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

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IAEA

International Atomic Energy Agency

Introduction

- Natural sources – omnipresent
- Chain of radionuclides – equilibrium status
- Industries – Low or significant levels of natural radionuclides present in most raw materials
- Large quantities
- Some times process lead to enhanced concentrations

The concerns?

- Industry workers – potential exposures
  - gamma
  - Inhalation of aerosols in dusty environment
  - Radon and progeny inhalation
- Public
  - Tailings
  - Water contamination
  - Air discharges

What is NORM ?
Definitions: IAEA Safety Glossary (version 2.0):

Radioactive material

Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity

NORM

Radioactive material (as defined above)

containing no significant amounts of radionuclides other than naturally occurring radionuclides

So if it's not subject to regulation, it's not NORM !

TENORM:

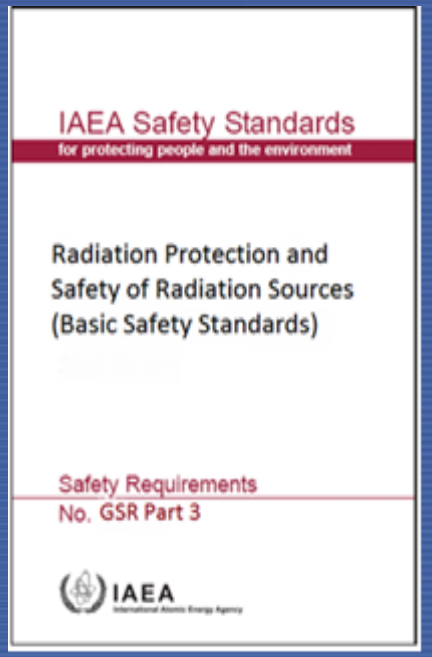
- Not defined in the IAEA Safety Glossary
- Its use is discouraged

RADIATION PROTECTION CHALLENGES

1. Standards and regulatory approaches

The new BSS – Interim Edition Published

Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
GSR Part 3



The International Safety Standards

- The IAEA Safety Standards reflect **international consensus**
- This consensus is necessary to promote a **common approach for ensuring safety**

1. INTRODUCTION

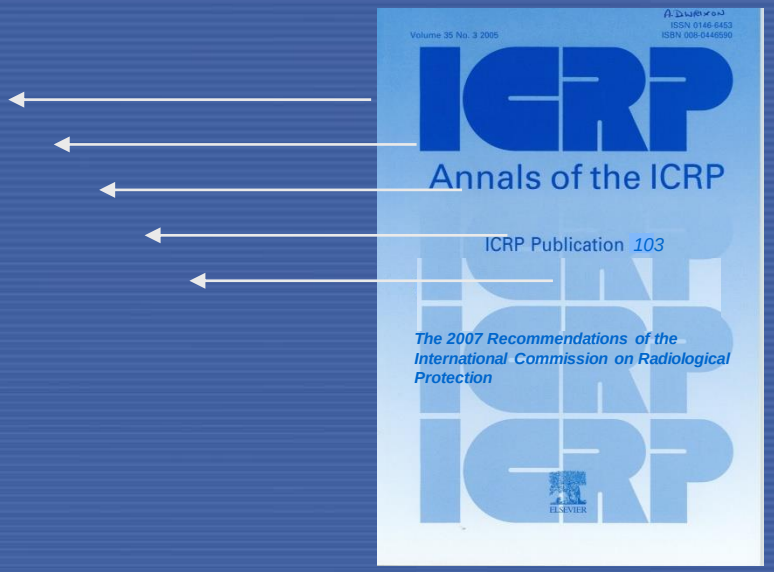
2. GENERAL REQUIREMENTS FOR PROTECTION AND SAFETY
Implementation of radiation protection principles
Responsibilities of government
Responsibilities of the regulatory body
Responsibilities of other parties
Management requirements

3. PLANNED EXPOSURE SITUATIONS
Scope
Generic requirements
Occupational exposure
Public exposure
Medical exposure

4. EMERGENCY EXPOSURE SITUATIONS
Scope
Generic requirements
Public exposure
Exposure of emergency workers
Transition from an emergency exposure situation to an existing exposure situation

5. EXISTING EXPOSURE SITUATIONS
Scope
Generic requirements
Public exposure
Occupational exposure

SCHEDULES
- Schedule I EXEMPTION AND CLEARANCE
- Schedule II CATEGORIZATION OF SEALED SOURCES
- Schedule III DOSE LIMITS FOR PLANNED EXPOSURE SITUATIONS
- Schedule IV CRITERIA FOR USE IN EMERGENCY PREPAREDNESS AND RESPONSE



Application of the Standards to NORM

1. **What** should fall within the scope of regulation?

2. If within the scope of regulation, **how** to regulate?

In both cases, follow the principle of **optimization of protection**

- Maximum net benefit
- Sometimes, no regulation is the best option
- If regulation is warranted, apply **graded approach**

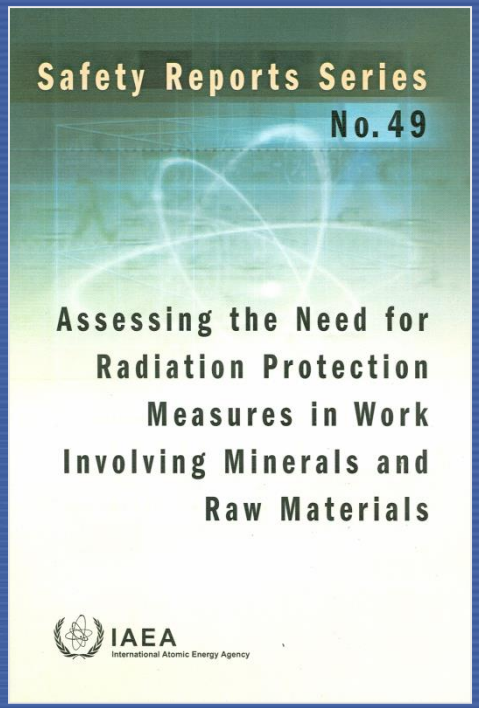
Standards and regulatory approaches

- New BSS – how to implement the requirements in industries
- Greater use of quantitative criteria
- Adoption of the BSS in national standards
- Industry sectors, SR49
- Building materials
- Harmonization of standards
- Acceptance of 1 Bq/g criteria
- Differences in standards between countries and even within a country
- Growing concerns over the need for an evidence-based approach to the making of policy and regulatory decisions

Industry sectors

Industry sectors most likely to require some form of regulatory consideration

1. *Uranium mining and processing*
2. *Rare earths extraction*
3. *Thorium extraction & use*
4. *Niobium extraction*
5. *Non-U mining – incl. radon*
6. *Oil and gas*
7. *Production and use of TiO_2*
8. *Phosphate Industry*
9. *Zircon & zirconia*
10. *Metals production (Sn, Cu, Al, Fe, Zn, Pb)*
11. *Burning of coal etc.*
12. *Water treatment – incl. radon*



2. Graded approach to regulation

One of the key principles in the BSS

application of the requirements for planned exposure situations

“shall be commensurate with characteristics of the practice or source and with the magnitude and likelihood of exposures.”

Particularly relevant for NORM industries

the exposures are generally (but not always) moderate with little or no likelihood of extreme radiological consequences from accidents.

What if the material is >1 Bq/g (or >10 Bq/g K-40)?

Apply a **graded approach** to regulation

1. Exemption (Decision not to regulate)
   - **If dose from gamma and dust is less than about 1 mSv/a, after taking existing industrial hygiene controls into account**
2. Notification
   - **If dose from gamma and dust << dose limit, after taking existing industrial hygiene controls into account (similar to exemption but regulator remains informed)**
3. Notification + registration
   - **Minimal additional controls for gamma and dust needed, after taking existing industrial hygiene controls into account**
4. Notification + licensing
   - **Specific measures to control actions of workers – needed only when dealing with very high activity material in significant quantities**

2. Graded approach to regulation

- Facilitates decision making process
- Realistic estimation of doses – workers & Public
- Effectiveness of Existing Occupational Health and Safety Measures
- Still concerns resulted by an over-cautious approach
- Sometimes questionable risk assessments derived from conservative modelling

Optimal use of regulatory resources

It is very important to ensure that the following does not happen in the process of the application of radiation protection regulations to the activities involving NORM:

3. Industry-specific approach

- No single approach is appropriate for all industrial processes – a challenge in deriving a uniform approach
- The nature and level of the radiological risk varies considerably from one industrial process to another
- Most of the actions taken to comply with regulation is situation specific and hard to generalise
  - Examples – Oil and gas industries,
  - Mining industries
- Strong call in NORM conferences for an industry-specific approach to the control of exposure to NORM
- Increasing attention of industries, workers and public on the ongoing efforts of the IAEA to develop industry specific safety reports

4. Resurgence of uranium exploration and mining

- World uranium industry on expansion
- Increasing exploration activities
- Abandoned mines being re-examined for the potential to re-open, or reprocess residues
- Planning for exploitation of uranium deposits in many countries new to uranium mining

5. Planned exposure situation or existing exposure situation?

- By default: Treat as **existing exposure situation**
- By exception: Apply requirements for planned exp. situation
- Exceptions are relatively few
- Don't interpret the words "planned" and "existing" too literally
  - Practicability is the most important consideration
  - Exposure is controlled regardless of the type of situation, it's just the mechanism of control that differs

Planned exposure situation or existing exposure situation?

The following exposures are always controlled in accordance with the requirements for existing exposure situations (i.e. no exceptions to the general approach):

- Exposure to natural radionuclides in:
  - Everyday commodities food, feed, drinking water, fertilizer and soil amendments, building material
  - Residual radioactive material in the environment (other than exposure of remediation workers)
- Public exposure to radon

Planned exposure situation or existing exposure situation?

The following exposures are always controlled in accordance with the requirements for planned exposure situations (i.e. always treated as exceptions to the general approach):

- Public exposure delivered by effluent discharges or the disposal of radioactive waste arising from a practice involving natural sources

Planned exposure situation or existing exposure situation?

The following exposures are controlled in accordance with the requirements for EITHER existing OR planned exposure situations:

Source of exposure	***Existing exposure situation***	***Planned exposure situation***
Material other than environmental residues and food, drinking water etc.	≤1 Bq/g (U, Th series) and ≤10 Bq/g (^{40}K)	>1 Bq/g (U, Th series) or >10 Bq/g (^{40}K)
Radon in workplaces: • Exposure required by or directly related to the work	✖	√
• Exposure incidental to the work	≤1000 Bq/m^3	>1000 Bq/m^3

Existing exposure situations – reference levels

Reference levels are not the same as action levels

- Action levels are levels at or below which remedial action (and thus the need for optimization) is not normally necessary
- Reference levels are levels above which it is inappropriate to plan to allow exposures to occur, and below which optimization of protection should be implemented
    - Retaining the same numerical value implies a significant increase in the stringency of control

Existing exposure situations – reference levels

General reference levels (applicable to both natural and artificial sources):

- Normally in the range 1–20 mSv/a
- Commodities: ≤1 mSv/a
- Radon:
  - Expressed in terms of radon activity concentration in air
  - ≤300 Bq/m^3 in homes
  - ≤1000 Bq/m^3 in workplaces
  - These values are roughly equivalent to 10 mSv/a in terms of latest ICRP thinking:
    - The risk per unit intake is now thought to be about twice the ICRP65 value

6. Reference levels and dose constraints

- Establishing appropriate or single national reference level is an issue in several countries
- the issue is complex when considering countries with federal and state level administrative systems.

- The ‘reference levels’ and ‘dose constraints’ sometimes have been either used or considered, as limits defeating the purpose of optimization.

- Confusion between the ‘reference level’ and the previously used ‘action level’ (at or below which remedial action and thus the need of optimization is not normally necessary) in terms of practical application in workplaces

Planned exposure situations – exemption and clearance

2. Automatic exemption without further consideration

- For natural radionuclides incorporated into consumer products or used as radioactive source or for properties as chemical elements (always in moderate quantities):
  - Use “Schedule 1” values of activity or activity concentration
  - Depending on radionuclide, 10^4–10^6 Bq or 1–1000 Bq/g
  - Based on ~10 μSv/a
- For all other cases (including bulk quantities) – particularly applicable to NORM:
  - Exemption if dose is less than ~1 mSv/a
    - Activity concentrations of 1 Bq/g (U, Th series) or 10 Bq/g (^{40}K) will satisfy this criterion in all reasonable situations
    - But these values are generally too conservative for use as exemption levels
    - For material below these activity concentrations, the requirements for planned exposure situations would not even apply

Planned exposure situations – exemption and clearance

Clearance

Same 2 alternative approaches as for exemption:

1. Case-by-case (qualitative criteria)
2. Automatic, without further consideration (numerical criteria):
   - ≤1 Bq/g for U, Th series

     AND
   - ≤10 Bq/g for ^{40}K

Planned exposure situations – exemption and clearance

	Criterion		
	Max dose	Max activity	Max activity conc.
Exemption: • Moderate quantities, consumer prod., source, chem. props	~10 μSv/a	10^4–10^6 Bq dep. on nuclide	1–1000 Bq/g dep. on nuclide
• All other (general NORM)	~1 mSv/a	--	--
Clearance	--	--	1 Bq/g (U, Th ser) 10 Bq/g (^{40}K)

7. Exclusion, exemption and clearance

- Differences in interpretation of the standards
- 1 Bq/g criterion subjecting material to regulatory consideration is variously referred to as an exclusion level, an exemption level, a clearance level or even a limit
- Tendency to apply the concept of exemption not only to planned exposure situations but to existing exposure situations as well
- Terms exclusion and exemption is tended to be used interchangeably

8. Exposure of workers

- The role of general occupational health and safety regulations in controlling radiological hazards at work, particularly in the case of airborne dust control, is becoming increasingly recognized as an important part of the graded approach to regulation.

- The acquisition of exposure data for workers and the assessment of dose still suffer from a non-standardized approach and incomplete information in several countries, making a reliable assessment of the need for, and extent of, regulatory control difficult.

- The radon concentrations in most of the workplaces concerned except uranium and thorium ore processing were generally less than about 100 Bq/m^3. Some of the uranium mines are reported to have higher radon concentrations which pose additional challenge for protection of workers in the industry.

Radon in workplaces

- Recently, ICRP has observed an increased risk for exposures to radon. Combining this with the new dosimetric approach to derive dose conversion coefficient for intake of radon pose a great challenge to control exposures to radon in workplaces especially in uranium mines.

- Doubling of the dose ?

- Radiation protection measures against radon in uranium mines

9. Exposure of public

- Considerable uncertainty in dose estimation
- Conservative modelling
- Implausible exposure scenarios
- lack of uniformity in the approach to the use of NORM as a component of building material
- strong need for an evidence based approach in assessing radiation protection of the public from NORM
- Social licencing and public communication are also important challenges

10. Transport issues

- Triggering of alarms at ports
- Growing concern worldwide – needs improvements in the design and operation of such monitoring systems and in the training of operators.
- Screening of commercial vehicles
- Alarms due to NORM contamination
- Segregation criteria
- Monitoring systems

Transport regulations on NORM

- IAEA Transport regulations TS-R-I, 2009
  - Basis for Transport of dangerous goods regulations (UN)
  - Int. Maritime dangerous goods code IMDG
  - Technical instructions for transport by air, ICAO
- CRP – Appropriate level of regulatory control for the safe transport of NORM

Transport regulations on NORM

The concentration and total activity exemption levels both have to be exceeded in a consignment before transport regulations apply.

Para 107 (e) of TSR-I

For NORM, the exemption level for transport purposes is10 Bq/g for Th-nat and U-nat.

What about if the radionuclides are not in equilibrium ?

For example Ra-226 separated from its parent…

Unnecessarily strict ? Need for consideration on a case-by-case basis ?

11, Management of NORM Residues

- Increasing acceptance on the concept of use of NORM residues rather than disposal
- Many instances of residue recycling and use
- Instances of dilution
- Doses received from the use of NORM residues within acceptable levels some conditions are considered by regulatory bodies
  - Examples : Sweden - ^{238}U decay series do not exceed 3 Bq/g, for historical NORM residues
  - India - the use of phosphogypsum in building materials is permitted if the ^{226}Ra concentration does not exceed 1 Bq/g (after dilution with lower activity material if necessary).
  - EC : Building materials can be used without restriction if the dose from indoor external exposure does not exceed the background outdoor external exposure by more than 1 mSv per year
- xxx

Management of NORM Residues/wastes..contd..

- Lack of uniformity in the approach to the use of NORM as a component of building material
- Agreement on the value of 1 mSv as a general reference level for building materials, there was less of a common view on how this should be translated into measurable quantities such as activity concentration.
- A restriction based only on external exposure might not be sufficient to adequately control radon exposure
- Some countries in Europe – additional criterion specifically to control radon exposure from building materials
- Different views on whether the 1 mSv dose criterion should refer to the total external dose from the building material or just the contribution from NORM contained within it.

12. NORM Waste

- A risk-based and situation specific approach is essential for the establishment of good practices for the management of NORM waste.
- Some of the waste considered for disposal
  - Tailings and other waste from the processing of uranium ore
  - Tailings, slag and chemical processing wastes associated with the production of thorium and rare earths
  - Radium-rich scale from the oil and gas industry
  - Sludge from water treatment facilities

13. Legacy issues

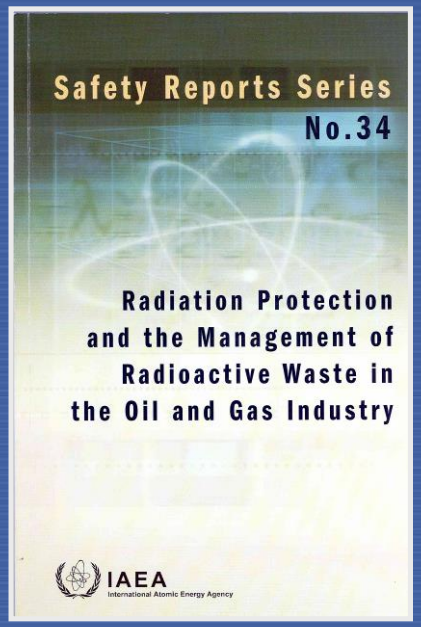
- Former industrial activities
  - Uranium mining sites (example : cental Asia)
  - Heavy metal mining and processing sites
  - Monazite and thorium processing sites
  - Fertilizer plants
  - Thorium mantle factories
  - Old oil production fields
  - Scrap metal dumps
  - Tailings sites
- Coordinated international efforts for remediation - a challenge

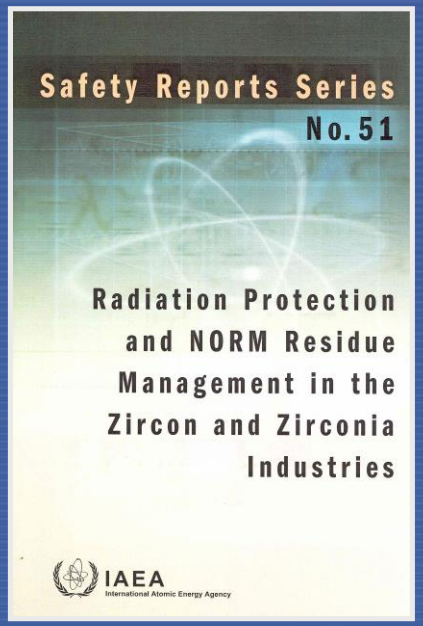
14. Lack of trained radiation protection professionals in industries

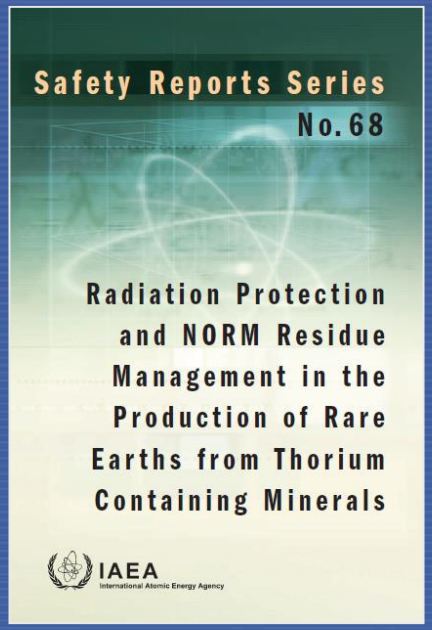
- Appropriate training & qualification
- Young professionals shortage

IAEA Industry Specific Safety Reports

Industry-specific reports







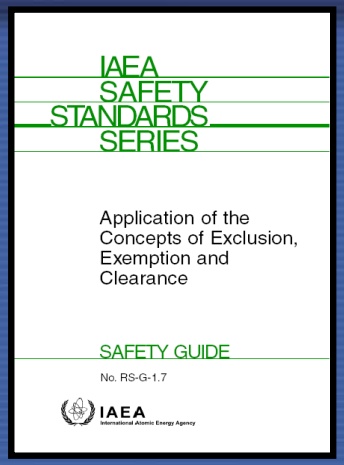
Industry-specific reports (in draft)

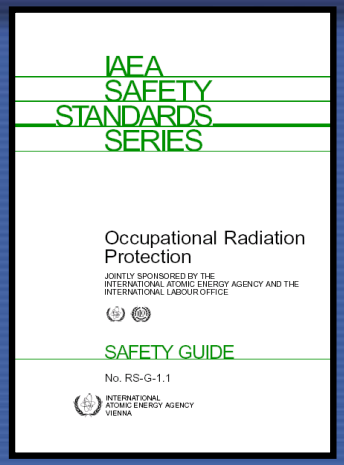
Phosphate Industry

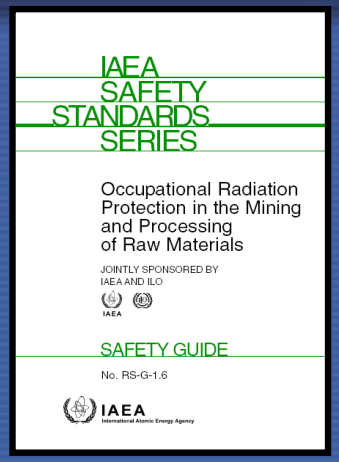
Titanium Dioxide and Related Industries

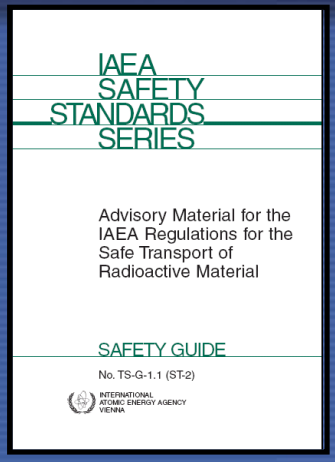
Industrial uses of Thorium

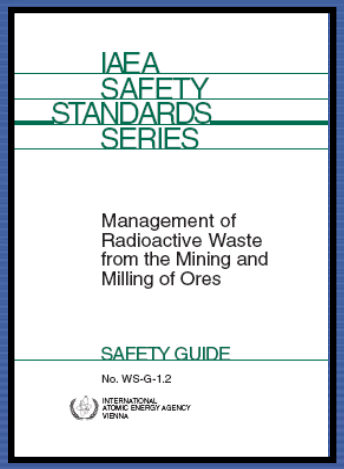
Safety Guides containing specific recommendations on natural sources











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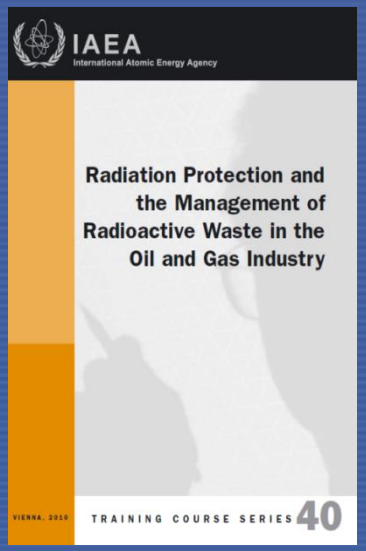
Public exposure to natural sources

Other guidance materials on NORM

Training materials

Generic NORM

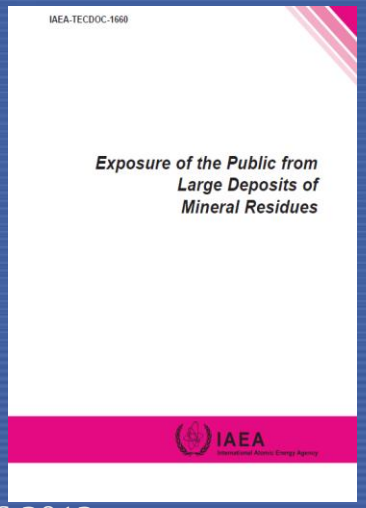
Oil and gas industry



New TECDOC

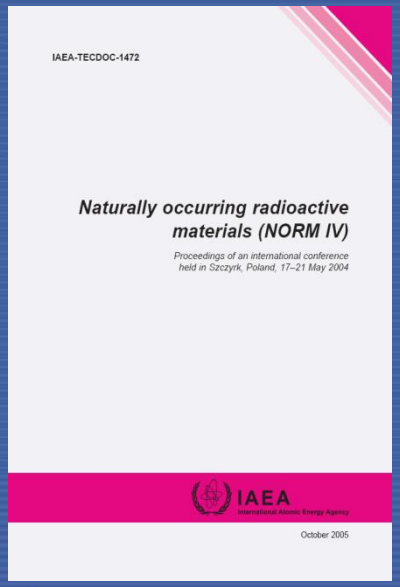
IAEA TECDOC 1660, 2011

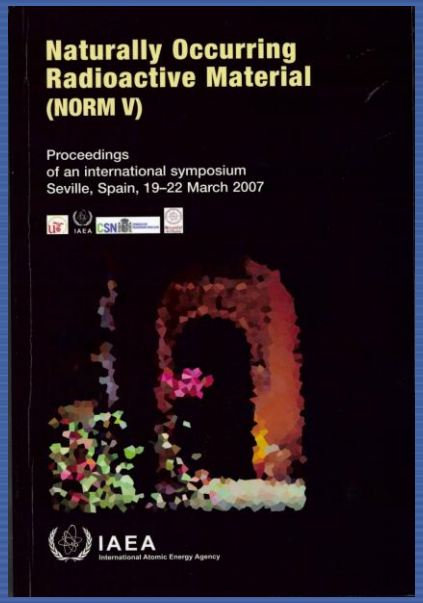
Exposure of the Public from large Deposits of Mineral Residues



The NORM Symposia

Amsterdam, Netherlands 1997
Krefeld, Germany 1998 (NORM II)
Brussels, Belgium 2001(NORM III)
Szczyrk, Poland 2004 (NORM IV)
Seville, Spain 2007 (NORM V)
Marrakesh, Morocco 2010 (NORM VI)





NORM VII Symposium - 2013

Beijing, China

April 22-26, 2013

Announcement soon ……

Summary

- Considerable progress towards harmonization of standards and regulatory approaches for the control of exposures to NORM
- The new BSS provides more numerical criteria, for exposure to natural sources
- The selection of criteria for the scope of regulatory control is a critical issue for NORM industries. If the activity concentration exceeds the exemption criterion, a graded approach for regulatory control should be applied.
- The selection of criteria for the scope of regulatory control is a critical issue for NORM industries.
- IAEA safety reports – for industry specific guidance
- Radon in workplaces

Many thanks for your attention…

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