.

P07.63
An Investigation into CT Dosimetry using an Elliptical Phantom

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Assessment of CT scanner performance relating to patient dose is based on measurements made in standard cylindrical phantoms. The phantom for the trunk is a Perspex cylinder 320 mm in diameter. This is not a realistic shape for most patients and is significantly larger than the trunk for the average patient in the UK. The cylindrical phantom has the advantage of uniformity and has allowed standardisation of dose measurements throughout the world. However, possible options for dosimetry using an elliptical phantom which would provide a more realistic representation of the trunk should be considered. Elliptical phantoms can also provide information on the operation of the rotational part of the automatic exposure control. This paper describes an investigation into the dose distributions within elliptical and cylindrical body phantoms. Measurements of the computed tomography dose index for single scan rotations and the cumulative dose for helical scans have been made with ionisation chambers. Dose distributions within a phantom have been studied using Gafchromic film and results for different dosimetry methods simulated. Peripheral dose levels in the anterior and posterior positions for an elliptical phantom are significantly larger than those for the lateral positions and may contribute to a more realistic assessment relating to doses to organs within the trunk. Phantoms based on an elliptical design would be lighter and so easier to handle, as well as being more representative measurements of doses to the trunks of patients. The design of an elliptical phantom for measurements of CT dosimetry is proposed and measurements to be undertaken recommended.

P07.64
Principles Behind Shielding Recommendations in BIR/ IPEM Report

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The first BIR/ IPEM report on shielding for diagnostic X-ray facilities was published in 2000. That report is being updated principally to reflect changes in imaging technology and practice and to update methods used for the assessment of scatter and the transmission of primary radiation.

In this presentation the underlying principles underpinning the publication are discussed. The design level for dose is based on the "As low as reasonably achievable" principle as set out by the ICRP and enshrined within European legislation. This has lead to the recommendation in the report of a general dose constraint of 0.3 mSv that is three-tenths of the dose limit for a member of the public. For pragmatic reasons this is interpreted as an air kerma constraint of 0.3 mGy. Since this is the dose constraint to an individual, use of realistic occupancy factors subject to a lower limit based on regulatory requirements for controlled areas is recommended. Workloads used in the report are based on patient dosimetry parameters that are readily available from dose audit and from published patient dose data. This presentation will set out the underlying principles that are applied in these guidelines.

P07.65
Demonstration of Anatomical Imaging Using Neutron Radiography

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Neutron radiography (NR) is a well-established technology used to non-invasively and non-destructively image industrial equipment and other materials that cannot be properly imaged using X-rays. Although the potential for biological imaging has been discussed since the 1960's, biological neutron imaging currently is limited to the autoradiography tissue slices less than 70 µm. This is because the neutron images generated from larger biological organisms suffer from a high degree of image blur, reduced image contrast, and poor image resolution (Brown and Parks, 1969); our data indicate this predominately is due to image contributions from hydrogen scattered neutrons.

NR is fundamentally different from all of the currently used clinical imaging modalities in that the operative particle primarily interacts with atomic nuclei rather than atomic electrons. Neutron interaction rates have little to no dependence on the Z value of the material to be imaged. For example, neutrons have a relatively high scatter cross-section with hydrogen and a low interaction cross-section with lead and steel. Therefore, biological imaging with neutrons could provide significantly different and complementary information to photonic imaging modalities, particularly with patients that have metallic implants (e.g., pace-makers, embolism coils, stents, and surgical clips) since current technologies cannot image near these implants. Therefore, it would be prudent to explore the potential of NR for clinical imaging as it may provide benefits not found in the predominant clinical imaging modalities. Additionally, we've estimated the total radiation exposure to a 30 cm thick patient to be less than 0.8 mSv (80 mrem) per image. This is significantly lower than doses typical of chest CT procedures and PET scans.

Feasibility was demonstrated using the Monte Carlo N-Particle (MCNP) code (Los Alamos National Laboratory) to quantify the contrast of air, adipose tissue, soft tissue, skeletal muscle, and cortical bone (as defined by ICRU-44) both with and without image contributions from scattered neutrons. Demonstrating the importance of scattered neutron removal during image formation, MCNP was used to simulate images of biological phantoms with various neutron energies to optimize image quality while minimizing neutron radiation exposure to the patient.

P07.66
Diagnostic Reference Levels (DRL's) and Target Dose Levels in The Netherlands

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Introduction: Diagnostic X-ray imaging plays an increasingly important role in the current healthcare system. The number of X-ray examinations is steadily increasing, and there is increasing use of advanced techniques such as computed tomography. This makes it possible to improve quality of care, but as a consequence radiation exposure to patients increases and radiation protection for patients who undergo X-rays must be sufficiently secured.

Materials and methods: A task group was initiated to define DRL's and target dose levels and to verify them in a field study. The examinations are mammography, radiography, computed tomography and diagnostic fluoroscopy, it includes diagnostic imaging of adults and children, and covers practices within the radiology and cardiology departments. The studies are a good reflection of current clinical diagnostic practice. During the field study dose area product (DAP) was measured for chest PA, abdomen AP, pelvis AP radiography and computed tomography dose index and dose length product was measured for chest and abdomen CT (respectively pulmonary embolism and acute abdominal pain). Data collection took place using written forms or extraction of dose values from PACS-Dicom databases. DAP meters in the field were compared with a factory calibrated Diamentor M4 to trace their deviations.

Results: DRL's and target dose levels were established for 22 examinations. 39 Institutions participated in the validation study. During the validation study none of the institutes exceeded the DRL's. Furthermore some appeared to perform well below target values, and many complied with the target values. In some cases a significant variation in the accuracy of DAP meters was encountered.

Conclusion: The introduction of diagnostic reference levels (DRL) in the Netherlands aims at avoiding practices with unnecessary high patient dose. The DRL is an upper limit for patient exposure that still can be considered as 'good medical practice'. But, even more important, the simultaneous introduction of target dose levels in the Netherlands aims at stimulating the optimization of practices. A target dose level is much lower than the DRL and is achievable with modern imaging equipment and optimized acquisition protocols. A field study revealed that all institutions complied with the DRL's although the Dutch DRL's are already amongst the lowest in Europe.the DRL's. The introduction of target dose levels, that are much lower compared to DRL's is recommended.

P07.67
Estimation of Half-Value Layer for Dual-Energy Computed Tomography Acquisition Using a New Copper Absorption Method

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Purpose: Materials can be separated or quantified by dual-energy computed tomography (DECT). Of late, DECT is often used in clinical situations, and dual-source CT (DSCT) is used to execute DECT acquisition. When DECT acquisition is executed by DSCT, one X-ray tube outputs X-rays with relatively low tube voltage (100 or 80 kVp), another tube outputs X-rays with relatively high tube voltage (140 kVp with a tin filter), and the two tubes simultaneously output X-rays when rotated. In DECT, it is difficult to obtain half-value layer (HVL), which is generally used to calculate a patient's absorbed dose, by the conventional aluminum or copper absorption method because of the technical limitation. This study aimed to estimate HVLs for DECT acquisitions by a new copper absorption method.

Materials and Methods: A 128-section DSCT (SOMATOM Definition Flash; Siemens Healthcare, Erlangen, Germany) was used in this study. Dose was measured while executing single-energy CT (SECT) acquisition with 120 kVp and DECT acquisitions with combinations of 100 and 140 kVp with a tin filter and 80 and 140 kVp with a tin filter after inserting a thimble-type ionization chamber into each 0.04–0.6-mm-thick cylindrical copper filter and placing them into the center of CT gantry. The thickness of the copper filter, which reduces the intensity of radiation by half (first HVL), was then calculated in each acquisition. The first HVLs were revised by excluding the contribution of all scattered radiation using the correction equation ($y=1.066x$ [x, measured first HVL; y, corrected first HVL]) shown in our previous study. Furthermore, the first HVL for SECT with 120 kVp was estimated using the conventional copper absorption method.

Results: The first HVLs for SECT acquisition with 120 kVp were observed to be 0.455 mm in the conventional copper absorption method and 0.453 mm in the new copper absorption method. The first HVLs for DECT acquisitions were found to be 0.493 mm for 100 and 140 kVp and 0.336 mm for 80 and 140 kVp with tin filters in both cases. The calculated effective energies were 58.6 keV for SECT with 120 kVp (conventional method), 58.5 keV for SECT with 120 kVp (new method), 60.3 keV for DECT with 100 and 140 kVp with a tin filter, and 52.4 keV for DECT with 80 and 140 kVp with a tin filter.

Conclusion: The HVLs for DECT acquisitions by DSCT can be successfully estimated using the new copper absorption method.

P07.68
Patient Doses from X-ray Examinations in Denmark

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The National Institute of Radiation Protection has the responsibility for setting diagnostic reference levels (DRLs) in Denmark. The DRLs for x-ray examinations are based on patient doses gathered from x-ray examinations carried out in hospitals, radiology clinics and chiropractic clinics. New Danish DRLs and updated guidelines for measurement of patient doses will be presented.

Background: DRLs for x-ray examinations were introduced in Denmark in the mid-1990s, and the first binding values were set in 2001. At this point, DRLs were set for conventional, CT and mammography examinations of adult patients. In 2006, the values for conventional examinations were revised, and DRLs for conventional examinations of children were added. In 2011, the guidelines for measurement of patient doses in CT were changed, and the changes in terms of examinations included were so extensive, that new DRLs are required.

Methods: Mails have been distributed to all medical physicists within diagnostic radiology, requiring them to submit patient doses for the x-ray equipment they are responsible for. According to Danish legislation, all x-ray equipment for medical use, except equipment for dental use, must be under the responsibility of a medical physicist.

Results: Forms for use in the clinics when recording and submitting patient doses have been developed, and these will be presented. The new forms contain a number of locked cells to ensure that only relevant data is recorded.

New DRLs and distributions of patient doses for conventional, fluoroscopy, CT and mammography examinations of adult patients will be presented. If sufficient data material is obtained, similar material will be presented for conventional and fluoroscopy examinations of children. A challenge for the data collection is that large parts of the data are not complete. Weight/height of the patient is missing, or the patient is outside the required weight interval.

P07.69
Radiation Dose Reduction Efforts in an Academic Medical Center

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This paper discusses the various opportunities for dose reduction in an academic medical setting. The move is widely believed to be in response to reports of rising exposure to medical radiation in the U.S. population.

The radiation protection community has always been conscientious about reducing worker dose; however, patient dose was left to the discretion of the physician. With the advent of new technology and imaging systems, the dose to patients and hence to the public has increased considerably. The U.S. Food and Drug Administration (FDA) recently announced an initiative to reduce unnecessary radiation exposure from CT, fluoroscopy, and nuclear medicine exams. One of the areas we are focusing on is the Emergency Department (ED. We have made an attempt to track the number of CT scans a patient receives in the system. An alert has been designed so that the ED physician has to stop and think about the decision to continue with the imaging.

Fluoroscopy is very common in the Hospital environment, especially in Interventional Radiology Suites and Cardiac Catheterization laboratories and also in the Operating Suite. Radiologists are generally cognizant of radiation safety issues whereas cardiologists and surgeons are not. In addition, there are patient safety issues associated with the use of fluoroscopy. Radiation monitoring of these physicians, who receive the highest doses, and who are not the most compliant individuals, is a Herculean task for the Radiation Safety Officer. In order to provide a safe environment for patients, physicians and employees, during fluoroscopy procedures, our hospital has established physician credentialing and fluoroscopy safety policies. We are also using dose rather than time as a trigger to follow-up of patients with extended fluoroscopic procedures. There are other modalities such as Nuclear Medicine where exposure to family members and members of the public can be reduced by providing appropriate instructions.

P07.70
Mean Glandular Dose Behavior Using Different Glandularity Phantoms

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The three quantities used for mammography are the incident air kerma (K_i), the entrance surface air kerma (K_e) and the mean dose to the glandular tissues within the breast, known as the mean glandular dose (D_G). For phantoms, the K_i is measured with a diagnostic dosimeter in the absence of the phantom, using the tube loading required for exposure of the phantom. DG is derived from measurements of the K_i and the half-value layer (HVL), using tabulated conversion coefficients (Dance et.al. 2000). The aim of this work is to present preliminary results of the DG behavior adopting protocols with different values of tube voltage, target/filter combinations and using different glandularity phantoms. Irradiations were done using a 3000 Nova model Siemens MAMMOMAT mammographic unit in a cranio-caudal view, with the compression plate in position and a load cassette in the bucky. Protocols with 26, 28, 30 and 32 kV were used for Mo/Mo and Mo/Rh combinations. The mean tube loading were calculated from three exposures using a solid state detector Fluke. Phantoms used for the determination of D_G had 45 mm thick, which approximately simulates a standard breast of thickness 53 mm, and glandularity of 0, 30, 50, 70 and 100%.

The D_G ranged from 1 to 6 mGy and 1 to 4 mGy, for Mo/Mo and Mo/Rh combinations, respectively. The preliminary results are in according to the reference level of 3 mGy established by the International Basic Safety Standards (BSS115) to breast of thickness 45 mm and glandularity 50%. The results showed that the D_G increases with the glandularity. With increasing voltage decreases mean glandular dose for dense breast. This feature is more pronounced for phantoms of glandularity 100%. Considering that the most radiosensitive tissue is the glandular, this work contributes to disseminate in clinical practice the optimization of procedure and establish reference levels depending of breast glandularity.

P07.71
Automated Collection of Patient Exposure Data : Recent Standards and Tools

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Collecting and applying exposure data is fundamental to most radiation safety programs and research projects. When such data collection and application is tedious and time consuming, it limits the breadth and effectiveness of such programs and projects.

Over the past several years, a number of standards have been introduced to facilitate and/or automate such aspects of Dose Safety Programs, National Data Registries and related activities:

• The DICOM Standard (Digital Image COmmunication in Medicine) has specified a Radiation Dose Structured Report (RDSR) object which can be stored and managed along with the digital images for every exam. It records many dose related details and metrics for CT, Angiography, Fluroscopy, Mammography and simple projection x-ray exams.

• IHE (Integrating the Healthcare Enterprise) has introduced the Radiation Exposure Monitoring Profile which defines a data distribution architecture and sets conformance requirements on imaging modality systems, archives, dose reporters and dose registries to automatically create and manage RDSR objects in the course of imaging workflow.

• MITA (Medical Imaging Technology Alliance) has drafted the XR25 CT Dose Check Standard which sets conformance requirements on CT scanners to generate pre-scan alerts when configured scan parameters exceed site configured dose thresholds.

• AAPM (American Association of Physicists in Medicine) has prepared guidance on the use of the XR25 standard and configuring the trigger thresholds.

Support for the above standards is already available in some products. Further details of these standards and the current state of implementation and testing by system vendors will be presented.

P07.72
Estimation of Effective Dose in Common X-ray Diagnostic Examinations in India

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Skin entrance doses (SEDs) for the seven types of diagnostic examinations viz., chest (AP, PA, LAT), lumber spine (AP, LAT), thoracic spine (AP, LAT), abdomen (AP), pelvis (AP), skull (PA, LAT) and hip joints (AP) was measured for 1209 number of diagnostic projections by carrying out measurements of air kerma at 101 X-ray machines installed in 45 hospitals in the country. The measurements were carried out by using silicon detector based dose Test-O-Meter. Air kerma value was maximum in case of limber spine-LAT (13.795 mGy) and minimum in case of chest-AP (0.238 mGy). Effective Dose (E) was estimated from the SED values by using the conversion coefficients suggested by NRPB-R 212, UK and PCXMC software, Finland. The skull (LAT) and chest (PA) examinations contribute minimum while pelvis examination contributes maximum to effective dose. In general, the values of effective doses obtained in this study by using NRPB and PCXMC software are found to be comparable with those published in UNSCEAR (2000) report and HPS. The maximum equivalent dose (H_T) to a body organ in each diagnostic projection was estimated by the PCXMC software. Value of H_T for an organ adrenals is minimum (0.151 mSv) in case of Chest-LAT examination and maximum (5.2 mSv) for spleen in case of limber spine -LAT examination. Values of E in case of all the projections was found to be less than 0.1 mSv and the associated risk was therefore considered to be negligible and can be used as guide for the justification of medical X-ray diagnostic examinations.

P07.73
Trends in Patients' Exposure Doses during Radiographic Examinations in Japan

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We have investigated changes in exposure doses in Japan in terms of the same items since 1974. An assessment was made of changes in exposure doses during a period of 37 years. Nationwide investigation was conducted seven times from 1974 to 2001 with regard to 14 target areas (21 kinds of projections). The investigations we examined are as follows: tube voltage (kV), tube current (mA), exposure time (sec), focus surface distance, thickness of total filtration and type of generator system for diagnostic radiography for a typical patient. Entrance surface doses were evaluated in terms of the respective exposure conditions based on basic experiment. The results showed that the exposure doses decreased to less than 50% during a 20-year period till 1994, with the exposure doses in 1974 assumed to be 100%. The exposure doses in 2011 were equivalent to, or increased over the exposure doses in 2001 in some areas. A comparison with the international basic safety standard for protection against ionizing radiation set up by the IAEA, that is, the so-called guidance level, indicated that the exposure doses in 2011 were less than the standard in all areas. The comparison with past investigations also demonstrated that F/S system using film-intensifying screen has been increasingly replaced with digital radiography (DR) system using imaging plates (IP) and flat panel digital radiography (FPD) system. A transition from F/S to digital systems occurred in 2003 for general radiography, and in 2007 for mammography. As far as the 2011 survey data is concerned, the majority of institutions have digitized their systems, with F/S still being used at only 3% of all institutions. Lumber spine AP, Chest PA and Guthmann. Overall, the doses decreased widely from 1974 to 1993, followed by a slightly increasing tendency. In chest radiography in particular, there have been remarkable increases; the dose became 96% in 2003 and reached 113% in 2007. In 2011, however, the dose decreased to the same level of 96% as the 2003 dose. For image receptors, doses decreased with the increase in the sensitivity of F/S. It appears that the doses increased with the introduction of CR systems and conversely decreased with the introduction of FPD. Further investigation is necessary to confirm this data.

P07.74
Collective Doses of Bulgarian Population from X-ray and Nuclear Medicine Examinations: 2010 update

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This study was aimed at assessing the trend in frequency of X-ray and Nuclear medicine (NM) examinations and the resulting collective doses of Bulgarian population.

A centralized national system was used to collect the number of examinations. Every medical center is providing information for the number of examinations in three age groups (0 - 15 years, 16 - 40 years and over 40 years) as well as by gender. Collective doses were calculated applying the recently updated national average effective doses, based on the national dose survey and methodology of the EC publication Radiation Protection 154.

The total number of X-ray examinations in 2010 was 4.2 million, and of NM examinations 21.5 thousand. The estimated total collective effective dose was 3230 man Sv/y from X-ray and 65 man Sv/y from NM . The main contributor to the collective dose is CT, followed by plain radiography, conventional fluoroscopy, interventional radiology, and nuclear medicine. The total number of examinations is relatively stable during the last years. The number of CT and interventional radiology procedures is increasing. The collective doses decreased since 2000 year mainly due to the decrease of the average effective doses per examination.

P07.75
Dosimetry of CT and Image Quality in Oncology Patient: Comparison of Two National Institute of Cancer.

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Introduction: In adult cancer patients, the radiation dose for computerized tomography can be bigger than not-cancer patients in the disease period, due to increment diagnostics by images for control of the disease, due to immunosuppression, chemotherapy agents, cancer itself, hematological disorder, infections multiples, controls of disease, etc. The aim of this study is to compare the radiation dose in abdomen examination and optimize the abdomen protocol, inculcate culture and awareness the radiation needless in late arterial, portal venous and delayed phase when to be possible the not-detection the disease in precontrast phase as a result of heighten contrast of lesions in liver like hepatics and metastasis disease. So, diminish radiation dose in computerized tomography of two principal centers of diagnostic of cancer in Brazil and Colombia.

Method: The research was developed in two tomographs, one Philips Brilliance 6 and the other Siemens Somatom 16 of public hospitals of Cancer, in Rio de Janeiro-Brazil and Bogotá D.C-Colombia respectively. Hundred studies of the protocols of abdomen with its diagnostics in CT to find out hepatics disease were evaluated through mAs, kVp, collimation, Cvol, DLP, image quality, noise and Body Mass Index (BMI). For study the operation mode of different abdominal protocols the Triple Modality 3D Abdominal Phantom (Model 057) was utilized. This phantom has main organs and structures the abdomen, where were evaluated the noise of image through one region of interest (ROI), defined each patient in the best image of diagnostic under criterion of one radiologist. The number the CT and standard deviation were evaluated in each ROI. Also, the software Image J was used to analyze the images. Otherwise, the dosimetry of Cvol and DLP for each routine protocol of abdomen was measured by means of one ACR Phantom of 16 cm and was compared with the studies done by ImPACT group. Checking up on final report the diagnostic for CT, the radiologist uses precontrast phase to a general visualization of disease and that many time the disease can be not find it. Thus, the use the radiation needless in the in late arterial, portal venous and delayed phase can be avoid if the precontrast phase is evaluate by one radiologist, who can determinate if the patient has small indication of lesion, so that, radiologist decide continue or not with this exams.

Results: The average values of Cvol were 12 mGy for when did not use modulation dose and 10.1 mGy, 10.6 mGy and 13.8 mGy for normal weight, overweight and obese respectively, using modulation dose (D-DOM). Therefore, these dose were reduced about 16%, 12% in normal weight and overweight, in return for obese the dose was increased in 15%. Of fifty patient at random of hundred patient studied, nineteen patients could be avoid to radiation due to late arterial, portal venous and delayed phase, because did not find any lesion in the precontrast phase.

Conclusion: The patients with one cancer disease can reduce their radiation dose when to be use dose modulate depending of their BMI in exams of CT and to be avoiding to radiation needless due to late arterial, portal venous and delayed phase when did not detect any lesion in precontrast phase.

Keywords: Cancer patients, computed tomography, radiation dose, computed tomography dose index, dose modulation.

P07.76
Preliminary Study Of Image Quality In MSCT Through Qualitative Parameters For Adult Abdomen Routine In Rio De Janeiro, Brazil.

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Background: The image quality is influenced by acquisition and reconstruction parameters and by the patient characteristics. This can lead to unexpected effects on the clinical diagnostic, increased exam repetitions or higher patient doses. Despite global efforts for an adequate evaluation of image quality and dose, it is common to find services where the evaluation of image quality and patient dose is inadequate or nonexistent, resulting on an unawareness of the diagnostic quality of the image and the dose associated with the study.

Method: Two different scanners at two hospitals, one private (Brilliance 40, Philips) and one public (MX 4000, Philips) were evaluated in terms of image quality and dose for adult abdomen protocol. Using data from literature, Impact and DICOM image, nCw was estimated for each scanner. The Cvol and PKL were estimated and compared with the reference values of the European Commission (EC). The ACR CT phantom was used for image quality evaluation. Samples of 76 adult abdomen routines were assessed by compiling data from the technical parameters and inherent parameters of each patient. The clinical images were evaluated qualitatively by expert radiologists as well as quantitatively in terms of contrast noise ratio (CNR) and noise.

Results: From the clinical images, the noise at the liver and the CNR between the lesion and surrounding tissue were analyzed. In low contrast lesions, the CNR ranges from 0.25 to 3.37HU with areas from 0.21 to 17cm2 .The results were similar in both hospitals. Average noise on the patient´s images were 14.25 HU and 9,75HU in the private and public hospital respectively. The average Cvol in both hospitals (13,3mGy and 6,3mGy for private and public hospital respectively) was lower than the CE recommended value for abdomen protocol. It was verified that the Pkl reported by scanner underestimate the real value in 2-18% on average. The noise, CNR and dose values were compared with patient body mass index (BMI) and the techniques employed. An increase of noise, lesion detection and dose were observed in patient with overweight. Regarding image quality evaluation, both met the tolerances of the modules of the ACR CT phantom. In module 3, a ring artifact was observed in the MX4000 scanner.

Conclusions: This study demonstrated the influence on image quality, lesion detection and diagnostic quality by the choice of technical parameters and patient BMI.

P07.77
Surveys of Radiographic Techniques for Radiation Shielding Calculations and Diagnostic Reference Level Determinations

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Two important topics in radiation protection for diagnostic radiology are the structural shielding and the diagnostic reference level (DRL). To design the shielding and determine the DRL, survey data are required for the radiological techniques utilized in modern diagnostic x-ray institutions. These surveys provide information on the kVp distribution of the workload per patient and the primary beam use factor for radiation shielding calculations (NCRP Report No. 147). They also provide data on the frequency distribution of the patient dose or phantom dose descriptor for DRL examinations (IPEM Report No. 77). The present work reports the results of a large scale survey on the radiological techniques used in the general radiographic rooms in Taiwan. In this survey, radiological data such as mAs, kVp, primary beam direction, number of exposures per patient, weekly number of patients, beam filtration, image receptor type were all manually recorded by the participating radiological technologists for each x-ray exposure over the course of a week. Data were obtained from a survey of 12 representative hospitals containing 24,844 projections and 13,470 examinations. These data represented about 6% of the total radiographic examinations in one week in Taiwan. The surveyed hospitals included six medical centers, three regional hospitals, and three district hospitals located at different regions. The 20 x-ray rooms monitored included 13 radiographic rooms, 4 emergency rooms, 2 chest rooms, and 1 vehicle with 11 DR, 8 CR, and 1 film systems. These figures were generally in consistent with the corresponding distributions of all radiographic installations in Taiwan. Intra- and inter-institutional comparisons of surveyed data have been made for the optimization analyses. These data were also compared with surveyed results in the NCRP 147 for shielding evaluations. Applying the presently surveyed data, the effective doses per exposure to an average adult phantom were calculated using the PCXMC 2.0 computer program. DRLs were then determined from calculated results on the entrance surface dose based on the third quartile values and the optimization considerations involving the cost-effectiveness analysis.

P07.78
Radiation Dose measurements Survey During Hystrosalpingography in Sudan

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Hysterosalpingography (HSG) is the most frequently used diagnostic tool to evaluate the endometrial cavity and fallopian tube by using conventional x-ray or fluoroscopy. Determination of the patient radiation doses values from x-ray examinations provides useful guidance on where best to concentrate efforts on patient dose reduction in order to optimise the protection of the patients. The aims of this study were to measure the patients' entrance surface doses (ESDs), effective doses and to compare practices between different hospitals. This study conducted in five radiological departments: *(A)* Omdurman Teaching Hospital (20 patients), *(B)* Alnilain Diagnostic Center, (20 patients) *(C)* Asia Specialized Hospital (10 patients), *(D)* Khartoum Teaching Hospital (12 patients) and *(E)* The National Ribat University Hospital (10 patients).

A total of 72 patients were examined (aged 23–44 y) for a period of 4 months. Patients' doses were calculated using DoseCal software. The X-ray tube outputs were measured using Unfors Xi dosimeter. Effective doses were estimated using National radiological Protection Board (NRPB) software. The mean ESD was 20.1 mGy, 28.9 mGy, 13.6 mGy, 58.65 mGy and 35.7 mGy for hospitals *A,B,C,D,* and *E* respectively. The mean effective dose was 2.4 mSv, 3.5 mSv, 1.6 mSv, 7.1 mSv and 4.3 mSv for hospitals in the same order. The study showed wide variations in the ESDs with three of the hospitals having values above the internationally reported values. Number of X ray images, fluoroscopy time, operator skills X ray machine type, clinical complexity of the procedures were shown to be a major contributor to the variations reported. Results have demonstrated the need for standardization of technique throughout the hospital. The results also suggest that there is a need to optimize the procedures.

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P07.79
Awareness and Efforts to Decrease CT Radiation Dose and Resultant CT Protocol Changes and Dose Reduction

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Purpose: CT radiation dose exposure has been steadily rising after the rapid introduction of multidetector-row CTs (MDCT). One of the efforts to decrease radiation exposure has been the foundation of a special committee for radiation dose control by educated members of the Korean Society of Radiology. The purpose of this study was to analyze the resultant CT protocol changes and dose reduction after awareness, efforts, and education to reduce radiation dose was implemented in 12 hospitals.

Methods: Twelve tertiary and secondary hospitals participated in this study. We selected two ten day length periods, one in March 2007 which is after rapid MDCT adoption, and one in March 2010 following the adoption of radiation dose education programs. The CT protocols and estimated CT radiation dose exposure of ten typical patients for each of ten scan types from each hospital were reviewed. Information about the CT machines, CT protocols, and the CT dose reports for each scan type were compared. The results were compared between the two periods and institutions.

Results: The data of 3,526 patients was collected from 32 CT machines at 12 institutions. In all institutions, tube voltage was changed from a fixed 120 kVp to a variable tube voltage. An increase from five institutions to ten institutions used tube current modulation. Ten institutions, which included all the initial institutions performing two phase abdominopelvic CTs, all changed to a one phase enhanced scan. For non-enhanced brain CT scans and CT angiography, CTDIvol significantly decreased. For brain CT perfusion scans, CTDIvol and DLP markedly decreased with a decreased standard deviation (SD). For abdominopelvic, cardiac, three chest CT types, and CT urography there was a markedly decreased CTDIvol and DLP. For dynamic liver CT, there was no difference in CTDIvol between the two periods, but DLP was significantly decreased .Different protocols and a wide range of radiation dose exposure were noted in all scan types in the two periods, however the SD of dose decreased in 2010 indicating a decreased protocol variability.

Conclusion: After awareness, efforts, and education about radiation dose, CT protocol changes included decrease of tube voltage, use of automatic exposure control, decrease of scan range, and limited use of multiphasic scans. Actual estimated patient radiation dose exposure markedly decreased and diverse protocols were more standardized. Continued education and efforts to reduce radiation exposure is necessary.

P07.80
Patient Radiation Doses from Radiographic Examinations in Korea

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Purpose of Study: Medical radiation imaging is valuable tool and provides great medical benefits in modern medicine. However the medical imaging procedures result in radiation exposure to patients. It has been reported that there are significant variations in national practice with medical imaging and thus radiation dose. The objectives of this study were to investigate nationwide practice of radiographic imaging in Korea and to measure radiation doses to patients from the imaging.

Materials and Methods: Number of hospitals involved in this study was 320, which was about 10% of all hospitals in Korea. Examination types included 22 conventional radiographic examinations. Entrance surface dose (ESD) was measured using glass dosimeters placed on human phantoms under typical x-ray equipment settings (e.g., kVp, mAs, etc.) at each hospital. In addition, information on x-ray equipment, technical parameter settings, dose reduction techniques, and others associated with patient radiation doses were collected.

Results: Mean ESD varied with examination types ranging from 0.2 mGy (wrist AP) to 8.8 mGy (L-spine LAT). In general, lumbar and thoracic spine imaging resulted in high dose (3.1- 8.8 mGy). Pelvis, abdomen, hip, skull, cervical spine, clavicle, shoulder, and chest imaging resulted in intermediate dose (0.9- 3.1 mGy). Extremity imaging resulted in low dose (0.2-0.6 mGy). Wide variations in patient doses were observed for the same type of examinations. These variations were as large as two orders of magnitude. There was no significant dose difference by hospital size or by equipment types. The large dose different could be attributed to equipment operation, especially use of automatic exposure control and current-time product setting.

Conclusions: We observed substantial difference in radiation doses received for the same type of examinations. Despite extensive improvements in radiography equipment and the introduction of various dose-reduction technologies, there has been no significant reduction in the patient dose. This indicates that equipment operation is more important factor rather than equipment itself to reduce patient dose. The wide variation in doses and importance of equipment operation strongly suggests that more attention must be paid to minimize and optimized radiation dose to patient.

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P07.81
Re-evaluation of the Use of Gonad Shielding for Patient X-ray Examinations

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Introduction: Gonad shields are widely recommended for radiography where the gonads are near or within the x-ray field. In order to avoid obscuring bony anatomy, ovarian shields are designed to cover only the pelvic basin. Radiography audits identify that gonad shield use is sporadic; and when used, placement is often poor. We re-evaluate the appropriateness and efficacy of shielding in light of the variability of ovarian position and the most recent revision of ICRP tissue weighting factors.

Methods: Gonad doses in adult and paediatric sized anthropomorphic phantoms were measured using TLDs during radiographic exposures with and without shielding. The results from the phantom studies were used to validate the use of PC X-ray Monte Carlo (PCXMC) dose calculation software for the estimation of the dose reduction offered by gonad shields. Radiographic examinations of the abdominal & pelvic region were simulated in PCXMC for standard numerical phantoms (0, 1, 5, 10, 15 year old & adult), varying shield size and position.

Results: Shielding of the testes can result in dose savings up to 95%; but even with good coverage, standard ovarian shields can only offer dose savings of up to 60%, irrespective of age. These maximum dose savings are achieved at the cost of obscuring bony anatomy. The Monte Carlo simulations demonstrate that shield positioning considered 'optimal' might only give ovarian dose savings of 17%. Simulations also indicate that even for small shield misplacements, dose savings could be as low as 5%.

Conclusions: Effective shielding of the testes can be achieved without reduction of diagnostic information. Ovarian shields may offer significant dose reductions for individuals in limited circumstances where upper pelvic anatomy is unimportant. Nevertheless, shield misplacement can result in repeated exposures, such that population dose savings from the use of ovarian shields may not be realised. We therefore consider that the routine use of ovarian shields should not be recommended.

P07.82
CALDose_X online: Web-based, Real Time Monte Carlo Calculations for Patient Dosimetry in X-ray Diagnosis

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CALDose_X 4.1 is a software package for the calculations of organ and tissue absorbed doses, as well as cancer risks for patients submitted to examinations of conventional radiography which can be downloaded from www.caldose.org. The program is based on conversion coefficients (CCs) between organ and tissue absorbed dose and measurable quantities, calculated with the MASH and FASH adult reference phantoms in standing and supine posture. In order to cover a greater variety of patient anatomies, 36 adult human phantoms, 18 per gender, 9 in standing and 9 in supine posture, for 3 different body masses and 3 different standing heights have been developed at the Department of Nuclear Energy in Recife/Brazil. However, the calculations of CCs for 36 phantoms would increase the data files to be downloaded by users dramatically. Therefore, it was decided to develop a software program, called CALDose_X online, which allows for the calculation of CCs or absolute organ and tissue absorbed doses, as well as cancer risks using real time MC executed from the website www.caldose.org. The software program covers 24 X-ray examinations for standing and supine posture for adult patients with body masses between 59.3 kg and 108.5 kg for males and between 48.6 kg and 94 kg for females. Standing heights cover the range from 167.3 cm to 185.6 cm for males and from 155.5 cm to 172.2 cm for females. Typical run time for the simulation of a radiograph is 60-90 seconds.

P07.84
Validation of Software for Dosimetry of Patients Submitted to CT Examinations in Belo Horizonte, Brazil

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Computed tomography has become the technique that provides the highest doses to patients submitted to examinations for diagnostic purpose. Aiming the protection of patients, diagnostic reference levels (DRL) were recommended in terms of in air or in phantom related dosimetric quantities like the CT air kerma-length product ($P_{K,L}$), the weighted CT air kerma index (C_w) and the volumetric weighted CT air kerma index (C_{vol}). Effective dose has also been used for comparing the risks to a reference patient from different imaging techniques and procedures. In Brazil, the dosimetric CT quantities are not yet routinely used for optimization purpose and DRLs were only established for head, lumbar spine and chest CT examinations in terms of the multislice average dose (MSAD). Therefore, doses provided to patients undergoing CT examinations are generally unknown although commercially available software like CT Expo, ImPACT CT and ImpactDose are available for dose assessments in patient dosimetry. The aim of this work was to validate the use of computational programs used for CT patient dosimetry through comparison against experimental measurements in antropormorphic and standard PMMA phantoms under routine CT chest protocols that are adopted in Belo Horizonte, Brazil. Absorbed dose measurements were done with TLD-100H thermoluminescent dosimeters inserted in selected organ positions in a Alderson phantom and $P_{K,L,}$ C_w and C_{vol} were obtained from measurements with a pencil CT ionization chamber in a standard body PMMA CT phantom. Measurements were done in model Brigth Speed 4 channels, GE unit for an adult routine chest protocol: 120kV, 230mA, 0,8s, 1,5 picth, 4x2,5mm collimation, 27cm length and dosimetric quantities were calculated by simulating the examination with the three mentioned programs. Results showed differences from 53% up to 126% for the CT Expo and from 36% to 62% for the ImpactDose between calculated and experimental organ equivalent doses in the range 1.1 - 20.4 mSv. Effective doses were assessed within 15% around the mean value of as 5.15 mSv; $P_{K,L,}$ C_w and C_{vol} varied from 393 to 470 mGy.cm, 20.2 to 26.1 mGy, 13.5 to 17.4 mGy and. Results allow concluding that validation of the computational programs is inconclusive in terms of organ equivalent doses due to differences between organ location and composition in mathematical and physical phantoms. If differences up to 60% are acceptable, the ImpactDose could be used as a tool for organ equivalent dose assessments. However, in spite of phantom differences, effective doses can be acceptably estimated within 15% by the adopted methods. Assessments of CT dosimetric quantities were also acceptable within 23%. Since C_W and $P_{K,L}$ results were lower that the internationally recommended DRLs of 30 mGy and 650 mGy.cm, they suggest there is still a room for seeking DRLs representative to the Brazilian CT examination conditions.

P07.85
Dose Reduction and Image Preservation After the Introduction of a 0.1 mm Cu Filter into the LODOX Statscan unit above 110 kVp

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Introduction: The LODOX Statscan unit is a low-dose whole-body X-ray scanner that utilizes a narrow fan-beam of X-rays to generate diagnostic quality images. Statscan uses a rotating anode X-ray tube (1 mm of aluminium equivalent inherent filtration and 1 mm added aluminium filtration) mounted on a C-arm. A collimated fan-beam of X-rays is emitted with an adjustable collimator width of 0.4 mm or 1.0 mm. Fixed to the other end of the C-arm is the detector unit, which consists of scintillator arrays optically linked to charge-coupled devices. The imaging technique factors have been selected by LODOX Sytems with the intention of optimising image quality and dose. Preliminary calculations suggested that a further dose reduction could be achieved by introducing a 0.1 mm copper filter for energies above 110 kV while maintaining image quality.

Method: Entrance dose 'free-in-air' was measured using a PTW-UNIDOS dosemeter and a 30 cc cylindrical ionization chamber (type 23361) for a range of examinations and views. Measured doses were corrected for ambient temperature and pressure, as well as kV sensitivity of the ionization chamber and focus-to-skin distance. The effective doses were obtained from the entrance doses using the PCXMC Monte Carlo code.

The image quality was assessed using the NORMI 4 FLU phantom, which has a resolution test pattern as well as low contrast and detail contrast inserts. Results: It was found that the insertion of the copper filter at energies above 110 kV resulted in a significant dose reduction, while image quality was maintained at these energies.

Conclusion: The filter is now standard on all new LODOX Statscan units.

P07.86
Radiation Doses to Patients from Barium Meal and Barium Enema Studies in the Western Cape Province, South Africa

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The uses of x-rays are continuously evolving in medicine, making diagnosis of injuries and diseases more practicable. It is therefore not surprising that x-rays contribute 90% of the radiation dose to the population from man-made sources. Moreover, these radiation doses are associated with both fatal and non-fatal cancer risks that are detrimental to adults between 20 to 60 years. Radiation doses to individuals therefore need to be actively monitored in order to minimise such risks. Barium contrast examinations were characterised as one of the radiological examinations that contributed greatly to the collective dose to the patients in radiology departments.

Determining the dose reference levels of such examinations would reduce the over-exposure of individuals to ionising radiation. Currently in South Africa (SA), there are no dose reference levels for barium meal (BaM) and barium enema (BaE) examinations. The dose levels measured in this study were compared with those from similar surveys internationally and sources of dose variations among the 3 hospitals were investigated.

Barium studies are radiographic procedures used to diagnose abnormalities of the digestive system. The ionising radiation used in these procedures is potentially harmful and therefore needs to be monitored.

This survey of patient doses served the following purpose:

• To investigate radiation dose received from the barium meal (BaM) and barium enema (BaE) examinations; and

• To recommend regional Diagnostic Reference Dose Levels (DRLs) for these procedures.

The objectives of the study were:

• To measure radiation doses for BaM and BaE;

• To compare the radiation doses with those previous international studies; and

• To investigate causes for dose variations.

The conclusion is that the median Dose Area Product values of 13.6 Gycm2 and 27.4 Gycm2 for BaM and BaE examinations respectively are the recommended DRLs for the Western Cape region, South Africa.

P07.87
Retrospective Radiation Dose Audit from Ghana's First 64 Multi-Slice Computed Tomography (Ct) Scanner

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A retrospective patient dose audit from recently commissioned General Electric (Light Speed VCT) 64 multi-slice computed tomography scanner, the first in Ghana has been carried out. The dose data was extracted from the dose report of retrospective examinations of head, chest, lumbar spine, abdomen and pelvis for a minimum of 20 standard adult patients from direct read out from control console. The dosimetric parameters analysed were volume computerized tomography dose index ($CTDI_{vol}$), dose length product (DLP) and effective dose (E). Mean values of $CTDI_{vol}$ were: head (51.0 mGy), chest (13.2 mGy), abdomen (16.5 mGy), lumbar spine (34.6 mGy) and pelvis (15.0 mGy). Similarly, the mean DLP values were: head (393 mGy.cm), chest (471 mGy.cm), abdomen (598 mGy.cm), lumbar spine (805 mGy.cm) and pelvis (518 mGy.cm). The mean E values were: head (0.90 mSv), chest (8.00 mSv), abdomen (7.60 mSv), lumbar spine (12.10 mSv) and pelvis (1.20 mSv). There were variations of mean values of CTDIvol and DLP when compared with European Commission diagnostic reference levels (DRLs), although that of lumbar spine slightly exceeded the DRL. Regular patient dose audits in diagnostic imaging centres and comparison with DRLs is recommended, since it offers a practical approach towards optimisation of patient protection.

P07.88
Estimation Of The Number Of CT Procedures Based On A Nationwide Survey In Japan

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In 2007, a nationwide survey was conducted to determine the frequency of CT procedures in Japan in order to compare the current use of CT among developed countries. The frequency of adult and pediatric CT scans was estimated using a model based on the results of the survey. The authors estimate that approximately 20.5 million procedures were performed in 2005 and 21.2 million in 2006. The number of pediatric CT procedures was calculated by multiplying the total number of CT procedures by the estimated fraction of pediatric (0–15 y) CT procedures. Annual pediatric CT procedures were estimated to have been approximately 580,000 in 2005 and 600,000 in 2006. The present study indicates that the number of procedures per thousand of population, 166 for total CT and 32–34 for pediatric CT, is lower in Japan than in the U.S.

P07.89
Dosimetric Evaluation In Orthopedic Surgeries Guided By Fluoroscopy In Sergipe, Brazil

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This work aimed to evaluate the performance of fluoroscopic equipments in the state of Sergipe, Brazil, together with the patient dose at orthopedic surgeries in a public hospital. The equipments performance evaluation was done through quality control tests, following methodology of the national regulatory agency (ANVISA). The dose monitoring was performed by recording the dose area product (DAP) for each procedure. Besides, patient's sex and age and technical information about the equipment and the procedure were also recorded. For dosimetry in fluoroscopy, it is also important to know the total exposure time. Due to the lack of time information in the equipment, it was developed a methodology to estimate the exposure time. This methodology took in account DAP against time graphs, constructed by measurements on the equipment used in surgical procedures. Dose monitoring was performed in a public hospital. DAP was recorded for 20 orthopedic surgical procedures. Most of the procedures were performed to repair fractures. The males appeared as majority (60%), and the predominant age group was around 38 years. The measured values for the DAP proved quite heterogeneous (even for the same procedure type). This DAP values variation can be attributed to procedure complexity, surgeon experience and many other factors. The estimated annual effective dose to surgeons and medical staff were between 0.1 and 0.01 mSv, below the legal limit. Femur procedure has stood as one with the highest average value for the DAP (3.2 ìGy.m ² x10 ²), highest average radiological parameters and presented one of the highest averages for the total time of fluoroscopy (46 s with a maximum of 82 s). Although there was no regular control and quality assurance programs in the concerned hospital, the tested equipment, in general, were in good working condition. However, the lack of frequent quality control monitoring is worrisome because it can make last unidentified malfunctions. The large range of results proved the complexity of the surgical procedures. The dose management data should be used as reference for future measurements.

Keywords: dose area product, fluoroscopy, dosimetry.

P07.90
Patients Exposure Doses for CT examination in Japan 2011

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We have investigated changes in exposure dose in Japan in terms of the same items since 1974. An assessment was made of changes in exposure dose during a period of 37 years. Nationwide investigation was conducted seven times from 1974 to 2001 with regard to 14 target areas (21 kinds of projections). Investigation of CT examination was started in 1997. In CT examination, doses were assessed in terms of CTDIvol. CTDIvol was calculated by determining CTDIw as defined by the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) and other organizations using PMMA cylinders 16 cm and 32 cm in diameter, and dividing it by BP. The trends from 1997 to 2011 in the doses in adult cranial and abdominal CT examinations, the doses increased slightly until 2007, with further increases to 21% for cranial CT and 33% for abdominal CT in 2011, compared with the 2007 levels. On the histogram for 2007 and 2011, the mean dose increased by 25% from 64 mGy to 79 mGy. Although the histograms are similar in shape, 2.4% of the institutions had mean doses exceeding 120 mGy. In 2007, the 4-row system was the most prevalent type, accounting for 39%. In 2011, the 64-row system accounted for 427%. Another noteworthy finding for 2011 was that systems with more than 64 rows, which were not available in 2007, were being used clinically at some institutions, although they accounted for only 6%. In 2011, CTDIvol in non-helical adult and child cranial were 82 ±50 mGy and 43 ±21 mGy. Chest adult and child were 16 ±16 mGy and 9 ±9 mGy. Abdomen adult and child were 23 ±26 mGy and 11 ±12mGy. The doses in children ranged from 40% to 60% relative to the adult levels, although some variation existed depending on the portion examined.

P07.91
Analysis of Average Glandular Dose for Mammography in 2011 Questionnaire

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Recently, patient exposure dose for mammography are varied because of a great progress of digital mammography, and furthermore enlightenment or study on mammography in Japan. Therefore, the newest patient exposure dose was necessary to know. We were obtained from ’2011 questionnaire carried out to the whole country in Japan was investigated. Furthermore, the average glandular dose based on ’2011 was compared with that of ’1993, ’1998 , ’2001 and ’2007. The average glandular dose can be calculated from the product of the breast entrance skin exposure and DgN (the average glandular dose per unit entrance skin exposure). The breast entrance skin dose was estimated from the dose of 457 institutions in ’2011, which was calculated from data measured at 93 institutions in Japan. DgN was used published table of 50% adipose-50% glandular breast composition and 4.2cm breast thickness corresponding to measured half-value layer (HVL) on each tube voltages. Then, patient exposure dose for mammography was estimated from exposure condition (tube voltage, mAs value) obtained ’2011 questionnaire.

The dose in ‘2011 estimated about 2.0mGy was the most highest in the past survey. This result was caused by the great popularity of digital mammography. The digital mammography have increased, accounting for about 97 % in the investigation this time.

The patient exposure dose for mammography in 2011 survey was increased .

P07.92
Patient Dose Reduction in common CT Examinations in Iran

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1. Introduction

Computed tomography (CT), is an X-ray procedure that generates high quality cross-sectional images of the body, and by comparison to other radiological diagnosis, CT is responsible for higher doses to patients. Therefore the European Union, in an ionizing radiation protection directive, has classified computed tomography as a high dose diagnostic procedure and has pointed to the need to reduce the dose to the patient[(1)]. The aim of this work is to study the CT practice in some CT units in different hospitals in Iran, in order to investigate the radiation doses imparted to patients during CT examinations.

2. Materials & Methods

In this study, patient dose is measured for four types of examinations. Information was collected in relation to standard protocols established for some common CT examinations and standard size patients. Measurements of CTDI were made by CT pencil ionization chamber and phantoms on head and body. The basic quantities used in CT dosimetry, are the CT Dose Index (Ca, 100) and CT Dose weighted (CW). Selected CT examinations are; routine head, routine chest, routine abdomen-pelvis and routine sinus. Data were collected from 120 patients.

3. Results

Data were collected for each protocol from 30 patients. The patients that are included in the survey were selected in order to correspond to the typical patient (weight 70±10 kg). The CTDI for routine brain protocols varied from 37.8 to 90.72 mGy. The DLP for the same examination was measured a mean value of 846.72 mGy.cm. A comparison between these values with the DRL which is given by the European Commission shows in Figure 1.

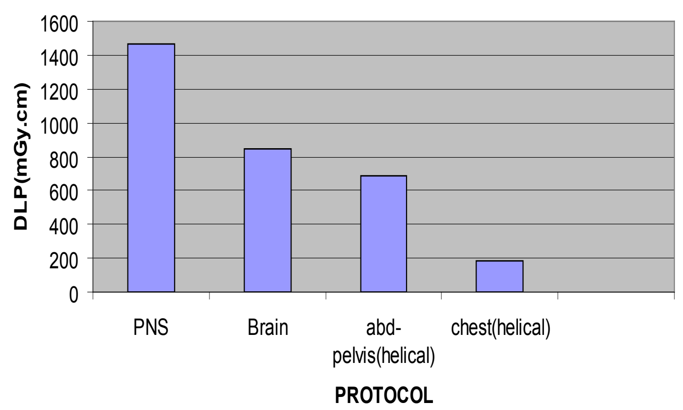

Figure 1: DLP (mGy.cm) for all applied protocols

The DLP values for 3 applied protocols of brain in some center were maximum. DLP values for applied sinus protocols were higher than brain protocols. Table 1. Shows the mean values of $CTDI_w$ and DLP which is determined in this study with published elsewhere.

Poster sessions C-D: Area 7

Table 1: Comparison of mean values of $CTDI_w$ and DLP

$CTDI_W$	IRAN	53 Taiwan	54 Italy	55 wales	56 Poland	57 Tanzania	58 Ireland	59 Berlin	60 UK
HEAD	54.68	55	59.6	46	19	43	57.5	49.6	51
CHEST	7.2	20	19.7	17	21.3	17	18.5	17.41	6.4
Abd-Pelvis	17.14	22	24.3	22	23.7	17	19.1		9.5
DLP									
HEAD	600.96	665	725	731	386	913	817	587	386
CHEST	182.7	455	473	663	447	783	434	502	203
Abd Pelvis	689.88	453	517	745	550	982	433		446

References

1 Council Directive 96/29 EURATOM. Laying down basic safety standards for the protection of the health of workers and general public against the dangers arising from ionizing radiation. OJ L 159:

29-6 (European Commission – Radiation Protection Division) (1996).

P07.93
Use of CT Dosimetry Spreadsheet for Estimating the Effective Dose in Dental Cone Beam CT

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The use of CT imaging in dentistry is continually being expanded especially after the consolidation of those techniques as important tool in planning and evaluating implants. The Cone Beam Computed Tomography, CBCT, appears in dental radiology as a revolutionary technique and has established itself as a radiological imaging modality that has advantages, in terms of visualization of structures, compared with intra-oral radiography and panoramic radiography. The CBCT technique is currently considered as a tomographic technique of low-dose radiation when confronted with conventional tomography applied to dentistry. The objective of this study was to evaluate the effective dose values for CBCT acquisition of different protocols using the database of the NRPB SR250. We evaluated four CBCT equipment, manufactured by Images Sciences i-CAT inc. model Classical i-CAT. Those equipment operate only with tube voltage of 120 kV, pulsed beam and tube current in the range 3-7 mA, according to the manufacturer's technical specifications. The image receptor is amorphous silicon flat panel, a-Si. This equipment enables to perform volumetric acquisitions with three fields of view, FOV, and four different voxel sizes. In the evaluation of effective dose in three-dimensional acquisitions, we use the CT Dosimetry Spreadsheet, version 1.0.2, created by British group IMPACT: Imaging Performance Assessment of CT Scanners and the database NRPB-SR250: Normalised Organ Doses for X-Ray Computed Tomography Calculated Using Monte Carlo Techniques. We obtained values of effective dose compatible with a volumetric acquisition, and, therefore, superior to the typical values of panoramic image. This study suggests a direct and practical way to estimate values of effective dose for cone beam CT in dental applications, thereby allowing simpler way to compare protocols and equipment. Unlike methods that use this methodology TLDs, it can be applied by the user of the equipment, requiring only prior knowledge of the index. The estimated values are low compared with the effective doses values generated from conventional tomography. However, these values are relatively high when compared with the typical effective dose values derived from other types of radiological examinations present in dentistry.

P07.94
What You Should Know about Medical Radiation Exposure for Reducing Radiation Exposure: Check Your Knowledge as a Radiation Expert

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PURPOSE/AIM

1. To provide basic information about radiation exposure for radiologists

2. To understand the concepts and techniques for reducing radiation dose during medical radiation procedures

3. To realize importance of reducing radiation exposure for both patients and radiologists

CONTENT ORGANIZATION

The exhibits will be presented in a quiz format. Including contents are as follows;

Radiation physics, source and characteristics of radiation

Radiation biology

Radiation safety and protection

Medical imaging and radiation; Radiography, CT, mammography, fluoroscopy, interventional radiology

Pregnancy and radiation

Pediatric radiation exposure

Radiation protection and radiation exposure for radiation workers

Introduction of international guideline and diagnostic reference level

SUMMARY

1. Knowledge about medical radiation is crucial for reducing radiation exposure during radiologic procedure for both patients and radiologists.

2. We will provide essential concepts and knowledges about medical radiation exposure by self-checking questions and answers including explanation.

P07.95
Validation of an Anthropomorphic Chest Phantom for Image Quality Control Tests and Dosimetry in Diagnostic Radiology

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In this study, an anthropomorphic chest phantom, made of artificial and no-artificial materials, was developed for studies focused on dosimetry and image quality analysis in chest radiology examinations. This phantom consists of a bipartite chest made of epoxy resin (soft tissue simulator), a pair of lungs made of foamed polyurethane (simulator of lung tissue), and a pair of lungs, heart and chest bones, all human. For validation purposes, comparisons were performed in terms of CT numbers and radiography optical densities (OD) using patient images and phantom images. For OD measurements, several anatomic points were evaluated, such as soft tissue, bone and lungs. For CT numbers, the measurements were performed in soft tissue, bones, heart and lungs real and artificial. Both CT numbers and OD results proved that the phantom is really similar to human chest and can be used properly for simulate the patient in dosimetry and image quality tests. In addition, for better image analysis, patterns simulating typical lung pathologies were inserted in the artificial (foam) lung, allowing evaluation of detectability of spherical microcalcification and nodules. Aluminum spheres, ranging from 0,1 to 1,5 cm, were used to simulate microcalcifications and epoxy resin spheres, ranging from 0,1 to 2,5 cm, were used to simulate nodules. The obtained images were very similar to patient illness images and it was possible to quantify the minimum diameter detectable for each pathology. With the intention of evaluating the anthropomorphic chest phantom for dosimetry with conventional x-ray beam, dosimetric quantities have been studied and analyzed. Measurements were made of entrance surface air kerma (ESK), using the anthropomorphic phantom and using a typical geometric phantom, and the backscatter factors (BSF) of the two phantoms were determined by incident air kerma measurements. The ESK and the BSF results were very similar and, in the last case, were close to theoretical values. Therefore, by all results of dosimetry and image characteristic, it is possible to state that the developed anthropomorphic phantom can be used in dosimetry and image quality control tests studies in diagnostic radiology.

P07.96
Characterizing Canine Dose from Computed Tomography Irradiation

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Stochastic effects of low dose radiation are a concern for the population due to absorbed dose from medical imaging process like Computed Tomography (CT). A study at Colorado State University characterized the dose delivered to a canine brain during a CT scan of full-scale physical canine phantom. Direct measurements of doses to the brain were performed using an ion chamber inserted into the phantom at specific organ locations. This study was the first step to building a system that utilizes the translational applications of dogs as models for humans for future studies to characterize the effects of low doses of radiation. Equivalent doses were calculated with a mean (± standard deviation) of 12.96 (± 0.45) mSv, 32.80 (± 0.77) mSv, and 49.24 (± 0.87) mSv for 90, 120 and 140 kVp respectively at a fixed 300 mAs in the brain of the canine phantom. These data were found to be a good fit for a ten year old child when compared to a parallel set for an adult and a child from direct beam irradiation. Preliminary results indicate a ten year old child will be a good overall fit for a dog; however, more research is necessary to better characterize the relationship for other organs of interest.

P07.97
Evaluation of the Scan Protocol in the measurements of Coronary Artery Calcium: Image Quality

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The aim of this study was to evaluate the influence of the tube current applied for studies of calcium score. The research was carried out in a private clinic of Rio de Janeiro, using a 64-slice MDCT scanner and an anthropomorphic cardiac CT phantom. In all images, the Agatston score, the volume and mass of the calcifications, and the noise for each current tube was determined. The average CT attenuation number obtained for all tube currents was 261.6 ± 3.2 HU for the CaHA density insert and -0.2 HU ± 2.0 for the water insert. The images obtained at lower tube currents were noisier and grainier than those obtained at higher tube currents. However no significant differences were found in the calcium measurements, which suggest a high potential of patient dose reduction, around 50%, without compromising diagnostic information.

P07.98
First Results on Patient Dose Measurements from Conventional Diagnostic Radiology Procedures in Montenegro

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This study is the first nationwide investigation aimed at estimating the patient dose for radiographic examinations in Montenegro, including some gastrointestinal studies. Measurements of patient dose in terms of entrance surface air kerma (ESAK) and kerma-area product (KAP) were performed on at least ten patients for each examination type, in each of 5 randomly selected health institutions in Montenegro, so that a total of 917 patients for 13 different examination categories were included in the survey. Exposure settings and individual data were recorded for each patient. Mean, median and third quartile values ESAK of patient doses are reported. The estimated mean ESAK values obtained are as follows: 4.7 mGy for pelvis AP, 4.5 mGy for lumbar spine AP, 7.8 mGy for lumbar spine LAT, 3.1 mGy for thoracic spine AP and 4.3 mGy for thoracic spine LAT. When compared with the European Diagnostic Reference Values, the mean ESAK for all studied examination types are found to be below the reference levels, except in chest radiography. Mean ESAK values for chest radiography are 0.9 mGy for PA projection and 2.0 mGy for LAT. Values of maximum/minimum factors for all these institutions are 78 for PA and 88 for LAT projection in chest radiography.. The results exhibit a wide range of variation. For fluoroscopy examinations, the total KAP was measured. The mean KAP value per procedure for barium meal is found to be 22 Gycm2, 41 Gycm2 for barium enema and 19 Gycm2 for intravenous urography. Broad dose ranges for the same types of examinations indicate the necessity of applying practice optimization in diagnostic radiology and establishment of national diagnostic reference levels.

P07.99
Reference Doses for Dental Radiography

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In order to establish updated reference doses for intra-oral dental examinations, data from about 450 quality control tests performed during 2010 by the Radiation Protection Service ACPRO, S.L. were analysed. The statistical study focuses both on x-ray dental equipment that uses a digital radiographic system (DRS) and on systems that use radiographic film (RF).

Four groups of interest were defined for the establishment of reference doses: standard adult with RF, paediatric patients with RF, standard adult with DRS and paediatric patient with DRS. The third quartile patient entrance dose for mandibular molar intra-oral examination was determined for each of the gruops and was used as the proposed reference dose.

Results show a reference dose of 3.4 mGy for adults with RF, 1.9 mGy for paediatric patient with RF, 1.2 mGy for adults with DRS and 0.7 mGy for paediatric patient with DRS. In consequence, it can be concluded that the use of digital imaging systems implies a reduction of the order of 60% on patient entrance dose. In addition, the use of the paediatric mode available for most of the intra-oral dental x-ray devices implies an additional reduction of the order of 40% on patient entrance dose.

The obtained reference dose values for each group of interest can be used as a guide for acceptable clinical practice. In fact, the present results are in agreement with the reference dose of 4 mGy recommended by the NRPB for an adult mandibular molar intra-oral radiograph. We can also conclude that the use of digital imaging systems is highly recommended in order to minimise patient dose, as well as the selection of the paediatric mode for examinations of children.

As a complement, the influence of the x-ray equipment working kilovoltage, the focus-skin distance and the x-ray radiation waveform on patient entrance dose was analysed. Furthermore, we checked whether patient entrance dose distributions present sizeable variations with the brand of x-ray equipment.

P07.100
Necessity to Update Radiation Dose Calculation Programs of Computed Tomography

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Objectives: There are several dosimetry methods to estimate radiation dose from computed tomography (CT) scans. Among them CT dosimetry computer programs have been used widely and successfully for radiation protection purpose under ICRP 60 standards. However, it is necessary to update or develop CT dosimetry programs under the new ICRP 103 radiation protection standards. The objectives of the present study were to compare radiation doses calculated by different CT dosimetry programs, to review limitations of the current dosimetry programs, and to suggest necessary studies for improved dosimetry.

Method: Radiation doses from various CT scanners were calculated using three different CT dosimetry programs. Organ doses from CT scans for head, chest, abdomen/pelvis, and whole body examinations were calculated at the same technical settings and compared one another. Limitations of the current CT dosimetry programs were reviewed and necessary studies to improve CT dosimetry were suggested.

Results: Generally, radiation doses calculated by different CT dosimetry programs were comparable although relatively large differences were observed for some specific organs or tissues. For some CT scanners, there was big difference in doses to all the organs and tissues. CT dosimetry computer programs have been commonly used due to their user friendliness. However, there were some limitations including unrealistic anatomical structure of human phantoms. New ICRP radiation protection standards recommend use of computational anthropomorphic phantoms based on medical tomographic images rather than mathematical phantoms. The other ones include limitation to apply to different patient ages, limited number of organs and tissues for dose calculation, inflexibility of patient height and weight, and non-applicability to new CT technology.

Conclusion: It is necessary to use CT dosimetry programs with consideration of potential dose difference and their limitations. It is necessary to develop or update CT dosimetry programs to overcome the limitations and to improve CT dosimetry.

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P07.101
Australian Per Caput Doses from Diagnostic Imaging and Nuclear Medicine

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The Australian use of CT increased strongly from its introduction in 1976 until 2009 with an associated increase in per caput dose from the use of radiation in medicine. Per caput doses from medical uses of radiation are now comparable to the natural background as the largest source of radiation exposure to the Australian population. The frequency of diagnostic imaging of diagnostic imaging procedures together with estimates of doses per procedure are reviewed based on data from the Australian national health insurance scheme, estimates of procedures funded by other mechanisms and best estimates of doses per procedure. Estimates of doses per procedure are informed by data from a national survey of diagnostic reference levels commenced in 2011.

P07.102
Digital Repeat Analysis in Digital Mammography

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This procedure has as an objective establishing the main reasons to mammography rejection. The rejection analysis is an important tool from the quality control programs, which contributes to the evaluation of the image´s quality standard. The analysis methodology is based on the recommendations from *Honea et al.*. For a two months period, the rejected examinations in the technician´s workstation and also in the PACs (Picture Archiving Communication System) were evaluated in order to number the causes of examination rejection after introducing a digital mammography system. The results show the possibility of separating the rejections into two types: the ones which would lead to more expositions, contributing to the increase of dose for the patient, and the ones which would lead to the need of reorganizing the results presentation, creating more work and increase of expenses.

About 21.37% of the rejected examinations lead to its repetition. The rejection rate for inadequate positioning was of 2,56%. However, the examinations which were rejected by the doctors for not presenting diagnostic quality, sum 10,26%. These can incorporate both rejection for wrong positioning or inadequate exposition and grid artifacts, totalizing 14,52%.

The causes of rejection which did not lead to the need of repetition totalize 78,63%. However, they cause additional expenses and demand work time from the involved crew. The major rejection, 18,38%, correspond to duplicated film, followed by rejections without identified cause, with 13, 68%.

The rejections by incorrect patient´s name totalize 11,11%. From these, 7,26% were with changed identification and 2,99% were without identification. These errors can cause extremely serious problems of link between patient and examinations result. The rejection analysis was a very useful tool to show the relevance of implanting the RIS protocols and the worklist tool. The analysis of the rejection results may contribute to the definition of the sectors involved in the production of images which must be accompanied in a more continuous way.

Keywords: Digital radiology, Analysis of rejection , dose reduction

P07.103
Methodology to Dose Optimization in Computed Tomography in the Routine of Chest Exams

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This work describes a methodology to dose optimization in computed tomography in the routine of chest exams. The optimization would obtained by study of the noise increase in specifics clinical images, by computational simulation, using the software ImageJ. The modified images would be analyzed by chest specialists radiologists. Were accompanied 56 computed tomography of chest to observe the clinic routine and reproduce the technique on exposure of the phantom. The software used was tested by analyze of water phantom images, which was not successful. The methodology could not be applied to routine, because this, the objective was partially achieved. The incompatibility of the modified images with the software used in clinics computers not permitted the analysis of images by the radiologists team. It was also concluded, that need continue the study regarding the dose optimization in computed tomography to the routine of chest exams. Because some of effectives Dose Length Product (DLP) values informed by tomography equipment is able to evaluation patients, with biotype correct corresponding the 20,4% of the total sample, was divergent if compared to the reference level according the European guidelines on quality criteria for computed tomography. It was observed that 62.9% of patients were overweight or obese were justifying the increase in the effective values of DLP. Data of exams collected were sent to the doctors, important fact in this work, because they realized that they need to evaluate the clinical protocols according the clinical requisition.

Keywords: Computed tomography. Dose. Chest exams. Noise level.

P07.104
Effect of Reconstruction Algorithm Filter on Image Quality Adult Head Examination

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Background: Nowadays it is available different kind of reconstruction filters according to the clinical diagnostic propose. The aim of this study was to assess the influence of the mathematical filters on patient dose and image quality of head CT procedures. Method: The ACR CT accreditation phantom has been designed to evaluate a broad of image quality indicators: position accuracy, CT number accuracy, slice width, low contrast resolution, high contrast resolution, CT number uniformity and image noise. The phantom was scanned with three different tube current values and reconstructed by using the three reconstruction algorithms. Results: The evaluation of CT number accuracy was carried out using a bone filter. In comparison to ACR reference standards, the number of CT for acrylic was 6% lower. For polyethylene, bone, air and water the CT number difference was lower than 4 % for all reconstruction filters and tube currents. To evaluate low contrast was determined the Contrast to Noise Ratio (CNR). According to the manual, the CNR must be greater than one for adult and pediatric head and abdomen protocols. For pediatric abdomen the CNR should be 0.5. The soft filter presented the best low contrast resolution: CNR values were 1.25, 1.33 and 1.24 respectively to 375 mAs, 300 mAs and 250 mAs. For 375mAs, the standard filter (using in routine procedures) showed a CNR = 1.09 and even lower values for smaller mAs. For bone filter the CNR was lower than 0.31 to all values of tube current. The better high contrast resolution was obtained with bone filter, where the average value of MTF was: 58%, 39% and 19% for spatial frequency of the 7, 9 and 10 lp/mm respectively. With the other filters were possible to distinguish 6 lp/mm (MTF: 22% to standard filter and 16 % to soft filter). Using the bone filter the levels of noise was approximately 80 % greater than the noise for soft and standard filters. The soft filter had low levels of noise, presenting a variance around 0.1%. The CT number uniformity to the different reconstruction algorithms and the tube current values has showed a variance of 0.34 % to standard filter and 12.6% to bone filter.Conclusion: Reconstruction algorithm is an important factor for CT images, especially for low resolution structures. It is also an alternative to reduce patient dose. To obtain images with adequate low contrast resolution and at the same time to reduce the dose the soft filter is indicated in the acquisition parameters. In this case it is possible to use in the procedure 250 mAs without compromise the image quality. However if standard filter is used it will be necessary to increase the mAs value in 33%. To obtain high spatial resolution the bone filter showed the best option when compared with others filters. For bone filter, the spatial resolution was 9 lp/mm while for the other filters it was lower than 6 pl/mm. The noise level was greater than 80 % in relation to soft filter and the CT number uniformity was 12.6 %.

KEYWORDS: Reconstruction algorithm, Computed Tomography and Optimization

P07.105
Comparison of CT Dose Modulation Systems: Results in an Optimization Process

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Background: The tube current modulation systems are an important tool for patient dose reduction and to improve image quality. However, in order to optimize the procedures it is essential to know the operation mode of the different systems available in the multislices scanners. Before the implementation of the current modulation in the service routine it is fundamental verify the performance of the system. In general, the users don't have the necessary information about the features of the systems which difficult their correct application in the CT exams. The aim of this study was to verify the variation of noise level and the respective dose values during the exposure of the abdomen phantom. Method: The project was developed in a private hospital in Rio de Janeiro. The modulation systems of the Philips Brilliance 64 are: DDOM (frequency modulation) and ZDOM (longitudinal modulation). For this study the Triple Modality 3D Abdominal Phantom - model 057 was used. This phantom includes inserts which represent the main organs of the abdomen. For conduct the dosimetry and the evaluation of image quality the following parameters were collected: slice thickness, kVp, mAs, collimation, pitch, scan length, number of slices per rotation, reconstruction increment and window view. The image noise was evaluated in Regions of Interest (ROI) defined in each simulated organ. The number of CT and standard deviation was determined in each ROI. The software (Image J) was used to analyze the images. The relationship between noise and mAs was evaluated in each image obtained for different modulation systems. The C_{vol} and DLP were determined using the dosimetry data and the technical factors applied in routine abdomen examination. Results: The average values of C_{vol} were 6.88mGy and 6.39 mGy for ZDOM and DDOM respectively. When the exposure was done without modulation the C_{vol} was 7.35mGy. Using the DDOM system it is possible to reduce the C_{vol} value in 13.0% without compromise the image quality. The same level of noise for all regions of the phantom was achieved applying ZDOM and DDOM. When the procedure was carried out without modulation the noise variation reached up to 21.6% for ribs. The images obtained without modulation showed a lower noise levels for kidney, rib and soft tissues in relation to the images obtained with ZDOM and DDOM. This fact can be explained by the reduction of the mAs by the modulation system in some regions of the phantom. However, it doesn't represent a degradation of the image. Conclusion: The modulation systems showed a more constant noise to all anatomical region of the abdomen phantom than the system without modulation. The image quality remains similar regardless of the changes anatomical of the abdomen, DDOM system presented the lower dose and increased noise without compromise quality image.

KEYWORDS: computed tomography, radiation protection and modulation.

P07.106
Determination Of Airkerma Values In The Group Of Most Frequent Radiographic Examinations Like A Basis For Patients Doses Estimation In Slovakia

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In our study we discuss the factors that need to be considered in optimising the performance of radiographic technique. For estimation of patient doses we used in our work dosimetric quantity called entrance surface airkerma (ESAK). In this work we have collected data set of patient doses obtained under standard conditions of exposure and focal distance of 100 to 150 cm and range of tube voltages between 40-125kV. For each of the selected types of examinations was calculated ESAK quantity from measured absorbed dose in the air. Based on the final processing of the results we were able for each department separately to develop methodology for estimating patients doses and patient doses summaries for selected types of radiographic exposures. Our study we focused on estimation patient doses in the group of most frequent radiographic examinations in selected hospitals in Slovak republic.

P07.107
BEAMnrc Simulation to Assess the Absorbed Dose in Compact Tissue of Diaphysis of Long Bone Exposed by X-ray Beam

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The absorbed dose inside the compact tissue of diaphysis of long bone in simple radiography, using X-ray machine with 102 kv and 100 mA, was measured inside the phantom of femur by TLD100h for different locations. BEAMnrc and DOSXYZ were used to calculate the dose in the same locations. The agreement at the center of field is as much as 5% deference averagely. Then with DOSXYZ, PDD was found and the absorbed dose was calculated inside femur. The results show that in this kV and mA , the average amount of absorbed dose inside bone, within a voxel with 5mm×2cm×5mm as dimensions, is 3.8 cGy that is comparable to surface dose.

Keywords:

Monte Carlo simulation, BEAMnrc, DOSXYZ,PDD

P07.108
Experimental Studies of X-ray Scatter in Diagnostic Radiology

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In diagnostic and interventional radiology procedures the majority of the radiation created is absorbed within the patient. However a proportion of radiation is released into the surrounding area by either direct transmission though the x-ray housing (tube leakage), or as scatter from the patient. If uncontrolled this emitted radiation can result in the unintentional exposure of staff and the general public.

The current accepted methods for determining the x-ray shielding requirements for radiology installations are based upon the attenuation properties of the shielding material in question. When using these methods in isolation, the combination of rising patient workloads (more radiation) and lowering of dose constraints has lead to a general increase in the specified barrier thickness.

Current guidance literature takes no account of additional multiple scatter originating from the walls, floor and ceiling which results in radiation effectively being 'emitted' back into the x-ray room. Areas within the room assumed to be protected from radiation may not be. Choosing to increase the barrier thickness may provide only minimal protection from this additional scattered radiation. The magnitude of this multiple scatter is very difficult to quantify and is usually assumed to be very small when compared to first-order scatter originating from the patient/tube head. For these reasons this component is conventionally ignored during room design calculations.

The presence of this additional multiple scatter radiation behind protective screens has been verified with radiation survey measurements taken during medical physics acceptance tests of several new x-ray installations. In one particular case, the air kerma rate behind a shielding screen was over three times that expected from calculations using currently accepted attenuation-only model for shielding design. In this case the shielding requirements were redesigned, resulting in expensive modifications and delays.

Further evidence of multiple scatter at diagnostic radiology energies have been observed by the production of air kerma profiles / maps behind existing protective barriers using a variety of x-ray detectors. Some limited monte carlo simulations based on real installations have also been also performed. These simulations have permitted the affect of altering parameters such a barrier thickness, dimension and location to be observed, each with some unexpected results……

The primary objective of this work is to produce a generalised methodology for calculating the optimum shielding arrangement for diagnostic radiology installations to include a mechanism to correct for multiple scatter interactions.

P07.109
Comparison of Mean Glandular Dose in a sample of patients from Colombia and Brazil

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The aim of this study was to estimate the mean glandular dose (MGD) in two mammography centers, one on Medellin (Colombia) and other in Belo Horizonte (Brazil). Screening mammography is the method used to detect breast cancer, but this practice has an associated radiological risk related with the dose deposited in the glandular tissue of the breast.

The centers were selected randomly, they were evaluated and exposure conditions of each mammogram were recorded. In both centers, mammography was performed a quality control program, which measured the output of the equipment, half-value layer HVL and quality control of the image, quality criteria were acceptable. Then, the values registered were the compressed breast thickness CBT, tube potential (kV), tube load (mAs) and the type of view projection, craniocaudal (CC) and mediolateral oblique (MLO) for 50 patients in each center.

The average MGD per film for the sample of patients in Colombia was 1.36 ± 0.83 mGy and 2.05 ± 0.78 mGy for the sample of patients in Brazil, was take into account a percentage 50% glandular tissue and using conversion factors g of Dance. Significant differences were found between MGD from CC and MLO projections. In first mammography center the doses were 1.30 ± 0.57 and 1.43 ± 0.68 in the CC and MLO projections, respectively. In the second center the doses were 1.83 ± 0.61 and 2.30 ± 0.85 in the CC and MLO projections, respectively. The dose in the MLO projection is always greater than the dose in the CC projection. The results show that the average dose of two centers, are below guideline levels of dose proposed by international protocols.

P07.110
The Activities Of Regulatory Authorities In Medical (Radiation) Practices And Their Potential To Influence Optimisation Of Medical Exposures

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ICRP has identified three fundamental principles of radiation protection:

• Justification

• Optimisation

• Dose limitation

For medical exposures dose limits do not apply, so dose restriction is dependent on optimisation, through appropriate equipment performance and good professional practice.

Regulatory Authorities (RA) undertake a range of activities including licensing and inspection, to ensure that the fundamental principles of protection are applied. During inspections, optimisation has been considered through equipment QC and assessment of local doses against DRLs. In most cases, RAs' review of optimisation via good clinical practice has been almost non-existent.

To assess the potential impact of RAs on optimisation, a survey was undertaken of 29 European RAs to gather information on their licensing, inspection activities and the professional background and clinical experience of staff.

This demonstrated that RAs across Europe are ill equipped to provide critical assessment of optimisation of practical aspects. Most RAs use medical physicists to provide the professional component of their staff but only 50% have initial clinical training. The up to date clinical competence of these staff is unclear – none have a requirement to maintain clinical skills. Often medical physicists have a theoretical understanding of medical exposures but no practical training or experience of carrying out clinical procedures. Similarly, little information exists regarding clinical competence of auditing bodies. As a consequence, both RAs and audit bodies can only have a limited impact on optimisation.

Examples of good practice within Competent Authorities across Europe have been sought to assist development of training programmes to ensure that staff undertaking inspections or audit can demonstrate adequate clinical training and up-to-date knowledge to be able to advise and influence the optimisation of medical exposures. The role of clinical staff within RAs has also been addressed.

P07.111
Specification of Shielding Requirements for PET/CT facilities

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The BIR/IPEM report describing methods for assessment of shielding requirements for medical X-ray facilities has been revised to take account of developments in equipment and techniques.

PET CT was not widely available when the first edition was published but transmission data and methodologies have developed over recent years. This paper describes the difficulties associated with designing shielding for PET CT, in particular the requirement for greater barrier thicknesses as a result of the high energy of the 511keV gamma ray emitted, and the requirement for patients to rest within the facility during the uptake phase and the consequent exposure of staff from multiple sources during most of the working day.

P07.114
Occupational External Radiation Dose to Personnel Involved in Veterinary Positron Emission Tomography Procedures

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Positron emission tomography (PET) is a diagnostic imaging modality used in the clinical setting for disease detection and treatment assessment. Several studies have been conducted concerning the external radiation dose to hospital personnel from PET radiopharmaceuticals, but to date no specific parallel studies have been done for veterinary PET personnel. Because of the need to anesthetize veterinary patients, veterinary personnel are potentially interacting with animal patients for a longer time period than technologists performing human PET imaging. Although veterinary personnel may be interacting more closely with animal patients undergoing PET imaging, radiopharmaceutical doses are generally smaller for animal patients because they weigh less on average.

Considering the differences between human and veterinary practice, this study used electronic personal dosimeters to determine per patient external radiation doses to veterinary personnel working with PET at Colorado State University's James L. Voss Veterinary Teaching Hospital over a period of four months. Participants in the study included nuclear medicine technologists, the on-duty anesthesiology technologist, and occasionally an observer. Individual doses, along with the details of the staff member's activities, were recorded for available personnel for each PET study. Twenty-five scans were conducted over the course of this study: thirteen different dogs, six different cats, and a sheep (with two cats and three dogs having repeat scans). The mass range of the animals was 2.8 to 76.5 kg, with an average of 28.9 kg. The average amount of activity injected was 6 MBq per kg. The dose per scan ranges were as follows: 0 to 30 μSv (7.8 μSv average) for the nuclear medicine technologists, 1 to 22 μSv (8.3 μSv average) for the anesthetist, and 0 to 2 μSv (0.4 μSv average) for the observer. Worker external radiation doses in this study were compared to doses presented in the human literature, and a simple dose model was developed to compare two different veterinary PET protocols.

P07.121
Radiation Exposure to Medical Staff in Neuroradiology, Liver Chemoembolization and Pediatric Cardiac Interventional Procedures

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The use of interventional procedures for diagnosis and treatment of various vascular lesions has increased in recent years, due to the fact that these procedures have low invasiveness. But, despite their benefits, they may result in high radiation doses to the patient and to the medical staff from radiation scattered by the patient. Depending on the type and the complexity of the interventional procedure the doses to the staff can be significant. The aim of this work is to evaluate the exposure to the medical staff during three types of interventional procedures: neuroradiology, liver chemoembolization and cardiac procedures. This study was performed at a large hospital in Recife, Pernambuco, Brazil equipped with an x-ray unit (Siemens Artis Zee) with flat panel detector. The dosimetric measurements were carried out under the methodology and approach of the regional program of IAEA ¡V RLA9067, during 70 procedures, 40 being for neuroradiology and 10 for liver chemoembolization for adult patients, as well as 20 cardiac procedures for paediatric patients. The radiologists monitored had TLD-100 chips attached next to the eyes, close to the thyroid (above the shielding), on the thorax under the apron, at the hands in the region of the pulse, and at the feet. The results showed that the highest doses for the physician occur during liver chemoembolization, reaching five times the values found for neuroradiology and interventional paediatric cardiology. Average dose next to the left eyes was 333µGy, 58µGy and 83µGy for liver chemoembolization, paediatric angioplasty and cerebral embolization, respectively. The equipment had no protective lead screen and the physician did not wear lead glasses.

P07.122
Skin Surface Doses in Cardiac Interventional Procedures Measured in Latin America Facilities: Regional IAEA Program

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The optimization of radiation doses is a crucial principle to interventional radiological procedures since it can avoid radiation injuries for patients. In order to convert it into a mandatory requirement it is necessary to know the dose reference levels. The aim of this work is to evaluate the patient's skin dose distribution to measure and record the maximum radiation doses on patients' skin surfaces in interventional procedures at five facilities in Latin America, as well as to identify potential high doses and their correlation with gender, body mass index (BMI), fluoroscopy time and type of procedure. We evaluated the maximum skin doses (MSD) through a skin surface monitor placed under the patients. The Gafchromic film XR-RV2 was placed in such a way that allowed us to identify how the doses were distributed over a back skin area in two selected cardiac procedures, coronary angiography (CA) and angioplasty (PTCA). For ethical reasons the participants (Brazil, Costa Rica, El Salvador, Mexico and Venezuela,) are here represented by letters (from A to E). This study was sponsored by International Atomic Energy (IAEA-RLA/9/067 program). Each participant collected data at least of 24 patients and the results of MSD (cGy) 3rd quartile were for CA, PTCA and both procedures, respectively: A (150, 100 and 700), B (50, 600 and 700), C (400, -- and 400), D (50, 125 and 200) and E (100, 400 and 400). Considering all patients (195), 71% of them are male. Some of the patients were submitted to previous procedures, as follow: A (43%), B (32%) , C(12 %) D (28%) and E (16%).Their ages vary from 16 to 88 years old (median of 61 y) and the BMI average is superior to 27.5 kg/m2, indicating patients overweight. The fluoroscopy time (min) range was: A (2-57), B (2-47), C (4-45), D (2-20) and E (2-54). The linear correlation values (r2) between MSD and fluoroscopy time including all procedures were: A (0.41), B (0.72), C (0.11), D (0.44) and E (0.46). This study found a very week correlation between BMI and MSD. It was possible to verify the variability of dosimetric measurements that can be explain by differences at patients` characteristics, type and complexity of the procedures. The results showed that 81.5% of all patients were exposure to skin doses less than 2 Gy, demonstrating that there is a potential risk of injuries in the interventional cardiac procedures.

P07.123
Comparison of CT dose modulation systems:results in an optimization process

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Background: The CT tube current modulation is an important tool for patient dose reduction and to improve image quality. To optimize is essential to carry out an evaluation of the system performance. The aim of this study was to verify the variation of noise and patient doses during a simulate abdomen procedure. Method: In a private hospital of Rio de Janeiro was available the Philips Brilliance 64 including the modulation systems. The Triple Modality 3D Abdominal Phantom used includes inserts representative of the main organs of the abdomen. The dosimetry and image quality evaluation and technical factors were collected in different conditions. Image noise was evaluated in Regions of Interest defined in each organ. The CT number and the standard deviation were determined in each ROI. The Image J was used to analyze the images. The relationship between noise and mAs was evaluated in each image. The C_{vol} and DLP were determined using the dosimetry data and the technical factors applied in routine abdomen examination. Results: The average Cvol values were 6,88mGy, 6,39 mGy and 7,35mGy for ZDOM, DDOM and without modulation respectively. The noise value reached up to 22% for ribs. The same level of noise was achieved applying ZDOM and DDOM in all phantom. Comparing the results, the lower levels of noise was in kidney, rib and soft tissues. In certain positions, the modulated mAs values were lower than the mAs applied without modulation. In the same conditions, the ZDOM system presented a higher noise than DDOM, causing consequently an impact in the image quality Conclusion: For abdomen procedures, a constant noise was obtained applying the modulation systems. The image quality remains similar regardless of the anatomical regions changes. Although, DDOM system reduces the dose increasing the noise, the image quality impact was not significant for the diagnostic.

KEYWORDS: computed tomography, radiation protection and modulation.

P07.124
Effect of Reconstruction Algorithm on Image Quality in Scanner GE Using ACR Accreditation Phantom

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Background: The objective was to assess the influence of reconstruction algorithm on image quality in CT scanners.

Method: The CTs evaluate were: GE Lightspeed QX/I multislice. The ACR CT accreditation phantom was applied to evaluate image quality indicators. Three different tube currents and reconstructed algorithms were applied. This evaluation was based on European Guidelines criteria

Results: The maximum difference obtained in the accuracy CT number test was 6%. The CNR must be greater than 1.0 for the adult and pediatric head and abdomen. The soft filter showed the best results: 1.25 to 357 mAs, 1.33 to 300 mAs and 1.24 to 275 mAs. The filter standard, in routine procedures, showed the best result, 1.09 utilizing 375 mAs. The bone filter presented values lower than 0.31 to all values of tube current. The bone filter had the best high contrast resolution and an average MTF of: 58%, 39% and 19% for spatial frequency of the 7, 9 and 10 lp/mm, respectively. The other filters distinguished 6 lp/mm. Image noise and uniformity obtained using bone filter showed levels of noise greater than 80 % in relation to soft filter and 75% to standard filter. Reconstruction using soft filter had low levels of noise with small variation 0.1%. The CT number uniformity to the different reconstruction algorithms and the tube current values showed a variance of 0.34 % to standard filter and 12.6% to bone filter.

Conclusion: Although the importance of reconstruction algorithm for the optimization process, few users apply it properly. Patient dose reduction and diagnostic image can be obtained using the correct protocol, which involves the reconstruction algorithmic.

KEYWORDS: Reconstruction algorithm, Computed Tomography and Optimisation

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P07.125 Individual Dose Estimation of the Medical Stuff in Interventional Treatment Using TLD Method

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This study aims to survey the effective dose of medical personnel during the interventional treatment operation. We performed thermoluminescent dosimeters to measure Hp(10) for the chest and Hp(0.07) for the hands. The 438 radiation workers (185 doctors, 152 technologists and 101 nurses) had TLD badges worn on the left chest or the collar if there had a lead apron outside and TLD rings on the finger which may be recived the highest dose. In the results, the dose of chest and hands among the medical stuff is from 0.93mSv/a to 52.3mSv/a and 0.20 mSv/a to 227.47mSv/a respectively. There are 2.1% interventional workers□f effective dose exceeded the annual dose limit to the body□i20 mSv/a□j. The doctors have had the highest radiation dose among the interventional medical stuff, followed by technologists, and finally other staff. By means of the results of this work, the use of appropriate shielding facilities and the reduction of time during the interventional operation should be concerned.

P07.126
Effect of Reconstruction Algorithm on Image Quality in Scanner GE Using ACR Accreditation Phantom

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Background: New algorithmic are now available. However few users know how to use this properly. The aim of this study was to evaluate the influence of CT reconstruction algorithm on image quality under different conditions. Method: was evaluated. The CT phantom was used for image quality evaluation of GE Lightspeed QX/I. Different tube currents and kernels were applied. Results: The maximum difference obtained in the CT number accuracy was 6%. The soft filter showed the best results for CNR: 1.25 to 357 mAs, 1.33 to 300 mAs and 1.24 to 275 mAs. The CNR for the filter standard was 1.09 to 375 mAs. The bone filter presented values lower than 0.31 for all tube current. However, the spatial resolution was 10 lp/cm. Comparing the noise obtained using bone and smooth filter, the difference was 80 % and 75% to standard filter. Reconstruction using soft filter had lower levels of noise with variation around 0.1% even changing the mAs value. The CT number uniformity to different kernels and current values showed a variance of 0.34 % and 12.6% for standard and bone filter respectively. Conclusion: Although the importance of reconstruction algorithm for the optimization process, few users apply it properly, affecting the patient dose and image quality.

KEYWORDS: Reconstruction algorithm, Computed Tomography and Optimisation

P07.127
Is Magnetic Resonance Imaging Equally Effective In Detecting Intra-Ductal In Situ Breast Lesions As Of Mammography?

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Aim: Objective of this literature review was to investigate sensitivity with which ductal carcinoma in situ (DCIS) is diagnosed by mammography and by breast magnetic resonance imaging (MRI). This review compares the clinical usefulness of breast mammography and MRI of the breast in the therapy of breast cancer.

Introduction: Ductal carcinoma in situ (DCIS) of breast is a heterogeneous disease, refers to abnormal proliferation of cells within cells of milk ducts. It is commonly non-invasive and generally not considered as breast cancer unless it spreads into the surrounding breast tissue. Diagnosing breast cancer in its intra-ductal stage might be helpful to prevent the development of invasive breast cancer. Increasing use of imaging modalities has led to better detection of pre-invasive lesions, DCIS or intra-ductal cancer.

Materials & Method: Data for review were identified by search of science direct. A total of nine articles were analysed regarding effectiveness of MRI and mammography in detecting DCIS. Most of the articles were based on prospective and retrospective observational studies.

Results: The nine research studies suggest that combined use of mammography and MRI improved the diagnostic accuracy of detecting DCIS.

Conclusion: Evaluation of literature critically shown that both MRI and mammography effectively detect DCIS. However, MRI in contrast to mammography is more sensitive in detecting histo-pathologic extent of DCIS. MRI could help improve the ability to diagnose DCIS, especially DCIS with high nuclear grade. However, mammography acts as an important screening tool for early detection of breast cancer.

P07.128
Effective Dose Assessment In Pediatric Diagnostic Radiology In Antioquia Colombia

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For purposes of assessing the radiological risk in x-ray examinations of the chest in pediatric patients in the province of Antioquia, Colombia was estimated organ dose and effective dose in two age ranges: 1-5 and 5-10 years of age in the largest hospital in the city of Medellin, Colombia. The effective dose was obtained from the application of conversion coefficients for dose measurements at the entrance to the surface (ESD) in 167 radiographic studies in the AP and LAT . The results were validated with PCXMC 2.0 computer program and other work reported in the literature.

P07.129
Average Glandular Dose and Entrance Surface Dose in Mammography

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Purpose: In general, dose evaluation for mammography uses average glandular dose (AGD). In Mammography, Entrance surface dose (ESD) is high, which is well known, but actual clinical data of ESD are not reported so much. This study investigated AGD and ESD for patients whose doses were estimated from 200 mammography examinations using European Organization for Quality-Assured Breast Screening and Diagnostic Services (EUREF) protocols. In addition, ESD is compared to breast surface dose for multidetector CT.

Materials and Methods: The digital mammography system (Amulet, Fujifilm Solutions) has full-field flat panel detector. This system uses an automatic exposure control system, which adjusts to exposure output in order to obtain appropriate image density in clinical practice. AGD is estimated from technical parameters, which are half value layer, breast entrance exposure, compressed breast thickness and breast tissue composition. Technical parameters to calculate ESD are breast entrance exposure, compressed breast thickness, and backscatter factor.

First of all, AGD and ESD were estimated using PMMA accrediting phantom by EUREF. This is tested by every 10mm using automatic exposure control system from 10 to 60 mm. Then, 200 women from the age of 40 to 70, who examined mammography in Toyota memorial hospital, were estimated according to AGD and ESD. Finally, breast surface dose in an anthropomorphic phantom was measured using thermoluminescent dosimeters during chest CT scan.

Results: On examination of 40mm PMMA, AGD and ESD were 1.61 mGy and 6.06 mGy respectively. ESD was 3.8 times higher compared with AGD. In 60mm PMMA, AGD and ESD were 3.38 mGy and 18.68 mGy, and ESD was 5.5 times higher compared with AGD.

The result of calculating patient data shows that AGD and ESD per view averaged 1.71 mGy and 6.60 mGy. ESD of 21 patients were above 10 mGy, and the highest was 18.96 mGy. The measured breast surface dose for CT was 15.07 mGy. This dose was 1.1 times higher compared with two views of mammography.

Conclusion: A mammography examination involves twice of exposure to obtain cranio-caudal and mediolateral oblique views. The result of study indicates that a total ESD of a mammographic examination is equally high to breast surface dose of CT, and dose evaluation for mammography should be considered both AGD and ESD.

P07.130
Local Diagnostic Reference Levels for Common Radiographic X-ray Examinations

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Dose measurements were performed in common radiographic X-ray examination for radiographic dose audit and to propose local reference dose levels (LDRLs) to be used as a mean to promote optimization of the radiation protection in Al-Jaziera State, Sudan. Technique factors were used to calculate the entrance surface air kerma (ESAK) for patients who underwent skull (AP& LAT), chest (PA), pelvis (AP), abdomen (AP) and lumbar spine (AP& LAT). Six Hospitals and 388 radiographs were included in this study. Mean entrance surface air kerma (ESAK) ranged from 0.072 - 0.69 mGy for chest PA, 0.338-6.46 mGy for Skull PA, 0.195–5.8 mGy for Skull LAT, 0.595–3.42 mGy for Pelvis AP, 0.772–6.31 mGy for Lumbar Spine AP and 2.1–15.2 mGy for Lumbar Spine LAT, 0.742- 5.79 mGy for Abdomen. Mean ESAK values obtained in the present work are comparable to those reported by UNSCEAR and are below diagnostic reference levels proposed by IAEA. Com-parison of the current doses with reference doses provided a mean for radiographic dose audit. Local diagnostic reference levels were proposed to as mean for future dose optimization.

Keywords— Local diagnostic reference levels, X-ray proce-dures, ESAK, Radiation Protection.

P07.131
Evaluation of Patient Doses in Conventional ,Computed and Digital Radiography

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The transition from film screen-radiography (FSR) to computed radiography (CR) or digital radiography (DR) can involve an increase in patient radiation doses due to the wide dynamic range of the digital imaging systems. The current study intends to measure and compare the radiation dose to adult patients during (i) chest X rays (CXR) (ii) lumbar spine (LS) using (i) FSR, CR) and DR. Entrance surface doses (ESDs) were calculated from patient exposure parameters using Dos-Cal software. A total of 202 patients were studied. The mean ESDs were 0.27 mGy for the AP/LS, 0.67 mGy for LA/LS and 0.18mGy for the CXR in FSR. The mean ESDs were 1.03 mGy for the AP/LS, 1.55mGy for LA/LS and 0.10 for the CXR in CR and The mean ESDs were 0.91 for the AP/LS, 1.53mGy for LA/LS, 0.09mGY for the CXR and 0.2mGy for other in DR. The ratio of ESDs for CR to SFR were +44%%, +26% and +57% higher than those for SFR during AP/LS. The radiation dose in this study showed wide differences in terms of dose, exposure factors and inter-examiners. Radiation dose optimization is crucial for further dose reduction.

P07.132
Radiation Dose Reduction by using low dose CT Protocol of Thorax

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The use of computed tomography (CT) in medicine is today an essential tool for diagnosis, follow-up and intervention purposes. Nowadays CT makes up to 67% of radiation from medical sources or 10% of the total radiation dose. Therefore especially emphasizes is on the importance of reducing doses and the introduction of procedures with the lowest possible dose received by the patient. The so called low dose CT protocol was studied for the some chest diagnosis however it was not investigated for the patients with lymphoproliferative diseases. Lymphoproliferative diseases, including most lymphomas involve a large number of younger and middle age patients i.e. patients in the reproductive period of life. A CT exam of these patients is indispensable method for the diagnosis, and later for long life monitoring of the effectiveness of therapy.

The aim of this work was to compare the patient doses during two different CT protocols of thorax in patients with this diagnosis. The entrance surface doses were measured and compared using standard CT protocol of thorax which implies 120 kV and 160 mA conditions and low dose CT protocol using 120 kV and 30 mA conditions while maintaining display quality.

The study involved 60 patients. Each patient underwent two different CT thorax protocols during regular follow up of the disease. The doses were measured using LiF:Mg,Ti (TLD-100) thermoluminescent (TLD) and GD-352M radiophotoluminescent (RPL) dosimeters on the thyroid, eye lens, sternum and gonads.

The results showed that low dose protocol yielded with the reduction of doses by the factor of 2-15 on the eye lens, 1.3-8.5 on the thyroid, 2.7-6.6 on sternum and 0.3-12 on gonads, respectively. The doses were significantly lower using low dose CT protocol while the image quality for lymph node presentation was satisfactory according to European criteria. Therefore the use of low dose CT protocol as a standard for patients with lymphoproliferative disorders is highly recommended.

The authors wish to thank Maria Ranogajec-Komor for discussion of dosimetry results. The presenting author is grateful to Chiyoda Technol Corporation, Japan for the support of participation.

P07.133
Adding an Aluminum Sheet to Copper Shield for Reducing the Absorbed Dose in Computed Tomography: a Pilot Study

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Purpose: Copper shield is an example of the radioprotective shields used for reducing absorbed X-ray dose to the radiosensitive organs in computed tomography (CT). The aim of this study is to evaluate the effectiveness of adding an aluminum sheet to the copper shield in order to attenuate secondary X-rays generated from the copper shield.

Materials and Methods: Photon energy spectra of primary X-ray beams (120-kVp tube voltage and approximately 50-keV effective energy) were obtained using a high-purity germanium detector when a commercially available bismuth sheet, copper plate (0.1–0.3-mm thick and 99.9% pure), or copper plate in combination with an aluminum sheet (0.2–0.4-mm thick and 99.9% pure) was placed between the X-ray tube and the detector. The detector was collimated using a lead pinhole collimator to avoid detecting secondary X-ray beams. In addition, the absorbed doses in the Mix-Dp phantom were measured at depths of 0, 3, 6, 9, and 12 cm from the surface of the phantom by inserting dosimeters into the phantom when the bismuth sheet, copper plate, or copper with aluminum sheet was placed at the surface of the phantom.

Results: There was a tendency for more photons of primary X-ray beams to attenuate as the thicknesses of the copper and aluminum increased. The photon energy spectrum in the case of the bismuth sheet was similar to that of the 0.2-mm-thick copper plate. More photons of primary X-ray beams were attenuated in the case of the copper plate with the aluminum sheet compared with only the copper plate; however, this difference was negligible in case of the 0.3-mm-thick copper plate. The absorbed doses were increased in the case of the 0.1-mm-thick copper plate with the aluminum sheet compared with only the 0.1-mm-thick copper plate. However, the absorbed doses were decreased in the case of the 0.2-mm-thick copper plate with the aluminum sheet compared with only the 0.2-mm-thick copper plate, and were decreased as the thickness of the aluminum sheet increased. The differences of absorbed doses were negligible between the 0.3-mm-thick copper plate and the 0.3-mm-thick copper plate with the aluminum sheet.

Conclusion: The photon energy spectrum of a primary X-ray beam in the case of placing a commercially available bismuth sheet is similar to that of a 0.2-mm-thick copper plate. The addition of an aluminum sheet is effective in attenuating secondary X-rays generated from a 0.2-mm-thick copper plate.

Poster sessions C-D: Area 7

P07.134
Dosimetric Monitoring of Workers Exposed to Ionizing Radiation in Radiology Services in Burkina Faso, 2009-2011

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We realized, from 2009 to 2011, dosimetric monitoring of 150 workers from 29 radiology departments in order to protect against the harmful effects of ionizing radiation using thermoluminescent dosimeters (TLD-100 (LiF: Mg, Ti) type 0110)

The dosimeter was worn by each worker, on the front of the torso, between the shoulders and the waist, for two months, and then was collected by agents of LNSP to be read with HARSHAW-TLD reader model 4500.The sum of bimonthly doses was made at the end of the year and compliance with dose limits was evaluated using the requirements of International Basic Safety Standards (IAEA BSS.115). The workers were monitored after subscription of their radiology services. Data of workers who were not monitored all over the year and whose dosimeters were lost or damaged have been removed.The results showed that within 259 annual doses of workers, 60% were below the detection limit of 0.1 millisievert (mSv) and 40% between 0.1 and 20 mSv (annual dose limit). These results of annual individual doses complied with the international standard during the 3 years of exposure and allowed us to state that the workers involved have been well protected against the harmful effects of ionizing radiation.

Keywords : ionizing radiation, monitoring, TLD, Burkina Faso

P07.135
Analysing of Absorption Characteristics of Lead-Free Manufactured Samples Using in Medical X Ray Application for Protecting Radiation

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Lead protectors are mostly used against to ionizing radiation using in diagnosis and therapy and they are considerably heavy. In addition, lead has a high toxicity. For these reasons, evaluation of radiation absorption capacities of lead-free manufactured materials as alternative to lead materials was aimed in this study. In this direction, tin, antimony, bismuth and tungsten were selected as alternative elements to lead because of their toxic characteristics, atomic numbers, densities, K-edge absorption energies and obtainable easily. Four samples were manufactured by mixing polymer material and 50 %, 70 %, 80 % and 85 % metal powder which includes selected elements. Absorption characteristics of these samples were measured against to primary and scattered x-ray at digital x-ray machines. Also, same measurements were repeated for 0,25 and 0,50 mmPb lead-free aprons to compare with manufactured samples.

Evaluation result of data, % shielding effect of each sample was determined in the energy range of 50 – 125 kV and their absorption capabilities were compared with lead-free aprons. Also, lead equivalent of samples were calculated. Radiation absorption capability of the first sample is lower than two reference aprons'. Radiation absorption capabilities of other samples are higher than 0,25 mmPb apron's. But none of samples' performance reaches to 0,50 mmPb apron's.

P07.136
Non-Medical Imaging Exposures: A Pilot Study Of The Italian Situation

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Recommendations and directives, that have been recently published or are in phase of approval by international organizations (ICRP, IAEA, EC), have reworked the framework of the so called medico-legal procedures, i.e. those defined as "performed for insurance or legal purposes without a medical indication". The reason for this revision was the inadequacy of the current legislation that treats these practices as a sub-group of medical exposures and does not cover properly all kinds of practices that nowadays go well beyond the insurance and legal purposes. The most evident news is in terminology, the name being changed to "non-medical imaging exposures". The new recommendations and directives distinguish between the procedures that are carried out in medical structure with a medical indication and by medical personnel, and those that are carried out outside the medical structures, mainly for security and screening reasons. Despite some differences, in both circumstances special concern is paid to issues like justification, informed consent, dose constraints, and responsible person.

In the last years, several questionnaires were distributed in Europe to gather information about the procedures followed for this kind of practices. These were aimed at evaluating the situation in the Member States and were devoted mainly to topics of general concern, such as the way these procedures are classified in the Member States, whether or not they are covered by national legislations, who is considered the person responsible for the procedure, etc.. In Italy, as in many other countries, the situation is not well monitored. The survey promoted by the SENTINEL project in 2006 highlighted a scarce knowledge on established practices. Nevertheless, it is expected that the debate will take off in Italy after the publication of the new EU directives.

In this work a pilot study is reported aimed to gather information on established practices in Italy with attention to aspects like frequency, location, responsibility, and especially range of doses. These were directly estimated (when possible) from on-field experience or obtained from the scientific literature. The outcome of this study is far from being either exhaustive or complete, but it represents the first tentative in our country to draw a picture of non-medical imaging exposures and can help to identify the strategy for future and more complete studies.

P07.137
Negatives Results In Radiological Examinations In Hospitals Of Peru -2010

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The Health World Organization and the International Atomic Energy Agency (IAEA) have indicated that in medical diagnosis there is abuse and inappropriate use of ionizing radiation.

The objective of this research is to determine the percentage of radiological examinations with negative results on a day of work at three hospitals in Perú (Lima and Callao cities): National Hospital Edgardo Rebagliati Martins (NHERM), National Hospital Hipólito Unanue (NHHU) and National Hospital Daniel Alcides Carrión (NHDAC)

Methodology: We performed a cross-sectional, descriptive and prospective study. We evaluated all radiological examinations (conventional radiology, interventional radiology, mammography and computed tomography CT) obtained in one working day of the three hospitals during the months of June and August.

Results: In total 1306 radiological examinations were conducted in three hospitals

A number of 888 tests were carried on at NHERN being found negative in 50.6% of conventional examinations, 0% in interventional examinations, 42.8% of mammograms and 27.1% of CT scans. The percentage of negative radiological examinations of all studies was 40.7%

In the 224 studies that were performed at NHHU negative results were found in 52.4% of conventional radiology examinations, in 25% of the interventional , 100% of mammograms and in 38.5% of CT scans. The percentage of all radiological examinations with negative results in this hospital was 51.3%

In the NHDAC 194 tests were taken. The percentage of negative results was 83% for conventional radiology studies, 5% for interventional examinations, 90% for mammography and 58.3% for CT scans. The percentage of negative results in all imaging studies in this hospital was 80.4%

Considering together the three hospitals the percentage of radiological examinations with negative results was 53.3% in conventional radiology, 4.5% in the intervention, 54.3% in mammography and 29.7% in the CT scans. In total the percentage of negative results in radiological examinations for the three sites was 48.5%

Recommendations: It should involve the physician in the justification of the radiological order and the development and dissemination of the Guide to Patient Protection to avoid unnecessarily expose patients to ionizing radiation.

Keywords : Health, patient radiation protection

P07.138
Medical Exposure Increase versus General Health Care Improvement – Contribution to the Discussion

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The poster presents the trends in the number of sources of ionizing radiation, the number of radiation workers and their doses and the number of radiological procedures performed in the Czech Republic. Mutual comparison of these data is a contribution to the current discussion on the increase in radiation exposure in medicine due to the increasing amount of ionizing radiation sources and procedures using ionizing radiation. Data were obtained from the registers kept by the State Office for Nuclear Safety of the Czech Republic, from databases of health insurance companies and from information provided by health care institutions.

Presented data clearly shows that the radiation sources used in health care are continuously renewed and their total number increases. At the same time, the structure of examinations and treatments carried out is changing and the number of examinations and treatments associated with higher patients' doses is growing. But it cannot be considered as a definitely negative phenomenon. Increasing number of sources and procedures is undoubtedly associated with increasing quality of medical care where obtaining of better diagnostic information or possibility of performing some therapy has positive benefits for the patient.

Moreover, in spite of the above mentioned results, the number of radiation workers and their average effective dose remains the same. Perhaps it indicates improving of technical advancement of devices and security features and culture

P07.139
"Pregnancy": A New Justified Model for Better Radiation Protection in Diagnostic Radiology

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Radiation in medicine, especially in diagnostic radiology plays an important role, so that rate of its application is increasing daily. In regard to linear non threshold (LNT) theory and that any amount of radiation can be harmful, many laws and standards have been enacted to protect against radiation that are applicable in all levels from physicians to patients. But there are many reasons and there is much evidence that these laws and standards among physicians and radiation technologists are ignored or not done correctly. So, for better enforcement of radiation protection rules, we suggest a new justified model as "pregnant woman model". According to this model, all patients (male and female) whom requested for radiography are considered as pregnant women that are in months which the fetus is very sensitive to radiation (such as the first three months of gestation). One of the main benefits of this model is that according to which, the infinite patient dose limit problem can be solved because of in addition to the patient that a person of public (that is so radiosensitive) is there with her. However by this model, we can perform the following legally:

· Better control of exposure conditions,

· use of dose reduction techniques more accurately,

· work more carefully and avoid the possibility of error and repeat radiographs,

· more respect for the individual radiation shielding,

· reduce unnecessary radiographies for lower abdominal and pelvic

· reduce unjustified radiography requests

· the use of non-ionization diagnostic imaging tools such as MRI and ultrasound or other paraclinical services for patients,

· more balance between risk and benefits,

· more respect to LNT assumption and ALARA principle,

· And more and more benefits.

Key words: Radiation Protection, justified model, pregnancy, LNT, ALARA.

P07.140
Stakeholder Involvement in Medical Radiation Protection: A Report of the HERCA WG "Medical Applications" Concerning the Involvement of CT Manufacturers

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Tremendous developments in CT technology have taken place over the last few years. The growing use of this technology is of great benefit to individual patients and to society as a whole. However, it has also led to a large increase in medical radiation exposure, which raises radiation protection concerns. Attention needs to be paid to control exposures delivered by CT since organ doses may reach values where scientific evidence is sufficient to conclude a statistically significant increase of radiation-induced cancers.

The national regulators in Europe have joined their efforts for strengthening radiation protection in medical radiology as well as in other exposure scenarios. In 2007, they founded the association of national regulatory bodies in radiation protection, called HERCA (Heads of the European Radiological Protection Competent Authorities). HERCA sees the need of actions to be taken against the increasing trend to higher medical exposures of the European population. It is the firm conviction of HERCA that all stakeholders involved in the radiological process should be part in this important initiative to reduce patient dose. In particular, HERCA considers the CT manufacturers to be one of the most important stakeholders in the field of medical radiation protection.

As a consequence, the HERCA-Working Group (WG) "Medical Applications" – through a dedicated sub-working group - initiated a dialogue with the CT manufacturers. As a result of this process, the CT manufacturers were willing to underline their responsibility on patient dose reduction by committing themselves to actions which provide the potential to achieve this goal. The actions being identified include:

- implementation of dose reduction measures in CT,
- dose management and reporting, and
- provision of specific training curricula.

A further important result of this process is the insight that international cooperation is increasingly important for success, and that this cannot be limited to an European level. To address this issue, HERCA is in a process to intensify its cooperation with other international regulatory and scientific bodies such as FDA and NCRP.

The HERCA-WG will report on these processes and the achieved results.

P07.141
French pluralistic Working Group « Patients Information for Diagnostic X-Rays Examinations »

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Analysis conducted in France to follow-up the evolution of patient exposure to ionising radiations shows that the number of diagnostic X-ray acts has highly increased these past several years, mainly due to the increasing use of Computed Tomography (CT).

Besides, adverse events and accidents which occurred these past several years in radiotherapy raised the awareness of patients and medical staff about the issue of radiation protection in the medical field and highlighted the lack of communication and information access in this field.

In 2008-2009, IRSN, in co-operation with the CEPN, lead a study to evaluate the knowledge of patients in radiation protection and the existing communication media in this field. This study allowed to involve some patient associations (AVIAM, Le LIEN) in the identification of the patients' needs. As this study shown a lack of knowledge, IRSN and AVIAM built in 2010 a pluralistic working group to develop the information of patients on radiation protection associated with X-Ray examinations. This working group includes various stakeholders interested in radiation protection in the medical field: patient groups, health-care professionals, professional societies, institutional actors, etc...

The aim of the working group is to identify the patients' need of information regarding radiation protection when they have diagnostic X-ray examinations and to propose recommendations and medias to facilitate the dialogue between the patients and their health care professionals with a view to avoid useless X-ray exposure.

A first brochure layout for patients had been elaborated. Its relevance and content is currently tested in some medical centres among patients and healthcare professionals.

This presentation will detail the objectives, methodology and results of this project after having presented the main results of the preliminary study.

KEYWORDS: Patients – Information – Diagnostic X-Rays Examinations.

P07.142
Towards Safer and More Effective Use of Radiation in Healthcare – Results from European IRPA 2010

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INTRODUCTION: Methods to improve justification of medical exposure and optimization of radiation protection especially in paediatric procedures were introduced in the European IRPA 2010. Population dose from medical exposure has increased and the vast majority of the dose arises from CT procedures. The benefits of the new techniques are so rewarding that a tendency to overuse the technology has occurred. Safety culture should be promoted in education and training to increase awareness in patient protection.

MATERIAL AND METHODS: Efforts to improve awareness of justification and to promote optimization globally were introduced by IAEA , WHO and Image Gently. In examples from several European countries the need for justifying and optimizing CT procedures was emphasized. Internal audits and clinical audits were proved to be effective methods for improvement.

RESULTS: Continuous promotion of safety culture is needed. The concept of "triple A" for justification is awareness, appropriateness and audit. Radiation protection should be part of education of referrers (physicians and dentists) as well as radiological practitioners.

Optimization of protection requires refining of imaging parameters; for paediatric procedures according to patient weight or size. This customizing procedure means making a compromise between patient dose and acceptable noise in the image (especially in CT and PET-CT). Multidisciplinary team in diagnostic radiology should learn from each other.

Internal audit and clinical audit is a way to monitor justification and optimization. The implementation of referral guidelines should be promoted. Examples of good practices were given from several countries. As suggested by ICRP, a follow-up for patients whose estimated peak skin dose was 3 Gy or greater has been implemented as a routine practice in Italy. Involvement and education of health service payment agencies (whether public health service or private health insurance) to relate payment to use of referral criteria has seen a sudden drop in the number of x-ray examinations carried out in UK. Internal audits have improved justification of CT for young adults remarkably in Finland.

DISCUSSION AND CONCLUSIONS: Justification and optimization are two main principals for radiation protection of patients and especially emphasized in paediatric imaging. Higher vulnerability of children to ionizing radiation dues to developing and growing tissues, longer life-span to express long-term radiation induced effect. Scientific evidence on increased cancer risks of patients due to medical exposure exists but further research is still needed.

Panel of experts concluded that referring guidelines should still be promoted. Optimization of patient protection should be carried out more in multidisciplinary teams. Clinical audits and internal audits should be used on the way towards safer and more effective use of radiation in health care.

P07.143
Evaluation of Patient Dose During Endoscopic Retragrade Challangiopancreatography

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Endoscopic retrograde cholangiopancreatography (ERCP) is an invasive technique that has been used for over 30 years in the diagnosis and management of pancreaticobiliary disorders. The intervention requires fluoroscopic and radiographic exposures, which impose radiation risks to patients. Therefore, it is important to measure and effectively manage patient radiation exposure. The objectives of this study were to evaluate the patient ESD, to estimate the organ and effective doses during ERCP in three hospitals in Khartoum. A total of 55 patients were examined in three hospitals in Khartoum state, Sudan during eight months (25, 45.45% in Fedail Medical Center (private), 11, 20% in Soba University Hospital, and 19, 34.54% in Ibn Sena Hospital (state). Thermoluminescence dosimeters (TLD)-GR200A) were used to measure patient entrance surface doses (ESD). TLDs were calibrated under reproducible reference conditions. The signal was read using a manual TLD reader (Fimel PCL3, France), the soft ware program was (Theldo version 1E1). Patient dose measurements of local entrance dose to the skin have been carried out using three TLD in a plastic envelope mounted on patient skin at mid point of radiation field at a part of interest of the central axis beam. ESD was used to estimate the organ equivalent dose (H) using software provided by the National Radiological Protection Board (NRPB-SR262).

The overall mean of ESD for all ERCP procedures was 42.4 mGy. The mean patient ESD in Fedail, Soba and Ibn sena centers were 26.7 mGy., 26.0 mGy., 72.4 mGy, respectively. The effective dose in three centers were 1.6 , 1.56 and 2.67 mSv respectively and the mean was 2.01 mSv. Patients ESD in Ibn sena hospital was higher compared to other centers. The liver organ equivalent dose was 4.43 and the pancreas was 3.36 mSv. Data shows asymmetry in distribution. These variations are due to the different indications, patient characteristics and pathological findings. The mean ESD result for all centers was lower 30% than the previous studies. Additional studies need to be conducted in order to establish reference dose levels in national level.

Key words: ERCP. Radiation dose. patient dose. Thermoluminescence dosimeters. Effective dose

P07.144
Example of Patient Dose Optimization in Interventional Radiology

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Introduction: In 2009, the department of radiology of the Academic Hospital of Clermont-Ferrand (France) declared to the national authority the overexposure of a 30 year-old patient (12 Gy skin dose), after two embolizations justified by life-threatening recurring post-partum bleeding. After this event, a process of patient dose optimization has been initiated within the department, with the technical support of the Institute for Radiation protection and Nuclear Safety (IRSN). The presentation details the method chosen for one of the three interventional systems, an ALLURA® PHILIPS equipped with one digital detector, used for vascular procedures.

Material and methods: Current practices were analysed before starting the optimization process: frame frequency, fluoroscopic mode and generator set-up (high voltage, current, additional filtration).

In a first step, practitioners tested and validated a lower frame frequency. Then, the manufacturer modified the generator set-up to harden the beam quality and to cut the soft x-rays with an additional filtration and by increasing high voltage. A new “low dose” fluoroscopic mode was also set up. Finally, image quality and entrance dose have been evaluated for the different fluoroscopic modes and the practitioners have been convinced to use the new “low dose” mode for the “routine” practice as often as possible. These measurements were realized with the test object Leeds TOR18FG and a Radcal 20x6-60 ion chamber located in front of a water phantom. In parallel to these technical aspects, information on radiation protection was given to all the medical staff.

Results: Results have been evaluated by comparing the average dose area product (DAP) for 50 consecutive procedures performed before and after implementation of this optimization process. The steps described above allowed to divide the average DAP by a factor 3.

Very encouraging results have also been obtained on the two other equipments. An attentiveness process has been established within the department involving all the actors: dose information record for all procedures, previously irradiated patients identification, patient information on the risk, appropriate patient follow up, including dermatological follow up if the skin dose is higher than 3 Gy and analysis of the situations having leaded to “high” doses.

Conclusion: Technical advices given by IRSN allowed the department to optimize significantly their interventional equipments. But the key of the success of this initiative was the implication of all the actors: practitioners, medical staff, radiographers, biomedical engineers of the hospital and manufacturer. In France, image quality has been the first criteria for years in interventional radiology. Most of the equipments, even recent ones, are not optimized. These results show that optimization is possible, with the willingness and implication of all the actors.

P07.145
Evaluation Of The Dose To Skin Of Patients In Interventional Radiology With The Use Of Radiochromic Film

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Purpose:

- Determine the interest of radiochromic films to quantify and map dose issued to skin of patients in interventional radiology,

- Compare those data with indicators given by facilities (PKS - Product Kerma Surface and Ka - air Kerma).

Materials and method: (We have used):

- Radiochromic films XR - RV3 - Gafchromic ® positioned on the skin of patients in 3 peripheral and neuro angio-suites, for 75 procedures (dilatation or arterial embolization) which can issue doses to skin likely to exceed the threshold of 3 Gy (threshold of determinist effect).

- An ionization chamber 10-6-60E (Radcal) for calibrating the films.

- Epson 10000xl scanner and analysis software ImageJ to exploit the films.

- Thermoluminescent dosimeters (TLDs) to validate.

Calibration of the films was conducted, with 2 qualities of X-ray beam (81 and 117 kVp), for Ka values from 10 cGy to 11 Gy. Following their reading, the images of the films were broken down in 3 colors (red, green and blue). Calibration curves were created for the red, green and blue colors. The total uncertainty of the measurement of the dose was calculated taking into account the experimental uncertainty and ionization chamber uncertainty. The calibration of TLDs was conducted for Ka values of 50, 100 and 200 cGy.

Results: Radiochromic films indicated dose to skin that PKS and Ka could underestimate. During the study period, they have identified 12 patients for which the dose to skin exceeded 3 Gy (Ka issue from angio-suites was less than 3 Gy), justifying a particular medical follow-up (skin effect risk). The temporal evolution of films was < 0.5% in 24 hours. The average difference between the two calibrations (81-117 kVp) was 1.44%. The red calibration curve was the most sensitive at low doses (< 6 Gy); for higher doses, the green calibration curve was used; the blue calibration curve was inoperant. The measures carried out with the TLDs validate the method used with films.

Discussion: In a clinical situation, the PKS and Ka are falsely reassuring; doses to skin given by films have increased the Ka values. There are uncertainties in measures from 3 to 20%, for doses ranging from 100 mGy to 6 Gy. Wrong positioning of films can affect the reliability of measured values.

Conclusion: Radiochromic films used, insensitive to visible light and of easy handling routine: - Allow measurement of the maximum dose received in the skin taking account of overlapping fields (+ areal distribution), quickly obtained at the end of the procedure, by simple reading of the film, - Confirm that the Ka should not be used to estimate dose to skin.

P07.146
The Identification, Communication & Use of Dose Constraints in the Optimisation of Interventional Radiology & Interventional Cardiology Procedures, & in the Training of the Interventional Staff.

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The Optimisation of Interventional Radiology (IR) & Cardiology Procedures is particularly challenging due to their inherent clinical complexity, the wide range of clinical examinations, the range of operators, & the relative infrequency of some of the more challenging procedures. We have analysed patient dosimetry records (DAP, entrance skin dose, & fluoroscopy time) for over 2,400 patients (over 150 different procedures) in IR & over 2,000 patients (10 different procedures) in Cardiology. We have identified, agreed & communicated 2 levels of Dose Constraints to facilitate continuing justification & optimisation for both the more frequent & the higher dose examinations. Subsequently, we analysed additional patient dosimetry records to determine the effectiveness of this optimisation & the communication process.

Results will be presented outlining the analysis, the process & the outcome for IR & Cardiology Procedures.

P07.147
Collaboration between IAEA and Latin-American Society of Interventional Cardiology regarding Radiation Protection

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Radiation doses to the lens of the eye of interventional cardiologists (IC) and paramedical personnel (PM) can be high and there is potential for radiation injuries: opacities (OP) and cataracts if radiation protection tools are not used. The International Commission on Radiological Protection (ICRP) has stated in its 2007 recommendations the need on optimization in situations of exposure of the eyes because of the uncertainty concerning this risk of lens radiation injuries. An international study was carried out between 2008 and 2009 under the coordination of the International Atomic Energy Agency (IAEA) with the collaboration of the Latin American Society of Interventional Cardiology (SOLACI). Three surveys were performed during annual congresses of SOLACI and included an evaluation of potential radiation-induced lens opacities in a cohort of IC, nurses and technicians working in cardiac catheterization laboratories, as well as a control group of non-medical professionals whose eyes were never exposed to ionizing radiation.

After observing the results with high rates of OP in IC and PM in 2010 SOLACI decided to create a radiation safety committee who is committed in its educational activities and web conferences with special interest in radiation protection (RP). SOLACI have also developed protocols for measuring patient doses and comparison of doses between different vascular accesses.

Currently in the general and regional conferences, SOLACI develops radiation protection activities that are widely accepted, judging by anonymous surveys that are placed at the end of each meeting.

These findings demonstrate the necessity to improve the education in radiation protection for interventional medical and paramedical professionals especially in the aspects affecting occupational doses and on the importance of using ocular radiation protection tools. Personal dosimetry methodology for these professionals should be revisited and the need of the proper use of personal dosimeters should be highlighted.

We believe that this type of collaboration between IAEA and SOLACI should continue in the future to further improve the culture of RP.

P07.148
Staff Doses in Interventional Cardiology and other Medical Practices in Sudan

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This study performed to evaluate the status of occupational exposure at three cardiology centres in Khartoum area and radiotherapy, nuclear medicine and diagnostic radiology departments at the Institute of Nuclear Medicine and Technology (INMO) in El Gezira. Thermoluminescence dosimeters (TLDs) were used to measure personal dose equivalent, H_p (10). For workers who use lead aprons, effective doses were calculated using double dosimetry algorithm.

Two TLDs were worn by each worker at the selected cardiology centres, one worn under a protective apron and the other worn outside and above the apron as specified by the ICRP. Each worker at the radiotherapy, nuclear medicine and diagnostic radiology departments was facilitated with one dosimeter to be worn on the chest.

The results showed that the annual doses received by the workers do not exceed 20 mSv. The study also indicated that doses received by workers in interventional cardiology, in particular the cardiologists are high compared to that received in the other medical practices.

P07.150
Calculation of Shielding for Interventional Rooms with Added Copper Filtration

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The BIR/IPEM report describing methods for assessment of shielding requirements for medical X-ray facilities has been revised to take account of developments in X-ray equipment and techniques over the last ten years. Earlier methods for determining shielding did not take into account the additional copper filtration that is often used in interventional rooms as a way of reducing patient entrance skin dose. The spectral and transmission features of the scattered radiation resulting from a primary x-ray beam filtered with additional copper are different from those from conventional beams. We have used practical measurements and Monte Carlo techniques to characterise this radiation and propose a modification to the existing techniques to take the additional filtration into account. The presentation will outline the problems with existing methodologies, describe the modification and its basis and provide an example calculation including elements that the shielding designer should look out for in preparing the specification.

P07.151
Radiation Protection of Children During Chest X Ray Depending on Human Factor

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The patient dose and radiation protection depend on many factors. Our study deals with the human factor such as the work of radiology technicians. If all technical malfunctions are excluded they are responsible for the patient dose. Technicians perform x ray examination with various end results: image quality, entrance surface dose, patient interaction etc. depending on their education and experience. In our hospital setting we have consecutively chosen the study group of 20 children that had the clinical indication for a chest X ray examination (standard PA), for each of three technicians working on the radiology ward. We used the same X-ray machine in all cases. 60 children were from 6 to 12 years old and all parents were informed about the aim and the experimental details of the study. All of them gave their informed consent.

RPL (radiophotoluminescent) and TLD (thermoluminescent) dosimeters were applied at the entrance of the beam in center of the X-ray field to measure the entrance surface dose (ESD). The three differently experienced technicians were unaware of the point of the study. Parameters that were noted were the kV, mAs and the size of the field.

The results show a good correlation in ESD between two technicians. Doses were significantly higher for the third one. After the results were known, protocols were designed and after educational interference we continued to measure ESD again on a group of 40 children. The doses were reduced and there was a good correlation between all three technicians.

With this work we want to clarify and show the importance of continuous education and good teamwork for dose reduction. In a sequel study with the same three technicians we hope to have results that would show a better dose reduction.

P07.152
Radiation Protection in Paediatric Interventional Cardiology in Latin America. Advances of the Regional IAEA program.

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The aim of this work is to present the advances of the pilot program on radiation protection (RP) in paediatric interventional cardiology (PIC) launched by the International Atomic Energy Agency in Latin America in 2010. The starting point of the program was a workshop involving several paediatric cardiologists leading this specialty in 11 Latin American countries. The workshop included training activities and the discussion of the program objectives and the methodology to collect and process data on patient and staff radiation doses.

Special attention was given to agree on a common quality control protocol for the x-ray and imaging systems used in the different catheterization laboratories, dosimetric parameters to be collected, patient age groups and a list of the most common procedures. For occupational protection, data on the use of personal dosimeters (and their dose values) and the use of ceiling suspended protective screens or goggles were also agreed.

The preliminary results showed that only 64% of the cardiologists used their personal dosimeters regularly and that only 36% were aware of their personal dose values. During the first step, patient dose data were available in only 5 centers from 4 countries: Brazil, Chile (2 centers), Colombia and Uruguay. Mean values for the age of the patients ranged from 2.9 to 5.7 years in the different centers. Median values of kerma area product (KAP) for the five centers (and all the patients), ranged from 1.7 to 38.5 Gy.cm^2 with a 3rd quartile (for the median values) of 12.5 Gy.cm^2. For fluoroscopy time (median values) ranged from 5.2 to 20.8 min.

For the 5 agreed age groups to split the global sample: 0-<1y; 1-<5y; 5-<10y and 10-<16y, the 3rd quartiles of KAP resulted in the following values: 6.2; 12.5; 13.5; 31.4 Gy.cm^2. This could be considered as an initial approach to diagnostic reference levels in PIC, but data from more countries are still missing and the impact of procedure complexity on patient dose values needs to be derived in the future. Optimization actions and occupational doses values and their correlation with patient doses are expected to be started during the next step of the program.

One of the most significant difficulties in auditing and optimizing radiation protection in paediatrics is the low number of procedures and the need to split the samples into 4 age groups. The lack of support of medical physicists in some of the countries is another relevant factor in impeding the rate of progress in these programs.

P07.153
Pediatric Exposition in Hemodynamics Services in the State of Bahia, Brazil

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The number of invasive procedures used in pediatric interventional radiology has increased in recent years, requiring the knowledge of the exposures for evaluation of risk of deterministic and stochastic events. In this sense, our objective was to investigate pediatric medical exposures in interventional procedures in two hospitals in Salvador, Bahia. It was evaluated eighteen procedures (14 cardiac procedures and 4 brain procedures), two hospitals and four equipment. The dose measurements were performed using the P_{KA} meters present in the equipment itself. The performances of the equipment were evaluated and parameters, such as measurements of kerma, kerma x area product and tube voltage, among others, were analyzed. It was recorded patient's age and sex and it was measured the air kerma and air kerma-area product (P_{KA}). The age range was from 0 to 14 years and its distribution showed that 27.8% of patients were in the range from 0 to 1 year, 22.2% in the range 1 -10 years and 50% of patients had more than 10 years. About the sex, 33.3% were female and 66.7% were male. In all age groups, it attended patients undergoing cardiac procedures, while there was no occurrence of brain procedures in the range 1 to 10 years. Measures of air kerma for brain scans indicate mean values, median and range, respectively 602.9 mGy; 601.0 mGy, 248.5 to 961.0 mGy. In cardiac tests, the values were 420.1 mGy; 475.1 mGy, 23.5 to 947.0 mGy. Measures of P_{KA} for the brain scans indicated values of mean, median and range, respectively 15712.5 mGy.cm^2, 15712.5 mGy.cm^2; 6415.0 to 25010.0 mGy.cm^2. In cardiac tests the values were 46141.9 mGy.cm^2; 34080.0 mGy.cm^2, 3792.0 to 129920.0 mGy.cm^2. The doses obtained in this study are close to the values obtained in recent studies[1,2] and show that for cardiac procedures exposures are close to reference levels for adults, indicating the need to establish diagnostic reference levels for pediatric patients and optimization for reducing exposures of those patients.

References: [1] Ubeda , C. Radiation dose and image quality for paediatric interventional cardiology. Radiation Protection Dosimetry, 1-10, 2010. [2] Tsapaki, V. et al, Radiation Doses in Pediatric Interventional Cardiology, Radiation Protection Dosimetry, 390-394, 2008.

P07.154
Evaluation Of Local Diagnostic Dose Reference Levels Arising From Paediatric CT Examination For Khorasan Province

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Introduction: CT is a high dose technique, children are more sensitive to radiation damage. This fact calls for serious actions to reduce radiation dose incurred by children. The purpose of this study was to establish LDRLs arising from four most common CT examinations for children of three age groups.

Materials and Methods: This work was carried out in seven randomly selected hospitals located throughout the Khorasan Province of Iran. CTDIW and DLP were measured by three sets of head and trunk PMMA phantoms and a pen dosimeter(Ion Chamber).

The DLP and effective dose (E) were calculated by following equations:

DLP= CTDIW. scan length

E= DLP. CF

Where CF is conversion factor of effective dose per DLP suggested by Shrimpton, P.C. and Hillier, M.C. NRBP-W67(2003). CF values are different for various parts of the body. Also different sets of values have been suggested for adult and children. Conversion factors for children are 0.003, 0.013, 0.015 and 0.015 mSv mGy cm for head, chest, abdomen and pelvic respectively. Third quartile of mean $CTDI_w$ distribution values is suggested as LDRL.

Results: Based on our findings LDRLs for four most common CT examinations of pediatric patients of Khorasan Province for the three age groups of 5, 10 and 15 years are presented in the following table:

Suggested LDRLs (mGy) arising from four common CT examination of children of three age groups in Khorasan- Iran

CT Examination	head	Lung	Abdomen	Pelvic
Age 5	23.32	18.48	17.94	17.94
Age 10	28.385	20.8	20	21
Age 15	32.25	22.7	22.83	23.2

Conclusion : This work has succeeded to establish LDRLs for children of 3-age groups arising from four most common CT examinations for the first time in Khorasan Province of Iran. The suggested LDRLs values are smaller than the corresponding values reported by UNSCEAR in 2007. Our results can be used as a base for future optimization studies in pediatric CT examination in Iran.

Keywords: CTDIW ; CT; DLP; Effective dose ; children

P07.155
Head Radiation Dose from Pediatric CT Examination on Single and 64-slice CT

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The peadiatric computed tomography (CT) scans have increased worldwide, contributing to higher population radiation dose. Technique diversification in peadiatrics exams and different CT technologies of multi detectors computed tomography (MDCT) has led a wide range of exposure levels making difficulty the optimization of doses at peadiatric clinical application. The objective of this study was compare the dose length product (DLP) in the cranial, in the eyes and in the thyroid, simulating peadiatric head exam undergoing CT singles slice and in MDCT 64, using clinical protocol. Forty thermoluminescent dosimeters (TLD100) were evenly distributed on surface of the head phantom along the sagittal axis. To single slice CT, Tomoscan AV-Philips equipment, 20 TLDs were exposed to scatter radiation and, 20 were exposed to primary radiation performed by 120kV, 300mAs, and slice thickness/spacing of 3/5mm and 5/7mm in the anatomic position equivalent of the supratentorial and posterior fossa regions, respectively. To MDCT, Brilliance 64-Philips, the TLDs was exposed to 120 kV, 400 to 359 mAs modulation, and slice/spacing of 2/1 mm to all head surface. The TLDs were calibrated for 120kV X-ray over the acrylic phantom. TL measurements were performed on Harshaw 4000 system. To single slice CT the dose were calculated based on previous study, by mean linear TL density for the region exposed to secondary radiation defined by position, $0.3 \leq p \leq 6$ cm, with the equation *ρ(p)=7.9(4)x10-2+7(5)x10-5p4.5(4)* cm^{-1}; exposed to primary X-ray for the posterior fossa region defined by position $6.0 < p \leq 9.6$ cm, and supratentorial defined by position $9.6 \leq p \leq 12.3$cm, were calculates by *ρ(p)=30(8)x10-1+47(10) x10-3p cm-1 and ρ(p)=0,87(7)-0,007(7)p* cm^{-1}, respectively. Using MDCT the dose was estimated to 12 cm; 2.5 cm to eyes, 5 cm to thyroid based on TLD response as function of phantom length. To the single slice CT equipment, the DLP to the cranium, eyes and thyroid were 1133(331) mGy, 39(15) mGy and 6,5(2.5)mGy, respectively. At exams with MDCT equipment the DLP to the cranium, eyes and thyroid were 1647 (82) mGy, 339(17) mGy and 404(20)mGy, respectively. These results show that the doses are superior using MDCT. The results for the eyes exposure might be able to induce cataracts since lens opacities can be induced as low as 100 mGy. The clinical protocol adopted in the MDCT generated high levels of thyroid doses not detected at single slice exams.

P07.156
CT-scan Irradiation: Protecting Patients by Means of Enhanced Medical Practice

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Radiation is an increasing concern in diagnostic imaging for which CT-scan has become the major contributor. X-ray parameter optimization, and technological advancements are effective in diminishing total doses but professional education, protocols and workflow optimization are also crucial. Beyond the adequateness of diagnostic requests, the imaging process itself can be optimized in order to protect patients from unnecessary radiation. We present here the multiple and simultaneous strategies we applied in our pediatric university hospital in order to enhance our diagnostic procedures while diminishing the overall doses to our patient population. From greater use of multimodality, to IV injection schemes, through better patient interaction and preparation, we will demonstrate how CT-scan irradiation can greatly be diminished by better practice alone.

P07.157
Radiation Dose To Pediatric Patients in Computed Tomography in Sudan

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The use of pediatric CT has been increasing rapidly with annual growth estimated at about 10% per year. Because of current and growing use of CT and the potential for increased radiation exposure to children undergoing these scans. In Sudan, there has been a remarkable increase in the number of CT examinations being performed. The purposes of this study are to: (i) to measure the radiation dose and estimate the related risks to both pediatrics and adults patients during CT for chest, abdomen and brain and (ii) propose a local diagnostic reference level for abdominal CT. A total of 80 patients were investigated. CT scanners that participated in this study are helical CT scanners (16 slices and dual slices). Organ and surface dose to specific radiosensitive organs was estimated by using software from National Radiological Protection Board (NRPB). For the pediatric group, the age was ranged between 0-10 years while the mean of weight was 13.53 Kg. The DLPs were 320.58 mGy.cm , 79.93 mGy.cm, 66.63mGy.cm for brain, abdomen and chest respectively. The CTDIvol were 25.06, 3.48, 2.46,mGy for brain, abdomen and chest respectively and the effective doses were 2.05, 1.8, 1.08,mSv for brain, abdomen and chest respectively. The study has shown a great need referring criteria, continuous training of staff in radiation protection concepts especially for pediatric. Further studies are required in order to establish a reference level in Sudan.

P07.158
Aspects Regarding Radiological Protection of Newborn Babies in an Intensive Therapy Unit

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Introduction: Ascertaining the newborn babies' treatment needing intensive care depends largely on the radiological diagnosis. Weight at birth, pregnancy age, and respiratory problems might determine a large number of X-ray examinations. Radiological examinations on newborn babies need special care as, at this age, the probability of radio-induced cancer grows in a time when life expectancy also increases.

On the other hand, all the organs may be in the radiation beam due to the small size of babies, resulting in an exposure of the whole body when making the radiography.

Material and method: This study has been carried out in an intensive care unit of a maternity ward between 2007 and 2010. It recorded the frequency and distribution of radiological examinations as well as the patients' ESD during the most important radiological procedures. We used a multi-functional device RMI – 242 in order to test the radiological systems quality. The examinations were made with an X-ray mobile device Polymobil 10, with a total filter of 3.4 mmAl.

Results: We found out a significant decrease of medical exposures starting with 2008 and the values of ESD in most radiological examinations were around the reference values, except for the pulmonary radiography which showed significantly higher statistic values ($p<0.0001$)

Conclusions: The decrease of radiological examinations could be explained by the fact that both the radiologist and the neonatal physician tried to get relevant diagnosis information avoiding useless exposures. We found higher values of ESD in pulmonary radiographies due to lower kilo-voltages that are being used, smaller film focus distances, and the fix filtering of devices, without the possibility of using added filters.

Key words: newborn baby, reference value, ESD (entrance surface dose)

P07.159
Risk of Cancer Associated with Cardiac Catheterization During Childhood: Setting up of a Cohort Study in France

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Children with congenital heart disease frequently undergo cardiac catheterization for diagnosis or intervention purposes. These procedures are known to give higher radiation doses to patients than other procedures in diagnostic radiology. Since children are particularly sensitive to the carcinogenic effects of ionizing radiation, a cohort study is being launched in France.

The study population will include all children who underwent at least one cardiac catheterization since 2000, who were under 10 years old and were permanent residents in France Considering the period 2000-2013, almost 8,000 children could be included. Cohort follow up will be done through linkage with the French paediatric cancer registries which record all childhood leukaemia and cancers in France since 1990 and 2000, respectively. The radiation exposure will be estimated retrospectively for each child.

This French cohort study is designed to provide further knowledge on the potential cancer risk associated with paediatric interventional cardiology. It will provide new information on typical levels of dose for these paediatric examinations in France. Besides, this study will help improve awareness of the importance of radiation protection in paediatric cardiology procedures.

P07.160
Use of Prospective Risk Analysis for Radiation Protection in Healthcare

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The use of risk analysis in healthcare is mostly based on surveying the radiation dose during regulatory working conditions and in case of an incident. Depending on the outcome, further radiation protection measurements are taken until the radiation dose is as low as reasonable achievable and no other dose limits are reached.

Another method of risk analysis is the Healthcare Failure Mode and the Effects Analysis (HFMEA) method. The HFMEA method is a proactive program for identifying and reducing safety risks to patients, visitors, workers, facilities and equipment. The objective is to identify where a process may fail (Failure Modes) prior to failure occurring. Each failure mode has a potential risk, with some risks more likely to occur than others. Therefore, each risk must be evaluated.

A multidisciplinary team approach is necessary to perform a HFMEA. After potential risks are evaluated, actions are placed into the process, in such a way that they significantly reduce the likelihood of the failure reoccurring.

We use the HFMEA method for a procedure in which an I-125 source is used as a tumour marker. The whole procedure involves several departments within the hospital, including the Radionuclide Centre, Radiology department and the Surgical Theatres. The I-125 source has a maximum activity of 14 MBq and a length of 4,5 mm. The source is inserted into the tumour in the Radiology department using ultrasound or X-ray. After patient treatment, the tumour is removed during surgery using the I-125 source as a marker. Prior to examination of the extracted tumour, the I-125 source is extracted from the tissue in the Pathology department. All I-125 sources are collected by the Radionuclide Centre and are later disposed of as radioactive waste. The failure mode in this procedure is the traceability of the I-125.

The HFMEA method is useful for determining the failure modes in a complex procedure such as described above, however the HFMEA is very time-consuming and therefore not suitable for application in all procedures.

P07.161
Optimisation Of The Defecating Proctogram

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The Defecating Proctogram is a useful dynamic fluoroscopic examination for investigating bowel dysfunction, for example rectal prolapse. The examination is performed by recording X-ray images of voluntary evacuation of barium paste, while a patient is sitting on a custom designed PMMA commode.

Due to inhomogeneous attenuation across the field of view, (air on the lower part - tissue on the upper) image quality can be severely affected by flaring. Additionally, the automatic brightness control system of the fluoroscopy unit potentially reduces doses and thus image quality. The adjustable filters in the X-ray unit appeared insufficient to compensate for the inhomogeneity. Hence, placement of a copper sheet on the side of the commode in order to homogenise the attenuation across the field of view was suggested as a potential solution.

Different copper thicknesses were tested. Initial dose calculations suggested an increase in dose and thus supplementary research on dose estimation was undertaken. Measurements for 0 mm, 1 mm, 2 mm, 3 mm and 4 mm of copper thickness were performed in order to determine the optimal thickness and evaluate the increase in dose. A crude phantom consisted of a cotton pillow case filled with saline bags (representing human tissue) and a plastic tube, filled with barium paste, placed inside (representing bowel filled with barium) was used. Measurements for each thickness were undertaken both for low and high volume of attenuating material within the field of view, which represented small and large patients respectively. The typical energy range was 73 - 80.5 kVp and the absorbed dose for 1mm thickness of copper was 1.58 times higher than the initial dose for 0 mm, while the increase for 2mm, 3mm and 4mm of copper was 1.80, 1.85 and 1.89 times higher respectively.

It was determined that 4mm of copper was the optimum thickness for a range of patient sizes. The increase in dose was considered acceptable as diagnostic accuracy was improved substantially, as well as improvement in soft tissue contrast was achieved due to flare reduction.

P07.162
Estimation of the Number of Ct Procedures Based on a Nationwide Survey in Japan

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A nationwide survey was conducted to determine the frequency of CT procedures in Japan in 2007. The frequency of adult and pediatric CT scans was estimated using a model based on the results of the survey. Survey questionnaires were sent to 2266 CT facilities: 1068 government hospitals, and 1198 other hospitals and non-hospital medical centers. The questionnaire requested information including the number of beds, outpatients per day, type of CT scanner, various body regions scannced, and the number of scans performed. Body regions scanned were classified into 35 regions. The duration of the investigation was 2 days for adults and 7 days for children. Patients were classified into one of six age categories: 0–3 months, 4–11 months, 1–4 years, 5–9 years, 10–15 years, or adult. The results of the study indicate that the number of CT procedures was closely correlated with the number of hospital beds. We estimate that approximately 20.5 million procedures were performed in 2005, and 21.2 million in 2006. The number of pediatric CT procedures was calculated by multiplying the total number of CT procedures by the estimated fraction of pediatric (0–15 years) CT procedures. Annual pediatric CT procedures were estimated to have been approximately 580,000 in 2005 and 600,000 in 2006. The present study indicates that the number of procedures per capita, for both total CT and pediatric CT, is lower in Japan than in the USA.

P07.163
Radiation Exposure to Staff in Interventional Procedures

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The number and complexity of interventional procedures performed in medical practice have grown enormously in China. The levels of doses to staff in interventional radiology vary tremendously. The purpose of this study was to investigate the radiation dose level of radiation exposure to staff during interventional procedures. There are two devices involving this investigation including the C-arm of the X-ray tube with image intensifier assembly and the C-arm of the X-ray tube with flat panel detector. Firstly, data were collected including the nature of the procedure carried out and exposure parameters employed (e.g. the type of imaging equipment, fluoroscopy time and the operator location). One phantom was put on top of the bed instead of patient. Another phantom stood a bed side instead of the operator. Dose measurements were performed by two methods, one with thermoluminescent dosimeters (TLD) at different organs and tissues locations of the phantom for the C-arm of the X-ray tube with image intensifier assembly, another with TLD at surface of the phantom for the C-arm of the X-ray tube with flat panel detector. To the C-arm of the X-ray tube with image intensifier, the effective doses ranged from 6.82-24.02Sv for cerebral angiograph, 17.8-36.3μSv for cardiac angiography and 5.52-23.90μSv for hepatic artery embolisation. To the C-arm of the X-ray tube with flat panel detector, the effective doses ranged from 4.22-18.15μSv for cerebral angiograph, 0.30-7.34μSv for cardiac angiography and 0.66-2.64μSv for other vessel angiography.

P07.164
Exposure Surface Dose of patients in TB Screen from Jiangsu Province of China

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Purpose:To estimate the exposure surface dose levels by X-ray chest radiography machines, we measured the exposure doses of TB Screen in Jiangsu Province in 2010.

Method:ESD of 930 subjects' preside and after position (PA) X-ray chest radiograph were measured by TLD with FLi (Mg, Cu, P) powders from 10 cities of Jiangsu Province in the fifth national TB screen of China.

Results The mean of X-ray ESD is 445±381μGy and three regions were shown on the dose distribution of subjects: 36 – 350μGy, 350 – 850μGy and more than 850μGy, which were accounted for 47.8%, 34.0% and 18.2% respectively. In addition, we found that shape, voltage, and exposure (mAs) are positively correlated with the ESD.

Conclusion The average of total ESD is slightly higher than 0.4mGy, which is the standard model' guidance level, but are significantly differences among different area. Except the type of individual's body, the level of ESD may directly influenced by the exposure conditions. Different machines or different operator with the same machines may be the major factors which resulted in different ESD. It's worth to emphasize that we not only need to check the quality of X-ray chest radiography machines, but also need to strength the operator's awareness of patients' radiation protection and improve the operator's diagnostic ability. In addition, it's helpful to decrease the ESD by selecting appropriate exposure condition to each patient.

P07.165
Radiation Protecion in Cardiologic Theatre in Tunisian Hospital

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Introduction: Fluoroscopically interventional procedures performed in cardiology are increased these last 20 years. Cardiologists are the most exposure among professionally exposed physicians. ICRP recommends some advices to reduce occupational doses as low as reasonably achievable.

The aim of this study was to determine cardiologic staff knowledge's about ionizing radiation and to determine the availability of Radiation Protection tools, in order to propose appropriate corrective measures.

Material and Methods: The study was performed in 3 cardiologic operating theater equipped with an image intensifier unit in 3 University-Hospital Center, in November 2011. We used a questionnaire in order to identify the knowledge about ionizing radiation (7 items), radiation protection (11 items), safety and security measures (15 items). We established a global score of knowledge to classify our population.

Results: 30 professionals were exposed to ionizing radiation. 24 of them (80%) answered to our questionnaire, 13 were men and the median of the age was 34 years (26-54). The median duration of the exposure was 6 years (1-33). CS were 9 surgeons, 12 nurses and 3 superior technicians. The mean of the global score of knowledge was 14,5 /29 (4-24). Lead aprons and thyroid shields, are available and are worn by all the CS. Conclusions: attempts should be made to improve cardiologic theater personnel's knowledge about radiation protection.

P07.166
Evaluation Of Doses In Multidetector Computed Tomography

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The greatest advances in CT technology in recent years resulted in the emergence of Multidetector CT (MDCT), with faster acquisition times, higher spatial and temporal resolution and lower reconstruction times. However, multidetector technology has not led generally to a reduction in a dose to patients; on the contrary have increased doses (10 to 30%). So the increase in these operating systems in our country, it created the need to run this study aimed to estimate the dose MDCT procedures given more frequently to optimize the dose given and minimize the radiology risk to the patients. Two systems were evaluated MDCT: Brilliance CT 16 – Philips and Aquilion 16 – Toshiba, one Set was used for quality control and measurement of dose in CT. We estimated the values of dosimetric quantities in MDCT (CTDIvol and DLP) in a sample of 25 patients by anatomical region explored in each system. The final results show that the optimization of scanning procedures and protocols, achieves a dose reduction from 8% to 38% in MDCT tested.

Key Words: dose, MDCT, optimization, quality control

P07.167
Radiation doses in head CT examinations in Serbia: comparison among different CT units

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A rapid increase in number of Computed Tomography (CT) examinations has been observed world wide. As CT examination of head is the most frequent CT, the purpose of this study was to collect and analyse patient dose levels in children and adults in different CT units for this procedure. Due to the high radiosensitivity and longer life expectancy for children, the radiation protection of pediatric patients in CT has been especially emphasized.

The study included 8 CT units from three manufacturers (Siemens, Toshiba and General Electric). Data for adults and pediatric patients were collected in terms of $CTDI_{vol}$ and DLP values. The doses were estimated as a mean value of 10 patients on each CT unit using the values available from the routine protocols. For pediatrics, doses were collected for four age groups (0-1year, >1-5years, >5-10years and >10-15years).

Comparing different manufacturers and the same number of detector rows it was observed that, in case of 16 slices units, doses were very similar on Siemens and General Electric scanner. CTDIvol and DLP on Siemens scanner were 60 mGy and 1066 mGy·cm, respectively, while on General Electric those values were 66 mGy and 1050 mGy·cm. However, this trend was not observed in case of 64 slices units. $CTDI_{vol}$ and DLP values collected on Toshiba were much higher (177 mGy and 2109 mGy·cm) than in case of Siemens scanner (59 mGy and 1060 mGy·cm). Doses on 16 and 64 slices Siemens scanners were very similar, while on 4 slices were higher. Dose values from this study were in line with DRLs, except in two units. In case of pediatrics, doses increase with age of patient and again Siemens scanner showed the lowest values while the highest values were observed on Toshiba.

P07.168
National Program of Radiation Protection of Patients (Argentina)

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Introduction: The medical radiation are undoubtedly the most important contribution to human exposure to ionizing radiation. Statistics indicate a growing trend in the number of practices as well as the amount of services particularly for Intervention cardiology. The quality of practice, justification and optimization are now an important issue for the scientific and regulatory bodies. Since the adoption of Directive 97/43/EURATOM, and the realization of the Malaga Conference most European countries have implemented action plans for radiation protection of patients, including the seeking of consensus regarding the optimization dose and the criteria for justification.

In this context, and convened by the Nuclear Regulatory Authority was held in our country, December 10, 2004, the first Conference on Patient Radiation Protection (PRP) in order to install in the medical community an active discussion on this topic. Then came a series of activities that today constitute the National PRP is sustained and driven by medical societies in the country and in particular the Argentine Society of Radiology and the Society of Radiation Protection.

Basic objectives of the PRP program:

1) Justification: The study is performed only when imaging studies are needed. (Refferal Guide)

2) Optimization of practice: That studies be carried to the doses received by the patient are the minimum necessary.

3) Prevention of risks: To avoid the occurrence of accidents and serious injuries in interventional procedures establishing quality systems and standards for the practice.

4) Training and Education: Including the prescribing physician and the whole team of interventional cardiology. (Recertification)

5) Dissemination of PRP criteria to the entire medical community

Results: PRP program has reached a reasonable maturity and this year marks the 6th Day of PRP at the National Academy of Medicine and 4 Regional Symposia one of which is dedicated to intervention in all specialties.

Conclusion: The establishment of national PRP is an appropriate measure that can systematically improve the quality of care in all specialties that used ionizing radiation. The active participation of medical and technicians societies is essential for program success.

Strategies to cope with different interests within society are described. Main problems, failures and difficulties are also described.

KEYWORDS: Radiation Protection of Patients; Procedures; Quality System; certification.

P07.169
Dose and Risk Assessments for Clinical Trials involving Exposure to Ionising Radiation

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The UK National Research Ethics Service (NRES) requires all NHS applications for research involving ionising radiation to be approved by a Medical Physics Expert (MPE) registered as a clinical scientist by the Health Professions Council. The lead MPE for the project is required to undertake for the Research Ethics Committee (REC) considering the application a dose and risk assessment of the total participant dose and the component representing additional dose over and above standard practice. Assessment of risks requires consideration of the age ranges of volunteers and their clinical condition.

In addition local MPEs are required to confirm that the protocol can be performed at the local site within the estimated range of dose indicated by the lead MPE, that local dose per examination will not exceed the maximum exposure estimated in the REC application and that the approved patient information sheet accurately reflects the additional radiation and risk to which local patients will be exposed.

These arrangements effectively implement relevant UK Ionising Radiation (Medical Exposure) Regulations, which include requirements for dose constraints or target dose levels for all research medical exposures to ensure that benefit outweighs detriment and that excessive doses are avoided. If studies involve administration of radioactive substances a site, procedure and holder "research ARSAC certificate" is required from the Administration of Radioactive Substances Advisory Committee if the research exposure is additional to normal clinical care. These legislative requirements are in keeping with ICRP 62, 103 and 105 recommendations and the Medicines (Administration of Radioactive Substances) Regulations.

This poster summarises lead and local MPE experience with 56 (at time of submitting abstract) consecutive proposals for clinical trials at the Royal Devon and Exeter Hospital involving exposure to ionising radiation. Some such proposals are relatively straightforward, others are not. Difficulties occasionally encountered include: lack of clarity regarding exposures in research protocol; consequent difficulty in dose assessment; dose estimation for non-standard exposures; contradictory information in different sections of application regarding doses and risks; inaccurate information about radiation and risk in patient information sheets.

P07.170
The European Medical ALARA Network - A European Initiative To Improve Engagement Of Stakeholders In The Medical Sector

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Optimisation has been a key issue in radiological protection for a very long time. In diagnostic radiology, optimisation is often described as; the balance between radiation dose to the patient and the diagnostic information given by the procedure. Consequently, the studies in the radiological protection community have dealt mainly with the "dose" to the patient and the "quality" of the images. The findings from such studies have not been widely applied in the clinic, and it is difficult to find a comprehensive approach in the clinic. To succeed more stakeholders have to be involved and a broad view on optimisation has to be applied and ways to communicate between interested parties have to be developed. A network serves this purpose.

One initiative in Europe is setting up the European Medical ALARA network (EMAN). One of the major tasks of the network is to serve as a meeting platform for different stakeholder and to initiate important measures to improve the situation. The network has investigated the different stakeholders needed in dealing with different issues. An example is given concerning the development and use of x-ray equipment:

The design and features of equipment are established through research and development, performed in research institutes and by the manufacturers. The equipment must comply with relevant standards. At some stage in the development it has to be tested in the clinical application. It is the clinic that has to decide what kind of equipment is needed and a selection process has to be performed with respect to different features of the equipment. When the equipment is installed examination methods must be established that are fulfilling the clinical needs. During the life cycle of the equipment quality control and maintenance have to be performed. The clinic has to decide whether the equipment still fulfils the clinical needs or whether the quality of the equipment performance is too depraved. In all these stages different issues will have an impact on the possibility to perform optimisation, e.g. in the development stage issues like dose efficiency of detectors and the ability to adjust radiation dose to different patients will have to be dealt with. There should be appropriate tools for monitoring image quality and radiation dose available for both the personnel in the clinic as for the manufacturers. Adequate parameters should be subject for monitoring in a meaningful way during maintenance and control activities. All this is demonstrating that many stakeholders are influencing optimisation.

EMAN has already engaged important stakeholders in the work of optimisation in CT, interventional radiology and x-ray outside the x-ray department. Results from this work will be given, and some success factors in networking will be presented.

P07.171
Information System for the Evaluation and Monitoring Services Mammography of the State of Minas Gerais

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Breast cancer is the second most common type of cancer worldwide and the most common among women. Although it is considered a relatively good prognosis cancer, the mortality rates for breast cancer remains high in Brazil and therefore it has been object of attention of the responsible government agencies. The Ministry of Health, in addition to stimulating the mammographic screening in the country, recommended the establishment of measures for monitoring the quality of mammography services that serve the National Unified Health System (SUS). Considering the alarming projections of occurrence of breast cancer and the recommendations of the Ministry, the Sanitary Vigilance of the State of Minas Gerais and the Development Center of Nuclear Technology developed a software Atalanta whose goals are to improve the management of information from tests and performance results of mammography services, and provide data for scientific research and evaluations to be performed by the SUS. The software, developed in accordance with the PRAXIS process, was built with web interface using current technologies consolidated worldwide, easy to learn and based on free software as the programming language PHP and PostgreSQL database. The information system consists of a database and interfaces that allow the registration of institutions providing mammography service, and the record of their equipments, personnel, training carried out, quality assurance tests yearly and monthly, installation and operating conditions, control of pendencies and storage of test images, among other features. The database system can provide subsidies for SUS analysis of the relationship between the amount expended on the payment of examinations, the quality of tests performed and their reflections in public health improvement.

P07.172
Radiological Protection and Quality Control of Diagnostic Radiology in China

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Up to 2010, there are 48,000 diagnostic departments, nearly 75,000 X-ray diagnostic facilities, 8,000 CT, and 7,000 dental X-ray units. There are 170,000 occupationally exposed workers in diagnostic radiology and 250 million for the annual total numbers of X-ray examinations. "Rule on the administration of radio-diagnosis and radiotherapy", as an order of the Ministry of Health No. 46, is issued by Minister of Health on January 24, 2006. It includes requirements and practice, establishment and approval of radio-diagnosis and radiotherapy services, safeguards and quality assurance, and so on. There are a series of radiological protection standards and quality control standards in diagnostic radiology, including "Basic principles for radiological protection of medical exposure", "Standards for radiological protection in medical X-ray diagnosis", "Radiological protection standards for the examinee in X-ray diagnosis", "Radiological protection standards for X-ray computed tomography", "Specifications for testing of image quality control in medical X-ray diagnostic equipment", "Specification for testing of quality control in X-ray mammography", "Specification for testing of quality control in computed radiography (CR)" and "Specification of image quality assurance test for X-ray equipment for computed tomography". Some standards have been drafting, including "Specification for testing of quality control in digital radiography (DR)", "Specification for testing of quality control in X-ray digital mammography" and "Specification for testing of quality control in X-ray digital subtraction angiography (DSA)". The Ministry of Health has strengthened the inspection for avoiding accidental exposure in medical radiation exposure. A system of inspection net has been establishing involved 17 provinces, and covering whole country future 3-5 years.

P07.173
A New Method for Quality Assurance in Mammography and Tomosynthesis: Equivalence of Automatic and Visual Evaluation

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Purpose: Compare the automatic and visual evaluation available using the new phantom presented in the oral sessions for quality assurance in mammography and tomosynthesis.

Materials and methods: The method presented in the oral sessions allows for simultaneous measurements of the patient radiation exposure and of the image quality. The image quality is measured through a visual and an automatic evaluation method. The equivalence of the visual method, based on the detection of Landolt rings, to the conventional quality assurance method in mammography is shown in the oral presentation. In this poster, the equivalence between that visual evaluation and an automatic evaluation of the contrast-to-noise ratio (CNR) was explored. To compare the methods, images were obtained with a flat panel system from Siemens in a series of gradually reduced doses and evaluated following the protocols for the visual and the automatic methodologies. The CNR was calculated using specific software on the phantom images. Each evaluation produces a global score for the image quality as well as scores for the whole dynamic range of the breast thicknesses and tissue densities simulated in the phantom.

Results: Using the automatic evaluation, the evaluation and average of 3 images provides an uncertainty of 5 % on average and a linear trend with the average glandular dose, as opposed to more than 10 % and no linear trend with the visual method. The whole evaluation takes less than half a minute per image. Acceptable and achievable thresholds in agreement with the CDMAM and PAS methods were found.

Conclusions: The automatic evaluation is more stable and time-efficient than the visual evaluation. The automatic method can save time and costs to clinics, as well as achieve a more efficient quality assurance in diagnostic mammography.

Keywords: Mammography, tomosynthesis, QA/QC, Image quality, CDMAM, PAS

P07.174
A New OSL-Based Dosimeter For Exposure Control Verification In X-Ray Mammography Imaging Systems

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Verifying that the output exposure of an x-ray mammography imaging system is within established control limits is an important component of the quality control programs designed to ensure patient safety. Such verification is often time consuming and expensive to perform. The purpose of this research was to develop a compact, easy-to-use dosimeter that utilizes optically stimulated luminescent (OSL) technology to facilitate quality control in x-ray mammography, and thereby provide a cost-effective solution for secondary or more frequent monitoring of output exposure levels.

The Mammography OSL dosimeter was used in conjunction with a standard geometric breast equivalent phantom. The active detection element of the Mammography OSL dosimeter is a a strip of OSL material 3 mm wide, 0.13 mm thick and 30 mm long with overlying filtration corresponding to 0 mm Al, 0.2 mm Al, 0.4 mm Al and 0.6 mm Al. The strip and filter are encapsulated in a light-tight plastic enclosure with exterior dimensions of 10 mm wide, 5.4 mm thick and 54 mm long. The active detector element was read using an automated reader, and the exposure to each region was calculated. The half-value layer (HVL), kVp and known target/filter combination were then used to look up an exposure-to-dose conversion factor using published tables provided by the manufacturer or an accrediting agency (e.g., the ACR). The exposure-to-dose conversion factors were multiplied by the entrance surface exposure (ESE) estimate obtained in the strip region corresponding to “0 mm Al” filtration to yield an estimate of the mean glandular dose (MGD).

The performance of the Mammography OSL dosimeter was evaluated using x-ray mammography systems with the common imaging detector technologies, including screen-film (SF), computed radiography (CR) and direct digital radiography (DR). ESE, HVL and AGD results obtained using the Mammography OSL dosimeter agreed with the ionization detector to within 10% with a coefficient of variation of $\leq$ 5%, depending upon the target-filter combination. These results indicate that the Mammography OSL dosimeter can be used to verify the output exposure levels of a mammography system in compliance with established regulatory requirements.

P09.58
Without Adequate Planning, Whatever Can Go Wrong Just May Go Wrong Irradiator Co-60 Source Loading Overexposure Event

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During a routine resourcing operation at a research Gammacell 220 irradiator in New Jersey in late 2011, a 44.77 TBq (1210 Ci) cobalt-60 source rod was accidentally retracted from all shielding in the presence of 7 workers. Workers from New Jersey, Pennsylvania, and California were involved in the resourcing activity. Efforts to reinsert the source rod took up to 45 seconds, resulting in radiation doses in excess of the 0.05 Sv (5 rem) total effective dose equivalent (TEDE) regulatory limit, the 0.15 Sv (15 rem) lens of the eye regulatory limit, and the 0.5 Sv (50 rem) extremity shallow-dose regulatory limit to several workers.

Worker doses had to be calculated based on re-enactments to establish the exposure times and distances from the exposed source rod. This was necessary due to the relatively close distances between some workers and the exposed source rod that rendered the dosimetry worn by the workers to yield inaccurate representations of the whole body radiation doses. The dose calculation process was further complicated due to significant changes in worker and source rod locations during this dynamic event as well as apparent inaccurate time estimates to perform tasks by workers in the re-enactments.

The principal cause of the event was determined to be poor work planning, which resulted in: 1) failure to recognize that a source rod had been engaged by the resourcing tool; 2) failure to de-activate the resourcing tool before retracting it from the shielded position to troubleshoot why a source rod had supposedly not been engaged; 3) failure to detect increased radiation levels even though two methods of doing so were supposed to have been available during retracting of the resourcing tool; 4) failure to readily reinsert the resourcing tool into its shielded position; and 5) failure to evacuate the area and take time to plan reinsertion activities.

P09.59
An Source Rebuild Method with Genetic Algorithm Based on Monitor Data

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To deal with unknown nuclear material releasing affair and carry on emergency action more effectively, a source rebuild model with a genetic algorithm (GA) [1] based on environmental and meteorological information was built. Insufficient spatial and temporal resolution and inherent uncertainty in source parameters and meteorological data make the prediction of subsequent transport and dispersion extremely difficult. The genetic algorithm was chosen as optimization algorithm to deal with these things happen to source rebuild. The method and some main parameters in model were presented in paper. And the source rebuild model was applied to estimating the location and strength of two unknown gas release sources from simultaneous measurements of gas concentration and wind data. The result shows: 1. the source rebuild model with a genetic algorithm based on environmental monitor data and atmospheric data is reasonable and feasible. 2. The source rebuild model is effective in 10^1km scale at least. At last, we discuss the necessity to use all meaningful monitor data to modify the method of source rebuild.

Keywords: Unknown unclear material releasing affair, Genetic algorithm, Source rebuild.

P09.60
Sorption Characteristics of Radionuclides in Environmental Aqueous Systems for Sorbents

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After the Fukushima accident, many kinds of radionuclides including cesium, strontium and iodine were released and detected in land areas. Some of them fallen out in the land areas entered environmental aqueous systems directly or indirectly. Radioactive levels of these environmental aqueous systems are lower than near around the Fukushima Daiichi Nuclear Power Station, but drinking water or irrigation water may be from the contaminated aqueous systems, it is very important to purify them.

For contribution to remove radionuclides in the aqueous systems, and to decrease radiation exposure of them, we conducted experiments of sorption characteristics for the sorbents which were made of bentonite or vermiculite. And we also carried out the same kind of experiments for active sludge (composed of bacteria and protozoans) which are used generally in sewage treatment plants to degrade of organic pollutants.

P09.61
Consequences in Norway after Hypothetical Accidents at Sellafield and the Leningrad NPP

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Two different worst case scenarios were considered to assess potential consequences in Norway after hypothetical accidents at Sellafield, UK and the Leningrad Nuclear Power Plant, Russia.

The first considered scenario involves an explosion and fire at the B215 facility at Sellafield resulting in a 1 % release of the total HAL inventory of radioactive waste with a subsequent air transport and deposition in Norway. Air transport modelling was based on real meteorological data from October 2008 with wind direction towards Norway and heavy precipitation. The estimated fallout in Norway was ~17 PBq of caesium-137 which is 7 times higher than the fallout from the Chernobyl accident. The highest deposition levels for this scenario were observed at the west coast of Norway and thus the largest consequences would be there.

The second scenario is a Chernobyl type accident at the Leningrad Nuclear Power Plant. Air transport modelling was based on meteorological data from 6-15 September 2001 with wind direction towards Norway and an average precipitation of 8.8 mm. The total deposition of Cs-137 and Cs-134 are estimated to be 4.3 PBq and 2.8 PBq respectively, which is about twice as large as the total deposition after the Chernobyl accident. The highest deposition levels for this scenario were observed in the northern part of Norway and thus the largest consequences would be found in that part of the country.

The modelled radioactive contamination data was coupled together with data on transfer to the food chain and statistics on production and hunting in order to assess the consequences for foodstuff in Norway. The assessment has been limited to the terrestrial environment with a focus on sheep, goats, wild berries, fungi, game and reindeer.

The environmental modelling results for the Sellafield-scenario indicate that up to 80 % of the lambs in Norway would exceed the food intervention level of 600 Bq/kg for radiocaesium in the first years after the fallout. As for the Leningrad-scenario, up to 57% of reindeer meat production would exceed the intervention level of 3000 Bq/kg for radiocaesium in the first years after the fallout.

This paper will present more detailed results about the possibly devastating consequences of the fallout for the food chains in Norway from the two accident scenarios.

P09.62
Pharmacological Modulation of Acute Radiation Disease by Meloxicam, an Inhibitor of Cyclooxygenase-2

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Current protective and therapeutic approaches to pharmacological modulation of acute radiation syndromes are based on combined modality treatments and deserve supplementations targeted at increasing treatment efficacy and at reducing doses of individual components with accompanying mitigation of undesirable side effects. Earlier studied non-selective cyclooxygenase inhibitors, known as classical non-steroidal anti-inflammatory drugs (NSAIDs), turned out in animal studies to be not only effective stimulators of radiation-suppressed hematopoiesis but also inducers of serious gastrointestinal side effects. Meloxicam, a selective cyclooxygenase-2 inhibitor, retains production of prostaglandins in gastrointestinal tissues and its therapeutic profile in terms of gastrointestinal side effects is much better in comparison with classical NSAIDs. This communication summarizes data from our experiments on the effects of meloxicam in experimental mice in pre-irradiation (protective) and post-irradiation (therapeutic) treatment regimens. Meloxicam stimulated hematopoiesis when given to mice in a single dose before irradiation or in four doses after irradiation with a sublethal radiation dose. Meloxicam was also found to increase survival of lethally irradiated mice when administered before or after irradiation. Our findings point to the possibility to use meloxicam as a part of combined modality approach in both protective and therapeutic treatment regimens. The work was supported by the Grant Agency of the Czech Republic (grants nos. 305/08/0158, P303/11/0128).

P09.63
Average Annual Effective Doses at Inhabitants Living on Contaminated Territories at Long Time After the Chernobyl Accident

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The method for average annual effective internal dose estimation of population had been developed. The Whole Body Counter -measurement Data Base for the period of 1989 – 2010 contains above 2 million records, which allow studying the internal dose peculiarities. The method was based on the results of the WBC-measurements, direct and indirect signs of dose formation, such as average density of soil contamination in the settlement by ^{137}Cs, access to the nearest forest and number of population in the settlement. The last one expresses an integral index of naturalization of farm, which promotes consumption of the contaminated food stuffs. Among rural settlements there are three classes differing by character of distribution of the average annual internal dose of inhabitants and also by radioecological and demographic characteristics. The classification model determining the belonging of any settlement to one of the classes and the regression model of estimation of the average annual internal dose of inhabitants were developed.

The method had been used in creating of the “Catalogue of Average Annual Effective Dose of the population of settlements of the Republic of Belarus which are situated in the zones of radioactive contamination” for realizing a “zoning” of Belarus settlements. The cost-efficacy of use of the average annual effective dose estimation method was $ 200 000 per 5 years. Average annual effective dose exceed 1 mSv/year for 191 Belarus settlement among 2613. About 48 000 persons are living in these settlements.

There was estimated the effective annual dose of the population of three the most contaminated regions from the basic ionizing irradiation sources: natural, medical X-ray-diagnostics and the Chernobyl contamination, on the average 3,5 – 4,0 mSv/year. The natural ionizing irradiation sources and medical X-ray-diagnostics most contribute into the dose. The contribution of the Chernobyl component is 1-5%.

P09.64
Plutonium Levels in Air and Vegetables from a Contaminated Area: A Review of Results and Estimation of the Related Inhalation and Ingestion Doses

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As a consequence of a military aerial accident ocurred in 1966, four thermonuclear weapons fell to earth causing radioactive Pu contamination in and around the town of Palomares, an area located in the southeast of Spain, on the Mediterranean coast. Since that year, a radiological surveillance programme was established and continued in the resulting contaminated area. The results are informed to the Spanish regulatory body. As a part of this programme, the monitoring of Pu concentrations in air and vegetables was established in order to determine the magnitude of the risk of internal contamination in the inhabitants of the zone. In relation to the air monitoring, different sampling points were selected in both rural and urban areas. The air is sampled at these stations in a continuous way, by high volume samplers equipped with a PM-10 inlet. The filters are changed weekly. Concerning vegetation studies, samplig campaigns were designed taking into account the representative crops in the area, the growing season for the cultivated species and the level of soil contamination supporting the cultures. Air and vegetation samples are analyzed by sequential radiochemistry methods and the separated Pu is then measured by alpha spectrometry.

In the paper, a review of the most representative results obtained along the years is presented. Special attention is given in the paper to the last decade results. Individual and average annual concentrations of plutonium at the different sampling locations are shown. Trends in the air Pu levels, air particles size disribution and the distribution of the contamination in the different parts of the plants are analysed. The inhalation and ingestion doses incurred by the population living and working in the area are also estimated under different scenarios.

P09.65
Evaluation of Dose Probability Due to Incidents According to the Type of Nuclear Research Reactors

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This work is intended to establish a risk probability analyses evaluation of incidents according to the type of nuclear research reactors. With this aim, two different IAEA databases were used: Research Reactor Data Base (RRDB) and Incident Report System for Research Reactor (IRSRR). This evaluation employs a Probabilistic Safety Analysis (PSA) for two distributions, Fischer and Chi-square, and the analyses were done considering a 90% confidence level. All calculations used theory and equations listed at IAEA TEC-DOC – 636 and applied to Scilab version 5.1.1, computational model. All results obtained with this probability analysis allowed to conclude that the incidents lead to events with radiation doses in a reference interval of normal and stochastic effects established by ICRP-64. The methodology applied to raise information from both databases, RRDB and IRSRR, made possible the construction of probability analyses of incidents. Hence, based on the survey it will be possible to forecast and prevent future nuclear research reactor incidents and their aftereffects.

P09.66
Loss of Control of a High Activity Well-logging Source - The Lessons Learned

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Oil and gas well-logging involves placing technologically sophisticated logging tools into a well to measure the physical parameters of the well, the geological properties of the rocks around the well, and the presence of elements in the rocks. The logging tools can either be nuclear or non-nuclear, depending on the scope of the logging operation.

This paper describes an incident that occurred on a UK north-sea drilling rig in April 2008. A company was carrying out logging operations on a drilling rig and lost control of a high activity caesium-137 source during transfer of the source from a transport container into a logging tool. The radioactive source was discovered on the drill floor approximately four to five hours after the failed loading operation. During this time a number of workers from a variety of employers accessed the area. Loss of control of a radioactive source of the size involved in this incident was extremely serious. It was only by good fortune that no-one came into close contact with it and received a radiation dose large enough to cause injury.

The paper discusses the investigation findings by the Health and Safety Executive, the UK health and safety regulator, and the lessons learned.

P09.67
Consequences of Burying or Cremating Radioactively Contaminated Fatalities

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HPA was commissioned by the UK's Home Office to provide advice and guidance on the safe handling of fatalities exposed to chemical, biological or radiological agents. As part of this work exposures to professionals and members of the public resulting from the burial or cremation of radioactively contaminated fatalities were modelled for a number of radionuclides. Results for an illustrative level of contamination are presented, together with those from the disposal of associated radioactive waste. Issues related to the burial and cremation of radioactively contaminated fatalities are also discussed.

P10.37
Challenges of Managing the MoD Radon Monitoring Programme

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Dstl manage the radon programme across the MOD estate in the UK and overseas. This incorporates a diverse range of workplaces such as caves, offices and single living accommodation (SLA). Using HPA data, and guidelines from the HSE, academia and the Building Research Establishment (BRE), a formal monitoring programme across the MOD estate has been in place since 2005. The programme covers thousands of workplace areas, with the aim of safeguarding the health of military and non-military personnel now and in the future. Broadly ranging levels of comprehension, together with the complexities of multi-user sites and structural changes within MOD provide significant challenges to the implementation of an effective radon monitoring programme. The findings of the monitoring programme to date, together with local management and remediation actions and RPA recommendations will be presented.

P10.38
Radon Regulations in Dwellings: Is it Time to Move Towards a More Compulsory Approach?

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Abstract. Radon regulations in dwellings have been in force in many countries for several years. Most of these regulations use a recommendation approach, so that the dwellers may or may not accept the actions recommended to be performed to reduce radon risk. In genaral, the effectiveness of such recommendations, evaluated in terms of percentage of dwellers with radon concentration above action levels that decide to reduce radon concentration in their delling is very poor. Therefore a lot of work in done by national and local authorities in order to increase awareness and eventually the number of remedial actions. However, not alwys the result of such efforts is satisfactory. Forthcoming International and European Basic Safety Standards will strongly increase the requirements for protecting population from radon in dwellings, but the type of regulation (compulsory or recommended) is essentially left to the decision of national authorities. In principle, a compulsory regulation could have many advantages in terms of expected effectiveness, although a careful evaluation of methods, costs and feasibility of verification that regulation is actually and correctly followed would be needed. This issue will be presented and discussed.

Preferred mode of presentation: oral or poster

P10.39
Present Status of Radon and Radium Activity Measurements in Well and Bottled Water at the Federal University of Technology (UTFPR, Brazil)

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This article describes the present status and results obtained concerning ^{222}Rn activity measurements in drinking water collected from artesian bores in regions in regions within the city of Curitiba during the period of 2009 - 2010. The measurements were performed at the Laboratory of Applied Nuclear Physics of the Federal University of Technology in cooperation with the Nuclear Technology Development Center (CDTN) of Brazilian Nuclear Energy Committee (CNEN). The experimental setup was based on the Professional Radon Monitor (ALPHA GUARD) connected to a specific kit of glass vessels Aqua KIT through the air pump. The ^{222}Rn concentration levels were detected and analyzed by the computer software DataEXPERT by GENITRON Instruments. The collected average levels of ^{222}Rn concentration were processed taking into account the volume of water sample and its temperature, atmospheric pressure and the total volume of air in the vessels. Collected samples of water presented an average ^{222}Rn activity of about 60 Bq/L which is almost 6 times greater than the maximum level of 11.1 Bq/L recommended by the USEPA (United States Environmental Protection Agency). It has to be noted that few artesian drillings presented the radon activity of almost 200 Bq/. Further measurements are planned to be performed in other regions of Parana State and will involve the mineral water sources, explored artesian drillings as well as soil samples. Another subject of this work is the preliminary results concerning ^{226}Ra activity measurements in bottled mineral water offered on the market in Curitiba-PR, Brazil. The experimental setup was based on the Professional Radon Monitor RAD7 (Durridge Company, Inc.). This detector is equipped with a special kit of glass vessels and which allows the identification of ^{222}Rn activity concentration in small (40mL and 250mL) water samples. Before performing the measurements, we verified the background of RAD7 detector together with Radon In Water Accessory (RAD H20) using the samples of distilled water. The evaluation of radium (^{226}Ra) soluble salts in water and its activity concentration was performed when ^{222}Rn in water samples reached the secular equilibrium since its production rate (^{226}Ra activity) became equal to its decay rate (^{222}Rn). For this purpose, collected water samples were stored in hermetic bottles of 250mL during 45 - 50 days before the measurements. The minimum and maximum ^{226}Ra concentration ranges were of 0.03 and 2.95 Bq/L, respectively. Further measurements are planned to be performed with other brands of bottled mineral water present on the market in Parana State, Brazil. The authors are very thankful to CNPq, CAPES, CNEN-IRD-CDTN and Fundação Araucária.

P10.40
Investigation of Radon Isotopes Content In Dwellings and Public Buildings of Russian Federation

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It is known that population exposure is conditioned by natural and medical irra-diation sources practically in the whole, and their impact in the whole dose is about 70-80% and 20-30% correspondently. For the most cases 50% of the natu-ral exposure doses are conditioned by radon isotopes in the air of buildings. All territory of Russia is situated northerner the 40 parallel and is characterized by noticeably rigorous climate, so radon content in buildings is higher here than av-erage world value. So it is interesting to estimate population exposure levels due to radon content in dwellings. This information is collected already 10 years in the frames of existing State System for control which annually collect measure-ments results from all regions of state; these data is accumulated and analyzed in Federal Scientific Organization Saint-Petersburg Research Institute of Radiation Hygiene after Professor P.V. Ramzaev" (RIRH)

Data on the levels of population exposure due to radon content in dwellings are very important, so for colleting of these data special State System of Control was developed in Russia. Beginning with 2001 the results of radon content in dwellings are annually collected in the uniform format and are sent to Federal Database which is situated in RIRH, where they are accumulated, systematized and analyzed.

Analysis of accumulated during 10 years information on radon content in dwell-ings allow to obtain for the existing period objective picture of the distribution of the state population according to exposure levels from radon isotopes and it's short-living daughter decay products. Big territories with high content of radon in dwellings are found out in the country, in some territories there are found dwellings with radon content exceed-ing adopted country norms in several times.

Existing in Russia system for the collection of information about natural expo-sure doses is rather effective instrument for the collection of the data on radon problem; the system includes levels of the population exposure from radon. In the frames of this system the data on all components of natural exposure are col-lected: radon and external exposure of inhabitants in build-ings, drinking water and food products, etc.

P10.41
Natural Radioactivity In Ceramics

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To control the content of natural radionuclides in traditional building materials in Europe an integrated indicator of radioactivity is used in the form::

$$I=\frac{C_{RA}}{300}+\frac{C_{Th}}{200}+\frac{C_K}{3000} \quad ,(1)$$

where C_{Ra}, C_{Th} and C_K are the radium, thorium and potassium activity concentration in Bq/kg in the building materials.

In Russia a similar magnitude was proposed even in 1979 as follows:

$$A_{eff} = C_{Ra} + 1{,}3\ x\ C_{Th} + 0{,}09\ x\ C_K,(2)$$

where the same notation as in (1), but for the specific activity of radium and thorium it was obligatory to have radioactive equilibrium with its daughter products.

Comparison of the values in forms (1) and (2) shows that the index I is more rigid than the value adopted in Russia *Aeff*. On the other hand, in Russia for building materials, used in various types of building, different limits on the value *Aeff* are imposed. For the construction of residential buildings the value *Aeff* should not exceed 370 Bq/kg, for the construction of buildings and roads in settlements - 740 Bq/kg, and for the construction of roads outside urban areas - 1500 Bq/kg. Moreover, these conditions must be met all types of building materials, so that they are automatically followed either in building materials or in products. However, this requirement also creates a serious obstacle in controlling natural radioactivity in ceramics, where the components with *Aeff* with significantly higher 1500 Bq / kg (zircon sand, some types of pigments, etc.) are used. To resolve this conflict, these products were isolated in a separate class of building materials, for which special researches to establish the restrictions on the content of natural radioactivity in them were made. The calculations and experimental studies have shown that for the values *Aeff* in ceramics up to 1000 Bq/kg supplementary irradiation dose for people in the worst-case scenario does not exceed 90-100 mSv per year.

In these studies, it was analyzed two ways of human exposure due to natural radioactivity in ceramic products - external exposure because of gamma-ray of natural radioactive nuclides in the ceramic products, and internal exposure because of emanation of Radon isotopes in the products. And the first way gives almost 80 % contribution to the total exposure dose of people.

P10.42 Thoron, Radon and their Progenies in the Indoor Environment in Workplaces Located in an old Public Building in Rome (Italy)

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In a study performed in a sample of workplaces, located in an old building in Rome (Italy) the concentration of radon and thoron were measured by using different radon and thoron techniques. Different methodologies both active and passive were employed to estimate radon and thoron concentrations. Radon measurements were carried out using SSNTD with CR39 as detector, EIC and ionizing chamber (Alpha Guard and scintillation cells), instead for the evaluation of indoor thoron concentration just EIC were used.

In particular thoron were estimated using three Electret Passive Environmental ^{220}Rn (Thoron) monitors (R-T E-PERM®) positioned at increasing distance from the wall at an height of about 150 cm from the floor in order to evaluate the spatial dependence of the thoron concentration from walls. Since thoron monitors respond as to thoron as to radon and also to ambient gamma radiation, togheter with the three R-T E-PERM®, one R E-PERM® (Electret Passive Environmental ^{222}Rn monitor) were placed. The thoron concentration was evaluated by the difference between R-T E-PERM® and the R-E-PERM® contribution (referred to radon and gamma).

Moreover, radon and thoron progenies concentration in air were estimated by using LR115 type nuclear track detectors and the Radon Daughter Monitor Fix-Filter-System (Tracerlab, Germany).

To follow temporal variations of radon and thoron concentrations in air a series of monthly monitoring were repeated. A detailed analysis of the distribution of radon, thoron and their decay products inside workplaces is reported, and estimations of radon and thoron equilibrium factors (F_{eq}) were performed.

Due to the presence of Central Italy tuff as bulk building material, radon and thoron concentrations are very high: radon average concentrations varied from few hundreds till to about 3000 Bq/m^3 while average thoron levels are in the range of 200 – 500 Bq/m^3, apart from a room in which a thoron concentration equal to 6000 Bq/m^3 has been measured. Results demonstrated that thoron concentrations varied more widely than radon.

The evaluation of radon and thoron equilibrium factors let us estimate the dose received by workers.

This study confirms the necessity to pay attention to radon and thoron exposures in Central Italy buildings in particular where local building materials have been used.

P10.43
Indoor Radon Levels And Influencing Factors In Dwellings In France

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Introduction: In France, exposure of the general population to ionising radiations is mainly due to radon. Radon is a known lung human carcinogen and is classified as so by the International Agency for Research on Cancer since 1988. In this context, the aim of our work was to improve knowledge on radon levels within French dwellings and their determinants. This study is the first available concerning determinants of domestic radon exposure in France.

Materials and methods: Various indoor air pollutants were measured in a sample of 567 dwellings between 2003 and 2005 by the Indoor Air Quality Observatory. This randomly drawn sample was representative of all main dwellings in metropolitan continental France. Dwelling characteristics and indoor radon levels (Kodalpha LR 115 detector placed during two months in the living room and one bedroom of each dwelling) were collected. Sample design and weighting factors were taken into account for the descriptive statistics and for the study of radon levels determinants (using Generalized linear models).

Results: Radon levels were available for 472 main dwellings (299 houses and 173 flats). Arithmetic and geometric means were 62 Bq.m^{-3} (95% CI: [51, 73]) and 38 Bq. m^{-3} [34, 42] respectively. Radon level was lower than 400 Bq. m^{-3}for 467 dwellings (representing 83% of the housing stock). Indoor radon levels were significantly affected by: the status of the area regarding the radon risk (higher levels in “priority” areas as defined by the French legislation), the presence of a fireplace (higher levels when present), construction material of the dwelling (higher levels for wood and granite), floor level (radon levels decreasing when floor level increased), presence of a heating or air conditioning system or a collective central heating system (lower levels when present).

Conclusion: In this analysis, indoor radon levels measured are consistent with those obtained in previous French surveys. Apart from geographical location, which was already known to highly influence indoor radon levels, our study is the first one in France that identifies dwelling-related determinants of indoor radon levels, and thus of individuals radon exposures.

P10.44
Detection of Rn-222 and Ra-22 in Environmental Samples by Scintillation Method – Case of the U-mine Vinaninkarena, Madagascar

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^{222}Rn is considered as the major source of radiological exposure of natural radiations to the population. It represents about the half of exposures of natural radiation sources in the world (UNSCEAR, 1993). ^{222}Rn gets into human body with inhaled air and sometimes with drinking water. Then, the objective of this work is to know the ^{222}Rn concentrations in water and in indoor atmosphere, and the risk in order to set up a method of monitoring and to identify high radon level areas. A specific method of detection using liquid scintillation with special emphasis on α/β discrimination, the use of solvent extractive and enrichment of radionuclides have been developed for the determination of both ^{222}Rn and ^{226}Ra in water. The method is simple, rapid and sensitive. It was shown that the proposed method was suitable for a large scale monitoring and routine analysis. Considerable concentrations of ^{222}Rn were found in water and air samples from Vinaninkarena – Antsirabe, Madagascar. ^{222}Rn concentrations obtained by in situ and in laboratory measurements have been compared to the results of an international intercomparison campaigns organised by the German Society for Liquid Scintillation Spectrometry in 2001. An assessment model of the dose due to ingestion and liberation of radon from water is presented and compared with other models especially to the Crawford Brown's model.

Keywords: liquid scintillation, radon, radium, exhalation, extraction, enrichment, dose

P10.45
Results of a Radon Mitigation Action in Schools in South Italy: Methodology, Effectiveness and Economical Considerations

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Starting from the experimental results of a previous radon survey carried out in about 500 schools located in Puglia, a region in South Italy, a plan of mitigation actions has been designed and realized in buildings in which the national action level was exceeded.

Mitigation actions need to be supported by a measurement program in order to characterize the building, to identify most effective radon sources and radon entry points, to evaluate real time radon level variations and finally to determine the effectiveness of the mitigation action itself. For these reasons, in our remediation plan a measurement protocol has been applied. It consisted in time integrated monitoring by SSNTD and electrets (EIC) dosemeters and active measurements by ionization chambers and scintillation cells: details about sampling technique and time are summarised in Table 1. All the collected data were useful to evaluate the effectiveness of the mitigation considering possible correlation between microclimatic parameters and the actual mitigation action. Data acquired in the previous survey, arising from measurements performed for each school in three random rooms, were confirmed by a new six-months monitoring in all ground floor and underground workplaces.

Most of the mitigation actions described in this paper consisted in the active soil depressurization (ASD) with an effectiveness of more than 90%. The usage of active monitoring helped us to optimize the working time of the installed fans in order to minimize annual operating costs.

This mitigation plan is the result of a combined effort made by scientific institutions and local administrations to obtain a maximum health benefit for the public keeping the costs of both the measurements and the mitigation action campaign as low as possible.

Table 1: measurement protocol used as support of radon mitigation actions

Sampling time	sampling technique	sampling strategy
six months	SSNTD dosemeters	passive
Two weeks	EIC dosemeters (both SLT and LST configurations)	passive
One month	ionization chamber and/or scintillation cell devices	active

P10.46
The European Atlas of Natural Radiation – A status report

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One of the tasks of the European Commission (EC) under the Euratom Treaty is to collect, validate and provide information about radioactivity levels in the environment. The EC develops and operates various systems for achieving this under routine and emergency conditions. In addition, in 1998 the EC published the "Atlas of Caesium deposition on Europe after the Chernobyl accident". In order to provide the public with a more balanced view of the annual dose that it may receive from environmental radioactivity, the EC decided to explore the feasibility of a European Atlas of Natural Radiation (EANR). A first survey of information available on indoor Rn levels in Europe yielded a mosaic of national approaches with hardly comparable results due to different policies, data-processing and mapping techniques. Thus a procedure for generating a methodically harmonized European-wide map, while respecting data-privacy issues, was developed.

By now 22 countries have provided indoor Rn data, and efforts continue to include more. However, this will not lead to an Rn map covering all of Europe: national radon surveys focus on certain areas, and some territories are uninhabited. Moreover, indoor Rn is also controlled by anthropogenic factors like building styles and living habits which are subject to change over time, and so are therefore indoor Rn concentration and maps showing its distribution.

Consequently we started with a "geogenic radon map", which should show "what earth delivers" in terms of potential Rn hazard. While the "indoor Rn" approach is closer to actual exposure and dose received by the population, the geogenic map is independent of changing anthropogenic factors and will allow clearer definition, identification and delineation of "radon-prone areas". At the moment (Sept. 2011) we compile a report with information about data available and methods used in the various countries, and steer an international expert group discussing the topic. Out of this, a "cooking recipe" for the possible methods to create a geogenic map is being developed, and the experts will discuss it and decide how to proceed at a workshop in late autumn 2011.

In this paper we present the current state of the EANR including statistics, methods, first results and the outcome of the workshop. While still focussed on radon, we will also discuss the ideas and progress made in other components (e.g. cosmic rays, terrestrial gamma radiation) for the long-term goal of a map of total dose by natural radiation.

P10.47
Dose Reconstruction for National Radon Survey in Korea Using the Probabilistic Assessment Methodology

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In Korea, nationwide surveys on radon were conducted in 1989, 1999-2000 and 2002-2005 to estimate the effective dose for the general public due to radon. The total number of dwellings was about 5600. In 2008-2009, a new radon survey in 1100 public buildings was conducted. Exposure to radiation is managed not only by radioactive concentrations in environmental media, but also by human behavior, physiological characteristics, and external factors. However, environmental dose reconstruction is typically taken to mean a dose reconstruction that is undertaken for members of the public. Frequently in environmental dose reconstructions, the exposed individuals did not have individual radiation monitoring, and environmental-monitoring data are sparse, which means that there is a greater reliance on modeling than there is in medical or occupational dose reconstructions. The dosimetric quantity to be calculated in a dose reconstruction also must be considered that depending on the exposure scenario and associated pathways. Monte Carlo simulations are commonplace in quantitative risk assessments(QRAs). Designed to propagate the variability and uncertainty associated with each individual exposure input parameter in a quantitative risk assessment, Monte Carlo methods statistically combine the individual parameter distributions to yield a single, overall distribution.
In this study, a two-dimensional(or second-order) Monte Carlo analysis(2D MCA) was proposed to estimates the uncertainty in the effective dose due to radon. The 2D MCA addresses two types of variables; U-type in relation to uncertainty and V-type in relation to variability. Also, in order to estimate the dominate exposure factors the sensitivity analysis was conducted. Various forms of information were extracted from the results of 2D MCA. The summary for variability of annual effective dose from 2D MCA were given for each scenario in 2.5th, 5th, 10th, 50th, 90th, 95th, and the 97.5th percentiles.

Key words: National radon survey, dose reconstruction, probabilistic assessment, 2D MCA

P10.48
Measurements of Concentration of Radon in Indoor and Outdoor air in Kumamoto Prefecture, Japan

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A series of radon surveys using diffused-junction photodiode dosimeters were conducted in Kumamoto city, Kumamoto Prefecture, and at several the basement of the building in Kumamoto city. In Kumamoto Prefecture, the highest outdoor radon concentration was 31.4 ± 15.4 (SE) Bq $m^{-3}$and the lowest, 6.4 ± 3.4 (SE) Bq m^{-3}. The outdoor Radon concentrations at some survey sites increased as the ground surface approached. The highest radon concentrations in the public bathhouse were 130.2 ± 64.4 (SD) Bq m^{-3}. Average indoor radon concentrations in the houses were 55.9 ± 2.9 (SE) Bq m^{-3}. Indoor and outdoor radon concentrations within a square kilometer region in Kumamoto city showed the irregular distributions, which might be easily influenced by the local geology and meteorology at each survey site. Average radon concentrations at several the basement of the building in Kumamoto city were 110.9 ± 72.1 (SE) Bq m^{-3}.

P10.49
Study on Unattached Fraction of Radon Progeny and its Environmental Influence Factors

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The exposure of radon and its progeny contributes more than half of the natural radiation exposure received by the public. The unattached fraction of radon progeny is an important parameter in radiation dose estimation through dosimetric process; however, not so much data has been reported. For a better understanding on temporal variation and its environmental influence factors of the unattached fraction of radon progeny, a series of field measurements were performed periodically by adopting a new developed integrating monitor for measuring unattached fraction of radon progeny, and an instrument for measuring aerosol concentration in both indoor and outdoor environments.

It was shown by the latest results that the ranges of unattached fraction of radon progeny in indoor and outdoor environments all over the year were 8.5%~38.5% and 9.4%~25.2%, respectively. Seasonal and diurnal variations of the unattached fraction of radon progeny were also analyzed. It comes to the conclusion that during the winter season the unattached fraction of radon progeny is stable in indoor environment because of the little change on aerosol concentration, temperature and humidity indoor in Beijing area, while on the other hand, it changes a lot in outdoor environment due to the great undulation of atmospheric factors, and the average of the unattached fraction of radon progeny is higher in outdoor environments than that of indoors. While in summer, the unattached fraction of radon progeny in indoor environment was close to the values of outdoor environment, and both of them had lower average than that in winter.

Key words: radon; unattached fraction; aerosol; dose conversation factor

P10.50
Long-Term Indoor Radon Measurements in the Chelyabinsk Region, Russia.

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Radon surveys were conducted in 3100 dwellings of 50 settlements over four summer and winter seasons during 2008-2010 in accordance with special program developed by FMBA. Long term indoor radon measurements using the integral track detectors (REI-4, TRACK-REI-1M equipment kit) were carried out over two-four months accompanied with inspective measurements of radon and its progenies. The measurement database is established by the Research and Technical Center of Radiation-Chemical Safety and Hygiene FMBA Russia. It was shown that in Chelyabinsk region EEC (equilibrium equivalent concentration) varied over the range of 10-2000 Bq/m^3. The values above 200 Bq/m^3 were observed in 10% of dwellings, exceeding the normative levels established by the Russian safety standards (NRB 99/2010). The mean EEC values exceed the national and world EEC reported by UNSCEAR and are estimated as 65, 94 and 80 Bq/m^3 for summer, winter seasons and at annual averaging, respectively. According to results of the survey, the percentage of homes with the measured EEC values from 200 to 400 Bq/m^3 and above 400 Bq/m^3 was estimated at the ranges of several to 40 % and 1-10%, respectively. The mean EEC_{winter} / EEC_{summer} ratio is estimated over the range 0.9-8. This ratio for the cities and urban- type settlements is within the range 1.5-2.5 and proved to be lower than in rural communities. The effective dose of radon exposure to the public in dwellings was distributed as 75 % (lower 5 mSv), 16% (5-10 mSv), 9% (above 10 mSv) according to the findings of at least two season measurements.

P10.51
Radon Regulatory Framework in Russian Federation: State of Affairs and New Challenges.

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Radon is the major contributor to the public exposure in Russia. The paper presents the main issues of radon regulatory framework in Russia and discusses some new challenges pronounced by WHO and ICRP. The legislative basis of radiation safety assurance in RF is as follows: Federal Laws (FL) - Radiation Safety of the Hygienic and Sanitary and Epidemiological Well-Being of the Public. The national radon regulatory framework is based on three documents: The Radiation Safety Standards (NRB-99/2010), the Basic Sanitary Rules for Radiation Safety, (OSPORB-2010) and Hygienic Standards of the public safety against the natural radiation. According to the above regulatory documents the indoor concentration of radon and thoron progenies (in terms of equivalent equilibrium concentration (EEC)) should not exceed 200 Bq/m^3 and 300 Bq/m^3, whereas new buildings should be built so that 100 Bq/m^3 and 150 Bq/m^3 are not exceeded for dwellings and industrial buildings, respectively. The effective dose induced by the natural radiation in the workplaces should not exceed 5 mSv/year (EEC 310 Bq/m^3 and 68 Bq/m^3 for radon and thoron, respectively). Regulation of radon exposure in the workplaces bases on the graded approach elaborated in OSPORB-2010. The diversity of the climatic and geological features provides a wide range of natural circumstances and complicates radon regulation in Russia. According to the results of the national radon survey (1995-2000), about 1,500,000 individuals receive annual doses above 10 mSv from this natural radiation source. For the purpose of radiation protection of the Russian population against radon, the national program took its rise in 1994 after approval of the purpose-oriented federal target program (FTP) «RADON» by the Government of the Russian Federation. At present, the main issues of this program are under implementation on the continuing basis under FTP «Nuclear and Radiation Safety Assurance». The information on the radon measurements and relevant doses to the public are accumulated in the frames of the following state programs: Integrated Individual dose Control System, Radio-Hygieniñ Certification and Social-Hygienic Monitoring. New challenges pronounced by ICRP in the statement (ICRP statement, 2009) along with the high priority and complexity of radon problem for Russia need multiplex inter-sectorial and -regional efforts coordination. That is why, the radon national action plan is to be developed and this work began recently.

P10.52
National Action Plan 2011-2015 for Radon Risk Management in France

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Radon risk management is entered in the second cancer plan and is part of the second national health & environment plan issued by the French government in June 2009.

A first action plan was drawn up, in 2005, by the French nuclear safety authority (ASN), in cooperation with the French directorate for housing, town planning and countryside (DHUP), the French radiation protection and nuclear safety institute (IRSN), the health monitoring institute (InVS) and the French scientific and technical centre for construction (CSTB). The review of this first action plan has been published in April 2010.

The 2011-2015 action plan follow directly on from the 2005-2008 plan, enabling some of the actions to be continued, particularly in the fields of private housing and new building. In addition, a French Act n° 2009-879 dated 21 July 2009 has supplemented the provisions of the French public health code with respect to radon risk management, such that radon activity measurement is now mandatory in private housing.

Five keys areas for action have been identified:

1. Developing a new radon risk management policy for domestic premises ;

2. Implementing a radon risk management for new building projects ;

3. Overseeing the implementation of regulations for radon risk management in public places and workplaces ;

4. Developing and implementing new management tools and organizing the network of construction professionals ;

5. Coordinating policy studies and research.

Each of these areas has been broken down into specific actions (30). Regional initiatives have been agreed for many of the actions, in order to enhance the skills of existing local practitioners, to encourage the emergence of new ones and to promote the sharing of good practice.

P10.53
Investigation of air thoron (220Rn), radon (222Rn) and gamma radiation dose rates in an area rich in thorium (232Th) ore in Norway

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Investigation of enhanced radioactivity levels was conducted in Fen Complex, a Norwegian area rich in naturally occurring radionuclides, especially in thorium (^{232}Th). Study site comprised both locations with naturally occurring radioactive materials (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM); all freely accessible. In situ measurement of gamma dose rates, long-term seasonal surveys of thoron (^{220}Rn) and radon (^{222}Rn) outdoor levels, as well as, gamma spectrometric analysis of soil samples were done. Based on long-term survey, ^{220}Rn and ^{222}Rn reached air concentrations up to 1786 and 67 Bq m^{-3}, respectively. The gamma dose rates in the air were also significantly enhanced, in range from 2.6 to 4.4 µGy h>$^{-1}$. Seasonal variation in all investigated radiation parameters was demonstrated. The correlation analysis showed the positive relationship of air radiation levels with abundance of ^{232}Th in soil of the area. Soil activity concentration of ^{232}Th (2848 – 8395 Bq kg^{-1}) was significantly higher than the world and the Norwegian average value (45 Bq kg^{-1}), while ^{226}Ra was present at moderately high levels (89 – 171 Bq kg^{-1}). Calculated external hazard index showed elevated radiation risk (11 – 33). The annual outdoor effective radiation in this area was estimated to be in range from 3.0 to 7.7 mSv, comparable or higher than average total (indoor and outdoor) annual exposure dose for rest of Norway (2.9 mSv). On the basis of all obtained results, this Norwegian area should be considered as enhanced natural radiation area (ENRA).

Poster sessions C-D: Area 10

P10.54
Radon in Agricultural Workplace: Greenhouse Facilities Using Underground Air in Jeju Island, Korea

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Recently, there are a great number of agricultural facilities (ca. 700 of agricultural facilities such as greenhouses, glasshouses and cattle shed) using underground air for production of varying kinds of agricultural products (e.g. orange, paprika, plants etc.) in Jeju Island, Korea. The air contains constant temperature (14 – 19°C) and relatively high CO_2 that are used to maintain indoor temperature of greenhouse facilities and promote the growth rate of crops via increasing photosynthesis. For use of underground air, large blower systems were installed at varying depth (30 - 60 m) of the underground borehole at each facility. These systems provide significant contributions for increasing the agricultural productivity and reducing heating costs.

Jeju Island was created entirely from volcanic eruptions approximately 2 million years ago, and mainly consists of basalt and lava. With this reason, the surface rocks of the Jeju Island contain relatively very low concentration of uranium and radium that are parent radionuclides of radon. However, because of the basement granitic rocks are present below the island's porous volcanic rocks, and the vertical fractures and joints are well developed, radon emanated from the rocks is relatively easily diffused into inter-rock space. Therefore, the air in the inter-rock space containing significant amounts of radon (over several thousand Becquerel per cubic meter) is expelled by the blower system, and, eventually, increase radon concentration in the facilities. For example, the average indoor radon concentration of some greenhouses reaches several hundred Becquerel per cubic meter during working time. It mainly depends on the capacity and utilization of borehole blowers in each facility.

The aims of this study are investigation of indoor radon distributions and the evaluation of the annual effective dose due to inhaled radon of workers in agricultural facilities using underground air in Jeju Island. Although all workers' annual effective dose caused by inhalation of radon were below the action level in the workplace (10 $mSv\text{-}y^{-1}$) recommended by the International Radiation Protection Committee (ICRP), those are not negligible at some facilities. Especially, working environments of agricultural facilities such as greenhouse should be considered as a notable workplace to apply the optimization of existing exposure.

P10.55
Preliminary Study On Radon Exhalation Rate of Natural Soils Of Western Crete

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The establishment of a direct evidence of an association between residential radon and lung cancer risk , has been complemented by national studies of radon in building materials and in soil. This work presents a comparison of the radon exhalation rate from natural soils of the Chania county of Crete, under laboratory conditions. The soil sample and a continuous radon monitor are placed in an air tight container. The radon exhalation rate is determined from the change, with time, of the concentration of the radon exhaled from the soil sample. The experimental conditions are adjusted so that a) the alpha counting time is relatively short, of the order of 10 hrs, so that the linearity of the exhalation rate is not significantly affected by the 91,2 hrs half- life of radon 222 and b) the radon concentration is relatively low so that back diffusion does not significantly affect the exhalation rate. The exhalation rate is thus equated with the slope of the radon concentration versus time, and is obtained by linear least square fit of the data. The different soil types have also been investigated via XRD and XRF analyses. Different terra rossa soils exhibit significantly different radon exhalation rates.

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P10.56
Radon Levels in Manita Pec Cave (Croatian NP Paklenica) and Assessment of Effective Dose Received by Visitors and Tourist Guides

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The Manita peć cave is located within Croatian National Park Paklenica and it is the only cave open for visitors in the park among 70 others speleological objects. The cave is formed in thick layers of light grey limestone from middle to upper Jurassic. With the length of 175 meters it belongs to shorter speleological objects, but of great interest among tourist because of numerous cave ornaments and proximity to popular tourist destination on the Adriatic coast. Numerous European biospeleologists explored and searched cave for fauna with discoveries of new species. The temperature and humidity are stable during a year with valus about 10 ˚C and 100 %, respectively.

In June 2010, the 15 months monitoring of natural radioactivity from radon and its short lived progeny according to Action plan of National park management has been started. Integrated radon measurements by means of solid state nuclear track etched detectors (two LR-115 type II films per detector cup in order to determine equilibrium factor) were conducted during every season of the year. Additional measurements were performed during summer period because of intense tourist visits. The daily variations of radon and its progeny were measured by AlphaGUARD measuring system (AlphaGUARD PQ 2000 PRO connected with Radon WL Meter TN-WL-02).

Average radon concentration in summer 2010 as well as in 2011 was 1.1kBq m^{-3}, and was much higher than in other seasons (0.03 kBq m^{-3} in winter 2010, for example). The obtained values categorize Manita peć cave among caves with lower radon concentration than world average (2.8 kBq m^{-3}). The daily variations in radon and its progeny concentrations as a influence of tourist activity during cave tours were not observed. Equilibrium factors were in range from 0.1 to 0.9 with arithmetic mean 0.49 and standard deviation of 0.18. Statistical t-test shows that radon concentration is uniformly distributed within cave in every season. The highest average effective dose from radon and its short lived progeny received by visitors during their 30 minutes tour was in summer period and equals 1.86 µSv. Exposure to average effective dose rate of 3.7 µSv h-1 during summer would result in the maximum effective dose of 0.416 mSv for tourist guide in the cave who spent all of the working time inside.

P10.57
Practical Procedure for Routine Measurement of Radon Exhalation Rates from Building Materials

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A practical procedure and the necessary setup for routine measurement of the free exhalation rate of ^{222}Rn from building materials are described. The setup includes an ionization chamber-based continuous radon monitor and a relatively large-volume radon accumulation chamber. The procedure accounts for the effects of leakage and back diffusion. It also enables the experimentalist to interact with the setup in real time via a PC, e.g. to determine the optimum accumulation time before the effects of back diffusion sets in. The free exhalation rates (in $Bqm^{-2}h^{-1}$) of selected building materials used in Kuwait are 2.31 for marble, 4.01 for ceramics and 4.52 for granite.

P10.58
Elevated Radon Concentration At The Entrance Of An Unused Old Coalmine Near An Urban Area, Western Crete, Greece

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Previous studies have found two areas in Greece with relatively high radon concentrations both indoors and in the ground, one of which is located in Vrysses Apokoronou, Western Crete . This study investigates t he hitherto remaining unknown origin of the reported high radon values in the Vrysses area. Our study is focused in a location where lignite mining was in operation till 1961. The lignite deposits are situated within Miocene marls in a depth of 30 meters below surface approximately. In this work an unusually high concentration of radon gas namely 2500 Bq /m^3, has been measured at the entrance of the collapsed old mining tunnel, in the air, one meter below the soil surface. The continuous radon monitor CRM 1028 was used for the collection of data. Elevated radon concentrations have also been measured in air further away from the lignite mine entrance.

P10.59
The Level and Distribution of 222Rn and 220Rn Concentrations in Soil Gas in the South of China

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In order to understand the level and distribution of ^{222}Rn and ^{220}Rn concentrations in soil gas in the high-background- radiation area, ^{222}Rn and ^{220}Rn concentrations surveys were carried out for the first time at 67 locations in South China, using RAD7 portable radon system (Durridge Company Inc), covered the total area of 1800 km^2 in Zhongshan City and Zhuhai City, Guangdong Province in 2011. The sampling grid was 10 x 10 km and the interval between two locations was about 1 km in a typical profile.

The RAD7 radon monitor contains a solid-state ion-implanted planar silicon detector and built-in pump with a flow rate of 1 L min^{-1}. A solid-walled and hollow stainless tube of 8 mm internal diameter and 80 cm length were installed at sampling location. Soil gas was driven into RAD7's internal sample cell by its built-in pump and was measured in sniff mode with 3 min. sampling time, while the pump was running continuously. In all the measurements the cycle time was at least 30 min. depending on soil permeability. Three sites were observed at every location. The final result is an average of the many cycles from these three sites.

Preliminary surveys of ^{222}Rn and ^{220}Rn concentrations in soil at sampling depth of 80 cm in selected locations of Zhongshan City and Zhuhai City revealed several patterns. (1) ^{222}Rn and ^{220}Rn concentrations in soil were significantly different in the surface areas covered by weathered granite of Yanshan Period and Quaternary sediments. The ^{222}Rn and ^{220}Rn concentrations at the depth of 80 cm varied from 3.27 to 1199.24 and 6.65 to 461kBqm^{-3}; and the average were 140.74±201.78, 37.50±49.86, 294.42±81.36, and 23.30±25.84 kBqm^{-3} for weathered granite products and sediments, respectively. (2) Positive correlation was found between ^{222}Rn and ^{220}Rn concentrations. The ratios of the average of ^{222}Rn to ^{220}Rn concentrations were 0.48 and 1.61 for weathered granite products and sediments, respectively. (3) The high positive correlation between ^{220}Rn concentrations and ^{232}Th activity concentrations was found. (4) ^{222}Rn concentrations increased with increasing sampling depth in the locations covered by weathered granite products and sand, however ^{220}Rn concentrations had no statistically significant variations from depths of 20 cm to 140 cm with an interval of 20 cm. It is worth to pay attention to the question of so high soil ^{220}Rn concentration in Zhuhai City and Zhongshan City.

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Keywords: Radon; Thoron; Soil gas; High-background-radiation; China

P10.60
Indoor Radon Concentration in Schools and Kindergartens in Belgrade in 2010

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Public exposure to radon and its radioactive daughters, present in the environment, results in largest contribution to the average effective dose received by human beings. Radon and its air bone daughters can cause a significant internal health hazard, especially when radium content in the soil is high or the radon and its daughters are concentrated in enclosed areas such dwellings, schools and kindergartens.

Active coal detectors are used for testing the concentration of radon in schools and kindergartens in Belgrade during the 2010. The method of measurement is based on radon adsorption on coal and measurement of gamma radiation of radon daughters (^{214}Pb and ^{214}Bi).

Carbon filters were opened and exposed in closed rooms 3-6 days. Detectors were placed at height of 1 m above the floor and walls. Upon closing them, the measurement was carried out after restoring the balance between radon and its daughters (at least 3 hours) using NaI detector. Detector was calibrated by ^{226}Ra of known activity in the same geometry. Project of massive measurements of Rn-222 concentration in schools and kindergarten buildings in Belgrade includes 9 municipalities.

During 2010 indoor measurements are completed in 10 kindergarten, 23 primary school, 13 gymnasium and 2 music school buildings.

Results from all the mesurements in 2010 (there were 227)show that: 82% were below 200 Bq/m^3 , in 11% of radon measurements concentrations were in the range of 200-400 Bq/m^3. Activity concentrations of ^{222}Rn in school buildings were in the range from 40.7 Bq/m^3 in New Belgrade municipality, to 227 Bq/m^3 in Rakovica municipality. Activity concentrations of ^{222}Rn in kindergartens were in the range from 50.9 Bq/m^3 in Zvezdara municipality, up to 161.4 Bq/m^3 in Zemun municipality. In 7% of measurements results were over 400 Bq/m^3 and for these buildings additional measurements are required, which should be followed by reparations of the facilities.

Simultaneously with the measurements of radon concentrations, samples were taken from 13 building materials used for the renovation, as well as 22 soil samples from school yards. Gamma index of building material ranged from 0.01 to 0.98 which met the requirement for installation in the interior.

Activities of natural radionuclides in soil from school and kindergarten backyards were within the average values for the region of Belgrade, where testing is done by the program monitoring of radioactivity in the environment of Belgrade.

P10.61
Radon Concentration in Soil Gas and Radon Exhalation Rate in Some Areas of Ramsar in the North of Iran (High Levels of Natural Radiation Areas)

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Background radiation levels are from a combination of terrestrial (from the ^{40}K, ^{232}Th, ^{226}Ra, etc.) and cosmic radiation (photons, muons, etc.). The average absorbed dose rate in air outdoors is about 60 nGy/hr from terrestrial gamma radiation (UNSCEAR 2000). Around the world though, there are some areas with sizable populations that have high background radiation levels. The highest are found in Yangjiang, China; Kerala, India; Guarapari, Brazil; and Ramsar, Iran. Some areas of Ramsar, a city in northern Iran, have among the highest known background radiation levels in the world. The high background radiation in the "hot" areas of Ramsar is primarily due to the presence of very high amounts of ^{226}Ra and its decay products, which were brought to the earth's surface by hot springs.

The higher radiation levels are due to high concentrations of radioactive minerals in soil. Noble radon gas (^{222}Rn) originates from radioactive transformation of ^{226}Ra in the ^{238}U decay chain in the earth's crust. Only a fraction of the radon atoms so created is able to emanate from the mineral grains and enter the void space, filled either by gas or water. From here, radon moves further by diffusion and, for longer distances, by advection dissolved either in water or in carrier gases. Eventually it exhales into the atmosphere.

Ramsar lies between the Elburz Mountains and the Caspian Sea at an average elevation near sea level (the Caspian Sea is about 30 m lower than sea level). This region is geologically young with an abundance of subsurface geothermal activity that is directly responsible for the elevated radiation levels present.

Based on the results of pervious studies the location of the study area was determined and twenty measurement points were fixed in this area. The following measurements have been carried out: radon activity concentration in soil gas, radon exhalation rate from ground and gamma dose rate. The radon measurements were carried out using the AlphaGuard equipment, and potable survey meter GR-130 was applied for gamma dose rate measurements. The ranges of the obtained results are as follows: 5 - >2000 kBqm−3 for radon concentration (C_{Rn}), 0.04 – 2 Bqm^{-2} s^{-1} for radon exhalation rate (ERn), and 0.08 – 35 µSv h−1 for gamma dose rate. The concentrations of ^{222}Rn in soil gas were found to be higher than the estimated mean worldwide flux of ^{222}Rn of 0.016 Bq m^{-2} s^{-1} (UNSCEAR 2000). Measurements of exhalation rates of radon from soil show a variability that reflects the variability of radon concentrations in near-surface pore spaces. Concentrations of ^{222}Rn in soil gas vary over many orders of magnitude from place to place and show significant time variations at any given site. The study is planned to be continued with measurements being carried out at a number of additional points.

P10.62
Local Authority Radon Measurement Programmes in Irish Social Housing

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The Radiological Protection Institute of Ireland (RPII) focuses radon awareness raising activities on high risk areas. A series of public awareness campaigns in the high radon area of north county Cork resulted in significant publicity and a marked increase in the number of home and workplace measurements in the area. On foot of this, the administrative bodies for the region with responsibility for social housing decided to measure radon in all social housing in county Cork. The three state agencies with responsibility for radiation protection (RPII), social housing (Cork County Council) and public health (Health and Safety Executive) collaborated to effectively assess measurement results, tackle remediation, deal with the consequent health implications of the results and communicate this to tenants. The experience gained in this process was used to document guidance to other local authorities in carrying out this work. Following on from this, and with the support of the Department of Environment, Community, and Local Government, the relevant Government Ministry, many local authorities in Ireland have implemented a radon measurement programme. Where high levels are found they have been remediated. This paper presents an overview of the county Cork measurement programme, RPII guidance to local authorities on implementing a radon measurement programme and a summary of the results of these measurements from a number of counties including county Cork where over 4,000 homes were measured.

P10.63
The Effectiveness of Radon Preventive and Remedial Measures in Irish Social Housing

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It is estimated that approximately 100,000 Irish homes have radon concentrations above the national reference level for radon in homes of 200 Bq/m^3. To minimise the number of new homes with this problem, building regulations require that all new homes built since July 1998 in high radon areas are installed with radon barriers during construction. A high radon area is any area in which it is predicted that 10% or more of homes exceed 200 Bq/m^3. Many local authorities in Ireland routinely carry out radon measurements in their housing stock. Analysis of data from measurements in homes located in high radon areas built both with and without radon barriers allows the impact of the building regulations to be assessed. This paper looks at the data from two local authorities; county Cork, which is in the south of the country and county Carlow which is in the south-east. In county Cork a reduction of between 20 and 70% in the mean radon concentration was observed due to this requirement. This is in good agreement with earlier studies of the impact of the requirement to install a radon barrier in private homes in high radon areas. Barrier installation also resulted in a reduction in both the number of homes exceeding the reference level and the maximum concentration measured in homes. Homes exceeding the reference level were remediated by installing an active sump. The results of this remedial work are also presented and show that the mean reduction in radon concentration achieved was 92%. These data are in good agreement with studies of active sump effectiveness in private homes and schools.

P10.64
Ventilation, Radon and Thoron: Results from a Dutch Survey

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Since the 1980's, three nationwide radon surveys have been held in the Netherlands. The results of the first two surveys indicated that indoor radon concentrations in Dutch houses are low compared to those in many other countries, but increased with year of construction of the dwelling. It was assumed that this increasing trend was a consequence of improved insulation and consequently reduced ventilation in newer houses and increased use of concrete, leading to buildup of radon gas exhaled by building materials. In 2006 the National Institute for Public Health and the Environment conducted a survey in Dutch dwellings built between 1994 and 2003 to monitor the development of indoor radon concentration and to study the relation between ventilation and radon concentrations.

Ventilation flows were estimated using an approach based on measurements of the distribution of a tracer gas. Obtaining an estimate for all air flows in individual houses from the experimental data was not possible. However, the use of mean air flow values across categories of houses has yielded valuable information. Based on mean values, air exchange between the central hallway and surrounding rooms is much more important than that between the individual rooms. Moreover, ventilation appears to reduce the amount of radon that accumulates in living spaces, such as bedrooms and living rooms.

Surprisingly, radon measurements showed concentrations that were markedly reduced from those found in the previous survey. Since there had been no drastic changes in building procedures in the Netherlands during the time period between the two surveys it was unlikely that this reflected a true decrease in radon concentrations. We found that the detector used in the earlier surveys measured not only radon, but also thoron and the "radon" concentrations determined in earlier surveys were, to some extent, thoron concentrations. Contrary to what was assumed in the past, thoron can be expected to contribute significantly to the dose that inhabitants in newer Dutch dwellings incur.

P10.65
Indoor Radon Measurements in Some Dwellings and Workspaces in Morocco

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Radon is an inert noble gaz. Its most common isotope, and the one that is commonly known as radon, is ^{222}Rn, which arises in the radioactive decay chain of uranium-238. Uranium occurs naturally in varying levels in all rocks and soils. Some fraction of radon produced in rocks and soils escapes to the air; therefore radon is present in the atmosphere, thus simply by breathing, people everywhere are exposed to radiation from radon itself and also from shirt-lived radon decay products. It is well established that the inhalation of the short-lived decay products of ^{222}Rn and their subsequent deposition along the walls of the various airways of the bronchial tree are the main pathways of radiation exposure of the lungs.

In Morocco, As a way of prevention, we have measured the volumic activities of indoor radon-222 and we have calculated their effective equivalent dose in some dwellings and enclosed areas in Morocco. The obtained results show that the effective equivalent dose of activities measured in indoor dwellings and in enclosed areas are inferior to the admissible annual limit fixed by ICRP for population and for workers.

P10.66
Activity Concentration of Radon in Soils Before Building in Southwestern Region of Nigeria.

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Extensive radon research has been done in many parts of the world in family dwellings while investigation of radon situation in soils before building is sparse. Therefore a survey on radon in different areas of Southwestern Region of Nigeria has been conducted to assess the activity concentration of radon in soils before building family dwelling, workplace or office. Assessment of activity concentration was done using a high-resolution gamma spectrometric system. Measured radon activity concentration ranged from 1.2 ± 0.5 Bq l^{-1} to 104.4 ± 2.5 Bq l^{-1}. The results showed that high radon activity concentrations were obtained in areas with rocky terrains in the region.

P10.67
Indoor Thoron Progeny Measurements in High Background Radiation Area of Orissa, India

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Exposure to radon, ^{222}Rn, is supposed to be the most significant source of natural radiation to human beings. Although radon presents the main concern of inhalation dose contributor for general public, recently thoron, ^{220}Rn has gained increasing attention among health physicists. Recent studies have shown that the exposure to ^{220}Rn and its progeny can equal or several times exceed that of ^{222}Rn and its progeny. The results of thoron progeny measurements in the houses of high background radiation area (HBRA) of southeastern coast of Orissa, India are presented here. Both active and passive methods were employed in cemented, brick and mud houses of the area. CR-39 track detector was used for the measurement of environmental thoron progeny, both in active and passive modes. The concentration of thoron daughter products, using integrated long term measurement technique, was found to vary from 0.49±0.17 Bq/m^3 to 20.61±0.80 Bq/m^3. However, the equilibrium equivalent concentration of thoron progeny (EECTn), using grab sampling method, was found to vary between 0.02±0.01 Bq/m^3 and 1.02±0.06 Bq/m^3. The indoor and outdoor gamma dose rates in the study area vary from 0.124 µGy/h to 0.257 µGy/h and 0.109 µGy/h to 0.361 µGy/h, respectively. A comparison between the results obtained with both active and passive methods is presented in this paper.

P10.68
Distribution of Radon Exhalation Rate from the Soil Surface in Japan

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There have been many reports published on the health effects of radon exposure. Radon comes from soil, rocks and building materials. The soil can be regarded as the main source. Emanation of radon gas into the atmosphere is dependent on local ground surface and soil conditions. The radon exhalation rate is one of the important factors that influence indoor and outdoor radon concentrations. In this study, both the annual and the seasonal radon exhalation rates from soil surface in Japan were estimated by uranium-238 concentration, radon emanation coefficient, radon diffusion coefficient calculated by Rogers's formula, and global ecosystems database. Since the radium-226 concentration in soil has not enough data, uranium-238 concentration reported by Agency of Industrial Science and Technology was used in this estimation. The radon exhalation rates in summer were generally higher than those in winter. The distribution map of radon exhalation rate in Japan was also made using these data. A regional variation in the radon exhalation rate was obviously found. Distribution area of acid rock with high-level uranium-238 concentration is generally large in the southwest region in Japan. Therefore, the radon exhalation rate in Japan was generally higher in the southwest region than in the northeast region.

P10.69
An Analysis of Radon Remedial Measures

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Radon gas in the home is a major source of public radiation exposure and an established cause of lung cancer. A range of techniques are available to reduce high indoor radon concentrations in homes. Information on some 2,700 radon remediation projects has been analysed with the aim of identifying the most effective remedial measures and major factors that influence the performance. Overall, an active sump system is most likely to offer a substantial reduction, on average 6 fold. Other methods are less effective, reducing levels by a typical factor of about 2. Passive ventilation and sealing are least effective. Each remediation method showed a trend in performance with respect to the initial radon concentration. Higher initial radon concentrations offer greater relative reductions when remediated. However, homes with higher initial concentrations were less likely to achieve reductions below the Action Level (200 Bq m^{-3}). This information will be used to update guidance for householders and others such as contractors, using fact sheets, presentations at radon householder events and the UKradon website.

P10.70
Construction of Natural Radiation Exposure Study Network - Achievements and Future Directions

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A project entitled “Construction of natural radiation exposure study network” commenced in 2009. Nine institutions are now being involved in this project and this project will be finished in March 2012. The aim of the project are to assess the dose for natural radiation exposures using state-of-the-art measurement techniques in four Asian countries (China, India, Korea, and Thailand) and their outcomes will be distributed worldwide. Conventional measurement techniques have been improved and been optimized. Since internal dose assessment is more difficult than the external one, in particular, some new technologies were introduced in this research field. For instance, a discriminative measurement technique of radon(^{222}Rn) and thoron(^{220}Rn) was introduced in some epidemiological area together with a passive thoron progeny measurement technique. Although information on their particle size distribution has not yet been sufficient so far, a simple but effective device was developed so as to measure the particle size distribution for further understanding on the internal dose assessment. This presentation demonstrates achievements and future directions on the project.

P10.71
Risks from Radon

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In its Statement on Radon (November 2009), the ICRP revised the upper reference level for radon gas in dwellings (i.e. "where action would almost certainly be warranted to reduce exposure") from 600 Bq m^{-3} to 300 Bq m^{-3}. The recommended level for workplaces is 1000 Bq m^{-3}. National authorities are advised to consider setting lower reference levels in accordance with ALARA.

The ICRP recommends a risk coefficient of $8x10^{-10}$ per Bq h m^{-3} for exposure to radon-222, without reference to smoking habits. On the basis of the ICRP's recommendations:

• The estimated risk of lung cancer from radon could be greater than the observed risk of lung cancer from all causes, which is actually known to be dominated by smoking

. • The estimated risk of death from exposure to radon at work and at home (at concentrations that are high but compliant with the upper reference levels) could be greater than the observed risk of travelling by car (e.g. between home and work), which would be surprising if true.

Epidemiological studies around the world have shown that the effects of radon on the incidences of lung cancer are uncertain at levels below 100 Bq m^{-3}. The assumption of a linear relationship at radon levels below 100 Bq m^{-3}, implying a constant risk coefficient, is not justified. There may be no risk from radon at these levels.

The average levels of radon in dwellings in Australia and Britain are respectively about 11 and 21 Bq m^{-3}. Levels are less than 50 Bq m^{-3} in 99% of dwellings in Australia and in more than 90% of dwellings in Britain. The estimation of risks and health effects from radon at these levels is essentially meaningless. The author is not aware of any direct evidence of risks from inhaling radon in Australian dwellings or in currently used workplaces in Australia.

A number of case-control studies have shown clear positive correlations between the incidence of lung cancer and the concentration of radon above 200 Bq m-3. However, the estimation of the values of risk at radon levels less than about 200 Bq m^{-3} depends on extrapolation from risks observed at higher levels. Risks to non-smokers from radon are much less (perhaps 25 times less) than risks to smokers.

It is concluded that the ICRP Statement on Radon (November 2009) – without qualification – and radon policies in the US and UK, have the potential to cause unwarranted concern. Some people may be made to feel they should spend money modifying their homes and workplaces to protect occupants from exposure to radon when they do not need to do so. For smokers, the incremental risk of lung cancer from inhalation of radon is significant but relatively small at the ICRP-recommended domestic reference level of 300 Bq m^{-3}. For non-smokers, the risk from radon is much smaller and is less than the risk from all other causes (except smoking) at radon levels up to at least 600 Bq m^{-3}.

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P10.72
Practical Issues in Retrospective Estimation of Long-Term Radon Exposure with Lead-210 in Household Dust

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Recent studies of people exposed to radon have confirmed that radon in homes represents a serious health hazard. Since radon levels in a home can vary significantly over time, a long-term measurement period (3 to 12 months) will give a much better indication of the annual average radon concentration than short-term tests. Although detectors for long-term radon testing are commercially available, many homeowners wish to know radon levels much sooner. Alternative methods to quickly estimate long-term indoor radon concentrations are therefore explored.

Radon decays to a long-lived isotope ^{210}Pb with a half-life of about 22 years. Measuring concentrations of ^{210}Pb in household dust could be an alternative method of determining indoor radon levels. This retrospective method for estimating long-term radon concentration was explored in over a hundred Canadian residential homes in 2008. The results demonstrate that ^{210}Pb concentrations in household dust relate reasonably well to radon concentrations in homes.

With lessons learnt in the 2008 survey, another 3-month radon survey was conducted in 109 homes in maritime cities of Canada. Household dust was collected in 70 homes surveyed. Results of paired values of ^{210}Pb in dust and ^{222}Rn concentration in homes are presented here. The correlation coefficient between ^{210}Pb in dust and ^{222}Rn indoors was established. No significant improvement in correlation coefficient was found compared to previous survey. In this second study, association between ^{210}Pb and ^{226}Ra in dust was also investigated. Practical issues inherent in field studies with this retrospective method are discussed.

Poster sessions C-D: Area 10

P10.73
Measurements of Radon Entry Parameters in the Buildings

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There are two basic radon entry mechanisms: diffusion due to the gradient of radon concentration in the environment and advection caused by the pressure difference between building envelope and outdoor atmosphere. Air exchange rate between outdoor and indoor atmosphere has significant effect on the amount of radon concentration.

The experimental technique of the assessment of radon entry rate and air exchange rate in the room is developed and experimentally verified. The technique is based on the analysis of time series of radon concentration under active and steady-state conditions of room use. For measurements the radon monitor AlphaGUARD was selected. In the steady state condition natural ventilation in the room is usually less than in the active mode. In the steady state the accumulation of radon is a process of attaining of the equilibrium between radon entry and its removing by ventilation. For assessing of the radon entry rate and air exchange rate in the room it is proposed to use for analysis the whole curve of radon accumulation, not only the value of radon concentration at the end of exposure. A series of measurements of radon concentration is described by nonlinear mathematical regression, characterized by the accumulation of radon in a room in steady-state condition of room use.

For sufficiently long-term measurements, including warm and cold seasons, the dependence of ventilation rate on the difference between indoor and outdoor temperature was studied. For each room dozens of daily radon accumulation curves has been analyzed. It is demonstrated that the study of dependence of radon entry rate on temperature difference T between indoor and outdoor atmosphere allows to estimate the dominant radon entry mechanism - diffusion mechanism (absence of the dependence on T) or convective (Rn entry rate increase at T increase). It is shown that simultaneous measurements of time series of radon concentration and pressure difference between building envelope and outdoor atmosphere allow assessing such room parameter as Effective Leakage Area.

P10.74
Climatic and Seasonal Influences on Radon Time Series in an Environment of Low Anthropogenic Activity

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Between June 2003 and March 2008 (1766 days), radon concentration and ambient temperature were monitored at hourly intervals in an environmentally-stable, rarely-visited basement in a public-service building. Sampling periods totalled 1025 days, the longest continuous sampling period and interval between sampling periods being 335 and 271 days respectively.

Mean daily, monthly (calendar) and annual concentrations and temperatures were derived. For each calendar month, averages over corresponding months of at least three separate years were calculated. Similar means were generated from meteorological data collected 10 km from the measurement site. Overall mean and standard deviation (SD) radon concentrations were 73.0 Bq.m^{-3} and 62.7 Bq.m^{-3} respectively, corresponding mean and SD internal temperatures being 26.2 C and 1.7 C, respectively.

Cross-correlation confirmed mean radon concentration as essentially independent of external temperature, atmospheric pressure, wind-speed, rainfall and relative humidity, with Correlation Coefficients, R^2, all less than 0.06.

Statistically-derived Seasonal Correction Factors (SCFs) are conventionally used to convert radon concentration over a sub-year period to a notional annual mean. It is recognised that this approach is not universally valid: a recent proposal uses external temperature to derive a local SCF, assuming positive temperature-difference between a building interior and its environment.

To test this, SCFs were derived using monthly mean radon concentration, external temperature and internal-external temperature-difference, using correlation with UK SCFs to quantify goodness-of-fit. SCFs derived from external temperature provide excellent fit to UK SCFs (R^2=0.97), with internal-external temperature-difference equally well-correlated (R^2=0.91). Radon concentration is essentially non-correlated with the UK SCF set (R^2=-0.21).

Details of the experimental method and analysis will be presented, together with further observations on seasonal variability of radon concentrations.

Poster sessions C-D: Area 10

P10.75
Activity Concentration of 222Rn Measured in Drilled and Dug Well Drinking Waters and Resulting Radiation Doses to Population of Ogun State, Nigeria.

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Radon studies have been conducted in many countries of the world in indoor air but such studies in drinking waters are sparse. We present the results of ^{222}Rn activity concentration measurements in drilled and dug well drinking waters from three large cities in Ogun State, southwestern Nigeria. The measurements were done suing high-resolution high-purity germanium (HPGe) detector (Canberra Industries Inc.). Measured 222Rn ranged from 0.26±0.01 to 0.88±0.09 Bq l-1 and 0.25±0.02 to 0.72±0.10 Bq l^{-1} in the drilled wells and dug wells respectively. The activity concentrations were used with ingested dose conversion factors to estimate annual effective dose rates due to ingestion of 222Rn as a result of the consumption of water from these wells. Estimated annual effective dose rates ranged from1.32±0.11 µSv y^{-1} (in a dug well) to 4.66±0.48 µSv y^{-1} (in a drilled well); 0.49±0.04 to 1.71±0.18 µSv y^{-1} and 0.64±0.05 to 2.25±0.23 µSv y^{-1} for infants (0 – 1y), children (2 – 7y) and adults (≥ 17 y) respectively. All these values fall below the World Health Organisation (WHO) recommended limit of 0.1mSv y^{-1} for public exposure for all ages.

P10.76
Cost Effectiveness of Radon Protection in New Homes in the Newly Defined Small Radon Affected Areas

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In the UK, excessive levels of radon gas have been detected in the built environment, including domestic housing. Areas where 1% of existing homes were found to be over the Action Level of 200 Bq m^{-3} were declared to be radon-affected areas. Building Regulations have been introduced that require that new homes built in areas where between 3 and 10 % of existing houses are above the Action Level should be built with basic radon protection using a membrane, and houses in areas over 10 % should be built with full radon protection using an active system.

Initially these affected areas followed administrative boundaries, known as counties, with areas of over 500 km^2. However, with increasing number of measurements of radon levels in domestic homes recorded in the national database, these areas have been successively refined into smaller units - 5 km grid squares in 1999, down to 1 km grid squares in 2007. This, together with improved geological mapping, has led to more precise definition of radon-affected areas.

One result is the identification of small areas with raised radon levels within regions where previous analysis had not shown a problem. Some parts of areas that were considered radon affected are now considered low or no risk. However, our analysis suggests that the net result of improved mapping is to increase the number of affected houses. Further, the process is more complex for local builders, and inspectors, who need to work out whether radon protection in new homes is appropriate.

Recently, the Health Protection Agency has recommended that all new homes across the country should be built with integral radon protection - whether or not the area is radon affected - as the cost of installing a heavy duty damp-proof membrane, as a radon barrier, only introduces a modest additional cost, and some risk reduction, albeit small, is achieved wherever the house is located.

Our group has assessed the cost-effectiveness of radon remediation programmes, and has applied this analysis to consider the cost-effectiveness of providing radon protection in new homes, both in the newly defined areas, and countrywide. This includes modelling the potential failure rate of membranes, and whether testing radon levels in new homes is appropriate.

The analysis concludes that it is more cost effective to provide targeted radon protection in high radon areas, although this introduces more complexity.

P10.77
Indoor Radon Exposure in Belarus

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According to the geological data more than 40 % of territory of Belarus belongs to a category of potentially radon-prone area. Indoor radon monitoring in more than 3000 dwellings and public and industrial buildings of 400 towns and villages has been carried out. Some settlements for monitoring were randomly selected, but most part of them was chosen from radon-prone areas, determined from analysis of tectonic faults distribution and deposition depth of radon generating granitoid of the crystalic foundation. Nitrocellulose film LR-115 type II (Kodak, France) was used as SSNTD. Exposure term in indoor air was 1.5 – 3.0 months, tracks were counted using a spark method.

Distribution of volume activity (VARn) in different regions of Belarus is presented in the article. Effective doses of irradiation of population due to indoor radon is estimated. Exceeding of established standards of Belarus in studied premises in different regions of Belarus is shown in the paper.

P10.78
The Impact of improved Radon Mapping on the Cost Effectiveness of UK Domestic Radon Remediation Initiatives for Existing Housing

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In the UK, excessive levels of radon gas have been detected in the built environment, including domestic housing. Areas where 1% of existing homes were found to be over the Action Level of 200 Bq m^{-3} were declared to be radon-affected areas. Initially these areas followed administrative boundaries, known as counties, with areas of over 500 km^2. However, with increasing number of measurements of radon levels in domestic homes recorded in the national database, these areas have been successively refined into smaller units – 5km grid squares in 1999, down to 1km grid squares in 2007. This, together with improved geological mapping, has led to more precise definition of radon-affected areas, and enabled the recent implementation of an on-line system whereby householders can obtain an estimate of the radon potential for their home, and judge whether a radon measurement is advisable.

One result is the identification of small areas with raised radon levels within regions where previous analysis had not shown a problem. Some parts of areas that were considered radon affected are now considered low or no risk. However, our analysis suggests that the net result of improved mapping is to increase the number of houses which should be tested. Further, the process is more complex for local planners, and the new system introduces an additional step for the householder at a modest additional cost.

However, despite various publicity campaigns, only around 40% of house-holders in affected areas have measured radon levels, and only 10 to 15% of those finding raised radon levels have remediated their homes. The changes should ensure that more affected houses are identified, but this depends on the public response to publicity of the new affected areas.

Our group has assessed the cost-effectiveness of radon remediation programmes, and has reviewed the analysis to consider the actual and potential cost-effectiveness of the latest remediation campaigns. It is noted that the additional step will add only a marginal cost. Moreover, cost-effectiveness remains strongly dependent on the percentage of houses over the action level in an area, and on the percentage of householders who carry out remediation once they have found high levels. At current response rates, our research suggests that remediation programmes are not currently justifiable in areas where less than 5% of houses are affected. The paper makes recommendations for the development of appropriate public health initiatives.

P10.79
An Aid to the Study of the Behavior of Radon and Air Pollutants in the Atmospheric Boundary Layer

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Intensive observations of atmospheric activity concentration of ^{222}Rn, concentrations of air pollutants (NO, NO_2 and SO_2), and of the atmospheric boundary layer were carried out at Kabutonishi Town, Kasaoka City, Okayama Prefecture in Japan. Concentrations of ^{222}Rn at night were lower than those at Akawase and Uchio reported in previous papers. Smaller increases in the concentration of ^{222}Rn at night and slow decreases of the concentration of ^{222}Rn during morning calm could be clearly explained by meteorological observation including Doppler sodar. In the daytime, ^{222}Rn levels were almost the same as those at Akawase and Uchio. Although atmospheric conditions were near weak stability at night, it was possible to obtain information regarding advection using NO, NO_2 and SO_2 originating from motor vehicles. In addition, information regarding advection was obtained from observations of NO, NO_2 and SO_2 originating from factories and ships in the daytime, including a period of morning calm. These results support and supplement our opinion expressed in an earlier publication that a set of ^{222}Rn and air pollutants can provide useful information regarding local conditions of the atmospheric boundary layer.

Poster sessions C-D: Area 10

P10.80
Evaluation of Indoor Radon Level Due to High - Exposure Building Material Used in Iran

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Abstract- Indoor radon measurements in granite stones in the Iran, were carried out, by means of a high-resolution HPGe gamma-spectroscopy system and radon meter RN-20.The activity concentrations of ^{226}Ra in the selected granite samples ranged from 3.8 to 94.2 $Bqkg^{-1}$and obtained effective radon exhalation rate from calculation due to ^{226}Ra activity concentration were 1.24 - 30.71 $mBq.kg^{-1}.h^{-1}$ and direction measurement using radon meter were from 81.24 - 841.59 Bq/m^3.For standard rooms (4.0 mx5.0 m areax2.8 height) that ground has been covered from granite stones, we calculated radon concentration. The average concentrations in this molding were in the range of 1.85 - 46.07 $Bq.h^{-1}$.Maximum recommended as a reference level for radon concentration by the World Health Organization is 100 Bq m^{-3} WHO (2009).

Key words: Radon, Granite, Activity, Exhalation rate, Measurement, Molding

P10.81
Presence of a Radioactive Gas in Archeological Excavations, Determination and Mitigation

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The atmosphere of tunnels, caves and chambers in archeological sites contain a Radon radioactive gas, generated from the natural uranium content in soil. Anomalous radon levels were measured at several excavation stages, during the recent archeological discovery and excavation of the tunnel build 2,000 years ago by the Teotihuacans under the feathered serpent temple, in Mexico.

The tunnel under excavation has a semi cylindrical shape of 3 m in diameter is at 15 meters below the earth surface, with a vertical rectangular entrance of 4x4 m^2 with a probable length of 100 m. The radon concentration in soil inside the tunnel is around 5000 Bq/m^3; however, natural convection in the tunnel atmosphere reduces the maximum concentration down to 1500 Bq/m^3 if no activities produce further air turbulence.

During normal activities in the tunnel the maximum radon concentration was of the order of 700 Bq/m^3, after mitigation actions, this level was reduced down to concentrations lower than 30 Bq/m^3.

This paper presets in the detail the actions for radon remediation in this archeological site and the corresponding considerations that ensure a negligible radon risk for workers.

P10.82
Environmental Risk Assessment of Radon from Ceramic Tiles

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Radon-222 exhalation from different ceramics tiles depends upon the radium (^{226}Ra) concentration and porosity. Raw zirconium sand is one of the substances widely used in the ceramic industry and it is naturally radioactive. This can produce unjustified concern and subsequently perturb the market of these products. The radon exhalation rates for all ceramic tiles companies in the vicinity of ceramic surface were in the range 28-44 mBq.m^{-2}.h^{-1} or 2.0 to 4.8 mBq.kg^{-1} .h^{-1}. The porosity of ceramic tiles is found in the range 0.19-0.28. The assessment of radium activity of ceramic tiles was found in the range 16-38 Bq.kg^{-1} for glaze surface and 23-64 Bq.kg^{-1} for clay surface, respectively. The average equivalent dose in contact to the ceramic surface was found 22 mSv.y^{-1}. The exposure in working level in the vicinity of ceramic tile was found in the range 2.4-3.8 WL, respectively. This give risk indication to people whom spend long time in closed ceramic tiles stores to avoid staying for long time in such places.

P10.83
Aspects Of Health Defence In the Environmental Radiation Protection From Radon

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The involvement of the medical and physical aspects is very important for health defence in environmental radiation protection because the physical surveillance involves principles of safety, dose assessment, interaction of radiation with matter, etc., while medical surveillance, through medical acts of evaluation and clinical management, aims at health maintenance using occupational and environmental medical methodologies.

The authors have carried out research on the medical surveillance in fifty workers exposed to radon in water pipes of the city of Naples, with an average age of 45 and with a working experience of 20 years. The workers were subjected to spirometry, electrocardiogram and common laboratory analysis (haemachrome, blood urea, glycemia, plasma proteins, transaminase, urine). Radon 222 was measured in the underground and basement where the operators work. The exposure time was also recorded.

The clinical and laboratory data have shown that the workers' general state of health was good where working conditions respected the safety norms in accordance with radioprotection legislation.

With reference to the risk of radon and natural radioactivity in the home and work environment, the authors maintain that the people exposed should participate in the programmes of formation and information also with specific questionnaires about the physical characteristics of the sites inclusive of anamnesis : family medical history, lifestyle (physical activity, sport, smoking and drinking habits, diet, use of drugs or medicines), exposure to toxins, viruses or non-ionising radiation, risk perception, subjective health and psycho-physical condition. The anamnesis must include the particularly typology of the ground, destination of the rooms, airing, type of stay, microclimate and thermal comfort. Finally, it is important to ensure that all exposed workers undergo epidemiological surveillance including medical and physical data.

Poster sessions C-D: Area 10

P10.84
The mesurment of radon in the environment: publication of a new ISO standard

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Radon is considered as the main source of exposure of the public to radiation contributing up to 52% of the total natural internal dose. Due to the universal presence of radon in the environment, the radiological exposure of the public is assessed based on radon activity concentration in the various environmental compartments. The credibility of such assessment relies on the quality and reliability of radon measurement data including the sample representativity of the radiological conditions. The recent expansion from national stakeholders to a regional and world wide perspective requires that the activity concentrations result obtained on environmental samples in a state are reliable and reproducible to be compared to similar data from any other parts of the world. The standard-setting approach, based on mature test method reviewed by international experts in the field, seemed to lend itself to a settlement of technical aspects of potential comparison.

In 2007, the members of the ISO Technical Committtle 85 on Nuclear energy, nuclear technologies, and radiological protection agreed that the drafting of a standard on the measurement of the activity concentration of radon-222 and its short-lived decay products in the atmosphere (ISO 11665) was of global relevance and appropriate to the relevant sectors and stakeholders. Published in 2012, this standard gives the general guidelines for sampling and describes the test methods needed for laboratories responsible in charge of the monitoring of radon in indoor and outdoor environments. ISO 11665 is organized in ten parts, among which:

- five parts deal with test methods of indoor and outdoor radon activity concentration or potential alpha energy concentration of short-lived radon decay products (ISO 11665 parts 2 to 6);

- three application standards deal with radon release from soil, rock, building interface, building materials into the atmosphere (ISO 11665 parts 7, 9 and 10);

Following the recommendations of the World Health Organisation on the need of standardized indoor radon protocols to ensure accurate and consistent measurements, part 8 was drafted to deal with risk management in buildings. This part covers the applicable requirements to determine the annual average activity concentration of radon in a building and to identify the source and transfer pathways of the radon in this building. These requirements apply also to the effectiveness control and the sustainability of remedial actions.

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P10.85
Low Energy Construction, Ventilation Strategies and Indoor Radon

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Low energy and passive house construction practices are characterized by increased insulation, high tightness of the building shell and controlled mechanical ventilation with heat recovery. This goal, regarding airtightness of foundation, is synergetic with the aims of radon prevention in new construction. The key question in prevention of radon entry from soil into living spaces is the prevention of air leakages in the foundation. In order to be able to control the ventilation and the corresponding heat flows in low energy buildings the building shell should be air tight. On the other hand, as an interaction of mechanical ventilation and high air tightness of the building the underpressure in the building can be remarkably enhanced. In the case there are leakage paths in the foundation, this leads to increased air leakage from soil and consequently to increased indoor radon levels. This new situation is a challenge for construction of air tight foundation. The control of air flows and pressure differences needs also special attention. Indoor radon and pressure difference measurements confirm theoretical assessments

P10.86
A Novel Estimation of the Exposure of the Population of Israel to Natural Sources of Ionizing Radiation

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The goal of this study was to assess the average effective dose from natural sources to the population of Israel as well as its distribution, taking into account the local and unique living characteristics.

The building industry in Israel has a few distinctive properties: almost all buildings are made of concrete or concrete blocks and since 1985 fly ash (in which the concentration of radioactive materials is higher than in other building materials) has been gradually added to cement and concrete. Another characteristic of buildings built since the early 1990's is a shielded area built in every apartment that is known as a DSS (Dwelling Shielded Space). The DSS is a room built from thick concrete walls and ceiling that can be hermetically sealed and is intended to protect its residents from a missile attack. In many apartments the DSS is used as a bedroom. Account was also taken of the building type: 15% of the households live in single-family houses, while 85% dwell in multistory buildings.

In order to assess the average indoor radon concentration and its distribution, results of a 2006 radon survey in single-family houses were incorporated with results from a new radon survey in multistory buildings. Both surveys included long-term measurements using CR-39 SSNTDs. The survey in multistory buildings assessed the influence of the fly ash addition and the DSS on the radon concentration by dividing the dwellings into two groups: buildings older than 20 years, built before fly ash was added and without a DSS and buildings newer than 10 years, built with fly ash and with a DSS. Another feature that could cause higher radon concentrations inside new buildings is the better sealing of doors and windows in new building techniques.

It was found that the average radon concentration in new buildings was significantly higher than in old buildings.

Doses were estimated from indoor radon concentrations on the basis of the updated information included in the 2009 ICRP Statement on Radon.

In addition, external exposure due to the presence of natural radionuclides in the ground and in building materials with different fly ash contents (according to the age of the building) was estimated. Internal exposure due to food and water consumption was also assessed.

Finally, the distribution of the annual dose to the population of Israel from cosmic radiation was assessed, taking into account the elevation above sea level of the different cities and towns.

P10.87
Exposure to Radon from Concrete with Fly Ash: a Proposed Model, In-Situ and Laboratory Measurements.

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Recycled industrial by-products containing high concentrations of Natural Occurring Radioactive Materials (NORM) are extensively used in the construction industry. The average ^{226}Ra, ^{232}Th and ^{40}K activity concentration in the fly ash (FA) produced at power plants in Israel is 150, 130 and 300 Bq/kg respectively. The major use of FA in Israel is its addition to cement and to concrete which may increase the activity concentration in the building product.

The increase of ^{226}Ra activity concentration, the mineralogical characteristics of the FA and of the concrete may influence on the radon exhalation rate and consequently on the radon exposure of the public.

This paper present a study conducted to investigate and quantify that influence. Concrete samples containing different concentrations of FA (0 to 150 kg/m^3 of concrete) were prepared both in the laboratory and at the building site, reflecting controlled and common production processes. Their free radon exhalation rate and the emanation coefficient tend to decrease in concrete containing FA.

Dwelling Shielded Spaces (DSS) are rooms made of massive solid concrete, equipped with air-tight steel door and window. The free wall exhalation rate was determined under sealed conditions and under normal living conditions. No significant changes in the free exhalation rate from the wall were found for concrete with or without FA.

The ventilation rate for several living and sealed conditions at DSS were determined. At sealed conditions the average air exchange rate is lower than 0.007 per hour while for normal living condition the average ventilation rate is higher than 1 per hour.

Short term radon concentration at sealed and normal living conditions and the annual average radon concentration were predicted using a mathematical model based on the radon transport from the building product surface into the room. The annual average radon concentration from the building materials in a DSS is estimated to be 40 Bq/m^3.

Poster sessions C-D: Area 10

P10.88
Living in an excavated housing. Relationship between typological features and indoor radon in underground dwellings. Creville

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Traditional architecture has been forgotten or underestimated for many years but there is no doubt that underground housing is a phenomenon of unquestionable interest to study even more in the difficult economic situation we are living nowadays.

Although excavated dwellings can be a part of the global human living experience by using natural conditions through simple architectural proposals based on ground inertia, the truth is that this type of constructions may develop certain problems related to radon gas because of the dependence between the existing soil conditions in the constructive location and the concentration of radon in indoor spaces. Thus, it seams necessary to analyze the influence of radon in this type of cave-houses, due to their specific constructive features and their connection to the land as underground spaces in direct contact with the ground.

The aim of this paper is to show the living conditions of different tipologies of excavated housing in the underground dwellings of Crevillente (Spain) and to analyze the relationship between their typological features and environmental conditions with the existence of radon gas, as well as their sources and recommended levels. These underground housing propose different modes to deal with the territory but also allow us to study the most adverse exposure situation related to the existence of radon in traditional underground architecture and to analyze the connection between natural radioactivity in the interior of this kind of buildings, their sources and influences.

KEYWORDS underground housing, indoor radon, buried typology.

Poster sessions C-D: Area 11

P11.01
Man-made Radionuclides in the Soil and Vegetation Covering Nearby the Site for SNF and RW Temporary Storage on Kola Peninsula

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When studying the current radiation conditions of the soil and vegetation covering nearby the STS of SNF and RW in Andreeva Bay over 2009-2010, radiation ecological monitoring was used as the methodical basis. The findings of such monitoring helped to characterize the radiation ecological conditions of such environmental media as soil, vegetations, berries and lichens.

Types of soil typical for the Health Protection Zone (HPZ) and Supervision Area (SA) of the STS have been determined. For the vegetation, berries and lichens, edificatory species and -dominant species forming the vegetation covering of HPZ and SA have been identified.

Radiation ecological monitoring of the soil covering showed that the closer places of the RW storage, the higher the radionuclide concentrations in soil. ^{137}Cs and ^{90}Sr activities varied from 24.05 and 2.73 Bq/kg in SA, respectively, up to 160482.57 and 23960.32 Bq/kg in CA, respectively. ^{60}Co presence is typical only for the CA soils.

In CA, the motley grass and Chamaenerium angustifolium are the most representative types in terms of man-made radionuclide contents. ^{60}Co presence is typical only for Empetrum nigrum. In RSA, maximum ^{137}Cs activities are typical for Empetrum nigrum and Cornus suecica, while ^{90}Sr is typical for different types of mosses. In uncontrolled area (UA) and SA, radionuclide contents are very low and comply with the background values typical for this region. Concentration of man-made radionuclides in berries both in RSA and in SA is many times lower than the current Russian norms. ^{60}Co presence is typical for lichens, and representatives of Cladonia species can accumulate radionuclides more intensively than Peltigera aphthosa.

Accumulation of man-made radionuclides by the soil vegetation covering of the supervision area is very low, therefore, we can conclude that the industrial site of the STS does not affect the SA.

Having in mind potential further contamination of the STS area, the dynamic survey of the radiation situation is necessary both during the routine operation and at the stage of SNF and RW removal.

P11.02
Radio-Ecological Regulations for Remediation of the Sites for Temporary Storage of the Spent Nuclear Fuel and Radioactive Waste

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Analysis of radiation and hygienic situation taking the obtained findings into account permits to conclude that after removal of the spent nuclear fuel from the sites for temporary storage (STS), hard and long-term remedial work will be required. Having in mind up-to-date approaches to radiation safety assurance when developing the remediation scenarios, the main attention was focused on justification of the residue contamination-induced dose constraints for workers and for the public. Four principal options of remediation of the sites for temporary storage have been considered: renovation, conversion, conservation and liquidation. The basic and derived quantitative radiation and hygienic criteria have been stated for each option.

The paper gives the system of the recommended values of dose constraints and reference levels. The principal criterion to reach the goals of the radio-ecological remediation of the STS is non-exceeding of the established dose constraints and reference levels induced by the residual contamination. Reducing dose below the proposed values of dose constraints shall be performed in compliance with the optimization principle. The criteria developed relate to the conditions of the facilities and the STS area after termination of their radio-ecological remediation, however, these criteria can be also used at the interim stages of remediation conduction, depending upon the remediation option selected.

P11.03
The Common Reed Seeds' Viability From Water-Bodies With Different Levels of Radioactive Contamination

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Radioecological situation in Ukraine after Chernobyl disaster, occurred in 1986, remains still complicated. It requires systematic and long-time monitoring of ionizing radiation effects and analysis of biological characteristics of living organisms in conditions of long-term ionizing radiation impact. Aquatic-plant communities constitute significant part of fresh-water ecosystems suffering from radionuclides intake. Early ontogenesis is one of life-cycle periods, most vulnerable to ionizing radiation exposure, therefore it is important to investigate radiation disorders of seeds germination and germs growth. Seeds of the common reed (Phragmites australis (Trin) Ex. Steud) of 2009 vegetation year were sampled from closed and weakly-flowing polygon water bodies within the Chernobyl exclusion zone. For comparison seeds were sampled from Verbne Lake and Kyiv Reservoir, water bodies with background level of radionuclide contamination. Total absorbed dose rate for plants was calculated with the dose conversion coefficients (DCC) use, taking into account dose rate from incorporated radionuclides and external sources. Liveability indexes and abnormalities of different types were investigated in laboratorial conditions. Correlation between total absorbed dose rate and abnormalities of different types was calculated. Total absorbed dose rate varied in range 0.03-12.0 cGy/year. In polygon water bodies calculated liveability indexes: germinating ability (60-73 %), germinating energy (31-57 %) and survivability (38-53 %), significantly differed from ones in water bodies with background level of radionuclide contamination (83-93, 87-91, 48-54 correspondingly). High total percent of germs abnormalities in the most radioactive contaminated water bodies of Chernobyl exclusion zone (49-69 %) relatively to water bodies with background level of radionuclide contamination (8-14 %) was determined. Correlation dependence between total absorbed dose rate and abnormalities: root necroses ($r = 0.535$), ontogenesis disturbances ($r = 0.532$) and geotropism disturbances ($r = 0.907$), was defined. Thus, vitality of seed progeny of the common reed, growing in conditions of long-term ionizing radiation impact in water bodies of the Chernobyl exclusion zone, reduces with the increase of total absorbed dose rate. The common reed is wide-spread species in the reservoirs of different types, and also enough sensible and convenient object of radiation monitoring of aquatic ecosystems under impact of nuclear fuel cycle enterprises. This species can be used as one of the reference hydrobionts at development of fundamentals of the protection of the environment from ionising radiation with use of the standard based on non-human biota.

P11.04
Long-Term Effects of the Low-Level Radiation Exposure on Aquatic Biota within the Chernobyl Exclusion Zone

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Analysis of effects of long-term irradiation on non-human biota, inhabiting the radioactive contaminated territories, has importance for ecological hazard understanding, associated with changing of environment due to human activity. Due to slow water cycle, lakes are the relatively closed systems allowing with a minimum uncertainty to estimate general balance of energy and matter in ecosystem and also to analyze the dynamics of biogeochemical processes and their influence on radionuclide distribution and migration in the conditions of changing biotic and abiotic factors. This determines one of key values for freshwater radioecology of researches of lake ecosystems, located within radioactive contaminated territories, as areas of accumulation of the main long-lived, technogenic radionuclides, areas of the enhanced chronic dose rate on aquatic biota, and also areas of high probability of radiation effects realization. Our investigations were carried out during 1998-2010 in lakes with different levels of radioactive contamination within the Chernobyl accident exclusion zone. The absorbed dose rate registered in range from 1.3 mGy/year to 3.4 Gy/year. The highest rate was found in lakes within dammed flood land territory of the Pripyat River. The rate of chromosome aberration for snails' embryo from the control lakes was about 1.1-2.0%. About 3.3 and 5.7% of aberrant cells was registered in snail's embryo from the rivers of the exclusion zone. The highest rate of aberration was found in snails from lakes within the dammed territory on the left-bank flood lands of the Pripyat River - 21-23%. In the embryo of snails from some others closed water bodies registered in range 18-20%. The highest chromosome aberrations rate in root meristem of higher aquatic plants (17.8-10.8%) were registered in lakes within the left-bank flood lands of the Pripyat River, the lowest one (4.5-2.2%) - in plants from the river ecosystems. During period of sudies a tendency to decrease of chromosome aberration level in molluscs from all lakes of the exclusion zone was registered. The probabilistic prediction of the chromosome aberration rate for gastropod snails in lakes of the Chernobyl exclusion zone have shown that spontaneous mutagenesis level (2.0-2.5%) can be reach in Azbuchin Lake and Yanozsky Crawl in 2020s-2030s and in Dalekoye-1 Lake and Glubokoye Lake - in 2060s-2070s. In hemolymph of snails from Dalekoye-1 Lake, Azbuchin Lake and Glubokoye Lake the quantity of death cells averages 36.2%, 39.2% and 43.8% respectively, the part of phagocytic cells averages 44.3%, 41.2% and 45.0%, as well as decrease of the young amoebocytes quantity to 13.2%, 20.1% and 9.5% respectively. The insignificant quantity of abnormal cells and micronuclei has been observed as well. In the control lakes the part of death cells averages from 2.2 to 5.3% and the quantity of phagocytic was at level 3.0-4.2%. The quantity of young amoebocytes has increased here to 79.7-89.6%.

P11.05
High Natural Background Radiation Areas and Interaction between Nature, Scientists and Public

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High natural background radiation areas (HNBRAS) are defined as areas where that annual effective dose to the public is above a defined level such as annual dose limit. The most studied HNBRAS in Iran, Brazil, India and China are investigated in many fields of health, biology, radiobiology, epidemiology and psychology. From these scientific issues in HNBRAS there are many challenges between nature , scientists and people who live in those areas that can be affect on policy making and the life styles. We can summarize these challenges in three categories: Scientific issues, Environmental issues and Public issues: Scientific issues: scientists who work on these areas try to find how high radiation is not harmful and what is the mechanism of radiobiologic adaptation of human and non-human species to natural radiation. So, in some countries HNBRAS have become centers for many studies and scientists think these areas are their personal laboratories and nature and people also are the free materials and methods. Also, their studies and publications caused that radiation protection rules and LNT assumption for medical based radiation protection is ignored and some conservative man think how to reduce the radiation protection and shielding equipment.

Environmental issues: high natural background radiation is a part of life and is not a waste that must be disposed carefully or a crisis that must be managed quickly. So, excessive studies on HNBRAS are sometimes cost and time consuming. Also some scientists believe those works are interventions in nature or in other words, are not green. Hence, environmental protection agencies try to oppose to some scientific works in these areas.

Public issues: people of a community are the main center of all challenges so that policy making is related to public risk perception and risk communication. So, any abnormal behavior can cause irreversible social damage. People who live in HNBRAS have been free materials in many useless studies and sometimes these studies have had adverse effects on social and their personal life. However, some people think they are patients whereas they are normal and they have no differences with other people in low natural background radiation areas.

Keywords: HNBRAS, Nature, Scientists, Public

Poster sessions C-D: Area 11

P11.06
Structure Of The Cell Wall Of Mango After Application Of Ionizing Radiation

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Cells of the mesocarp of mango cultivar Tommy Atkins were analyzed by Transmission Electron Microscope -TEM to evaluate the effects of doses of 0.5 and 1.0 kGy applied immediately after the fruit and after storage for twenty days at a temperature of 12 °C followed by five days of simulated marketing at a temperature of 21 °C. No change was found in the structure of the cell wall, middle lamella and plasma membrane of fruits when analyzed immediately after application of doses. Mesocarp cells have undergone changes in the structure of the cell wall, middle lamella and the plasma membrane after storage. Fruits that received a dose of 0.5 kGy showed slight changes in cell wall structure and disintegration of the middle lamella. Fruits that received a dose of 1.0 kGy had greater changes in the structure of the cell wall, middle lamella degradation and displacement of the plasma membrane.

Keywords: Cell wall; mango; storage; ionizing radiation.

P11.07
An Anthropocentric View Cannot be used to Achieve Radioprotection of Biodiversity

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For more than a decade, work by various groups and institutions has been done to try to harmonize radioprotection of biota (biodiversity) with radioprotection of Man. In order to achieve this goal, *"Reference animals and plants"* - RAPs (bee, duck, frog, pine tree, rat etc) have been developed by ICRP in 2008. These RAPs are "standardized species" to be used for monitoring population effects of exposure to ionizing radiation.

The intended strategy is to measure effects on individuals and from there draw conclusions regarding effects on a population level. Attention needs, however, to be drawn to the character of the RAP. It is a parallel to *Reference Man* (ICRP 23) and thus a static "average" individual without population features. In other words, as opposed to processes relating to real species adapting along with a changing external environment (an ecocentric dynamic perspective), the RAP represents "the present" - not the future. In addition, what is bad in the evolutionary sense (flexibility and sustainability) for the individual is often beneficial for the population (the species). For instance, if your siblings die, you get more food and space and therefore your own chance for transferring your genes to the next generation increases.

To summarize, the RAP, represents the individual (ego) and static perspective. This parallels to a large extent the present framework for radiation protection of humans - an anthropocentric perspective. However, protection should be about long-term sustainability and have an ecocentric perspective. It is time to analyze the radically different consequences of using either one of these two perspectives. While the anthropocentric perspective has its good points, it is not relevant for an ecocentric perspective.

P11.08
Investigation of Specific Local Ecosystem Arised on the Tenorm Slag and Ashes

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Precautionary principle is explicitly laid down in the EU treaty and is one of the starting points of its environmental policy. European Commission made a statement [1] in February 2000 regarding the use of precautionary principle indicating that principle should be applied where there is a reasonable suspicion of the existence of a health or environmental risk. Furthermore, the Commission indicates that measures based on the precautionary principle should not be aimed at completely precluding any risk; it assumes that such an effort is unrealistic. Decades of industrialization and extensive exploitation of natural resources have left certain number of areas in the country heavily polluted. It is essential that old environmental burdens left behind by past state-controlled industry be addressed: problems that were once (theoretically) the governments have now been transferred over to new owners, in most cases without clear specification of environmental responsibility. Old environmental contaminated industrial sites often represent a serious risk for humans who live in or near the polluted/contaminated areas, because of either their direct negative impact on the human health or, indirectly, through pollutants in the food chain production. One of the measures based on the precautionary principle is hazard characterization of the site enabling the acceptable remediation program to be laid down. The site of interest was heavily polluted with coal sludge and fly ash originating from a local industrial power plant. Coal burned had high content of NORM. The precipitation tailing dam was constructed direct at the sea costal line separated from the direct sea water influence with the simple but firm stone made wall preventing the precipitated sludge the direct impact with the sea water. Around seven years after the last amount of sludge was pumped to be precipitated in the tailing dam the radiological characterization due the assumed high TENORM content of the sludge was initiated in order to collect the comprehensive radiological data for the remediation program of the whole chemical industrial site. The plant was closed. No human activities were performed nearby the tailing dam and the site was during this period left on its own. The totally independent micro ecological terrestrial system was generated on the precipitation tailing surface. The biota (flora) developed on the ground consisting only of the TENORM coal sludge and ash was a research challenge in order to acquire as many as possible relevant radiological data about biota behavior while populating the site, growing and feeding itself exclusively with the nutrients incorporated in TENOM sludge and fallout. The impact of the terrestrial flourishing biota with the sea water life immediately at the coastal tailing dam protecting wall is investigated too. The project is in progress and some of the preliminary radiological data on biota developed are presented. Research is targeted towards the knowledge collection about the local Meditteranean biodiversity and micro biota systems which can be used during the remediation processes of this specific TENORM polluted site. The results are expected to be helpful while investigating the technological attributes of coal sludge and ash TENORM to be reused in other products despite of its enhanced natural radioactivity burden.

[1]Commission of the European Communities. Communication from the Commission on the precautionary principle. Brussels: Commission of the European Communities, 2000; (publication nr COM(2000)1).

P11.09
Study on the Bioaccumulation of 210Po in the Biota of Pondicherry, South East Coast of India

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The distribution and bioaccumulation of ^{210}Po a natural radionuclide in Pondicherry coastal ecosystem (East Coast of India) has been analyzed in water, sediment and biota (Fish, Prawn, Crab, and Bivalve). ^{210}Po measurement in environment matrices assumes importance because of its toxic to living system and it is accumulated firmly by organism and magnified via food chain (Cherry & Shannon, 1974). The activity concentration of ^{210}Po in water, sediment is 3.0 ± 0.3 mBq/L, 3.05 ± 0.4 Bq/Kg respectively. Among fourteen species of sea food organisms analyzed the bivalve mollusc (*Perna viridis*) registered the maximum activity of 131.28 ± 6.12 Bq/kg. High activity registered organism was subjected to further analysis of ^{210}Po in the internal system ie. Digestive gland, Foot, Gill, Mantle. It evidenced that digestive system registered high activity of 58.2 ± 2.1 Bq/Kg. To understand the impact of ^{210}Po at the cellular level the high activity registered organisms internal systems were subjected to histological studies, which show distinct high level of alterations in the cells of digestive gland and the gills. From the study it is understand that sedentary organisms accumulate higher level of ^{210}Po, and high activity result to increase the damage at the cellular level. Present study provides the scientific information on the behavior of ^{210} Po in the coastal environment, which is valuable impact for the scientists and policy maker.

P11.10
Biological Effects of a 25-Year Low-Dose Chronic Exposure on Higher Aquatic Plants of the Chernobyl Exclusion Zone

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As a result of 1986's Chernobyl accident a huge, primarily populated agricultural areas and wetlands on the north of Ukraine where transformed into unique sites (now the Exclusion zone) for radiobiological and other studies. During past 25 years after accident, the Ukrainian population to some extent accustomed to the potential radiation hazards and learned to live with its consequences. In recent years, more and more support at government level has arrived at a solution to revise the status of the contaminated territories, the possibility of settlement and agricultural use. However, this decision can only based on careful analysis of complex studies on radiation effects received in the post-accident period. Our research of higher aquatic plants from water-bodies of the Exclusion zone focuses on the evaluation of the mutagenic hazards of aquatic environment contaminated with radionuclides. The highest rate of chromosome aberrations (up to 22% in root meristem) was registered for the first years of studies. The power law dose dependence for the frequency of chromosome aberrations was determined. The last few years we have seen a downward trend for the chromosome aberrations rate (up to 5-11%). A shift of the chromosome abnormalities spectrum in the direction of multiplied and by reducing the part of single fragments was detected. During the observation period, the number of aberrations per aberrant cell has increased from 1.1 to 1.9 for all 13 species of plant from three different ecology groups. A significant reduction in reproduction ability of one of the dominant species from littoral cenosis directly correlated with absorbed dose rate. The appearance of a large variety of abnormalities in the germinating seeds of this species on the background of variation in seed germination rate from depression to stimulation is noted. It was defined for plants from the most radioactive contaminated water-bodies (absorbed dose up to 5.12 cGy year^{-1}), the decreasing of parasite resistance, for example to fungi actinomycetes and gall mite. Thus, despite the fact that radioactive contamination of the Exclusion zone did not result in any significant negative impacts on plant species diversity, it is obvious a manifestations of the reactions, indicating the presence of radiation impact. The cytogenetic effects resulting of genome instability, mutations and decreased fertility has a significant importance. Primarily, this is due to cumulative radiobiological processes during many generations and suggesting the possibility of incomplete implementation of long-term effects of chronic exposure at this moment. Just because these phenomena against the background of the apparent cenosis prosperity can pose a real threat of negative consequences manifestation in the future, and should be considered when making decisions about changing the status of the contaminated areas and their possible agricultural use.

P11.11
Comprehensive Assessment Of Ecosystems Conditions Of Reservoirs With A Different Levels Of Radioactive Contamination

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Urals Research Center for Radiation Medicine in collaboration with Central Research Laboratory Mayk Production Association, since 2007, carry out complex ecological researches of ecosystems of reservoirs for liquid radioactive waist storage R-11, R-10, R-4, R-17, R-9 and comparison reservoirs – the Shershnyovsky reservoir. Annually complex ecological researches included carrying out of hydrochemical, radioecological, hydrobiological works. The condition of biocenosis is estimated on indicators of all primary ecological groups of hydrobionts: bacterial plankton, phytoplankton, macrophytes, zooplankton, zoobenthos and ichthyofauna. Besides, biotesting of water and bottom deposits, definition of radiosensitivity of cultures of the hydrobionts allocated from investigated reservoirs, an estimation genotoxic effects at fishes were made. The carried out researches have shown that ecosystems of the Shershnyovsky reservoir and reservoir R-11 (the average content in water ^{90}Sr – 1,3 x 10^3 Bq/l, ^{137}Cs – 3 Bq/l) are typical for reservoirs of South Ural. In reservoir R-10 (the average content in water ^{90}Sr – 3,3 x 10^3 Bq/l, ^{137}Cs - 37 Bq/l) and reservoir R-4 (the average content in water ^{90}Sr – 4,9 x 10^3 Bq/l, ^{137}Cs - 490 Bq/l) were registered decrease in a specific variety of a zooplankton and a zoobenthos though ecosystems of these reservoirs kept functional integrity. In reservoir R-17 (the average content in water ^{90}Sr – 1,3 x 10^5 Bq/l, ^{137}Cs – 3,6 x 10^4 Bq/l, total activity alpha-radiating radionuclides – 43 Bq/l) and in reservoir R-9 (the average content in water ^{90}Sr – 1,2 x 10^7 Bq/l, ^{137}Cs – 6,7 x 106 Bq/l, total activity alpha-radiating radionuclides – 3 x 10^3 Bq/l) were registered signs of ecological regress of ecosystems which were expressed in decrease in a specific variety of a phytoplankton, zooplankton, zoobenthos and macrophytes (ichthyofauna is absent). Thus the biocenosis of reservoir R-9 has been reduced practically to phytoplankton and zooplankton monocultures. Cytogenetic researches have shown that radiating influence on fishes with dose rate 27 μGy/hour and above leads to increase of frequency of micronuclei in erythrocytes of peripheral blood. At an estimation of radiosensitivity of cultures of the green algae (*Chlorophyta*) allocated from reservoirs R-17 and R-4, increase of radioresistance of a phytoplankton in comparison with culture from the Shershnyovsky reservoir is revealed.

P11.12
Transfer of wet deposited radiocaesium and radiostrontium in Brássica napus L. and Tríticum aestívum L.

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This research project sought to determine how depositing radionuclides in a growing crop stand influences the concentration in the edible plant parts, and the degree to which this influence is dependent on development stage, weather, and length of the time period prior to harvest. There is a limited amount of information available regarding how the deposited amount and time of deposition on growing crops influences the concentration in harvested products. By using the data from the deposition trial, it is possible to calculate transfer factors for the two radioisotopes to edible plant parts (seeds and grains) and also to calculate the concentrations of the two radioisotopes to the final food products (rape oil and wheat flour).

The study, which was conducted at an agricultural field at Ultuna, Sweden during the summers of 2010 and 2011, analyzed the concentration of wet deposited ^{134}Cs and ^{85}Sr in seeds and grains on spring oilseed rape (*Brassíca napus L.*) and spring wheat (*Tríticum aestívum L.*). The radionuclides, ^{134}Cs and ^{85}Sr , were deposited at six different growth stages using simulated rainfall. LAI was measured with a LAI 2000 device. Biomass samples were dried and weighted and radioactivity was measured with High-Purity Germanium (HPGe) detectors.

The results revealed that the highest concentration of ^{134}Cs and ^{85}Sr in the oilseed rape seeds at harvest occurred after deposition in the "beginning of ripening" growth stage. The relative concentration of ^{134}Cs in seeds at harvest was found to be greater than it was for ^{85}Sr after a deposit at this growth stage. For the grains on spring wheat, the highest concentration of ^{134}Cs at harvest occurred after depositing at the "ripening (dough ripeness)" growth stage; for ^{85}Sr , this occurred at the "ripening (ripe for cutting, straw dead)" growth stage.

In both crops, the transfer of ^{134}Cs was generally higher than for ^{85}Sr . This can be explained by the differences in movability between the two radionuclides inside the plant; specifically, caesium is more movable than strontium. The transfer was higher for both radionuclides in spring wheat grains than in spring oilseed rape seeds for deposits at the later growing stages.

In a well-developed stand, the majority of deposited radionuclides are intercepted and taken up directly by the leaves. The concentration in the seed and grain is a combined effect that involves the total level of radionuclides intercepted by the entire plant and translocation within the plant.

P11.14
Combined Action of Radiation and Mercury on DNA Damage and Repair in Coelomocytes of Earthworms

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The presence of chemicals including natural and man-made radioactive materials can affect biological objects. Many reports indicate the genotoxic potential of mercury and its compounds in a variety of organisms. Ionizing radiation can damage DNA through a series of molecular events depending on the radiation energy. The combined action of ionizing radiation with another harmful factor like mercury is hard to predict in advance. International Commission on Radiological Protection (ICRP) requires the effect data of ionizing radiation on non-human biota for the radiological protection of the environment. Based on their radioecological properties and their important role in the soil ecosystem, earthworms have been identified by the ICRP as one of the reference animals to be used in environmental radiation protection. The influence of ionizing radiation on the earthworms (Eisenia fetida) is determined by the sensitive radiation-associated end points such as reproduction, growth and survival. This study was designed to investigate the acute genotoxic effects of ionizing radiation or combined action of radiation with mercury chloride. The levels of DNA damage and the repair kinetics were assessed in the coelomocytes of E. fetida exposed to ionizing radiation from 0 to 50 Gy alone or after pretreatment of mercury chloride from 0 to 160 mg/kg. The Olive tail moments (OTMs) were measured during 0 ~ 12 hours after irradiation. The results showed that the increase in DNA damage was depending on the dose of radiation. The more the oxidative stress was introduced by irradiation, the longer the repair time was required. When exposed to ionizing radiation after pretreatment of mercury chloride, the OTMs were much higher than those exposed to radiation alone. The results indicated that genotoxic effects increased due to the combined action of radiation with mercury. The repair time in the animals treated with the combination of mercury chloride and radiation was nearly eight times longer than that in the animals treated with ionizing radiation alone. This study confirmed that mercury ions gave an inhibitory effect on the repair process of radiation-induced DNA damage.

P11.15
Determination of 238U, 232Th and 40K in Zircon Sand Products from a Processing Plant in Brazil

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The presence of natural radionuclides from the thorium and uranium series in beach sands is a well-recognized fact. The radioactivity is normally attributed to the presence of zirconium along with other heavy minerals such as kyanite, ilmenite and rutile (density 2.9 g.cm^{-3}). Potassium-40 is another important radionuclide found in beach sands, although in concentrations relatively lower than the ones derived from the progeny of the uranium and thorium series. Zircon sands may contain a significant concentration of natural radioactivity, because thorium and uranium may substitute zirconium in the zircon crystal lattice. Processing of ores containing small amounts of natural radionuclides by the industry may enhance the activity concentration in the products forming the so-called TENORM (Technologically Enhanced Naturally Occurring Radioactive Materials). This work was carried out aiming to determine the ^{238}U, ^{232}Th and ^{40}K contents of the mineral products extracted from the sands processed by an industry located in northeast Brazil, with emphasis on zircon. Measurements were performed through gamma spectrometry, by using a high purity germanium detector (HPGe) coupled to a multichannel analyzer. The results obtained by this technique were compared with the ones obtained (for ^{238}U and ^{232}Th) by alpha spectrometry by means of a surface barrier detector. Activity concentrations in zircon sands ranged from 5.46 ± 0.14 to 19.29 ± 0.46 and from 1.01 ± 0.07 to 7.16 ± 0.04, for ^{238}U and ^{232}Th, respectively.

P11.16
Measuring U-238 and U-235 Decay Products By the Spectrometer PRIPYAT-2M

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The PRIPYAT-2M gamma-ray coincidence spectrometer, with six NaI(Tl) detectors, registration geometry close to 4π and large detection chamber, allows development of coincidence methods which have shown some benefits (measurement time shorter for an order of magnitude, no additional sample preparation, relatively high detection efficiency and a good sensitivity) compared to the methods of measurements where one-detector spectrometers are used. Although there are 18 and 15 descendants in the series of ^{238}U and ^{235}U, respectively, only a few of them emit γ-rays which can be used for easy detection in γ-spectrometry. The γ-rays usually being used in gamma spectrometry for ^{238}U activity measurements are: γ-rays which follow β--decays of ^{214}Pb to ^{214}Bi (Eγ = 351.932 keV, Iγ = 37.6 %; Eγ = 295.224 keV, Iγ = 19.3 %), and ^{214}Bi to ^{214}Po (Eγ = 609.312 keV, Iγ = 46.1 %; Eγ = 1764.494 keV, Iγ = 15.4 %; Eγ = 1120.287 keV, Iγ = 15.1 %), as well as γ-rays which follow β--decay ^{234}Th to ^{234m}Pa. For example, detection efficiency of the 609 keV photopeak in the double coincidences mode of counting of the PRIPYAT-2M spectrometer was found to be 0.103, with minimum detectable activity of 0.9 Bq for 500 s real measuring time. The activity measurements of ^{235}U and its descendants are usually performed by detecting γ-rays which follow -decay of ^{235}U to ^{231}Th (Eγ = 185.71 keV, Iγ = 57.2 %; Eγ = 143.764 keV, Iγ = 10.96 %; Eγ = 163.358 keV, Iγ = 5.08 %). However (because of energy below 200 keV) they are not suitable for detection with spectrometer PRIPYAT-2M, and it is necessary to use the other gamma lines for detection and activity measurements of ^{235}U and its descendants. Therefore, a possibility of detecting the other radionuclides in uranium decay series by the multidetector coincidence spectrometer PRIPYAT-2M has been tested.

P11.17
Radiocesium in Mycorrizhal Macro Fungi in Finnish Lapland in 1980-2011

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Radiation and Nuclear Safety Authority has monitored radioactivity concentrations in mycorrizal macro fungi at the Kivalo research area in the southern part of Northern Finland since early 1980's. In this study statistical values of radiocesium activity concentrations were calculated and ecological half-lives in fungal species estimated. The aim of this study was to explore changes in ^{137}Cs concentrations with time in various fungal species growing in different habitats. Fungal species of *Suillus variegatus, Lactarius rufus, Lactarius vietus, Russula decolorans, Russula paludosa, Russula xerampelina, Russula vinosa, Cortinarius armillatus* and *Rozites caperatus* were collected in pine, spruce, birch and mixed stands and activities of gamma-ray emitting radionuclides in these samples were measured. The most common types of fungal species in pine forest were *Suillus variegatus* and *Lactarius rufus*. In the studied period from 1980 to 2011 the ^{137}Cs concentration in Suillus variegatus decreased from 3000 to 1000 Bg/kg d.w. and in Lactarius rufus from 2500 to 250 Bg/kg d.w.. The ^{137}Cs concentration in the most common fungi in spruce stand, Russula decolorans and Russula paludosa, decreased from 1000 to 500 Bg/kg d.w, and in the most common species in birch stand, *Russula xerampelina* and *Cortinarius armillatus*, from 6000 to 500 Bg/kg d.w.. The activity concentrations of ^{137}Cs in *Suillus variegates, Russula vinosa, Lactarius vietus, Russula xerampelina* and *Cortinarius armillatus*, the most common species in mixed stand, decreased from 9000 to 250 Bg/kg d.w. during the research period. The results show that the ^{137}Cs activity concentrations in fungal species decreased with the increase of ecological half-lives from 8 to almost 30 years in the period from 1980 to 2011. It was also observed that the concentrations of ^{137}Cs differ for fungal species growing in different habitats. The ^{137}Cs concentrations in fungi collected from fresh heat were higher than those in fungi from dry heat (=statistical significance).

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P11.18
Determination of Uranium in Soil by KPA using Diphonix® resin

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The Nuclear Regulatory Authority of Argentina (ARN) performs an environmental monitoring programme around installations of the nuclear fuel cycle that includes the sampling and analysis of different radionuclides in several matrices. Uranium is an important radioactive element that is determined in water and soil samples specially regarding uranium mines.

This paper describes a procedure for the uranium determination in soils samples by KPA (Kinetic Phosphorescence Analyzer) and its later verification by alpha spectrometry.

The uranium determination in this matrix generally implies certain analytical problems and the conventional methods for its purification are quite tedious and not always effective.

One important aspect to be taken into account of the KPA technique is that the sample must be in optimal conditions. In this sense it is necessary to eliminate all the interferences (organic matter, chlorides, iron, etc.) that attempt against the quality of the measurement. One approach to avoid the troublesome and often unexplainable problems collectively referred to as “matrix effects”, is to pre-concentrate actinides into a common form that would then behave uniformly and predictably during a subsequent separation scheme. In this work it is shown how using Diphonix® and Uteva® resins we manage to eliminate the interferences of the samples in order to be in adequate conditions for the measurement.

P11.19 Temporal Evolution of the Spanish Labs Intercomparisons in the Radionuclides Determination in Environmental Samples

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The Spanish Regulatory body (Nuclear Safety Council, CSN) funds and organizes periodically, in collaboration with CIEMAT, intercomparison exercises among the Spanish labs that report data to it, for controlling their performance when analysing radionuclides in different type of environmental matrices. These exercises allow supporting: the quality standards for the Spanish environmental radiological monitoring programmes, the credibility of radiological data provided to International Organizations and the veracity of the scientific research realised by the Spanish labs that appears in articles published in national and international journals.

This paper shows the results obtained in these intercomparison exercises by more than 30 laboratories during the last 10 years highlighting: the increasing number of participants, their continuous quality improvement along time and the difficulties in measuring certain type of natural and artificial radionuclides in environmental samples.

A critical review of the evaluation of these intercomparisons as well the statistics employed in the different exercises have been done in this paper.

P11.20
Importance of Meteorological Condition on Environmental effect of Radioactive Material from a Nuclear Facility

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Environmental effect of the air pollutants released from an industrial facility into the atmosphere is closely related to the meteorological condition. Fukushima and Chernobyl nuclear accidents are both severe accident which give rise to the extensive contamination of radioactive material on the surrounding environment. The environmental effect of Fukushima accident seems to be lower than those of Chernobyl considering the meteorological conditions at the time of accident. Meteorological condition is the key factor for assessing the environmental effect of radioactive effluents of a nuclear facility. Therefore, the analysis of meteorological condition of a nuclear site is essential for the analysis of the radiation safety of a nuclear facility. By the analysis of the site meteorological condition, it is possible to estimate the suitability of the site as a nuclear site. The method of integral quantities devised by Allwine and Whiteman is useful for analyzing the site suitability by characterizing the flow condition with the meteorological data measured at the site.

This paper describes the roles of meteorological condition for both normal operation and accident of a nuclear facility and the analysis of the site meteorological condition by categorizing the atmospheric flow condition of a Korean four nuclear sites and Jordan research reactor site using integral quantities for characterizing stagnation and recirculation. Authors have applied a method for categorizing the flow conditions using the distribution curves which represent the flow condition of the whole area of Korea.

KEYWORDS: environmental effects, meteorological condition, stagnation, recirculation, integral quantities, nuclear facility

P11.21
Characterization of Artificial Radionuclides and Sedimentation in Sediment Core of Crater Lake, Baengnokdam of Mt. Halla, Korea

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In this study, we investigated the distribution of ^{137}Cs, ^{237}Np, $^{239+240}$Pu activities, and ^{240}Pu/^{239}Pu isotopic ratio and sedimentation characteristics in sediment cores collected in crater lake, Baengnokdam of Mt. Halla, Korea from September to November 2004. Baengnokdam of Mt. Halla usually holds water in the spring, summer and fall when it rains. Also, we can see the crater with water in winter when snow melts. But sometimes the crater is dry because of this fall's drought. Baengrokdam has a circulation of water due to the weather conditions. Sediment cores were collected at 15 sites from a zero site, boundary between vegetation and water in the south-west of the crater lake, to the 75 m site of the north-east by 5 m interval in a dry season. Sediment cores, with a length of 100 cm, were sectioned at 10 cm intervals. For each samples, ^{137}Cs activity was determined using HPGe detector system after dryness. ^{237}Np, $^{239+240}$Pu activities, and ^{240}Pu/^{239}Pu isotopic ratio were determined using multi-collector ICP-MS simultaneously after the extraction by acid leaching and the separation by extraction chromatography resin (TEVA.SpecTM). ^{137}Cs, ^{237}Np and $^{239+240}$Pu activities showed similar distribution patterns and the only one peak was observed in each sediment cores except for 10 m distance station from the zero station. The maximum ^{137}Cs concentrations per unit sediment by the site varied from 19.0 to 214 Bq kg-1. For all sediment cores except for 10 m distance station from the zero station, the results on ^{237}Np activity, $^{239+240}$Pu activities ranged from 0.0518 to 7.15 mBq/kg-dry, and from 0.00686 to 5.128 Bq/kg-dry, respectively. ^{240}Pu/^{239}Pu isotopic ratios averaged 0.159 less than the global fallout ratio (0.176). $^{239+240}$Pu/^{137}Cs activity ratios and ^{237}Np/$^{239+240}$Pu activity ratios averaged in 0.033 and 0.0086, respectively. Using the results of ^{137}Cs activities, the estimation of total amount of ^{137}Cs sediment varied from 7.4 to 29.8 kBq m^{-2} and averaged 19.5 kBq m^{-2}. As a result to estimate the sediment accumulation rate using ^{137}Cs, yearly sediment accumulation rates in the crater lake, Baengnokdam varied from 0.37 to 1.59 cm yr^{-1} and averaged 0.84 cm yr^{-1}, which indicated the crater lake had been accumulated at the rate of 0.84 cm yr^{-1} since 1963 so that its depth decreased gradually. In addition, the sediment accumulation rate decreased linearly from 5 m site of the highest value 1.59 cm yr^{-1} to 75 m site of the lowest value 0.37 cm yr^{-1}, which showed 4.3 times the difference. Therefore, we estimated the inflow of eroded material was carried from 5 m site to 75 m site, from the south-west to the north-east of the lake. To estimate the sedimentation characteristics more accurately, we need the additional investigation using ^{210}Pb

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P11.22
Concentrations of Radionuclides in Soil and Assessment of the Environmental Gamma Dose

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The main objective of this study was to identify and determine natural and artificial radionuclide activity concentrations in soil samples collected from seven locations in Serbia and asssessment of the enviromental gamma dose. Several different techniques for the assessment of environmental gamma dose are compared: high pressurized ionizing chambers at 2 locations and Geiger Mueller counters at 5 locations versus environmental thermoluminiscent dosimeters and dose evaluation from the activity concentration of radionuclides in soil. Environmental TLD badge has four crystals: two crystals CaSO4 and two crystals LiF. During the period january 2008- December 2009, simultaneous gama dose rate were obtained by electronic detectors (PIC and GM) and pasive devices (TLD) continuously. At the same locations soil samples were collected and gammaspectrometry measurements were made twice a year. The soil samples were purified from plants and rocks. Each sample was dried in an oven at 105oC-110oC to constant weight during 24-48 h. The dry soil was crushed and sieved (0.5 mm). The resulting sample was weighed and transferred into a Marinelli beaker. Natural and artificial radionuclides concentrations were measured using a high-resolution gamma ray spectrometer (HPGe detector ORTEC - 30 % efficiency at 1332 keV). Time of measurement was at least 20000 sec. The radionuclide activity of uranium and thorium series and ^{40}K, as well as the artificial radionuclide ^{137}Cs was determined. The activity concentrations of ^{232}Th and ^{238}U were calculated assuming secular equilibrium was established with their decay products. The exposure dose rate in air at 1 m above the ground is calculated using measured activities and conversion factor 0.427, 0.662 and 0.043 nGy h^{-1} per Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively. The ^{238}U acivity concentration varied from 26 to 146 Bq/kg, ^{232}Th acivity concentration ranged from 10 to 71 Bq/kg and 40K acivity concetration were from 160 to 725 Bq/kg. The ^{137}Cs activity concentration varied from 5.7 to 196 Bq/kg. The PIC exposure rate values were relatively constant for each location and they were in good agreement with the average LiF TLD values. Measured gamma dose rates are higher then calculated because the detectors measured also cosmic radiation in air besides the ground radiation.

P11.24
Radionuclide Concentration Factors in the Mullet (Mugilidae) Species Mugil cephalus - from Seawater, Sediment and Mud with Detritus

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Cesium-137, ^{40}K, ^{226}Ra and ^{232}Th in six whole Mugil cephalus individuals, two samples of muscles and two of skeleton, as well as in seawater, surface sediment and mud with detritus, have been measured by multidetector gamma-spectrometry. Cesium-137 was detected in two whole individuals only (0.18 and 1.09 Bq kg^{-1}), while the other radionuclides – in all samples. Potassium activity in whole fish ranged from 90.7 to 205.37 Bq kg^{-1}, radium – from 0.89 to 3.09 Bq kg^{-1}, and thorium – from 0.63 to 1.67 Bq kg^{-1}. The activity concentrations have been used to calculate concentration factors (CFs) for transfer of these radionuclides from seawater, sediment and mud with detritus to fish tissues. The highest CFs were – radium and thorium CF for skeleton (from seawater) with an average of 162.1 and 101.1, respectively, and then cesium CF for muscles (from seawater) with an average of 31.8. All CFs (from seawater, sediment and mud with detritus) showed accumulation of radium and thorium in skeleton significantly higher than in the muscles and whole individuals of M. cephalus species.

P11.25
Environmental Impact of Radioactive Discharges from the Ringhals Nuclear Power Plants into the Kattegat Sea

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Regulatory requirements for the protection of the environment are increasing due to both growing public concern and to the evolving integration of environmental impact assessments into the regulatory process. In order to progress the work, strategies have been formulated which include the use of reference organisms. The purpose of selecting key organisms is to narrow the problem and simplify the development of appropriate exposure and dose models in the areas of environmental radiation protection.

Extensive environmental monitoring programs have been carried out in the recipient sea areas outside the Ringhals nuclear power plants on a routine basis during more than three decades. Due to the long time series, large quantities of results of the environmental radiological conditions exist. The current environmental monitoring program in Sweden includes organisms that have been selected due to their abundance but also due to their characteristics as good indicators of the environmental conditions. The main purpose of environmental monitoring is to identify any activity build-up in the recipients due to the radioactive releases. Some of the sampling stations are therefore selected close to the release point. Usually, the sampling is performed twice a year (spring and autumn) but may vary due to the type of sample.

Small amounts of locally discharged radionuclides such as the activation products ^{60}Co, ^{58}Co, ^{54}Mn and ^{65}Zn are regularly detected in bottom sediments and in the selected organisms. ^{137}Cs mostly originating from the Chernobyl accident and the weapons-tests fallout is also frequently detected in the samples. The bladder-wrack *Fucus vesiculosus,* seems to effectively accumulate radioactive substances and thus serves as a good indicator of the environmental conditions. The activity concentrations of the most common activation product (^{60}Co) in *Fucus* have decreased by two orders of magnitude during twenty five years of sampling. The decrease coincides well with the decrease in the total release rates of ^{60}Co from Ringhals. Traces of other the released radionuclides can be observed in samples taken and similarly, the monitoring results indicate substantial decrease of detected activity concentrations. Consequently, the impact to the wildlife of the locally discharged radionuclides to the sea from the Ringhals nuclear power plants is very low, practically insignificant. The results show however, that in view of selecting reference organisms, the environmental monitoring program should be acknowledged, especially as an important data source.

P11.26
Providing Access to Environmental Radioactivity Measurements During Crisis and in Peacetime: Two Tools Developed in France by IRSN

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Allover French territory, thousands of measurements are produced every month, whether from IRSN, operators of nuclear facilities or other public, private or non-governmental organizations. In the event of a radiological accident, many additional measures will also be carried out in the field by those involved in crisis management. This multiplicity of actors and sources of information makes it difficult to centralize measurements and to provide access to experts and policy makers, but also to the general public. In order to answer this problem, two projects were launched by IRSN with the aim of developing tools to centralize information on environmental radioactivity in normal situation (RNM project for “National network of radioactive measurements”) and during radiological crisis (CRITER project for “Crisis and field”).

The RNM’s mission is to contribute to the estimation of doses from ionizing radiation to which people are exposed and to inform the public. In order to achieve this goal, this network collects and makes available to the public the results of measurements of environmental radioactivity obtained in a normal situation by the French stakeholders. After more than two years of operation, the database contains nearly 500,000 results. The opening of the public website (www.mesure-radioactivite.fr) was also a major step forward toward transparency and information.

The project CRITER therefore involves the collection of all possible data from all potential sources, transmission, organization, and the publication of the measurements in crisis or post-accident situation. For each event in which any radiological health and environmental consequences or extent media coverage requires the establishment of a crisis organization, a specific CRITER database is created. Thus a CRITER IT system was implemented after the Fukushima accident in March 2011.

Both projects have developed complementary tools with compatible data repository, allowing on one hand to form a national reference database with measurements taken in normal situation from all environmental compartments and around each nuclear facility, but also a crisis database able to centralize quickly the new measurements made available from all those on the affected area and to make it available to decision-making bodies.

P11.27
Inventories, Input, and Transport of Iodine Isotopes in Germany

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Anthropogenic ^{129}I enters the environmental compartments and changes iodine isotopic abundances. The natural ^{129}I /^{127}I ratios have been globally changed by several orders of magnitude. Measurements of ^{127}I and ^{129}I in some German soils revealed ^{129}I /^{127}I ratios of 10^{-7} to 10^{-10} [1, 2], whereas the ^{129}I /^{127}I ratio in a pre-nuclear Russian soil was found to be 5.7 x 10^{-12} [3]. Iodine from wet and dry precipitation is accumulated in soils, transported by surface waters, infiltrates groundwater, and makes its way through the biosphere. Many of the ecological pathways of iodine are still unclear.

The goal of this project is to investigate the continuous atmospheric input via dry and wet deposition, the inventories in the pedosphere and the output by river waters of ^{129}I and ^{127}I in Germany. For this purpose aerosol filter samples from 4 locations are analysed, as well as precipitation samples from 10 locations, and surface water samples from 15 locations along the major rivers in Germany. Sampling is supported by DWD (German Meteorological Service), BfG (Federal Institute for Hydrology), PTB (Federal Metrology Institute), and BfS (Federal Office for Radiation Protection). Additionally, sampling of different soil types at various locations in Germany, down to a depth of 50 cm, is in progress. The samples are taken from 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, and 30-50 cm, respectively. Deposition rates, deposition densities and transport rates will be calculated using inductivity coupled plasma mass spectrometry (ICP-MS) and accelator mass spectrometry (AMS) as analytical tools. Based on these data, a model will be established describing the different pathways of iodine isotopes in the environment. Results of the first soil profile analysed show a characteristic distributiond of the ^{129}I /^{127}I ratios, with the highest values in the organic rich topsoil layer (10.6 x 10^{-8} in 0-5 cm), and a distinctive decrease of the values with increasing depth: 3.2 x 10^{-8} (5-10 cm), 1.9 x 10^{-8} (10-20 cm), 0.9 x 10^{-8} (20-30 cm), 0.5 x 10^{-8} (30-50 cm). Rainwater drawn at the same sampling location in March 2011 showed a ^{129}I /^{127}I ratio of 5.9 x 10^{-8} .

[1] Ernst et al. (2003) Kerntechnik 68 (4), 155-167. [2] Daraoui et al. (2011) submitted to J. Environ. Rad [3] Szidat et al. (2000) Nucl. Instr. Meth. Phys. Res. B 172, 699-710.

P11.29
Iodine-129 And Iodine-127 In Seawater Of The North Sea And In Precipitation From Northern Germany

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Atmospheric nuclear weapons tests, nuclear accidents, and emissions from reprocessing plants have changed the natural abundances of ^{129}I ($T_{1/2}$=15.7 Ma) in a sustainable manner. Mainly as a consequence of the ^{129}I releases from the European reprocessing plants, ^{129}I is in disequilibrium in all environmental compartments of the Western Europe.

Surface water from the North Sea and the Baltic Sea, which were contaminated by the continous emission from reprocessing plants (La Hague and Sellafield), were analysed for ^{129}I by accelerator mass spectrometry (AMS) and for ^{127}I by inductively coupled plasma mass spectrometry (ICP-MS). Samples of seawater were taken during a cruise of the BSH FS-Pelagia between August 20 and September 09, 2009. This paper reports on the results obtained for ^{129}I and ^{127}I in 2009 and compares them with those from 2005.

The concentrations of ^{127}I in seawater of the North Sea are fairly constant with (44 ± 2) ng/g, with exceptions of coastal areas with high biological activity and of areas influenced by influx from rivers and the Baltic Sea. The results of ^{129}I/^{127}I ratios range between 1.5 x 10^{-8} and 2.7 x 10^{-6}: at least 4 orders of magnitude higher than the natural equilibrium isotopic ratio in the marine hydrosphere of 1.5 x 10^{-12}. The highest isotopic ratios are seen in the English Channel east of La Hague. The emissions from La Hague can be followed through the English Channel and subsequently through the North Sea. The variability of the ^{129}I/^{127}I isotopic ratios is exculsively determined by admixture of anthoropogenic ^{129}I. Together with time series of the iodine isotopes in precipitation in Northern Germany, the results demonstrate the dominating role of the liquid releases for the ongoing atmospheric fallout of ^{129}I in Western Europe. Comparing these results with our earlier studies shows the disequilibrium of ^{129}I in the environmental compartments.

P11.30
Radionuclides Contamination Within 60 Km from The Fukushima Daiichi Nuclear Power Complex after the Accident On March 11, 2011

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Radionuclides from the Fukushima nuclear accident were analyzed for the various kinds of environmental samples collected within 60 km from the Fukushima Daiichi nuclear complex to make clear the environmental contamination. The radiation dose measurement with a NaI survey meter using a car indicates a northwest distribution of heavily contaminated area from the Fukushima Daiichi nuclear complex. Soil cores collected at different times in the heavily contaminated area showed very small vertical migration of radionuclides with time. Iodin-131 and other short lived radionuclides were detected on the samples collected on April but disappeared soon and Cs isotopes were major on June sample. Waters collected at small streams contained I-131, Cs-134 and Cs-137 but the concentrations in water were not high compared to soil contamination level, suggesting very small migration of radionuclides from soil to water body and most of the radionuclides are retained on soil. Contamination of plants with Cs isotope was confirmed by Ge measurement and imaging plate analysis suggests that the surface deposition of radionuclides and accumulation in plants are responsible to plants contamination.

P11.31
Participation of the IFIN-HH Dosimetry Laboratory for Personnel and Environment (LDPM) at the Proficiency Test AQUACHECK-2011.

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Participation of the LDPM at the AQUACHECK-2011 proficiency test (PT), organized by the LGC Standards, UK, is presented, in terms of the following aspects.

- Type of sample: radioactive solution, in the domain of low radioactivity concentration, consisting from a mixture of unknown radionuclides.

- Type of required measurements and report was the gross alpha and beta equivalent radioactive concentration: Alpha - ^{239}Pu and ^{241}Am; Beta - ^{40}K, ^{90}Sr and ^{137}Cs

- The method of processing of the solution, in order to perform activity measurements;

- The measurement method, which consisted from the following steps: (i) A preliminary gamma-ray spectrometry measurement, to identify the gamma-ray emitters in the mixture; (ii) Measurement of the gross alpha and respectively gross beta activity of the prepared samples, using 2 types of equipment, calibrated in response for all radionuclides from the list ; (iii) Processing of the measurement data, by applying the necessary corrections and reporting the results.

After transmission of the measurement results, from all the 11 participating laboratories, the organizer of the PT, LGC Standards, processed the received values and published the following data: the reported values of the laboratories and the accomplishment of the z-score performance. Our laboratory, code AQ2757, obtained satisfactory results, passing the z-score test for all the reported values.

P11.32
Impact of Refuelling of the Krsko Nuclear Power Plant on the 14C Activity in the Atmosphere and Plants

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Monitoring ^{14}C activity in the atmospheric CO2 and in biological samples (fruits and vegetables) in the close vicinity of the Krško Nuclear Power Plant (NPP) was performed regularly since 2006 to estimate the possible influence of the plant on environmental ^{14}C levels and the possible contribution to the effective dose of local population through food chain. Atmospheric CO2 on two locations was collected regularly every two months, while the biological samples (apples, corn, wheat and grass) were collected twice a year (in June/July and September/October) on several locations very close to the plant in a radius of about 1 km from the Krško NPP, as well as on the control point at Dobova, 12 km from the plant.

Increase of ^{14}C activity in atmospheric CO2 was always observed during and immediately after the refuelling of the power plant, which has been performed every 18 months, and it is more pronounced on the location in the SW-NE direction that coincided with the most pronounced wind directions. ^{14}C activity in plants collected close to the Krško NPP is always higher than the activities on the control point, and depends both on the distance from the exhaust of the plant ventilation system and on wind direction. Significantly higher activities in plants collected after the spring refuelling in 2006 and 2009 was measured. This can be explained by the influence of plant effluents during the summer when the process of photosynthesis is the most prominent, while autumn effluents (2007 and 2010) do not significantly influence the ^{14}C activity in plants. The maximum increase of total dose to local population due to the release of ^{14}C from the Krško NPP in the years of spring refuelling was estimated to be 0.015 %, which is negligible.

P11.33
Dose Rate Measurements of the Phosphogypsum Deposition Site and the Surrounding Environment

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Phosphogypsum is a waste by-product derived from the production of phosphoric acid using wet process. It is precipitated during the reaction of sulphuric acid with phosphate rock. During phosphate ore processing, practically all ^{226}Ra gets incorporated into phosphogypsum, which classifies it as technologically-enhanced NORM – Naturally Occurring Radioactive Material. Phosphogypsum is stacked in large piles at the deposition site some 4 km southward of the factory, on the borderline of a Nature park. Because of the possible spread of phosphogypsum from the stack to the environment, constant monitoring of the surrounding area is necessary. The measurements were carried out on the deposition site and in the environment at 42 locations. The average dose rates ranged from 116 nSv/h in the environment to 362 nSv/h on the deposition site. The results show that dose rates decreased from the stack to the environment.

P11.35
Improved System for Collecting Stack Samples for Tritium and Carbon-14 Analysis

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At Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, exhaust stacks are sampled for radionuclides including tritium and carbon-14. Stack air moisture is collected for tritium analysis by drawing a sample of stack air through silica gel beads; stack gases are collected for carbon-14 analysis by bubbling a sample of stack air through sodium hydroxide solution. The collection vessels are glass with screw-top or friction-fit plugs and fittings, which can leak or break during transport, be costly to replace, and require a large weather-proof enclosure. LBNL staff designed a new collection system with small inexpensive plastic jars to contain the silica gel beads and sodium hydroxide solution. These jars have screw-top lids that tighten securely to prevent leaks during sampling and transport. From May 2010 through May 2011, both collection systems operated side by side, drawing samples from collocated probes in the LBNL Hazardous Waste Handling Facility fumehood stack. Samples were collected continuously for one-month periods, after which the silica gel and sodium hydroxide sampling media were replaced, and exposed media were packaged and sent to commercial laboratories for analysis for tritium and carbon-14. Emissions of tritium and carbon-14 from LBNL's Hazardous Waste Handling Facility are historically very low, and emissions during the test period were no exception. From May 2010 to June 2011, tritium was detected in fumehood stack emissions during 5 of the 13 months sampled. Measured quantities track closely between the old and new collection systems. During the test period, no carbon-14 emissions were detected in fumehood stack emissions. (This is not unusual; in 2009, none of the five monthly samples collected from this stack contained detectable carbon-14.) Nevertheless the results from both collection systems follow a similar pattern. In conclusion, the new system appears to provide equal collection efficiency for tritium and carbon-14 in stack air, and the new system is more robust, tighter, and cheaper than the old system.

P11.36
137Cs Inventory in South Adriatic

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In this paper are presented results of investigation of ^{137}Cs activity concentrations and sediments in South Adriatic. Inventory of ^{137}Cs in sediments and sea water is estimated. Sediment samples were collected during radioecological cruise organized by International Atomic Energy Agency in year 2007, while sea water samples were collected on yearly basis as a part of extended monitoring programme of the radioactive contamination of Croatian environment. Measurements were performed in the Radiation Protection Unit of the Institute for Medical Research and Occupational Health. In South Adriatic, i.e. in the area between Palagruža sill in north and straight of Otranto in south, sediment samples were taken on three locations. Correlation between measured radiological and geochemical parameters has been found to be quite significant. Mean value for ^{137}Cs activity concentration in sediments in south Adriatic was calculated to be (3.87 ± 0.66) E+4 Bqm^{-2}. Therefore, total inventory of ^{137}Cs in sea sediments in south Adriatic, which has area of about 60,000 km^2, has been estimated to be 2.32 E+15 Bq. Total inventory of ^{137}Cs in sea water in south Adriatic, which has volume of about 28172 km^3, has been estimated to be (8.51 ± 0.24) E+13 Bq. The highest value of ^{137}Cs activity concentration has been found on sampling location in Albania (1.24 E+5 Bqm^{-2}) while, for comparison, ^{137}Cs activity concentration on location Jabuka in middle Adriatic was found to be 5.79 E+4 Bqm^{-2}. It can be argued that sampling locations in Albania and Jabuka are influenced by river runoff, i.e. by the rivers Bojana (Buna) in Albania and Po in Italy. Therefore, caesium sediments in the South Adriatic Pit could be considered to originate by fallout. However, more results from more sampling sites are needed for more reliable estimates.

P11.37
"Data Mining" Of Environmental Radioactivity Surveillance Data

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Like many other countries, Germany routinely collects data on radioisotope concentration in a variety of environmental media. Most of the data are stored in a national data bank and summaries are published on a yearly basis by the government. These reports are a valuable source of information on levels of artificial and natural isotopes. Logically, the data have to be presented in summarized form, e.g. by giving maximum, minimum and mean value of a set of data.

On the other hand, the raw data behind are often very detailed, e.g. on geographical and time scales, and worthwhile being explored more precisely. Two examples are presented in this contribution.

1) ^{131}I in waste water treatment plant effluent and riverine samples:

^{131}I of medical origin is regularly found in the effluent of wastewater treatment plants (recorded by regional, federal state laboratories), from where it is transferred to rivers and distributed between water, suspended matter and sediment (recorded by national laboratories). Between about 100 and 500 concentration values per year are obtained, depending on the medium. The value distributions resemble log-normal, with a factor of roughly 100 between 5th and 95th percentile. The ratios between the median values are close to factors predicted by national directives for radioecological modelling of radioactive emissions. They thus support the adequateness of the underlying models.

2) ^{137}Cs in soil, grass and milk:

^{137}Cs deposition from Chernobyl in Germany is known to be highest in the southeastern part. This is reflected by the regional concentration data of 137Cs in meadow soil. Conversely, grass and milk concentrations are highest in some northern regions. Whilst no explanation for this effect is found yet (it might well be due to regional differences in sampling), the fact itself can only be seen by comparison of a larger number of regional data.

Both examples show the potential usefulness of a detailed investigation of routine surveillance data.

P11.38
Dose Assessment to Marine Biota: Evaluation of Key Environmental Parameters

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The dose assessment to biota is an important part of radioecological analysis and one of the key factors in need of consideration for the development of response strategies to radionuclide release into marine regions. Such assessment has to simultaneously describe the dispersion of radionuclides in water and sediment phases; bioaccumulation of radionuclides in biota and finally, calculation of doses to different marine organisms. It is obvious that such an approach comes up against the problem of complexity and the need for a large set of parameters. The sensitivity analysis of the model parameters can contribute to a better understanding of experimental data as well as define parameters which can play a key role in the evaluation of doses to marine organisms for different scenarios of releases of radionuclides into marine environment. In the present paper sensitivity analysis has been carried out using the NRPA compartment model for radioecological assessment, which includes the processes of advection of radioactivity between compartments, sedimentation, particle mixing, pore water mixing and a burial process of radioactivity in deep sediment layers. The contamination of biota is further calculated from the radionuclide concentrations in filtered sea water in the different water regions. Doses to biota are calculated for a wide set of reference marine organisms. The sensitivity analysis shows that the influence of model parameters can vary widely depending on the concrete radionuclude and the release scenario. It is also shown that the results can determine the most important parameters for different marine environments.

P11.39
Radiation and Ecological Conditions of the Offshore Waters nearby the Site for SNF and RW Temporary Storage at Andreeva Bay

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In 1960s, a large technical base of the Northern Fleet was established at Andreeva Bay on Kola Peninsular in Barents Sea. It was involved in support of nuclear submarines, acceptance and storage of radioactive waste (RW) and spent nuclear fuel (SNF). Since 1985, the waste acceptance has been stopped and the technical bases were re-constructed and re-equipped to serve as the sites for temporary storage (STS). In order to get the comprehensive information on the current radiation circumstances in the STS offshore waters for the purpose of its integrated assessment, the radiation ecological monitoring of the offshore waters nearby STS has been conducted. Information of ^{137}Cs, ^{90}Sr and ^{60}Co concentrations in the seawater, seaweeds, bottom sediments, invertebrates (mussels, Crustacea), and vertebrates (fish fauna) in the local areas of the STS coastal stripe has been obtained.

The radiation ecological monitoring of the environmental media demonstrated the significant exceeding of the typical background values of ^{137}Cs and ^{90}Sr concentrations in seaweeds and bottom sediments in the local areas of the offshore waters nearby the STS. The findings of the inspection permit to assume the effective migration from the high contaminated parts of the site via the ground water streams. Therefore, radioactive substances enter the offshore sea waters. Having in mind potential further contamination of the STS area, the dynamic survey of the radiation situation is necessary both during the routine operation and at the stage of SNF and RW removal.

The radionuclide accumulation by the invertebrates or by vertebrates is trivial, so, we can conclude that the STS industrial site does not impact on these parts of the ecosystem in Motovsky Gulf.

P11.40
Strontium Biokinetic Model For Mouse-Like Rodent

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Effects of radiation on biota at contaminated territory of East-Ural Radioactive Trace (EURT) for a long time have been studied by radiobiologists. However no appropriate methods of dose estimation were elaborated so far for that exposure situation. Unique characteristic of contemporary radiation exposure of the EURT biota is prevailing contribution of Sr-90 to received dose. Due to its metabolism considerable fraction of strontium is accumulated in bones of mammals. Non-uniform distribution of the radionuclide by organs and tissues should be considered for purposes of dose assessment. Dose received by internal organs depends on strontium intake and retention in skeleton and specific absorbed fractions of energy emitted due to Sr-90 decay. For purposes of dose assessments a biokinetic model of mouse-like rodent was developed. Model mouse-like rodent consist of seven compartments: blood, gastrointestinal tract (GIT), skeleton, soft tissues, urinary bladder, urine and feces. The system of coupled differential equations describing the behavior of radionuclide in the body can be solved using WinAct code. The model was adjusted and verified considering published experimental data on retention of strontium in skeleton of laboratory animals. Experimental data on intraperitoneal injection and gavage of strontium solution and dry were applied. Transfer rates linking blood with GIT, skeleton, soft tissues and urinary bladder are 3.0E-01, 5.0E+01, 5.0E+00, 4.0E+00 day^{-1} respectively. Rates of strontium transfer from GIT, skeleton and soft tissues to blood are 5.0E-01, 8.0E-01, 4.5E+00 day^{-1} respectively. Transfer rates of nuclide from GIT to feces and from urinary bladder to urine are 3.0E+00 and 4.0E+00 day^{-1} respectively. The model was used to simulate prolonged strontium ingestion situation that is similar to wildlife exposure characteristics at EURT. The activity of skeleton under situation of strontium daily intake was estimated. Strontium content in skeleton reaches a plateau after 40 days of ingestion. In the case of 1 Bq daily intake activity of Sr-90 in skeleton is 2 Bq.

P11.41
Assessment of Environmental Radioactivity in Natural Food Products from Northern Norway

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The issue of environmental radioactivity is of special concern to the Arctic region due to numerous existing and potential sources of radioactive pollution in the immediate and adjacent areas. Sub-Arctic and Arctic food chains can be short, providing a potentially quick uptake route for radionuclides to biota and man. Thus, it is important to conduct comprehensive environmental radioactivity monitoring programmes, especially in the areas widely used by population for collection of natural food products.

The goal of this research is to assess current environmental radioactivity levels in the terrestrial environment in the Northern part of Norway and the doses to man arising from consumption of berries, mushrooms and freshwater fish. Doses assessments for these natural food products will be made for the anthropogenic radionuclide Cs-137 in comparison with the naturally occurring radionuclides K-40, Po-210 and Pb-210.

The results from recent sampling campaigns to the Dividalen and Pasvikdalen areas will be compared with previously acquired data to reveal current trends in radioactive contamination in the Northern part of Norway.

P11.42
137Cs Distribution in the Northern Adriatic Sea(2006-2011)

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The dominant source of anthropogenic radionuclides in the Adriatic Sea is global fallout primarily from the Chernobyl accident in 1986 and indirectly from the Po river discharge. ^{137}Cs is considered to be the most important radionuclide delivered by the fallout used for the assessment of marine pollution by artificial radionuclides. The objectives of this study were radio-ecological assessment of the northern Adriatic by the analysis of ^{137}Cs concentration measured in seawater, sediments and marine organisms and determination of the bioindicator species. A comparison of radioactive contamination was made between different parts of the marine ecosystem including the area of the Po river delta, the protected area of Lim bay and the Rovinj coastal area in the period from 2006 to 2011. In the area of the Po river delta ^{137}Cs concentrations in seawater has returned to pre-Chernobyl values (2,48±0,78 Bq m^{-3}), although in sediment the values were slightly higher (8,70±1,08 Bq/kg). Inside Lim bay area ^{137}Cs concentrations in seawater were low (1,93±0,71 Bq m^{-3}) and in mussel Mytilus galloprovincialis (< 0,3 Bq/kg w.w.) even undetectable during this period. In the Rovinj coastal area ^{137}Cs concentrations in surface water remained constant (2,23±0,64 Bq m^{-3}), as well as in the surface sediment (1,88±0,63 Bq/kg). $^{-137}$Cs concentrations were detectable at very low activity levels in Mugil cephalus and Sardina pilchardus (< 0,3 Bq/kg w.w.). The data indicate that some species, like the intertidal algae Fucus virsoides (1,43±0,39 Bq/kg w.w.) and benthic fish Mullus barbatus (1,02±0,69 Bq/kg w.w.) are better bioaccumulators of ^{137}Cs than others. Fucus virsoides and Mullus barbatus could be considered as a good bioindicator for monitoring radioactive contamination in the Adriatic Sea. The radiological status of ^{137}Cs in the northern Adriatic Sea has returned to the pre-Chernobyl values, generally taking into consideration its natural fluctuation due to physical-chemical and hydrological parameters of the investigated area.

P11.43
Radiological Impact of the Hukushima Nuclear Accident on the Human and Biota in the Republic of Korea

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A severe nuclear accident occurred at the nuclear power plant in Hukushima, Japan on 11 March, 2011, and the large amount of gaseous radioactive materials was released into the atmosphere and dispersed by wind. About two weeks after the accident, the air activity of I-131, Cs-137, Cs-134 and Xe-133 higher than the usual level was observed in a wide region of the Republic of Korea. The radionuclides dispersed into the environment will be remain for long period and have potential of giving the radiological risk to human health and the ecosystem through the various pathways, and therefore the assessment of the radiological impact by the accident is essential to keep the human health safe and to protect the environment from the effect of ionizing radiation. The purpose of the present study is to assess the radiation dose for the human and biota in the Republic of Korea as a result of the Hukushima nuclear accident.

To calculate the human dose, four exposure pathways, the internal exposure due to ingestion of contaminated foodstuffs, the internal exposure due to the inhalation of airborne radionuclides, the external exposure from the radionuclides in the passing cloud, and the external exposure from radionuclides deposited on the ground were considered. Four radionuclides of I-131, Cs-137, Cs-134 and Xe-133 that were abnormally detected in the airborne samples after the Hukushima nuclear accident were considered in the dose calculation. To assess the whole body absorbed dose rate for non-human biota, the K-BIOTA (the Korean computer code to assess the risk of the radioactivity to wildlife) which is based on the equilibrium CR model was used. Two different target organisms were considered in the dose calculation for non-human biota. One is the Korean draft reference animals and plant (RAPs), and the other is the ERICA limiting organisms being used for the screening level assessment.

The airborne monitoring result measured by the KINS (Korea Institute of Nuclear Safety) showed that the airborne activity higher than the normal level was first detected on 28 March, 2011, and the highest peak were observed on 6 April. The estimated time-integrated air activity based on the air activity that were observed from 12 local monitoring sites ranged from 9.0 to 32.0mBq d/m3 for I-131, from 1.0 to 5.2mBq d/m3 for Cs-134, and from 0.9 to 4.65mBq d/m3 for Cs-137. The time integrated air activity for Xe-133 observed from one military site was about 12.5mBq d/m3. The measured fallout deposition during about three months after the accident was about 2.35Bq/m2 for I-131, 1.43Bq/m2 for Cs-134, and 1.58B q/m2 for Cs-137.

The first year total human effective dose resulting from the Hukushima nuclear accident was estimated to less than 1.4E-4mSv. It accounts for less than 0.006% of the annual dose (2.3mSv) received from the natural radioactivity through the normal life of human. The life-time total effective dose for the human was estimated to less than 3.3E-4mSv. The whole body dose rate for the Korean draft RAPs ranged from 1.5E-7 to7.0E-7mGy/d for the terrestrial organisms, and it was estimated to about 2.02E-5mGy/d for aquatic organisms. The whole body dose rate for the ERICA limiting organisms was estimated to 2.34E-5mGy/d for terrestrial biota, and 6.32E-3mGy/d for aquatic biota, respectively, which were far less than the IAEA standard (1mGy/d for the terrestrial animal, and 10mGy/d for the freshwater animal) to protect the environment from the effect of ionizing radiation. All of these results indicated that the radioactivity released into the atmosphere by the Hukushima nuclear accident would not give the hazard to the human and biota in the republic of Korea.

P11.44
High Background Radiation Area and Environmental Protection Programme

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There are several places in the world, where the level of natural radiation is unusually high, such as some regions of Ramsar city in Iran with outstanding high background radiation due to the existence of many hot springs with high ^{226}Ra content. ^{226}Ra with a high potency for causing biological damages, also presents additional environmental and health concerns due to the fact that decay into a Class-A carcinogen; radon (^{222}Rn). Public awareness about exposure to natural radiation sources has been growing in recent years at a rather accelerated pace. This growing awareness has prompted more widespread scientific investigations, mainly at national levels. Although due to the lack of observable detrimental effect in these areas, it has been suggested that no urgent limiting regulations are needed, however the authority takes the enhancement of environmental protection under National Environmental Protection Program, mainly by advanced environmental monitoring and employing innovative technologies and administrative methods to raise the level of environmental protection and control the problems threatening public health.

The conventional Physico-chemical methods have been widely used to remove radionuclides from wastewaters. These methods may be ineffective or expensive with a few major disadvantages. Biological treatment, such as biosorption, is an innovative technology available for the bioremediation of soils and waters contaminated with metals or radionuclides. Accordingly, the current work was undertaken to investigate the biodiversity of indigenous bacterial strains with radium biosorption capability in the soils and waters of high background radiation areas in Ramsar, using a combination of isolation, molecular approaches, biochemical analysis and equilibrium and kinetic studies.

Among several bacterial strains isolated, a novel biosorbent; Serratia sp. ZF03 strain, is suggested to be an efficient and excellent ^{226}Ra biosorbent (75–80% removal; up to 38 KBq g_1) desirable for engineering applications of biosorption systems and could be used as a lowcost and ecofriendly biosorbent for treatment of hot-spring waters containing high levels of ^{226}Ra in Ramsar.

The key cellular events that allow this strain to survive and undergo ^{226}Ra adaptation and biosorption was studied by characterization of candidate proteins that differentially express or newly appear in response to high ^{226}Ra stress using 2-dimensional polyacrylamide gel electrophoresis and mass spectrometry (MS/MS analysis).

P11.45
Long-term Management in Norway, 1986-2011. Use of Caesium Binders and Special Feeding Program to Reduce Radiocaesium Concentration in Grazing Animals

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During the summer months in Norway, large uncultivated areas of forest and mountain are used as pasture for sheep, goats and cattle. The first autumn after the Chernobyl accident in 1986, approximately 100 000 sheep were destructed due to very high levels of radiocaesium. In addition 320 000 sheep were on special feeding programme i.e. fed with fodder with low concentration of radiocaesium to reduce the levels before slaughtering. During the period 1986-2011, altogether 2.2 million sheep have undergone special feeding programme lasting from 1-8 weeks before slaughter.

In 1987, methods for live monitoring of animals were developed to avoid slaughtering animals with radioactivity levels exceeding the food intervention levels of 600 Bq/kg. In addition, efficient countermeasures like use of Prussian blue in concentrates, boli, saltlicks and clean feeding periods prior to slaughter period were developed and implemented. Use of Prussian blue in concentrates and saltlicks has been available since 1989, and reduces the levels of radiocaesium in meat and milk with approximately 50 %. In years with a high abundance of mushrooms, levels of ^{137}Cs increases in meat and milk owing to the ingestion of radioactive mushrooms by grazing animals. Experience from the last decade's turns out that abundance of mushrooms more or less controls the levels of ^{137}Cs in livestock animals.

Ecological half-lives of ^{137}Cs in milk from different regions in Norway vary between 4 and 12 years. Calculated ecological half-lives of ^{137}Cs in sheep vary from 3 to 11 years, with the longest half-lives in the most contaminated regions. Based on our experience, it is still necessary to maintain countermeasures for at least another decade to comply with food interventional levels for meat and milk in Norway.

P11.46
Radiation Protection Considerations in the Primary Approval Phases of Major Projects

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In Australia, mining projects involving uranium trigger national and state requirements for impact assessment studies prior to approval. The impact assessments cover a broad scope including environmental, social, health and economic aspects. The impact assessment process is prescriptive, starting with an initial terms of reference developed by the governmental regulatory agencies in consultation with the public. Following this, the impact study work is undertaken, which, when completed, goes through a public discussion period, followed by government assessment.

While predominantly a scientific and technical process, the assessment is invariably a mutli-layered exercise, which needs to incorporate varying political expectations and consideration of public perceptions.

In addition, it is also important to balance the integrity of the work with the ambitiousness of a project timeline.

For uranium mining or processing projects, radiation is one of the parameters that is investigated and draws an unusually disproportionate amount of scrutiny compared to other potential impacts and risks. This is primarily due to the general public's negative perception of radiation.

Because of this, radiological impact assessments can vary between being overly complex through to being oversimplified.

Attaining the primary approval for a project in a timely and efficient manner depends upon having a competent understanding of the radiological characteristics of the proposed project and providing an adequate balance between scientific fact, demonstrable competence and digestible information.

This paper provides an overview of the radiation protection considerations in some recent Australian impact assessments and draws out common themes contributing to the optimal balance between radiological technical competence and clearly communicating the radiological impacts in an understandable manner.

P11.47
Regulatory Radiation Protection Inspections at the Koeberg Nuclear Power Station (KNPS): Ensuring the safety of workers, the public and environment.

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NNR, Duynefontein, South Africa

The South African National Nuclear Regulator (NNR) was established in 1999 via promulgation of the National Nuclear Regulator Act, 1999 (Act No. 47 of 1999) to provide for the protection of persons, property and the environment against nuclear damage. NNR Inspectors are empowered via the legislation to perform compliance assurance inspections on the Licensee's system of protection to provide assurance of compliance with the conditions of nuclear authorisations and legislative and regulatory standards.

The NNR Inspector performs periodic compliance assurance activities on the Radiation Protection Standards that include but is not limited to the following: Operational radiation protection, Personnel Dosimetry and Medical requirements, Safety of radioactive sources, Environmental surveillance, Meteorology, Radioactive Waste Management and Nuclear Emergency Preparedness and Response.

The purpose of the poster is to present information on the processes and techniques used by the NNR Inspector to prepare, execute and report on inspections relating to the radiation protection program at KNPS. The poster contains information on the NNR process of developing checklists based on regulatory documents, licensee standards, and feedback from operating experience. The poster also contains information on the process of identifying, classifying and reporting on findings which may lead to further investigations, audits and in-depth regulatory analysis.

'Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning.' This quote from Albert Einstein best describes the task of the radiation protection inspector. The NNR compliance assurance program for KNPS is evolving and continuous improvements are being identified and implemented. The poster also addresses new NNR initiatives which includes cross-training of Inspectors to enhance skills and improve regulatory efficiency and effectiveness.

P11.48
Investigation of a Pollutant Behavior in Coastal Area by using a Hydraulic Prototype Model

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Most nuclear power plants in Korea were located near coastal areas. It is important to evaluate the dispersion characteristics of the liquid effluents released into the sea from a power plant under both normal and accidents. In this study, a hydraulic prototype model was designed and constructed to understand the physical phenomenon for the advection and dispersion of a pollutant using radioisotopes.

A laboratory experiment using a radioisotope was performed to analyze the characteristics of the transport and dispersion of a pollutant released from an industrial plant. In this study, Tc-99m, which has a short half-life, was used as a tracer in the second experiment. Tc-99m, milked from a ^{99}Mo/^{99m}Tc portable generator fabricated for medical purposes, had 0.141mEv of gamma radiation and a half-life of 6.02 hours. The detection was made using 2 inch NaI(Tl) scintillation detectors at four transverse lines in the downstream direction from the release point. The radioisotope was instantaneously injected into a flow as a point source in the hydraulic prototype model. Two-dimensional numerical models were used to reproduce the results of the wave hydraulic model. The measured and calculated concentrations were compared under the same conditions. The dispersion phenomenon which used the radioactive tracer was measured quite well by the advection and hydrodynamic dispersion throughout this experiment. As a result of a comparative study, the time of maximum concentration showed a slight difference between them, but the values of the maximum concentration were in relatively good agreement.

P11.49
The Radiological Characterization of the Dosimetry Secondary Standard Center of IFIN-HH, Bucharest, Romania

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The paper presents the measurements and results of the monitoring of the area of the Centre, where irradiation facilities, such as: high activity standard sources of ^{60}Co, ^{137}Cs and ^{241}Am, as well as an x-ray radiation generator, are placed, for the situation of complete shielding of sources and with the generator switched out.

The monitoring was performed with high sensitivity TL dosimeters, placed in 20 positions, situated in the following spaces: irradiation hall, command room, offices and auxiliary spaces. The monitoring was done in two long term rounds: 54 and 61 days. These precise measurements of the ambient dose equivalent H*(10) and its rate are imposed once by the radiation protection requirements, and also by the correct subtraction of background value when the calibration of dosimeters in the region of low level measurements are performed. The paper presents a detailed description of the method and the map of H*(10) rate distribution in the whole monitored area. Generally, these values are situated within the interval: 68 – 150 nSv h^{-1}

P11.50
Using Modelling and Measuring Toolq to Build Relevant Environmental Monitoring Programmes

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AREVA, Pierrelatte, France

Environmental monitoring of nuclear sites is governed by French law through regulatory decrees. On the Tricastin site (Rhone river Valley, France), the presence of five nuclear operators has led to pooling environmental monitoring through a common environmental monitoring plan. This plan includes all the requirements of the various facilities and aims to answer the questions of many stakeholders (residents, associations, scientific). The plan thus consists of more than 150 sampling points on which many chemical and radiological are implemented. 8,000 samples and 19,000 measurements have been carried out in 2009 under the regulatory oversight. Environmental compartments considered are air, water (surface water, rainwater, groundwater and drinking water), plants (grass and maize), soil, fauna, flora and aquatic sediments. The analytical results represent the overall activity measured in the environment due to local background noise (natural radioactivity), the discharge of AREVA and other human activities (fallout from atmospheric testing of nuclear weapons, fallout from the accident Chernobyl releases or releases of other nuclear facilities upstream of the Rhône). In parallel, an annual assessment of the dosimetric impact due to regular releases of the nuclear facilities is achieved by using computer code. This code models the transfer of radionuclides in the environment to man. To perform these calculations, the code estimated from the activities released and the weather conditions, the resulting activities in different environmental compartments. Calculations can therefore be compared to results of environmental measurements. This comparison was done for all the measurement data of radioactivity from the site of Tricastin acquired between 2007 and 2009. A total of 75 cases-studies related to 29 radionuclides (^{232}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{99}Tc, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{233}Pa, ^{125}Sb, ^{95}Zr, ^{208}Tl , ^{212}Bi, ^{212}Pb, ^{224}Ra, ^{228}Th, ^{234}Th, ^{231}Th, ^{234}Pa, ^{129}I, ^{3}H and ^{14}C), were examined. The main case with highlighted inconsistencies between estimates of computer code and measurement results led AREVA to change the procedure for air sampling for the measurement of tritium and carbon 14. Otherwise, the majority of cases show that the estimates from modelling are consistent with the results of measurements. However, most cases remain difficult to interpret. These cases indicate possible areas for improvement: improving the knowledge of local background noise and improving decision thresholds of analytical instruments. Beyond the lessons for our environmental monitoring plan, this study confirms all the interests of comparing the results of regular measurements with estimates of model calculations.

P11.51
Environmental Radioactive Air Sampling and Monitoring Program Considerations

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Considerations for environmental radioactive air sampling and monitoring are increasingly important as regulatory agencies promulgate requirements for the measurement and quantification of radioactive contaminants released to the environment. The concepts used in radioactive air sampling and monitoring include establishing a basis for sampling and monitoring, the criteria for sampling media and analytical requirements, and reporting and compliance. Additionally, sharing knowledge derived from routine operations and implementing tested and reviewed ideas can enhance the program. These elements can be used to demonstrate to stakeholders that the emission of radioactive materials to the environment is below regulatory limits and that reported doses from such emissions are reasonably accurate. Two forms of radioactive air monitoring include direct effluent measurements and environmental surveillance. For direct effluent monitoring, emissions may come from several industries such as medical isotope production laboratories, hospitals, and research institutes. For environmental surveillance, emissions tend to emanate from discrete pathways such as waste piles, abandoned buildings, breather tanks, or contaminated land masses. Direct effluent (point source) sampling of the exhaust is typically conducted downstream of the last disturbance, and all abatement controls while environmental monitoring stations are usually sited at or near the facility boundaries or nearby public areas. The Pacific Northwest National Laboratory Site has utilized these ideas to implement a comprehensive radioactive air sampling and monitoring program. In 2010, the facility began radiological operations with the potential for radioactive air emissions, and the results of associated sampling and monitoring were reported in 2011. Together, these concepts have been incorporated into a basis for an operational radioactive air program that is capable of assuring the public, demonstrating low emissions of radioactive material, and complying with environmental regulations.

P11.52
Strengthening Environmental Radiation Monitoring Around Kwale Titanium Mining Site in Kenya

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Environmental radiation monitoring in Kenya was started in 2007 to measure the radioactivity of foodstuffs imported from abroad. The monitoring process work was carried out by Kenya Radiation Protection Board (RPB). Through environmental radiation monitoring, sample collection, and data analysis, the Food and Environmental Monitoring Section (FEM) of the Kenya Radiation Protection Board (RPB) works to protect the public and environment from hazards associated with ionizing radiation. The purpose of this paper is to highlight suggestions for the improvement of environmental radiation monitoring around Kwale mining site and its environs in Kenya with respect to protection of members of the public and the environment against undue risk from radiation. Through review of environmental radiation monitoring documents and reports of various countries from Asia, Europe and America the author has come up with ways of strengthening environmental radiation monitoring in Kenya. The suggestions for improvement of the environmental radiation monitoring presented herein will serve as a guideline for the improvement radiation monitoring of doses received by the public and the environment in the future. Moreover, the suggestions will surely help us understand the cumulative effects of radionuclides released from titanium mining.

Keywords: Radiation, environment, monitoring, dose, radionuclide.

P12.01
Lessons for Health Physics Professionals after Fukushima Dai-Ichi Accident

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We are continuously learning the management skills and decision making guidelines by nuclear and radiological emergencies. The Chernobyl accident in 1986 has taught lessons a lot for nuclear crises management to mitigate the consequences of radiation exposure. Though Japan has managed the nuclear crises in better way which became a lesson to others yet many lessons and technical directives have been come out for Health Physics professionals. The radiological protection of the workers engaged in the management and the public in off-site is the key important during emergency. Throughout the nuclear crises, air-borne activity measurement, personal monitoring, instrumentations, dose limits, decision for evacuation, forecast of the dose/dose rate in public domain, administration of the iodine tablets, decontamination of the personal/land and radioactive waste management are the main concern. In the present paper after Fukushima Dai-ichi we essentially focus on reorganize emergency preparedness program to addresses personal monitoring, ambient dose/dose rate monitoring, provision to raise dose limits, operational intervention limits, emphasis on evacuation criteria, timing, area of evacuation, extension of emergency planning zone, approved methodologies for dose prediction, training to medical staff and others and defined single communication channel to media and public. In addition, role and responsibilities of regulatory body enhanced to approve site/station specific emergency preparedness procedures by considering safety systems to mitigate the situations and other possible means to cause the accident instead of general emergency guidelines. The lesson learnt from the accidents must be shared among Health Physics professional because during the emergency they are in-service group as well as advisor to take appropriate actions. The advice at each step for nuclear crises management is very crucial for operator as well the society.

Keywords: nuclear crises, Health Physics, dose limit, deliberate evacuation, monitoring, EPZ, OIL

P12.02
In-vivo measurements at German Competent Incorporation Measuring Bodies in the wake of Fukushima

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German citizens and other people being potentially exposed to radionuclides released by the accident at the nuclear powerstation Fukushima Daiji had the possibility to undergo an assessment of their body burdens at most of the German Competent Incorporation Measuring Bodies (mostly) free of charge.

The Coordinating Office on Incorporation Monitoring of the German Federal Office for Radiation Protection collected the results made available by the laboratories. Till the middle of September, the 19 involved laboratories in total reported 305 results. Most measurement results were below the limit of recognition. Only in 63 cases measurable activities showed up for at least one nuclide. About 75 % of all measurements were performed by just five of the laboratories.

Information sheets were handed out by BfS to the laboratories in order to assist with the calculation of doses. Dose values were estimated by the simplifying and conservative assumption that all intakes have taken place on March 12, 2011, by the pathway of inhalation.

The thyroid dose for the isotope I-131 has been estimated to be 80 µSv in case of the highest activity measured. The mean of all measurement values corresponds to 20 µSv. For the isotopes I-131, Te-132, Cs-134 and Cs-137 an effective dose of maximal 600 µSv resulted , the mean value being 140 µSv.

This may be compared to an external dose to be received on a return flight from Europe to Japan of about 130 µSv (calculated with EPCARD) [1]. In Germany the mean annual effective dose from natural sources of radiation is 2100 µSv [2].

[1] European Program Package for the Calculation of Aviation Route Doses (EPCARD); http://www.helmholtz-muenchen.de/epcard-portal/

[2] BMU, Umweltradioaktivität und Strahlenbelastung: Unterrichtung durch die Bundesregierung im Jahr 2009 (Parlamentsbericht), Berlin/Bonn, März 2011

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P12.03
In-vivo measurements at German Competent Incorporation Measuring Bodies in the wake of Fukushima

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German citizens and other people being potentially exposed to radionuclides released by the accident at the nuclear powerstation Fukushima Daiji had the possibility to undergo an assessment of their body burdens at most of the German Competent Incorporation Measuring Bodies (mostly) free of charge.

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[2] BMU, Umweltradioaktivität und Strahlenbelastung: Unterrichtung durch die Bundesregierung im Jahr 2009 (Parlamentsbericht), Berlin/Bonn, März 2011

P12.04
Openness to society in the context of Fukushima accident

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Openness to society is one of the main components of the IRSN work to enhance nuclear safety and radiation protection.

Ever since the Buenos Aires congress, the Institute developed its action and made its "charter of openness to society" public in April 2009.

Its includes three key commitments :

• Enhance transparency in presenting its work

• Share its knowledge

• Help stakeholders acquiring the skills necessary to actively participate and build risk assessment along with them.

IRSN implemented those commitments on various issues, some are detailed in other lectures.

This lecture will present the implementation of each of them in the aftermath of Fukushima accident in the light of the evolutions of the perception by French people of nuclear risks and their expectations with regard to transparency and pluralism.

KEYWORDS: Fukushima – Stakeholders – Openness to society.

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P12.05
Risk Perception Toward Nuclear Power in Taiwan After Fukushima 2011

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There have been tremendous media coverage in Taiwan on the nuclear disaster in Fukushima, Japan since March 2011. Due to the near completion of the construction of the fouth nuclear power plant in Gong-liao Town in northern Taiwan and its pending licensure, as well as over loaded nuclear wastes and aging nuclear power plants 1~3 in Taiwan, the debates on the safety of nuclear power plants have reached its new high in the following months since March.

We have conducted a systemic risk perception study in several towns near the operating power plants in northern and southern Taiwan, through communities several social networks, that more than 2,000 individuals responded to this survey conducted in those more than 17 years old between July to Nov., 2011. The perception toward nuclear energy, as well as nuclear waste, as well as several other environmental and health risks have been compared in those residing near the operating nuclear plants, as well as those stay much apart from the plants. The results have been also compared with a similar study conducted in 2000 in northern Taiwan, right after a mega earthquake disaster in central and southern Taiwan. We have been also collecting responsive perception from several other communities in main cities in Asia and in northern American in order to compare the differential perception on the same issue, as well as the determinants before and after the Fukushima nuclear accident.

The results have shown essentially interesting differences between different age groups, as well as the education, specialty, distance from an operating plant, as well as their governmental policies toward nuclear power plants and related emergency plans. The results can be very useful for safety and risk communication between the operators and the communities elsewhere in the world.

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P12.06
Regional Fukushima Fallout in Germany – Data and Models

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Airborne and deposited activity originating from releases of Fukushima could be detected in many regions of Europe. Data from our laboratory show contributions in rain water, river sediment, soil, grass and cow milk. Depending on the sample, one or several of the isotopes ^{131}I, ^{134}Cs and ^{137}Cs could be detected. Using the known Cs isotopic ratio of the Fukushima releases, old and recent contributions could be distinguished. Fortunately and as expected the detected activity levels were very low, and no consequences like restriction of consumption of food had to be envisaged.

On the other hand, these and other well-documented data offer the possibility to check the ability of standard models, like those underlying state regulations for limiting releases from nuclear installations, to predict environmental radioactivity levels from airborne isotope concentrations.

For the above listed media and isotopes, a comparison between measurement results and calculation based on German state regulations has been made. When data on regional weather conditions are included, the agreement between both data sets is quite good.

P12.07
Experience Of TCC IBRAE RAN In Scientific And Technical Support And Radiation Emergency Response

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The main directions of activities of the Technical Crisis Center (TCC IBRAE RAN) in the field of radiation emergency response are as follows:

• Evaluate and forecast the basic characteristics of the source of emergency radioactive release ;

• Predict environmental contamination taking into account the radiation monitoring data;

• Assess and forecast public exposure doses;

• Elaborate recommendations on public and environmental protection;

• Assess the efficiency of protective measures and optimize them for specific conditions taking into account radiological, economic and social conditions.

The paper presents the detailed description of TCC experts' activity to provide 24-hour scientific and technical support for EMERCOM of Russia and State Corporation "Rosatom". in the emergency situation on the Fukushima-1 NPP:

• Predict evolution of the situation at this NPP (in coordination with ROSATOM);

• Predict the radiation situation in vicinity of Fukushima Daiichi and Daini nuclear power plants in case of unfavorable scenarios of situation evolution;

• Predict the radiation situation in the territory of the Russian Federation in case of unfavorable scenarios of the Japanese accident evolution (in coordination with SPA 'Typhoon').

• Inform the media and the public and provide the actual, topical and scientifically valid information about the incident and its consequences for the human and environment.

The established system of scientific and technical support and response to emergency situations at NPPs proved to be highly efficient as the Fukushima accident showed.

KEYWORDS: Radiation accident, emergency radiation response, Fukushima accident

P12.08
Construction of Precise Contamination Maps in the Fukushima Region

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Several different kinds of maps on contamination due to the Fukushima nuclear accident were constructed based on the results of extensive environmental monitoring conducted from June 6, 2011 to July 8 in order to clarify the contamination conditions around the Fukushima site. More than 10,000 soil samples were collected and analyzed using Ge detectors to quantify radioactivity of several dominant radionuclides. Cs-137, Cs-134, I-131, Te-129m, Ag-110m, Cs-136 were detected, and the maps showing distributions of radioactivity per area were constructed for these radionuclides except Cs-136 which were detected only in a small number of samples. The I-131/Cs-137 concentration ratio changes according to the direction from the nuclear power plants, which indicates that the contaminations would originate from different radioactive plumes. Meanwhile, car-borne surveys were performed using taxis equipped with KURAMA systems which successively send dose and position data through a cellular network. The survey data were saved on the main server on time and shown on the screen with a Google Earth picture. Roads at more than 17,000 km were covered by the surveys, and precise maps showing dose rates in air was constructed. From these maps, it is clear that the features of contamination are affected by terrains specific to the Fukushima region. The basin located in the middle part of the Fukushima prefecture is relatively highly contaminated, and the contamination decreases with the altitude toward mountains on the both sides of the basin. This might suggest that a radioactive plume passed through at a low altitude in the basin, or it rained in this restricted area. A database has been constructed to record and maintain all these data. Further, maps and some numerical data are being published through the internet.

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P12.09
Measurements and Calculations of Beta Dose Rates on the Contaminated Ground at the Fukushima Daiichi Nuclear Power Plant Site

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The accident at the Fukushima Daiichi Nuclear Power Plant resulted in a substantial release of radionuclides to the atmosphere and caused extensive contamination of the environment. A number of fission and activation products released emit gamma-rays and beta-rays. Consequently, the emergency operation workers were exposed to both external gamma and beta radiations arising from the contamination of the site. Beta radiation primarily affects the skin. The assessment of skin doses in nuclear emergency situations is most important, as highlighted in the past reactor accidents.

The purpose of this study was to reconstruct the gamma and beta mixed radiation fields in the outdoor environment at the site, which were not well defined at the time after a series of radiological releases, by using computational dosimetry techniques, and to provide data applicable to assess the skin dose to beta-rays.

Measurements were made of beta and gamma dose rates from soil samples collected in the late-March at five locations within 1 km from the reactor Units 1 and 2. Each soil was packed into a plastic container. A thin and large window air ionization chamber with a shallow collecting volume, Oyo-Giken Model AE-133B, was set at a height of 5 cm above the soil surface. Beta and gamma dose components were discriminated with measurements with and without a 8-mm acrylic filtration. Prior to the measurement, the chamber was calibrated using the standard beta calibration sources.

The dose rate calculations with the Monte Carlo transport code were also performed to compare with and extend the above measurements. A computer model included soil, a plastic container and air, together with the source term of elemental compositions (106Rh, ^{129m}Te, ^{131}I, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{140}La-^{140}Ba, etc.) and concentrations determined by the measurements with a Ge spectroscopy system. Reasonable agreements between measured and calculated beta dose rates suggested that the amount of pure beta emitters, not included in the source term, was relatively small. The computer model was spatially extended and used to evaluate the height variation in beta and gamma dose rates over a flat ground on which the measured radionuclide mixtures were uniformly deposited. The beta-to-gamma dose ratio computed ranged from ~12 at 10 cm to ~1 at 200 cm, which will allow the beta skin doses at any site of the worker to be assessed from his APD gamma dose.

P12.10
Information: Lessons learnt from Fukushima crisis

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In France, the two words "radioactivity" and "nuclear" create fear. Their deep meaning is not well known by common people. The IRSN Barometer shows a very low level of confidence in institutions in charge of nuclear regulation and governance[1].

This mistrust comes from the Chernobyl's fall out management: the level of radioactive deposit and contamination was not communicated.

In crisis situation, the most important objective of information and communication is to give people references to understand the event with a high level of pedagogy, in order to help them to decide the best actions for their family, thus increasing the community and economical resilience.

IRSN tried to change this situation and has developed, the last ten years, a strategy to be able to have a quick and complete response in case of crisis. The competence and tools of IRSN have been tested during the Fukushima crisis.

The paper will present the foundation of IRSN communication strategy, the tools and the process. The results and their comments will also be included in the paper, like the figures or website, the media requests number and the media coverage. The conclusion will present the main lesson learnt form the crisis seen from France. [1]http://www.irsn.fr/FR/base_de_connaissances/librairie/Documents/publications_institutionnelles/IRSN_barometre_2011.pdf

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P12.11
Temporal Changes of Transfer of Fallout Radionuclides by Fukushima NPP Accident from Tree Crown to Litter Layer and Forest Soil

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The powerful Tohoku earthquake that occurred on 11 March 2011 triggered a violent tsunami that destroyed 600 km of coastline in Eastern Japan and damaged the cooling system of several reactors of the Fukushima Daiichi nuclear power plant. Gamma-emitting radionuclides (i.e., mainly iodine-131, caesium-134 and caesium-137) bubbled off the nuclear fuel and were released into the atmosphere. The total deposition of radioactive materials in fallout samples for Cs-137 ranged from 0.02 to >20 M Bq/m^2.

Experimental catchments have been established in Yamakiya district, Kawamata Town, Fukushima prefecture, located about 35 km from Fukushima power plant, and designated as the evacuated zone. Approximate Cs-137 fallout in this area is 200□-□1000 kBq/m^2. We established 3 forest sites: broad leaf tree forest and two Japanese cedar forest plantation (young and mature). In each site we installed towers of 8-12 meters. Using these towers, we sampled tree leaves, and measure Cs-137 and Cs-134 in the laboratory, and also we have measure Cs-137, Cs-134 content at various height in each forest using a portable High Purity Germanium (HPGe) detector (Ortech; Detective-EX). We also measured the throughfall, stem flow and litter fall inside of the forest. In each site, we establish the 20 m x 20 m plot to monitor the changes of fallout radionuclides through time with the portable HPGe detector.

The monitoring is now ongoing but we found significant amount of Cs-134 and Cs-137 has been trapped by cedar forest plantations especially young trees, but not so much in broad leaf trees. Also most of the Cs-137 and Cs-134 was trapped litter layer, and percolating the soil later is still small on the end of July. The trapped Cs-137 and Cs-134 is then washed by rainfall and found into throughfall and fallout radionuclides are found to increase in Japanese ceder planations but decrease in the broad leaf plantations. Therefore, in forest ecosystems, the fallout has been still ongoing, and effective remediation method in forested area (especially cedar plantation) can be removing the trees and litter removal.

P12.12
Artificial radionuclides in the troposphere of Seville (Spain) due to the Fukushima accident, associated fallout and impact on the trophic chain

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Radioactive emissions into the atmosphere from the damaged reactors of the Fukushima Daiichi nuclear power complex were transported in part across the Pacific Ocean to North America and then to Europe, despite the dispersion that the masses of contaminated air underwent, and their washing by rainfall during their displacement.

This paper shows the magnitude and temporal evolution of the radionuclide concentrations detected in the cited contaminated air masses at their arrival to Seville (Spain), where there is a station of the nation's environmental monitoring network equipped with high sensitivity devices for uninterrupted radiation detection. In the collected aerosol filters and during about two weeks were detected the presence of the following radionuclides: ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{131}I and ^{132}Te (together with its short-lived daughter ^{132}I) at minute levels and with characteristics ^{134}Cs/^{137}Cs and ^{136}Cs/^{137}Cs isotope ratios. The associated ^{131}I fallout due to this episode was also roughly estimated from additional wet and dry deposition measurements, while the presence of ^{131}I in gaseous form was evaluated through its collection with a pumping system equipped with a charcoal filter

It should also be noted that in Seville and surroundings, the presence of ^{131}I with origin in the Fukushima episode was detected in several key links in the human food chain: samples of milk (goat and cow) and derivative dairy products, as well as in various broadleaf plants. The maximum levels measured for this radionuclide were 1.11 Bq/l in samples of milk and 1.42 Bq/kg wet wt in broadleaf plants, with obviously negligible radiological implications. However, no presence of ^{132}Te or ^{134}Cs was detected in any of the samples of products for human consumption tested, while the possible changes in ^{137}Cs activities were in most cases masked within the global fallout levels.

P12.13
Fallout Of 131I, 134CS And 137CS In Southern Sweden, Following The Fukushima Nuclear Accident

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Radiation fallout (^{131}I, ^{134}Cs and ^{137}Cs) from the Fukushima nuclear reactor, damage in March 11 earthquake and tsunami, has been detected and measured in air filter and rainwater.

From March 14th to April 30th samples of air filters and rainwater has continually been collected in the city of Malmö (55° 37' N, 13° 01' E), southern Sweden. The radioactivity content in the collected samples has been measured in the facilities of Skånes University Hospital, Lunds University, low activity measuring laboratory. The radioactivity contamination in the air volume has been recorded ranging up to 15 mBq/m^3 for the ^{131}I and up to 2 mBq/m^3 for the ^{134}Cs and up to 2 mBq/m^3 for the ^{137}Cs. Corresponding values for the rainwater samples is 0,4 mBq/kg, 0,3 mBq/m^3 and 0,4 mBq/m^3.

P12.14
Egyptian Guidelines for Goods Imported from Japan After Fukushima accident

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Upon the request of the Egyptian Authorities, a national committee was formed within the Egyptian Atomic Energy Authority with representatives of several ministries related to the control of imported Goods. Guidelines for the control of imported goods were drafted. In general, attention was paid to food and non food consignments (raw material, equipments and spare parts). With the continuous radiological inspection of the imported goods, the guidelines were modified. Recently some shipments of used building and agricultural equipments were rejected.

P12.15
Radioactivity of Aerosol and Fallout in Belgrade – Consequences of Fukushima Reactor Accident

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Daily monitoring of radioactivity in aerosoles and fallout in Belgrade was initiated after the Fukushma reactor accident. Within a monitoring program, samples of aerosol and fallout were taken and analysed for traces of isotopes indicating Fukushima fallout in Environmental and radiation protection department of Institute for nuclear sciences Vinca. Gamma spectrometry measurements were conducted on these samples over about two months time period. Indication of fission products ^{131}I, ^{134}Cs and ^{137}Cs were followed daily in order to estimate the air contamination risk on the teritory of city of Belgrade.

Kewwords: Fukushima, ^{131}I, ^{134}Cs, ^{137}Cs,

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P12.16
Experiences in Japan - Providing Radiation Protection Advice in a Crisis

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In the days and weeks following the Fukushima accident, radiation protection specialists around the world were called upon to provide advice and support to assess the impact of the nuclear accident in their respective regions. Some experts were also called to give advice to foreign embassies in Japan which were concerned with their nationals living there. At this time the European Commission sent two radiation protection specialists to help assess the risks and consequences for EU nationals and local staff based in Tokyo - by interpreting data provided at official briefings, by reviewing data from other sources, and by performing local measurements in the Kanto, Ibaraki and Fukushima prefectures. This presentation will describe in detail our observations of the unfolding crisis in the early days of the accident, our experience of providing radiation protection advice to foreign nationals and local staff at a time when the scale of airborne and surface contamination spread was not fully known. We describe the nature of the concerns and the reassurance demanded by people with no easy means of interpreting for themselves the daily streams of news in the media about contamination of drinking water, foodstuffs, measured radioactivity levels on land, and discharges into the sea.

Based on our observations, we highlight important lessons that could be learnt in providing advice in a crisis situation, and communication of risks to those affected - the public, and officials. Data is also presented of measurements of dose-rate, and surface contamination in urban areas shortly after the accident and how this was used to make interpretations of the likely impact and consequences of the accident in the short to medium term.

P12.17
The Fukushima Accident Through the “Corriere Della Sera” Website

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The *“Corriere della Sera”* is one of the most prominent and relevant Italian newspapers: its long history started in 1876 in Milano, just a few years after Italy’s indipendence in 1861, and has a current diffusion of 500.000 copies per day.

Its web version (www.corriere.it) is one of the most visited websites in Italy, celebrating its continuous popularity, credibility and success.

It is well known that the Italian public opinion is very sensitive towards nuclear and radiological subjects: since many years, public, mass-media information on nuclear and radiological issues has been very limited, in Italy, and public discussions on radiological subjects were often polarised and extreme.

Since the very first day of the FUKUSHIMA accident, when journalists were building, hour after hour, the sequence of events at the crippled nuclear power plant, many popular newspapers strived to present an objective view of the facts, and to structure the continuous flow of information that was publicly made available.

Some newspapers’ websites showed sketches and simulations of the accident in the plant and its possible radiological consequences. Others interviewed experts in nuclear energy or in radiation protection, and presented an overview of projected risks and consequences. In most cases, those newspapers strived to explain to the public the (non-trivial) concepts of activity, committed dose, contamination, criticality, dose limits, risk, etc. (and it is in fact remarkable how some popular newspapers finally succeeded in offering a severe, scientific, while simplified, interpretation of the events to the general public!).

In the pre-FUKUSHIMA world, in a period which was called of *“Nuclear Renaissance”,* the Italian Government opened the way to the possibility of the comeback of nuclear energy production in Italy. During that period, after years of mis-information on nuclear issues, an objective and balanced public information could have been appreciated, both from *pro-nuclear* and *against-nuclear activists*, in order to present and clarify to the Italian population the arguments supporting or opposing that choice. But then the FUKUSHIMA accident happened.

While, in our Radiation Protection community, we discuss more and more the need for a *Radiation Protection culture*, a balanced presentation of the FUKUSHIMA accident’s cause and consequences may have proved to be an excellent opportunity to develop, present, clarify and improve the general public’s culture about radiation, radiological risks, natural doses, dose limits, etc. With the contribution of radiation experts, of environmental experts, of scientific journalists.

This article shows that, reading some of the news coverage on the FUKUSHIMA accident in the *“Corriere della Sera”* website, one of the most prestigious and historic Italian newspapers, unfortunately, one may have the feeling that that cultural opportunity was completely missed.

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P12.18
Environmental Consequences of Major Nuclear Accidents: The IAEA Outlook on Lessons Learned

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The paper provides an overview and a detailed comparative analysis of environmental aspects of two major nuclear accidents at the Fukushima-Daiichi NPP and Chernobyl NPP. Needs in further development of international recommendations on environmental monitoring, modelling of radionuclide transport in environmental media and assessment of the public exposure are also identified and discussed.

The 1986 major nuclear accident at the USSR's Chernobyl NPP resulted in a large-scale contamination of rural and urban environments, exposures of members of the public and serious deterioration of the local social and economic conditions. About 100 000 residents of the contaminated areas still receive annual doses above 1 mSv. The affected countries, supported by the IAEA and other international organizations, have undertaken large-scale protective measures, radiological monitoring and remediation of urban and rural environments. The mitigation of consequences the accident was complicated by the lack of validated site-specific and internationally recognised methodologies for assessing the environmental consequences, public exposures and for planning of countermeasures and remediation programmes. The experience and knowledge accumulated after the Chernobyl accident stimulated the development of advanced international approaches and methodologies.

After the 2011 accident at the Fukushima-Daiichi NPP, the Chernobyl experience was widely used for the analysis of environmental issues and for the implementation of the adequate protective measures and environmental remediation programmes. The new experience substantially complements the existing Chernobyl knowledge. It would be an important input to the revision of the IAEA Safety Standards and technical documents. The dissemination of the new data on environmental behaviour of radionuclides would be also important.

P12.19
The Fukushima Accident: Reflection in the Media and the Public Opinion in Belgium

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The experience after the accident in Chernobyl showed that nuclear accidents have a strong impact on the public opinion and often lead to political decisions related to nuclear programs. It also showed that media plays an influential role in shaping public opinion about nuclear energy.

25 years later, a serious nuclear accident happens again with broad consequences that are felt at international level. This paper analyses the impact of the accident in Fukushima in the Belgian media and public opinion. We study how mass media reported about the accident in Japan and how the public opinion related to nuclear energy changed.

The research methodology consisted of: i) content analysis of two quality newspapers in Belgium, covering the first two months after the accident; and ii) public opinion research, based on more than 1000 personal interviews conducted in Belgium in the third month after the accident.

Media analysis results showed, among other, that the main issue addressed by the articles was in the first weeks very diverse (energy, health issues, emergency management actions, tsunami and earthquake, nuclear technologies), but became limited towards the end of the time period analysed to emergency management actions, energy and nuclear technologies. It could be also noticed, that almost half of the articles focused on domestic, international or global issues, rather than the situation in Japan. The articles' orientation towards nuclear energy displayed a clear emphasis on the negative aspects in April 2011, at the time of the 25th aniversary of the Chernobyl accident. Although a great majority of the articles reported about radiation levels or health effects, only 13% have used specific measurement units.

The public opinion research showed that opinions are divided as regards the relevance of the accident in Fukushima for Belgium. At the same time, a shift towards a more negative opinion about nuclear energy was observed. The trend in the Belgian population during the last decade with respect to several items pertaining to attitudes towards nuclear is further discussed in the study.

P12.21 Monitoring the External and Internal Contamination of People Returning from Japan to Belgium after the Fukushima Nuclear Accident.

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A program for assessing the possible internal and external contamination of people returning from Japan was developed and implemented in Belgium in the weeks/months after the nuclear accident in Fukushima. The main goal was, apart from an independent verification of contamination levels, to inform and reassure the travellers and their families on individual contamination and associated health risks. Participation in the monitoring program was on a voluntary basis.

Because the number of persons to be measured was low, spectroscopic methods could be applied with low detection limits on individual radionuclides, yielding accurate activity measurements.

The monitoring program consisted of two sub-programs:

- The deployment of fast -but sensitive- mobile methods for detecting contaminations at the Military Hospital in Neder-Over-Heembeek (Brussels), located near the main Belgian airport, for a limited period in time (operational during 1 week when most people returned). These methods included the in-vivo measurement of the thyroid by high-resolution gamma spectrometry using a phantom calibrated germanium detector, resulting in detection limits of around 100 Bq of ^{131}I in the thyroid for a measurement time of 1 minute.

- The use of the SCK•CEN laboratories for anthropogammametry, in which thyroid and whole body measurements are performed in ideal conditions resulting in internal contamination detection limits of 25 Bq for ^{131}I in the thyroid and 25 Bq for ^{137}Cs in the body. The thyroid measurements were only done in the first weeks after the incident.

The possibility to measure personal goods (luggage) was included in both parts of the monitoring program.

During the monitoring program special attention was given to risk communication: internal communication (between actors) and external communication (to persons returning from Japan).

Small but measureable traces of external and internal (thyroid, as well as whole body) contamination were detected in only a limited number of travellers. From these measurements the individual doses were calculated, showing very low or trivial results. The radiation-induced health detriment, if any, would thus be negligible.

In this paper the different aspects of the monitoring program will be discussed, including the rationale behind the monitoring program, the organizational aspects, communication and details on measurement set-up and calibration of the mobile equipment. In addition, the measurement results will be presented.

P12.22
Evaluation of Internal Exposure of the Worker and the Residents Caused by the Fukushima Nuclear Accident

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The accident of the Fukushima Daiichi Nuclear Power Plant has caused internal exposure by radionulides to many people. JAEA have examined the workers and the residents by radiobioassay methods including measurement with a various types of whole body counters and analysis of urine sample. The committed effective dose was estimated using the intake scenarios according to the object of monitoring and expected level of exposure. In the examination of more than 500 workers who were in the plant at early stage of the accident or engaged in disaster-prevention activities, ^{131}I, ^{132}Te-^{132}I, ^{134}Cs and ^{137}Cs were detected and the maximum dose estimated based on the most severe scenario was 590 mSv. The monitoring for extended residents was started since about 4 months after occurrence of the accident. On this monitoring project, only ^{134}Cs and ^{137}Cs were detected instead of radioactive iodine. The monitoring data will be stored in the database for the Fukushima Residents Health Survey Project.

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P12.23
Landscape-Level Model Predictions Of 131I, 134Cs And 137Cs Transfer Through Terrestrial Systems In The 80-Km Fukushima-Daiichi Area Using The Symbiose Platform

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Spatially-distributed predictions of caesium and iodine transfer through terrestrial systems, and expected delivery to sea by watershed wash-off, have been carried out in the 80-km area around the Fukushima-Daiichi Nuclear Power Plant following the March 2011 earthquake. These numerical simulations have been achieved with Symbiose, a modelling platform for radiological risk assessment at a landscape-level, co-funded by IRSN and Electricité de France.

Spatio-temporal measurements of ^{131}I, ^{134}Cs and ^{137}Cs activities in the terrestrial environment, provided through the Internet by Japanese authorities, were first analyzed through statistical methods (non linear regression) and geo-statistical methods (regression-kriging). This preliminary analysis, along with some assumptions on atmospheric deposition mechanisms and meteorological conditions, enabled us to estimate the evolution in space and time of dry/wet deposition fluxes onto various terrestrial surfaces, as inputs to simulations.

Spatial simulation of the fate and transport of radionuclides with Symbiose requires the modelling of a site-specific landscape, consisting of discrete geographical objects. Geographical informations such as Landsat scene, hydrographic map and digital elevation model, have thus been processed in the 80-km area (*i.e.* image processing, network analysis, discretisation, aggregation…). The final discrete model consists of several hundreds of 2D objects (such as cropland, urban and forest polygons), organized in a hierarchy of watershed basins.

Simulations have been first carried out in order to reproduce/explain space-time evolution of ^{131}I, ^{134}Cs and ^{137}Cs activities in plants and animal products, using dynamical transfer models. Outputs were compared to measurements in foods and weeds. The observed levels and decreasing rates of activity in plants have been quite well reproduced, and provide insights to explain (at least partly) the significant variability observed among species and communes. Predictions of activity in animal products are much more uncertain due to a lack of knowledge about animal feeding diets. Some attempts have finally been made to assess the long-term evolution of radioactivity export to sea by the various watersheds, using a semi-empirical approach. Significant mass fluxes are expected, but still need to be tested against in-situ measurements.

Keywords : Fukushima-Daiichi accident, landscape modelling, terrestrial system, Iodine and Cesium transport and wash-off .

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P12.24
Learning From Experience at Fukushima: A UK Regulatory Perspective on Flood Risk Assessment and Management

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The accident at Fukushima-1 nuclear power station following the Great East Japan earthquake and tsunami of 11 March 2011 was unprecedented and led to serious environmental and socio-economic consequences. While seismic and flooding risks are already considered by UK nuclear sites, we must learn from this event to prevent accidents and improve emergency arrangements.

The paper describes how the Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and the Office for Nuclear Regulation (ONR) have worked together in learning the lessons for flood risk assessment and management.

The UK nuclear industry will review the design basis and safety margins for flooding at UK nuclear sites and consider the need to improve site-specific flood risk assessments. ONR will be making independent assessment of flooding studies for nuclear licensed sites, informed by the environment agencies' flood risk expertise.

P12.25
The Importance of the Time-Series in the Determination of the Influence of the Accidental Radioactive Contamination: "Fuskushima" Detection in Madrid

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The laboratories of the "Environmental Radioactivity and Radiological Surveillance" Unit from CIEMAT belong to the Spanish "radiological spaced net-work" funded by the Spanish Regulatory body (Nuclear Safety Council, CSN). These laboratories obtain natural and artificial radionuclides time-series in air at a very low-level of activity concentration by means of a High Volume Air Sampler, being lately these registers stored in a database.

The CSN informs about our data and those obtained from the other Spanish net-work participants to the Parliament and to those Institutions that request them within and outside our borders -as European Union, IAEA, etc.-. The CIEMAT-labs database contains the weekly/monthly registers of the I-131 activity concentration in particulate air samples and as Iodine gas and of the radionuclides such as Cs-137, Sr-90, Pu-239,240, Pb-210, U-238, since 2005. A special protocol for the radionuclides sequential analysis was established during the Fukushima accident in such a way that the air samples accumulated monthly were analysed weekly during March-April 2011 period. It means that radionuclides that are usually quantified as an average value (1 monthly sample contains four-five filters corresponding to 4-5 weeks) are analysed one by one (4 samples/1 per week) for the plutonium, uranium and strontium. The data so obtained can be compared to those from previous years to estimate whether or not the influence of this incident has occurred in our region. The radionuclides time-series and their ratios indicate the origin of the radioactive source, being both necessary for distinguishing the fallout from sixties from this possible contamination.

The importance of comparing the Spanish labs results obtained by the direct gamma measurements of the air-filters from Fukushima has been highlighted by University of Extremadura due to the specific geometry used for calibrating gamma spectrometers. The same air sample -where the Fukushima signal had been detected- was sent to the six participants of the "spaced net-work", being our results compared to them.

The participation of our Labs in other research-net works as "Rings of Five" will allow contrasting the radionuclides dispersion models to a world scale and to improve the knowledge of the behaviour of radionuclides in air in accidental and routine conditions.

P12.26
The Particle Size Distribution Of Radioactive Aerosols After The Fukushima Accident

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After the Fukushima accident the aerosol particle size distribution associated with the radionuclides released from the NPP was investigated (the time period from 24th March to 13th April 2011). The samplings were carried out by 5 stage cascade impactors on collection substrates placed on individual stages and on the back-up filter. Gamma spectrometric analysis using HPGe detectors was performed to determine the activities of radionuclides on each collection substrate from individual stages and on the back-up filter. The obtained spectra contained mainly ^{131}I, ^{134}Cs and ^{137}Cs, their aerosol activity concentrations were determined.

The values of activity concentrations of ^{131}I, ^{134}Cs and ^{137}Cs corresponding to different aerodynamic diameters of the aerosol were used to evaluate the particle size distribution mainly in terms of the activity median aerodynamic diameter (AMAD) and its geometric standard deviation (GSD).

The total activity concentrations of ^{131}I were in the order of magnitude $1.5 \times 10^{-4} – 1.0 \times 10^{-3}$ Bq/m^3, ^{134}Cs $9.4 \times 10^{-6} – 7.0 \times 10^{-5}$ Bq/m^3 and ^{137}Cs $2.2 \times 10^{-5} – 1.1 \times 10^{-4}$ Bq/m^3. The character of most distributions (from all the samplings) was similar, the particles were almost monomodaly distributed with the maximum of the activity attached to the particles with the aerodynamic diameters AD < 0.49 µm (usually more than 60% in dependence on the radionuclides), a lesser amount of the activity was attached to the particles of larger aerodynamic diameters; the aerosol with AD > 3 µm contained less than 10% of the activity. AMAD were from 0,3 to 0,8 and GSD from 3 to 4. The results were compared with the data obtained in May and June 1986 following the Chernobyl accident. After Chernobyl accident the mean AMAD of volatile radionuclides (among them ^{131}I, ^{134}Cs and ^{137}Cs) was 0.5 µm. The distributions and AMAD values determined after both accidents were very similar.

P12.27
RPII Radiation Monitoring Section Response to the Fukushima Accident and Lessons Learned

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This paper presents the results of additional environmental radioactivity monitoring carried out by the Radiological Protection Institute of Ireland, RPII, in 2011 following the accident at the Fukushima nuclear power plant in Japan. It will also discuss an internal review of the response and the lessons learned.

The RPII carries out an environmental radioactivity monitoring programme on a continuous basis and has published the results in a series of reports, all of which are available on the RPII website. In response to the situation in Japan the RPII took steps to increase the level of nationwide monitoring of air, rainwater and milk to reassure the Irish public that there were no harmful levels of radiation reaching Ireland from Japan and to inform the public about any levels of radiation detected. Details of the re-assurance monitoring programme and results showing increased activities measured during the additional monitoring will be presented.

Due to the decrease in levels of radioactivity detected from Fukushima to close to or below the limits of detection, the monitoring programme reverted to routine operation at the end of May 2011.

In order to collate the key points of the monitoring response to Fukushima and the lessons learned, an evaluation of the response was undertaken by the RPII personnel involved. The discussion was organised around a number of headings including:

- Demands placed on the radiation monitoring team
- Completion of generic emergency management functions
- Mobilisation of personnel and resources
- Task delegation and division of labour
- Information management
- Decision making and co-ordination
- Working relationships

Outcomes of the evaluation and recommendations made will also be discussed.

P12.28
Development of KURAMA and the Car-borne Survey in Fukushima

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A significant quantity of radioactive isotopes was released towards the surrounding area from the Fukushima No.1. nuclear power plant which was seriously damaged by the Great East Japan Earthquake and the following tsunami. We have developed a car-borne gamma ray survey system named as KURAMA(Kyoto University RAdiation MApping system) for the quick establishment of the air dose rate map in Fukushima prefecture and its surrounding area. Comparing with other conventional car-borne systems, KURAMA is characterized as its compactness and its better flexibility in measurements with the help of cloud technology and 3G network. KURAMA is now used in the projects of the regional air dose rate map performed by the prefectural government of Fukushima and the Japanese government, as well as the systematic survey for hot spots especially in residential regions in Fukushima prefecture. The outline, the current status, and the future prospects of KURAMA, as well as the projects where KURAMA is used as the measurement system, will be introduced.

P12.29
Learning From Experience At Fukushima: A UK Regulatory Perspective on Emergency Preparedness

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The accident at Fukushima-1 nuclear power station following the Great East Japan earthquake and tsunami of 11 March 2011 was unprecedented and led to serious environmental and socio-economic consequences. While off site emergency planning is already considered for nuclear emergencies in the UK, we must learn from this event to prevent accidents and improve emergency arrangements.

The paper describes how the Environment Agency, Scottish Environment Protection Agency and the Office for Nuclear Regulation (ONR) have worked together in learning these lessons for nuclear emergency preparedness and response.

The UK's Radiation (Emergency Preparedness and Public Information) Regulations 2001 require nuclear operators to carry out risk assessments to identify accidents that could result in nuclear emergencies. The UK approach to Emergency Planning Zones is that local authorities plan in detail for reasonably foreseeable off-site nuclear emergencies, informed by the operator's risk assessment. These plans have the ability to be 'extended' for nuclear events that are beyond reasonably foreseeable. The methodology used to carry out these risk assessments is being reviewed, taking into account lessons learned from Fukushima, to better inform emergency preparedness and response arrangements for both the Detailed Emergency Planning Zone and the 'Extendibility' zone.

Off-site nuclear emergency plans increasingly include arrangements to support the recovery of communities. Learning from Fukushima, including understanding how recovery can be affected by widespread damage to infrastructure, and ONR's review of risk assessments, will help improve recovery plans. The testing of recovery plans has become a feature of nuclear emergency exercises and future exercises will need to incorporate appropriate challenge reflecting the learning from Fukushima.

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P12.30
Arrangements for Nuclear Emergency Preparedness and Response in the UK – Lessons Learnt from Fukushima

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Within the UK, the authority for maintaining and regulating arrangements for nuclear emergency preparedness is established via legislation including:

• Civil Contingencies Act 2004.

• Health and Safety at Work etc. Act 1974.

• Nuclear Installations Act 1965 (as amended).

• Radiation (Emergency Preparedness and Public Information) Regulations 2001.

• Ionising Radiations Regulations 1999.

Key regulators include the Office for Nuclear Regulation (ONR), Environment Agency (EA), Scottish Environmental Protection Agency (SEPA) and Food Standards Agency (FSA).

The precautions taken in the design and construction of nuclear installations in the UK, and the high safety standards in operation and maintenance, reduce to an extremely low level the risk of accidents that might affect the public. However, in order to deal with a radiation emergency, nuclear installation operators consult with local authorities and many other agencies in preparing emergency plans for the protection of the public and their workforce. The plans are regularly tested in exercises supervised by ONR.

The delivery of an integrated multi-agency response in the UK is undertaken by the lead government department (Department of Energy and Climate Change) who have set up a Nuclear Emergency Planning Liaison Group (NEPLG) as a forum to discuss national issues and set consolidated guidance.

Following the nuclear accident at the Fukushima Dai-ichi reactor site, the UK's Secretary of State for Energy and Climate Change requested ONR's Chief Inspector of Nuclear Installations to examine the circumstances of the Fukushima accident to determine what lessons could be learnt to enhance the safety of the UK nuclear industry. An interim report was published May 2011 and a further report followed in autumn 2011. Among other things, the interim report tasked NEPLG to review UK emergency arrangements for dealing with a prolonged event at a nuclear site. NEPLG's initial response recognised opportunities to strengthen arrangements including those for:

• Radiation monitoring;

• Central Government response arrangements;

• Emergency services' capacity and capabilities; and

• Extendibility.

The opportunities identified by NEPLG will form part of a wider programme of work being taken forward by the Department of Energy and Climate Change.

P12.31
Special Environmental Monitoring Around Tokai-mura after the Accident of the Fukushima Dai-ichi Nuclear Power Station

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The nuclear accident at Fukushima Dai-ichi Nuclear Power Station of Tokyo Electric Power Co. (TEPCO) was caused by the Tohoku District – off the Pacific Ocean Earthquake. Various kinds of radioactivity were released from the power station just after the accident occurred and then reached our laboratories. Therefore, environmental monitoring was reinforced by observation of air dose rate, periodic collection of airborne sample, precipitation. The collected samples were used to determine radioactivity of gamma ray emitters by High pure Germanium detector. Moreover, rainwater and humidity were collected to do the usual routine monitoring.

Radionuclides of I-131, Cs-134, Cs-137 etc. were detected in airborne samples collected after 13th of March, continuously, although these nuclides had never been found in any samples for the last ten years around our site. Then, an airborne sample was used in chemical analysis to determine radioactivity of Sr-90, Pu-238 and Pu-239, 240. In the sample, Sr-90 was detected and the radioactivity ratio of Sr-90 to Cs-137 was approximately 1/3000. On the other hand, both Pu-238 and Pu-239, 240 were under detection limit. Radionuclides related to the accident were also found in other samples. These radionuclides such as Sr-90, I-131, Cs-134 and Cs-137 were determined around the accident station. Therefore, our monitoring detected influence of the accident into our site.

In this presentation, results of our monitoring will be summarized.

P12.32
Wet deposition of radionuclides and assessment of scavenging coefficients in France following the Fukushima accident

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The nuclear accident of Fukushima which occurred after the tsunami that impacted northeast coasts of Japan on 11 March 2011 led to significant releases of radionuclides into the atmosphere and resulted in the detection of those radionuclides at a global scale. Aerosols and rainwater samples, collected in several French locations by the Institute of Radioprotection and Nuclear Safety between 21 March and 22 April, were analysed to estimate wet deposition of ^{137}Cs, ^{134}Cs and ^{131}I and resulting scavenging coefficients Ë. Although relatively small compared with those measured after the Chernobyl accident, deposits were evaluated and compared with results from other countries. These deposits are commented with regard to the particulate and/or gaseous form of concerned radionuclides. Scavenging coefficients were calculated from these in situ measurements, with a scavenging coefficient for particulate 131I five times higher than that of the two caesium isotopes. Parametrization of Ë in terms of rainfall intensity R, $Ë=a^{*}R^{b}$, for particulate ^{131}I and ^{137}Cs was realized, and is in good agreement with previous studies for rainfall intensities higher than 0.1 mm h^{-1} (for ^{131}I) or few mm h^{-1} (for ^{137}Cs).

P12.33
Spatial and Temporal Evolutions of the Airborne 137Cs Level at European Scale after Fukushima and Comparison with the Situation after Chernobyl

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The routine monitoring of airborne radioactivity in France operated in the framework of the OPERA network since 1959 made it possible to compare the activity levels of the contaminated air masses from Fukushima to the one observed previously.

Figure 1 shows that the average airborne ^{137}Cs level remains 4 orders of magnitude lower than that registered in the days after the Chernobyl accident whereas the ^{137}Cs source term was 10 to 50 lower for Fukushima. This difference is due to the dispersion at long range distance between France and from Japan comparatively to Ukraine.

In the case of Chernobyl it took between 10 to 12 years ans to find again the same level than before the Chernobyl accident (or about 10 years to go down to the double value than before. The decrease of the ^{137}Cs atmospheric stock was very fast during the first days and week after this accident. Then the decrease was reduced. This reflects the involvement of several mechanisms: At short and medium term: the scavenging of aerosols occurs in a conclusive and causes main deposits on the surfaces (soil, plants, buildings,...) At medium term: These deposits spred over a large area acted as a secondary and delayed diluted source term for the atmospheric compartment. During this stage, scavenging and dry deposition still acts significantly on the atmospheric residual stock. The resuspension weakens gradually as the penetration of ^{137}Cs from the surface soil layers got deeper.

At long term: resuspension mechanism equilibrates deposition mechanism and the half-life decrease appeared mainly responsible of the very weak diminution of the ^{137}Cs level from year to year. Sporadically, high resuspension or particle re-emission events like saharan dust outbreaks or biomass burnings can explains higher magnitude at short time scale. 5 months after the Fukushima accident, ^{137}Cs airborne levels over France are only twice those encountered previously. The persistence of the ^{137}Cs in the atmosphere was thus weakly affected by this accident in France.

P12.34
Food Safety Regulations Implemented Following the Fukushima Nuclear Accident

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The earthquake and tsunami of historic proportion struck off the northeastern coast of Japan on 11 March 2011, followed by radionuclide releases from the Fukushima nuclear power plants. High radioactivity levels were detected in the surface soil and plants on 15 March, and food and water started being sampled for monitoring surveys on 16 March. “Provisional regulation value (PRV)” for contaminated food and water was set on 17 March by adopting the preset index values, except PRV for radioiodines in water and milk ingested by infants (adopted from the guideline level indicated by the Codex Alimentarius Commission) and that in seafood. For radiocesiums, uranium, plutonium and transuranic α emitters, index values were defined in all food and water not to exceed a committed effective dose of 5 mSv/y. Index values for radioiodines were defined not to exceed a committed equivalent dose to the thyroid of 50 mSv/y, and set in water, milk and some vegetables, but not in other foodstuffs. Index values were calculated as radioactive concentrations of indicator radionuclides (^{131}I for radioiodines, ^{134}Cs and ^{137}Cs for radiocesiums) by postulating the relative concentration of coexisting radionuclides (e.g., ^{132}I, ^{133}I, ^{134}I, ^{135}I and ^{132}Te for ^{131}I). Surveys were therefore conducted to monitor levels of ^{131}I, ^{134}Cs and ^{137}Cs. PRV for radioiodines in aquatic products was set on 5 April, because radioiodines at levels of concern were detected in fish sampled on 1 April. RPV has not been revised thereafter. As of 15 September, monitoring data of 21,507 food and 42,248 water samples have been reported. For radioiodines, PRV was exceeded in tap water, raw milk, vegetables, seaweed and coastal fish, and the last sample above PRV was taken on 21 May. For radiocesiums, PRV was exceeded in raw milk, beef, wild boar meat, wheat, tea leaf, vegetables, mushroom, fruit, nut, seaweed, coastal fish, freshwater fish, marine invertebrates. Of these, distribution and consumption of tap water, raw milk, vegetables, mushroom, fruit, coastal fish, freshwater fish, beef and tea leaf have been restricted. Here we overview the monitoring data, policy on the enforcement of restrictions, and the timing and duration of enforced restrictions. Then, the logic and issues behind PRV shall be discussed.

P12.35
Decontamination of the Contaminated Water by the Fukushima Nuclear Accident.

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A lot of radioisotope was emitted by the accident of the first nuclear power plant in Fukushima in an East Japan great earthquake, and high-concentration contaminated water flowed into the sea. Drinking water is not over the regulation value at present. However, there is still uneasiness to water and we are anxious about the influence on marine products. It aims at decontaminating the water polluted with radioisotope. Furthermore, it aims at securing safe drinking water and life city water, and preventing contamination.

The swim pool contaminated water of the junior high school and park of Koriyama-city, Fukushima was extracted. Four kinds of water purification systems of the OSMO Company were used as a decontamination system. One is an activated carbon filter and removal of radioactive iodine has an effect. Others are an ion-exchange membrane and a filton stone, and the ion-exchange membrane used two kinds, the object for pure water, and the object for soft water. It compared with what measured the activity concentration of raw water 500 ml by Becquerel-Monitor. The water which the sediment is also contained in the extracted water and is processed is 50. It is a liter. The sediment was also contained in the water which processed 50litters.

As a result, the raw water of the junior high school was 287.7 Bq/l. It decreased 13.3% using the activated carbon filter. In each the object for the pure water of an ion-exchange membrane, and for soft water, they were 72.2% and 79.1% reduction. However, it increased 3.8% with the filton stone. The raw water of a park is 71.7 Bq/l and this is low concentration. It decreased 41.1% using the activated carbon filter. The object for pure water and the object for soft water of the ion-exchange membrane decreased 100%. filton stones decreased in number 45.6%. It suggested that it could decontaminate efficiently by an ion-exchange membrane. There was a decontamination system chosen by activity concentration.

P12.36
Decontamination of the Ground by the Fukushima Nuclear Accident.

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A lot of radioisotope was emitted by the accident of the first nuclear power plant of Fukushima in an East Japan great earthquake. The topsoil which exceeds 20 mSv in a year by an air dose of radiation in Fukushima was replaced. The purpose of this research is to wash the ground of radioactive contamination. The safety of a schoolyard and a park is secured and the society which can live in comfort is aimed at. The radioisotope of agricultural products is reduced and it aims at stable eating habits.

Ground 10 g and each solution which were extracted from Fukushima Prefecture were put into the beaker, and the whole capacity was set to 500 ml. It agitated 200 times, the solution filtered using filter paper was measured by Becquerel-Monitor, and it measured by radioactivity per litter. Solution is pure water, 3.6% chloride, and macromolecule polymer of 10 time dilution, pH 12 alkaline water, and chitosan solution of 100 time dilution.

Macromolecule polymer solution is used for the printing technique of a fiber. Alkaline water is created by dissolving the powder of a scallop in water. It is macromolecule polymer solution that was the most efficient and it showed one about 5.8 times the ratio of this. The cesium 137 adhering to the ground pasted macromolecule polymer, and has judged that it separated from the ground. The decontamination effect of chloride was about 3.5 times the pure water. It seems that chloride reacted with cesium and had the decontamination effect by a chemical reaction. Chitosan solution was effective from the consideration to fields. The chitosan used in agriculture can be used in comfort. Chitosan shows 2.7 times and is the large method of expectation. The decontamination effect for which alkaline water was conspicuous did not show up.

The method of decontaminating the ground using various solutions can be chosen according to a use. This suggested possibilities that it could decontaminate, such as a schoolyard, a park and fields, and a forest.

P12.37
Comparison of Radioactive Fallout in the United States from the Fukushima and Chernobyl Accidents

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On March 11, 2011, an earthquake and tsunami of unprecedented magnitude led to significant damage at the Fukushima Daiichi Nuclear Power Plant in Japan. This damage resulted in both controlled and uncontrolled releases of radioactivity from multiple reactors at the plant. These releases have been considerable enough to be detected in several locations throughout the world. Due to the significance of this event and the widespread release of radioactivity, the Fukushima accident is now being compared in several aspects to the Chernobyl accident that occurred in 1986.

In the United States (US) and several other countries, radioactivity was beginning to be detected within a few days after the start of the Fukushima accident. In particular, commercial nuclear power plants detected radioactivity in multiple sample types as part of their operational radiological environmental monitoring programs (REMP). This was similar to what was seen from the radioactivity released as a result of the Chernobyl accident. The purpose of this paper is to present and compare the radioactivity concentrations detected in the entire commercial US nuclear power plant REMP samples from the Fukushima fallout. In addition, these concentrations and levels are compared to what was detected, and when, by US commercial nuclear power plants from the Chernobyl accident. Data was compiled and analyzed from all 104 US nuclear power plants in a variety of sample media types including air samples (particulates and iodines), drinking water, vegetation, food items, and milk. The Fukushima and Chernobyl sample data timeframes were 15/3/2011 to 14/4/2011 and 10/5/1986 to 25/6/1986, respectively. The principle radionuclides detected from both accidents included I-131, Cs-134, and Cs-137. Both the I-131 and Cs-134/137 radioactivity concentrations were roughly one order of magnitude less in the Fukushima samples.

P12.38
Airborne Radioiodine In Northen Serbia From Fukushima

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After the public presentation of the accident on the Fukushima power plant a devoted environmental radioactivity monitoring system was established. Aerosol, rain, milk and spinach samples have been collected daily. In the aerosol samples the activity concentration of ^{131}I has been measured to be of mBq order of magnitude while in the rain, milk and spinach samples about 1 Bq kg^{-1} of ^{131}I has been found.

Our results are compared with the reported values from other countries.

P12.39
Analysing The IRSN Risk Perception Barometer After The Fukushima Nuclear Accident

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Since 1990, IRSN conducts a yearly survey designed to understand how the French population perceives risk: the IRSN Barometer. In this survey, 30 risks are investigated from three different angles:

- seriousness of the risk,
- trust in the authorities,
- credibility of information given about these risks.

The 30 risks include situations widely covered by the media (traffic accidents, smoking, alcohol, etc.), as well as situations of which the public can be unaware (such as radon in homes) and situations perceived as low risk (X-rays, noise, etc.). The list includes nuclear power plants, nuclear waste storage, Chernobyl pollution impacts, chemical industries, chemical waste, transportation of hazardous chemicals, etc

The perceived seriousness of the risk is measured through answers to: “ do you consider the risks for the general population to be: almost nil; low; average ; high or very high ?”

Trust towards the authorities: “Do you trust the French authorities to correctly protect the public?” (Answers range from “No trust” to “Complete trust”) Credibility of information given about risks: “For each of the following situations, do you believe that you were told the truth about the dangers they represent for the population?” (Answers range from “No, not at all” to “Yes, definitely”).

Statistical analysis of the answers highlighted four groups of risks in relation with a logic of perception of the French people and confirmed that the risk perceptions of the French population. Their perception logic is based on the perceived seriousness of the risk, on their “trust in the protective measures taken by the French authorities” and on the perceived credibility of information.

The results since 1990, are showing a global stability, even if some slow evolutions can be identified. We propose to show the impact of the Fukushima nuclear accident on public opinon. In September 2011, more 1000 people will answer the survey, a representative sample of the French population according to the strata and quota sampling method. The results will be presented.

KEYWORDS: Risk perception - Fukushima nuclear accident – Openness to Society.

P12.40
In-Situ Dose Evaluations For Fukushima Population In 2011 Reveal A Low Doses And Low Dose Rates Nuclear Incident

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Internal and external doses for Fukushima population have been evaluated in-situ since April 8th 2011 by a scientist who has several methods of field dosimetry developed in his works over the world such as in Hiroshima, Tokaimula, Semipalatinsk, Chernobyl, Rongelap and Loulan of in the Silk Road.

Personal external doses for about three days which have been detected in three different months of and in three areas in Fukushima prefecture. These show us a monthly dose as less than 1.0mSv in an area including 20km evacuated zone in April, less than 0.10mSv in an area outside but near the 20km zone, and less than 0.05mSv among Shirakawa, Aizu and Fukushima cities in April, June, and August respectively. These results reviele us annual external doses of less than 10mSv and mostly less than 5mSv in Fukushima prefecture.

Thyroyd doses due to I-131 was evaluated by measurements gamma rays near the thyroid for 66 peoples between 8th and 10th in April. The doses which are extrapolated to March 12th 2011, 9mGy as the maximum and 3mSv as the average for them.

Portable whole body counter on 64 people was carried out and showed annual internal doses to be less than 1.0 milli sievelt. Ninety percent of them were less than 0.1 mSv.

In-situ dosimetry studie in Fukushima prefecture reveals very low dose and dose rate in radiation hygiene in Fukshima and suggests no health risk for population.

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P12.41
Preliminary Study of Dose Equivalent Evaluation with Optically Stimulated Luminesecnt Dosimeters for Residents in Marumori

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The magnitude 9.0 earthquake and tsunami in Japan on 11 March 2011, resulted in severe damage to the Fukushima Daiichi nuclear power plants (NPP), causing the month-long release of radioactive materials into the atmosphere. Aerial measuring results carried out by joint US/Japan survey shows the radioactive plumes spreaded towards the north-west from the NPP, causing the radionuclide deposition. Marumori in Miyagi, a neighboring Fukushima prefecture, is located at 46 km north-west from the NPP. A distribution map of radioactivity concentration in the soil by the MEXT (Ministry of Education, Culture, Sports, Science and Technology, Japan), published on Aug. 30th, revealed that this area was strongly affected by the radioactive plumes. We started to evaluate external dose equivalent for residents, infants, children, and adults in Marumori from Sep. 1st with optically stimulated luminescent (OSL) dosimeters. The OSL dosimeters are badge-style devices worn on a neck strap. Worn close to the torso, they measure radiation coming to the body as a whole. Comparisons are made between the OSL readings and the readings of environmental radioactivity level. We also examine the effect of decontamination of the environment to the external dose. The results are presented at the conference.

KEYWORDS: Fukushima nuclear power plant accident; dose equivalent; optically stimulated luminesecnt dosimeter; resident; Marumori

P12.42
Fission Product Activity Measurements in Air Particulate Filters Collected after Fukushima Accident at Palermo, Italy

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In the framework of routine operation of AGN-201 COSTANZA Nuclear research reactor, measurements of radionuclide air concentration are periodically performed by filtering an high volume of air through paper filters and by using HPGe gamma ray spectrometry. After Fukushima accident, a series of samplings was carried out with a daily frequency so to detect the possible arrival of radioactive contamination and follow its evolution. Air particulate collection was performed by suction of atmospheric air through 45cm × 45cm Sofiltra Poelman HYN-75 (Bleu type) cellulose filter paper using a high-volume air sampler located on the roof of our department 20 m above ground-level. The sampling time was generally set to 14 h from 6 p.m. to 8 a.m. the next day; the filtered air volume is typically about 10,000-13,000 m^3. After particulate sampling, the filters were sprayed with a suitable fixer, cut into strips, folded and pressed into 6 cm side and 0.7 cm thickness packets by a 15-t press. These samples are then measured by a low-background HPGe gamma spectrometric system. The analysis of the spectrometric measurements highlights the presence of ^{131}I, ^{134}Cs, ^{137}Cs and, only for a sample, traces of ^{132}Te-^{132}I and other fission products. The trend of air concentration values shows a rapid initial increase, related to the most significant release from Fukushima plant, followed by a steady decline in the values caused by a decay or further air masses dilution that has lead rapidly the levels below the detection limits of the measuring equipments. From a dose to population point of view, no significant values can be obtained. Compared with the values determined immediately after the Chernobyl accident, the concentration values are from 1,000 to 100,000 times lower while, for only ^{137}Cs, are comparable with the ones highlighted after the Algeciras (Spain) accident.

Keyword: Air Particulate, Fukushima accident, radionuclide concentration.

P12.43
Radiological Screening In South Africa Of Commercial Cargo Originating From Japan

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Following the 9.0 MW earthquake and subsequent tsunami that hit the north east coast of Japan on 11 March 2011 causing the Fukushima I Nuclear Power Plant to suffer major damage to reactors 1, 2 and 3, various initiatives specific to the import of commercial cargo originating from Japan were put in place in South Africa to ensure the safety of South African people, property and the environment. This paper summarizes the key aspects of the South African initiatives that were put into place. Information is given about the Radiological surveys done at South African ports of entry, findings and the lessons learned.

P12.44
Measurement on Air Filters from an Airplane Arriving from Tokyo Following the Fukushima Accident

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During the first weeks following the accident at the Fukushima NPP, an airplane arriving in Copenhagen Airport from Tokyo was found by airport personnel to have a count rate of radioactivity in the air filters higher than usual.

On March 20th, they measured 259 cps compared to a normal average level of 10 cps with a GM counter. Although this did not exceed a recommended investigation level of 300 cps, the National Institute of Radiation Protection (NIRP) was contacted due to the heightened public awareness concerning radioactive emission.

A team from NIRP was sent to measure the air filters in regard to dose rates and isotope composition. The team was equipped with a portable HPGe-based detector for gamma spectroscopy as well as dose rate meters, GM counters and surface monitors.

Measurements were made on-site for background levels and on a clean air filter as well as on the two used filters. Additionally, wipe tests were taken on the used filters and analysed later at NIRP.

Measurements on-site indicated the presence of I-131 and Cs-137 in the air filters, which complies with the expected emissions from Fukushima. The dose rates peaked at 2,4 μSv/h, with background readings of 0,2 – 0,3 μSv/h. So, it could be immediately concluded, that no hazard existed for personnel nor passengers. Further analysis of the measured gamma spectra identified several other radioisotopes: Co-58, Mo-99, Ru-106, I-132, Te-132, Cs-134 and Cs-136, which can all be traced back to Fukushima.

A new investigation level of 3000 cps was recommended to the airport. Airport personnel continued monitoring the air planes arriving from Japan. The next airplane arriving from Japan resulted in measurements at a maximum of 30 cps, which complied with usual maximum measurements.

P12.45
Estimation of Marine Source-term Following Fukushima Dai-ichi Accident

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Contamination of the marine environment following the accident in the Fukushima Dai-ichi nuclear power plant represented the most important artificial radioactive release flux into the sea ever known. The radioactive marine pollution came from atmospheric fall-out onto the ocean, direct release of contaminated water from the plant and transport of radioactive pollution by leaching through contaminated soil. In the immediate vicinity of the plant (less than 500 m), the concentrations in early April reached 68 000 Bq.L^{-1} for ^{134}Cs and ^{137}Cs, and exceeded 100 000 Bq.L^{-1} for ^{131}I.

Due to the accidental context of releases, it is difficult to estimate the total amount of radionuclides introduced in seawater from data obtained into the plant. An evaluation is proposed here, based on measurement performed in seawater for monitoring purposes. Quantities of ^{137}Cs in seawater in a 50 km area around the plant are calculated from interpolation of punctual seawater measurements. Rate of seawater renewal is deduced from the time-evolution of these quantities. This rate appeared constant with a period of seven days to divide by a factor of two the measured quantities of ^{137}Cs. These data allowed inferring thea mount of principal marine inputs and their evolution in time: a total of 27 PBq of ^{137}Cs was estimated up to July 18. Even though this main release may be followed by residual inputs from the plant, river runoff and leakage from deposited sediments, it represents the principal source-term that must be accounted for future studies of the consequences of the accident on marine systems. ^{137}Cs from Fukushima will remain detectable for several years around the North Pacific, and ^{137}Cs/^{134}Cs ratio will be a tracer for future studies.

Keywords: Fukushima, Japan, budget, source-term, ^{137}Cs, ^{134}Cs, ^{131}I, dispersion, renewal.

P12.46
Using Artificial Radionuclides to Assess Coastal Circulation Models: case-studies of La Hague (France) and Fukushima (Japan)

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Marine environment studies have used circulation models for years. Coastal models are now key components of operational forecast systems deployed during crises such as point-source pollution incidents. But, model reliability can only be assessed with field-based data that can be difficult to obtain when phenomena are involved on one hour to month time-scale with matching tens to hundreds of kilometers spatial scale. In this context, artificial radionuclides are unique validation tools. More precisely, Ifremer's MARS (Model for Applications at Regional Scale) model was assessed using in situ measurements of artificial radionuclides in two different contexts. In the first case, controlled tritium release from La Hague nuclear fuel reprocessing plant was mapped by sampling the plume with a 30 second period in an energetic hydrodynamic environment (tidal currents higher than $5 m.s^{-1}$). In the second case, the high caesium-137 accidental release into the sea from Fukushima Dai-ichi nuclear power plant in 2011 allowed to assess MARS model reliability in a lower energetic tidal environment (currents of $1 m.s^{-1}$), but strong general circulation (Kurushio and Oiashio currents). In both cases, results of confrontation between measurements and model predictions are presented.

Keywords: Fukushima, La Hague, dispersion, radionuclides, Cs-137, H-3, coastal circulation model, model assessment.

P12.47
The Transfer of Artificial Radionuclides in Milk and Meat after Fukushima Releases

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Sampling and radioactive measurements were carried out to evaluate the field transfer of artificial radionuclides from the accidental releases of Fukushima in milk and meat produced in the south of France. Milk (goat and cow) and meat (beef and mutton) samples were taken at four different sites where the herds were outside. At those sites sampling and radioactive measurements were carried out at three main periods (1) before the Fukushima plume (2) during the time the radioactive plume was observed (coarsely between 24 March and 15 May 2011) and (3) several weeks after the return to the initial level in the atmosphere. Such data allow us to evaluate the enhancement of activity due to the Fukushima accidental releases in studied animal products. In addition grass was also sampled to evaluate transfer factor of iodine and cesium in milk and meat respectively. According to the time trends of activity in milk the maximum iodine activity was reached in goat milk (2.1 ± 0.2 Bq L^{-1}) soon at the beginning of April depending on site, then it slowly decreased toward the detection limit one month latter. The grass to milk transfer factors of iodine are 2.8 10^{-2} and 3.6 10^{-3} d L^{-1} for goat's and cow's milk respectively. In meat the maximum activity was reached latter than in milk. Thus ^{137}Cs in veal meat was 0.19 ± 0.02 Bq kg^{-1} fresh weight in May 2011.

Poster sessions C-D: Area 12

P12.48
The Evaluation of the Dry Deposition Velocity of Iodine after Fukushima releases

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Sampling and radioactive measurements were carried out to evaluate the field transfer of ^{131}I (half-life = 8.05 days) from the accidental releases of Fukushima in the vegetation. Indeed the contamination, if significant, would cause exposure to humans via the vegetables. Thus measurement of ^{131}I has been carried out in the air and in the vegetation (grass and vegetables) between 21 March and 10 May 2011 by IRSN, at various sites located in the south of France. The time trends of activity in vegetation show that the highest values in vegetal (a few Bq kg^{-1} fresh weight, depending on site) were reached by 28 March and thereafter the activity slowly decreased and reached detection limit (< 0.1 Bq kg^{-1} fresh weight) by 10 May, in conjunction with the variability recorded in the air. The activity measured in the air and empirical equations from ASTRAL model were used to fit iodine in the vegetal with activity measured in field samples. Such approach allow us to evaluate dry deposition velocity of iodine on grass, ranging between 1 10^{-3} and 5 10^{-3} m s^{-1} from site to site, which was mainly derived from experiments up to now.

P12.49
Radiological Consideration Regarding Logistical Management of Radioactive Surface Contamination after Fukushima Nuclear Accident

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The protection of people after the Fukushima nuclear accident in Japan is discussed in this paper from the viewpoint of the dose assessment of surface radioactive contamination in logistical management implemented after the accident. Following the release of huge amounts of radioiodine and radiocesiums into the atmosphere due to the nuclear disaster, screening surveys of surface radioactive contamination started for people evacuated from their homes and for emergency workers at the Fukushima Daiichi site on a daily basis. Aloka type TGS-136 Geiger-Muller (GM) counters with a 5 cm bore have been typically used for the surveys. The criterion for decontamination was set as 100,000 counts per minute (CPM) by the Nuclear Emergency Response Headquarters, established by the Japanese Government, for both the surface of the human body and moving objects such as vehicles, equipment, machinery, and tools. The vast majority of the 223,747 people checked as of 9th September 2011 were under the criterion, and decontamination was performed for 102 people exceeding 100,000 CPM but their contamination levels fell below the criterion after such decontamination. Given the criterion for decontamination as the count rates of detectors, surface densities of radioactive contamination (Bq cm^{-2}) that correspond to the count rates were calculated by assuming some variation of the abundance ratio of radioiodine to radiocesiums based on the measured trends of the radioactive concentration in the air at the site of Fukushima Daiichi nuclear power plant. Doses that may arise from external irradiation, ingestion, inhalation, and skin contamination of the human body and the surface of moved objects were calculated by applying dose conversion factors (mSv y^{-1} Bq^{-1} cm^{2}) obtained in a previous study on the derivation of original surface-specific clearance levels. The results show that the annual effective dose that may arise from handled objects is less than 1 mSv, which can be considered as the intervention exemption level in accordance with the relevant recommendations given by the ICRP. Furthermore, the criterion for decontamination was also found to prevent the skin from the incidence of a deterministic effect because the absorbed dose of the skin that may arise from direct deposition on the surface of the human body was calculated to be lower than the threshold of the deterministic effect assuming the practical exposure duration. It is concluded that the screening survey implemented in the logistical management of radioactive surface contamination after the Fukushima nuclear accident can be considered as an appropriate emergency response and countermeasure from the radiological viewpoint.

P12.50
Radiation Dose Measured by a Car Borne Survey Method and γ Ray Spectrometry by NaI Detector in Fukushima Prefecture, Japan

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he Tohoku District-off the Pacific Ocean Earthquake and Tsunami caused by the earthquake attacked the Fukushima Dai-ichi Nuclear Power Plant of TEPCO on March 11, 2011. A nuclear accident followed at an unprecedented scale and huge amounts of radioactive material were released into the environment. Distributions of dose rate in Fukushima prefecture were measured on April 18-21, June 20-22 and October 19-21, 2011 by a car borne survey method using a NaI(Tl) scintillation survey meter. The distribution of high dose rate was observed at a northwest direction of Fukushima Dai-ichi NPP. The gamma-ray spectrometry by a NaI(Tl) detector was also done at several points. The gamma-ray peaks of I-131, Cs-134 and Cs-137 were mainly detected at the April in gamma-ray spectrum. Dose rate near Fukushima Dai-ichi NPP and at iitate-mura, fukushima-city was high (1- >30 μSv/h). Because of the distribution of dose rate was uneven, further investigation is necessary to estimate the external exposure in detail.

P12.51
Radioactivity in Zagreb and Fukushima Nuclear Accident

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On 11th March 2011, a catastrophic earthquake and subsequent tsunami set into motion a series of tragic events in Japan including the severe accident at Fukushima Daiichi nuclear plant. Radioactivity released into the air became involved into atmospheric processes and the transport of matter in the biosphere, leading to the migration of particles over long distances and across international borders, causing global contamination.

In the Republic of Croatia the radioecological monitoring of air on a regular daily basis has been carried out by the Radiation Protection Unit of the Institute for Medical Research and Occupational Health (IMI) in Zagreb since 1959. Radiation Protection Unit is by the Croatian Accreditation Agency accredited according to the requirements of the international standard HRN EN ISO/IEC 17025.

The absorbed dose rate has been continuously monitored at selected locations in Croatia. Monitoring includes determination of total beta activity in the air, gammaspectrometric determination of radioactivity in the air, either by large-volume air sampling on cellulose filters or on charcoal filters. In the period from 1st March to 1st July 2011 has not been observed any increase of the absorbed dose rate at the location of IMI in Zagreb. The average absorbed dose rate in that period was measured to be 118.4±1.0 nGy/h, ranging from 116.5 nGy/h to 121.2 nGy/h, whereas in the same period of 2010, the average values were 118.7±0.9 nGy/h.

However, in the mid March 2011, additional measurements were initiated to monitor the presence of radioactive matter in the air of Zagreb. Determination of radioactivity by high resolution gammaspectrometry showed the presence of radiocaesium and ^{131}I in Zagreb air. Maximum ^{131}I, ^{134}Cs and ^{137}Cs activity concentrations were measured in period from 31st March to 7th April and were as follows: for ^{131}I: 383±1 µBqm-3, for ^{134}Cs: 24.1±0.2 µBqm-3 and for ^{137}Cs 27.6±0.2 µBqm-3. Average ratio of ^{134}Cs/^{137}Cs activity concentrations in air was 0.73.

The effective dose incurred by inhalation of air contaminated by ^{131}I, ^{134}Cs and ^{137}Cs was estimated for the period 20th March – 12th May, and it was 1.5 nSv for adult person living in Zagreb. Therefore, such small dose did not significantly influence the total effective dose of ionizing radiation that was received by Zagreb inhabitants.

P12.52
Accident, Radiological consequences, and Management of the Consequences: The Fukushima Nuclear Accident

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Located in the Fukushima Prefecture of Japan, are the two nuclear power plants i.e Fukushima I or Fukushima Dai-ichi, and Fukushima II or Fukushima Dai-ni. The accident occurred after a 9.0 magnitude earthquake and subsequent tsunami on 11 March 2011. Fukushima I is a multi-reactor nuclear power site with six reactors. The earthquake triggered a scram shut down of the three active reactors at the plant .The ensuing tsunami inundated the site, stopped the Fukushima I backup diesel generators, and caused a station blackout. The subsequent lack of cooling led to explosions and meltdowns at the Fukushima I facility, with problems at three of the six reactors and in one of the six spent fuel pools. Japan's Nuclear and Industrial Safety Agency (NISA) estimated that 770,000 terabecquerels of radiation escaped into the atmosphere in the first six days. Sea water was injected into the reactors to try and cool them. A radioactive water treatment system was put in place to recycle the contaminated water.

At Fukushima II, the earthquake resulted in maximum horizontal ground accelerations below the design basis. All four units were automatically shut down immediately after the earthquake and the diesel engines were started to power the reactor cooling. The Tsunami flooded the pump rooms used for the water system transferring heat to the sea, the ultimate heat sink of the reactors. While the cooling system for unit 3 was undamaged, the other reactors were affected. Operators used a non-emergency system known as the Makeup Water Condensate System to maintain water level until the primary coolant systems could be repaired. Seawater from the tsunami remained in the plant. The plant planned to release it all back into the ocean to prevent corrosion of the tanks and structures holding the water. Some water was found to contain radioactive substances, and Japan's Fisheries Agency refused permission to release that water back into the ocean.

P12.53
Impact of Fukushima Nuclear Acident on External Dose Monitoring in Japan

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After a the 9.0 magnitude earthquake and subsequent massive tsunami on March 11, 2011 in Japan, several reactors at the Fukushima Daiichi nuclear power plant suffered severe damage. There was immediate participation of US Navy vessels and other DoD teams that were already in the area at the time of the disaster or arrived shortly afterwards. It included many activities, including humanitarian aid and disaster relief to Japan. The U.S. Navy uses LiF:Mg,Cu,P thermoluminescence dosimeters (TLDs) and the Harshaw model 8800 dose readers, which are developed and produced by Thermo Fisher Scientific.

The correct determination of occupational dose requires estimation of the background dose component by control dosimeters, which is subsequently subtracted from the total dose measured by personal dosimeters. The purpose of the control dosimeters is to determine the amount of radiation dose that has accumulated on the dosimeter from background or other non-occupational sources while they are in transit or being stored. Given the release radioactive material and potential exposure to radiation from the Fukushima Daiichi nuclear power plant, and the process by which the NDC calculates occupational exposure to ionizing radiation, analysis of pre- and post-event control dosimeters is warranted. The aims of this paper are to: (1) report radiation doses from control dosimeters used at five US Navy dosimeter-issue sites in Japan; and (2) compare them with historical data collected by the Naval Dosimetry Center prior to the Fukushima accident. In order to achieve these aims several thousand dose records from NDC database were analyzed.

The NDC has maintained all records for doses of control dosimeters used for background correction of occupational doses for these sites since 2002. The dose data from control dosimeters, collected prior to the Fukushima accident (date prior to March 11, 2011), were used to estimate normal (without the effect of the accident) daily radiation background in terms of deep, shallow photon, and neutron doses at the issue sites and doses received by dosimeters during transportation from issuing to processing facilities.

As result we showed that the dose-contribution of the radiation and released radiological materials from the Fukushima nuclear accident to background radiation doses is less than 0.375 µSv/day for shallow and deep photon exposure. There is no measurable effect on neutron background exposure. The later has at least two important conclusions. First, the NDC can use doses measured by control dosimeters at issuing sites in Japan for determination of personnel doses; and second, the dose data from control dosimeters prior and after Fukushima accident can be used for dose reconstruction of non-radiological (non-badged) personnel at these locations. Disclaimer. The views expressed in this abstract are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government.

P12.54
Contingency Plans for Monitoring People Returning to the UK after the Accident at the Fukushima Nuclear Power Plants

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On 11 March 2011 a massive earthquake and tsunami in Japan resulted in significant damage to the Fukushima Daiichi nuclear power plant. It soon became apparent that a large number of people, including UK citizens, might return to the UK as a result of concerns about radiation exposure.

HPA, in consultation with UK Government Departments, recommended that no systematic programme of monitoring would be needed unless further significant releases took place, and this recommendation was accepted. Criteria were developed that would initiate monitoring of people entering the UK from Japan in the event of a further significant release.

This presentation describes the preparations made by HPA for monitoring people at airports. These preparations comprised:

• A detailed plan for initiation of monitoring

• Triage processes to identify people likely to be the most contaminated

• Arrangements for monitoring external and internal radioactive contamination

• Calculation of action levels to choose between different follow-up actions

• Recording and reporting of monitoring results

• Detailed standard operational procedures for HPA staff

Preparations included arrangements for nominated HPA staff to remain in a state of readiness to carry out monitoring at London Heathrow airport at 24 hours notice.

In the event, a systematic monitoring programme for people returning to the UK was not required because doses were reliably predicted to be very low. The results of a limited number of monitoring measurements carried out at CRCE supports the decision not to institute a systematic monitoring programme.

P12.55
Towards Comprehensive Radiological Protection for PublicUsing Background-Cancer-Risk Based Approach

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Generally, the health effects of low-level radiation exposure, particularly below 1 mSv y^{-1}, cannot be observed in any epidemiological studies. The current radiological protection system for the public and radiation workers developed by the International Commission on Radiological Protection (ICRP) is, however, established assuming a linear nonthreshold hypothesis for radiation effects and is based on a precautionary consideration that there may be stochastic effects even in the low-dose region of 1 mSv y^{-1}. This leads to a need for an optimization principle for the public, that is, the individual dose in such a low-dose region should be reduced to as low as reasonably achievable (ALARA).

Experiences after the accident at Fukushima Dai-ichi Nuclear Power Station have given us important suggestions associated with our understanding for real radiation effects in a low-dose region. The main concerns of the public against low-dose radiation are due to the difficulty in realizing the ALARA concept and deeply related to the question why they need radiological protection measures for extremely low-dose radiation below 1 mSv y^{-1}.

Such an issue could be resolved by realizing the background risk of the public spontaneously. The index of radiation risk in the current radiological protection system is "detriment-adjusted nominal risk" based on cancer incidence data according to the definition by ICRP. The most effective means of resolving the issue may be the determining of the background cancer risk derived as the detriment-adjusted nominal risk using reliable data on background cancer incidence worldwide given by the International Agency for Research on Cancer. As a result of the comparison between the probability distribution of the background cancer risk adjusted by the detriment and the assumed risk equivalent to 1 mSv y^{-1}, it has been clarified that the risk to the public is sufficiently small and lower than the risk within the deviation of the background cancer risk if there is appropriate radiation protection compliance with a dose limit of 1 mSv y^{-1}. This should be considered in the next stage of radiological protection system development and shared between experts and the pulic on the basis of a comprehensive design for a radiological protection system.

P12.56
Lessons to be Learned from Fukushima

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In the years preceding the Fukushima disaster, most major nations in the world had come to the conclusion that, for reasons of energy independence and environmental responsibility, nuclear power must play a central role in their energy strategies for the 21st Century. A number of these nations, notably Germany and Switzerland, have now decided to phase out their use of nuclear power because of damage to the Fukushima Daiichi nuclear power station by a tsunami. Others have adopted the approach of learning the lessons of Fukushima and incorporating them into their plans for a nuclear future.

Some of the most important lessons are in the field of engineering, as they were in the case of the reactor accident at Chernobyl. In the aftermath of the Fukushima accident, for example, the protection of on-site power supplies from flooding is being reviewed and will be up-graded where necessary.

In the field of radiation protection, there are three particularly notable lessons that should be learned from Fukushima:

1. The safety features of the reactors, even though they were of out-dated design and were partially compromised by damage, provided significant scope for the management of the emergency and the limitation of radiation exposures.

2. The health effects of accidental exposure to radiation are substantially less than they are generally represented as being.

3. The risks from exposure to radiation at Fukushima were and are substantially less than they were at Chernobyl.

The paper will be based on the most up to date information that is available on doses to the workers and to the public, and will discuss the risks due to these doses.

P12.57
Relative Changes in Airborne Radionuclide Concentrations Observed in Chiba after The Fukushima Accident

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After accident of the Fukushima NPP followed by the great east Japan earthquake (March 11, 2011) background level of environmental radiation have been increased, especially in the east part of Japan.

In National Institute of Radiological Sciences (NIRS, Chiba, Japan), about 200 km south from Fukushima NPP, first peak of gamma dose rate was detected on March 15 around 5 p.m.

Immediately after this observation NIRS team started to measure the concentration of artificial radionuclides in the inside and outside air.

Two types of measurement by collecting samples on the filter were implemented: 1) low sampling flow rate (20 dm^3 min^{-1}) and 2) high sampling flow rate (566 dm^3 min^{-1}). After appropriate time collection filters were measured on system with the HPGe detector.

As results, the relative changes of airborne radionuclides concentrations were observed. The I-131 was detected up to April 9, however the ratio between high (Outdoor: 1.05 cpm m^{-3}, Indoor: 0.53 cpm m^{-3}) and low (Outdoor: 0.003 cpm m^{-3}, Indoor: 0.0008 cpm m^{-3}) values was about $3*10^2$ for Outdoor and $6*10^2$ for Indoor. On the other hand, Cs-134 and Cs-137 were measured throughout analyzed period and the amount of concentration from March to September has gone down by a factor of $2*10^4$.

In addition, positive correlation between radionuclides (Cs-134, Cs-137 and I-131) and gamma dose rate registered by NIRS Monitoring Post was observed.

Collected information about airborne radionuclide concentration can be helpful for estimation of internal dose due to inhalation.

P12.58
Environmental Dose Rate Monitoring System For The Field Of Dispersed Cesium-137

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Environmental dose rate measurement was performed using a moving measurement system consisting of a vehicle carrying time series data measurement equipment with a GPS. The response characteristics accompanying movement were measured using a GM-type survey meter, which performed energy calibration by Cs-137, and comparison with an environmental measurement point was performed. Dose rate was measured while moving toward Fukushima, and the data were compared with the dose rate released by the Ministry of Education, Culture, Sports, Science, and Technology. There were no marked changes in the fundamental measurement associated with distance from the radionuclide source, and the response characteristic of the survey meter did not alter with changes in speed. The measurement results in Fukushima Prefecture were in agreement with the dose rate map (Ministry of Education, Culture, Sports, Science and Technology). There was a significant difference between Kanazawa and Fukushima in dose rates inside and outside of a tunnel. As the background was high, especially within Fukushima Prefecture, the difference between the inside and outside of the tunnel was large. The measured value of the released distribution and the GM survey meter showed relatively good agreement. Moreover, the results confirmed that the GM survey meter could be used for dose rate measurement even in an emergency. Although soil withdrawal and decontamination work are in progress, it is necessary to carry out monitoring continuously.

P12.59
The Reductive Effect of a Mask for Pollinosis against Internal Exposure of Radioactive Materials Scattered by the Fukushima Daiichi Nuclear Disaster

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The reductive effect of a mask for pollinosis against internal exposure of radioactive materials scattered immediately after by the Fukushima Daiichi Nuclear Disaster was investigated. The mask was worn continuously for 18 hours from March 15, 15:00 to March 16, 09:00 at Hongo campus of the University of Tokyo, Japan. An adult without wearing the mask during this time was exposed excessively 5.6μSv in effective dose, and 46μSv in dose equivalent to thyroid. The radionuclides have been scattered are not only gaseous but also many components adhering to such aerosols and pollens. Wearing a mask for pollinosis could be reduced internal exposure of inhalation.

P12.60
Development of a Counting Geometry for the FastScan Whole Body Counter that is Independent of Subject size for Small Children to Large Adults

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The Fukushima Nuclear Power Plant accident has caused wide spread contamination. The nuclides of concern for incorporation were I-131 in the early phases, but now primarily Cs-134 and Cs-137. A large number of people have been affected and must be monitored for internal incorporation of these radionuclides. The Fukushima Prefecture government has procured several FastScan WBC systems, manufactured by Canberra. These systems were developed primarily to assay Radiation Workers, which according to US regulations must be over 18 years old. Consequently, calibrations for the WBC are done with reference calibration phantoms representing Standard Man in size.

But in this situation when measuring the general public, there are many non-adults, ranging from small infants to near-adults. The primary purpose of this investigation is to develop the efficiency calibrations for this wide range of subject sizes. An equally important goal is to develop a calibration geometry that can be accurate for wide range of subject sizes.

The FastScan is a linear geometry WBC system. The subject stands vertically in the counter. There are two large NaI detectors, each 12.5cm wide x 40cm tall x 7.5cm thick. These two detectors are aligned vertically on the same axis, and parallel to the vertical axis of the standing subject. The subject stands facing the detector, with his back against the back shield wall of the detector. For special cases, a second count is obtained with his back toward the detector and the front of his body against the shield wall. It is this special geometry where the front of the detectors is at a constant distance from the opposite side of the subject that allows the FastScan to be relatively independent of subject size. This is known to be true for adults, but not documented for small children.

Efficiency calibrations were performed for a wide range of BOMAB-type phantoms. These phantoms are groups of elliptical cylinders that when grouped together have a shape similar to the size of the person of interest. Shapes representing large [95th percentile adult male] to children 65cm tall were created. These shapes were then evaluated for efficiency in the FastScan WBC. A special version of the ISOCS software was used for these efficiency calibrations. This special version allows elliptical cylinders to be modeled, and allows multiple shapes to be grouped together.

Due to the placement of the detectors, if short subjects stand on the floor the efficiency will be too low. But if they will stand on a platform, then their efficiency is approximately the same as for adults. Three different platform heights [12, 20, and 27cm] will allow all sizes of children to be counted with the same efficiency as adults. This will allow a single efficiency calibration curve to be used for all subjects, and keep calibration errors less than + / - 15% for photons in the energy range of 200 – 1000 keV.

P12.61
Aerial radiological monitoring of East Japan after the Fukushima Daiichi NPP accident

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We measured the ambient dose-rate and the deposition amount of radioactive cesium by using four helicopters in the whole area of East Japan to investigate the influence of the radioactivity that released in the atmosphere due to the disaster of the Fukushima Daiichi NPP (Nuclear Power Plant), Tokyo Electric Power Company (TEPCO), occurred by the East Japan earthquake and tsunami on March 11, 2011. It reports on the measurement technique and the result.

A massive radioactive materials emitted from the NPP was released in the atmosphere due to the disaster and contaminated soils in the wide area in East Japan. Therefore, we have carried out the airborne radiation monitoring (ARM) in the whole area of East Japan, and investigated the influence of the radioactive cesium of the deposition to the ground level.

The ARM can plainly and promptly understand the distribution of the ambient dose-rate and the deposition of radioactive cesium by measuring gamma rays from the urban area to the forest over the wide range. An aerial radiation monitoring has following advantage. (1) The widespread distribution of radionuclides can be measured with short time by less manpower. (2) Descriptive contour maps of the deposition of the radioactive cesium can be depicted. (3) The radioactivity of the mountains and forests can be measured. We were each equipped with a different measurement system in four helicopters, and they are large-size NaI scintillation detectors (16 x 4 x 2 inches or 16 x 4 x 4 inches) are being used inside/outside of each helicopter in-flight. Both counting rates and the pulse-height distribution data (energy spectrum) were detected at each second. We also installed the GPS sensor in the helicopter, and measured the latitude, the longitude, and the altitude of the helicopter at the same time.

The flying altitude from the ground was obtained by subtracting the altitude obtained by the DEM (digital elevation model) data from that of the helicopter. The attenuation coefficient of air was obtained by flying at some altitudes (150 - 900 m) in above the test-line selected for the comparison with the ground data. Moreover, the conversion coefficient of the ambient dose-rate was calculated by the comparison of the ambient dose-rate measured by an NaI survey-meter with the counting rate at 1 m height evaluated by using the attenuation coefficient.

We also made maps of the dose-rate and the deposition of radioactive cesium by using the IDW (inverse distance weighted) procedure as an interpolation method of a GIS software.

It has been understood for the region where the dose-rate is high to extend from the NPP for northwestward, and wide to Gunma Prefecture from the vicinity of Fukushima City in the direction of the southwest. This map is utilized to determine the decontamination area and estimate the variation of contamination areas.

P12.62
Evaluation of Internal Doses for Chronic Intakes after the Fukushima Daiichi Nuclear Power Plant Accident

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Several studies have been made on a Level 3 Probabilistic Safety Assessment (Level 3 PSA) of the impact of potential nuclear power plant accidents at the Japan Atomic Energy Agency (JAEA). An internal dose calculation code (DSYS code) has been developed at JAEA since the code provides detailed internal dose coefficients to members of the public in a Level 3 PSA. The DSYS code can treat internal dosimetry for acute intakes of radionuclides using the International Commission on Radiological Protection's (ICRP's) respiratory tract, GI-tract, tissue dosimetry, biokinetic and bioassay models for ICRP Publ.71. The Fukushima Daiichi nuclear power plant accident that occurred in March 2011 has resulted in the radionuclide releases to the atmosphere and the contamination of large areas. There exists a need to evaluate long term doses for members of the public. The present study was carried out to extend the DSYS code for chronic intakes of radionuclides by inhalation and ingestion (DSYS-chronic code). In addition, averted doses to members of the public due to chronic intakes of radionuclides through tap water and food restrictions, which were implemented as urgent protective measures, were evaluated using the DSYS-chronic code. Consequently, it was found that the averted equivalent doses to the thyroids of members of the public were found to be a maximum value of 13.0 mSv in a local area of Fukushima.

P12.63
Development of The NIRS External Dose Calculation System for The Fukushima Residents Affected by The Nuclear Power Plant Accidents

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The great east Japan earthquake occurred on 11 March 2011 in the Tohoku District of Japan. After the quake, big tsunamis rushed to the coast of Fukushima, including the site of the Fukushima Dai-ichi Nuclear Power Plant. By the tsunamis, the emergency generators of electricity of NPP lost their ability. Subsequently, the reactors of NPS stopped, and the hydrogen explosions occurred emitting radionuclides including Cs-134, Cs-137, I-131, and so on.

After the accident, Fukushima prefectural government and Fukushima medical university planed the health management survey for the Fukushima residents and have performed in cooperation with National Institute of Radiological Sciences (NIRS). NIRS developed the external dose calculation system based on the dose rate maps and the action data of the residents for the period of 12 March – 11 July. The dose rate maps and action data of the residents during the period were used to estimate external doses in the NIRS calculation system. The data of the maps were based on the calculated doses by using the SPEEDI simulation code for March 12-14 and monitoring data for March 15 – July 11 reported by the Ministry of Education, Culture, Sports, Science and Technology. The background dose rates measured before the accident were subtracted from the dose values of the maps.

For grasping the exposure levels of the external doses of the residents, 18 evacuation patterns of the residents were assumed by NIRS before using the survey data of the residents. The results shows that the exposure levels of the residents who evacuated from the area within 20 km radius from the NPS were less than several mSv, and that the levels of the residents from the deliberate evacuation area were less than 20 mSv. Based on the calculated data by the NIRS system, Fukushima prefecture reported the external exposures of the 10,468 of the residents on Feb. 20. About 58% of the estimated doses of the residents were less than 1mSv. The dose levels of more than 99% residents were 10 mSv. The maximum dose were 23.0 mSv of the residents excluding radiation workers.

P12.64
The Experience of Risk Communication Activities Using Q&A Web Site About Radiation in Daily Life After Fukushima Daiichi Nuclear Power Plant Accident

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After Fukushima Daiichi Nuclear Power Plant Accident (hereinafter referred to as "Fukushima accident") happened on 11 March 2011, we have been providing the right information about radiation and radioactivity via a Q&A website. Immediately after the accident, volunteers of Japan Health Physics Society (JHPS) built up a website named Questions and Answers about Radiation in Daily Life. They carefully answered all of the questions posted on the website. In August, Steering Committee of the Q&A site was officially established in JHPS. Since then, the Committee has been engaged in the risk communication activities to the public. The Committee consists of 53 members of JHPS. About 40 of them are the members of Young Researcher's and Student's Association in JHPS. In response to the questions posted, the answers are prepared by the young researchers, emended by the experts who work as consultants, and confirmed by the executive members of the Committee.

We have analyzed characteristics of questioners and question contents of about 1,500 posted on our web site so far. It has been found that mothers of small children form the major portion of the questioners all through the period. We recognized that young mothers have been worrying about the health effects of their children due to accident. In addition, it is found that questions were concentrated into the information about the circumstances of the accident which were published by the government or released by mass media. Through this analysis, we have understood that what kind of information has been need by public under the situations where the radiation levels varied time by time after Fukushima accident.

We will set up a task group in JHPS to publish a book of our "Q&A". We will extract approximately 100 important questions from the website, and then arrange and publish them. We hope that the book will contribute the reduction of the public's anxiety of the radiation due to Fukushima accident. In addition, we hope that we will be able to send lessons learned from the experience of Fukushima accident to people all over the world by translating the contents into English, which we have got through the risk communication activities of Q&A web site.

P12.65
Development of radioactive databases and contamination map system

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Radioactive database and contamination map for the accident of Fukushima Dai-ichi nuclear power plant are described. In order to estimate the impact of the nuclear accident and take appropriate countermeasures, it is necessary to obtain precise data on the contamination conditions. Both systems have been developed to provide information to identify the current distribution of released materials and to support decontamination planning. The former is designed to provide quantitative data for detailed analysis, while another to provide intuitive images for the qualitative estimation. They contain measured data such as air dose rates by using radiation counters at around 2,200 locations within approximately 100km from the plant, and radionuclide concentration measured by sampling soils from the 5 cm surface layer at around five points at each location. The vehicle-borne survey results, mainly on national and prefectural roads in these areas, are also included for the purpose of ascertaining the distribution of radioactive substances around roads in detail. The number of survey data is amounted to about 150,000 for the first investigation conducted in June, and 700,000 for the second investigation in December 2011. The systems are open to the public at the site of Japan Atomic Energy Agency.

P12.66
Time Variation of Dose Rate and Gamma Spectrum of the Radionuclides Deposited on the Ground Due to the Fukushima Nuclear Crisis

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The fission products were released to the atmosphere, and then, were deposited on the ground by the Fukushima Daiichi Nuclear Power Station accident, which occurred after a 9.0 magnitude earthquake and resulting tsunami on March 11, 2011. This study reports that the time variation of the dose rate and gamma spectrum of radionuclides deposited on the ground was investigated at six points (Fukushima City, Shirakawa City, Kawamata Town, Aizuwakamatsu City, Koriyama City, and Iwaki City) located in Fukushima prefecture during the period of about a year after the accident. As a result, together with Cs-134 and Cs-137, the short-lived radionuclides such as Te-132 and I-131 were detected at all points after about one week of the accident. Their contributions to the dose rates were found to be equal to or more than those in Cs-134 and Cs-137. In particular, the distribution of I-131 to dose rate at Iwaki City, located in a area about 40km southwest of the Fukushima Daiichi Nuclear Power Station, was higher than that of the others, depending on wind direction and rainfall event. The dose rates also decreased exponentially with time due mainly to decay of the short-lived radionuclides.

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