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ICRP Radon recommendations
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Abstract- At its meeting in Porto (Portugal) in November 2009, the Main Commission of the International Commission on Radiological Protection (ICRP) approved the formation of a new Task Group, reporting to Committee 4, to develop guidance on radiological protection against radon exposure. The present presentation is a description of the Task groups' draft report which is currently posted on the ICRP website for public consultation. In this report, the Commission provides updated guidance on radiological protection against radon exposure. The report has been developed considering the recently consolidated ICRP general recommendations, the new scientific knowledge about the radon risk and the experience gained by many organisations and countries in the control of radon exposure. The report describes the characteristics of radon exposure, covering sources and transfer mechanisms, the nature of the risk, the exposure conditions, the similarities with other existing exposure situations and the challenges to manage radon exposure. To control the main part of radon exposure the Commission recommends an integrated approach focussed as far as possible on the management of the building or location in which radon exposure occurs whatever the purpose of the building and the types of its occupants. This approach is based on the optimisation principle and a graded approach according to the degree of responsibilities at stake, notably in workplaces, and the level of ambition of the national authorities. The report emphasises the importance of preventive actions. The report also provides recommendations on how to control radon exposure in workplaces when workers' exposure can reasonably be regarded as being the responsibility of the operating management. In such a case workers' exposures are considered as occupational and controlled using the corresponding requirements on the basis of the optimisation principle and the application, as appropriate, of the dose limit.

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

1. INTRODUCTION

The objective of the future Publication is to describe and clarify the application of the Commission's system to the protection of the members of the public and the workers against radon 222 and radon 220 exposures in dwellings, workplaces and other types of locations.

Radon 222 is a radioactive decay product of uranium 238 which is present in the earth's crust in varying concentrations. Because radon is a gas, it is capable of movement from the soil to indoors. This movement is dependent on the type of building and/or location. Radon 220 is a radioactive decay product of thorium 232 also present in the earth's crust. Both radon 222 and 220 may also come from some building materials. The concentration of radon in a building may vary from several orders of magnitude.

Because radon is inert, nearly all of the gas inhaled is subsequently exhaled. However, when inhaled, the short-lived radon progeny can deposit within the respiratory tract. Depending on the diffusion properties of the particles (size distribution of the aerosols), the decay products present in the air deposit in the nasal cavities, on the walls of the bronchial tubes and in the deep lung. Two of these short-lived progeny, polonium-218 and polonium-214, emit alpha particles and the energy deposited by these alpha particles may lead to health effects, principally lung cancer.

The Commission made recently a thorough review and analysis of the epidemiology of radon for both workers (underground miners) and the general population (ICRP, 2010). There is now compelling evidence that radon and its progeny can cause lung cancer. For solid tumours other than lung cancer, and also for leukaemia, there is currently no convincing or consistent evidence of any excesses associated with radon and radon progeny exposures. For radiological protection purposes the Commission now recommends a detriment-adjusted nominal risk coefficient for a population of all ages of $8x10^{-10}$ per Bq h m^{-3} for exposure to radon-222 gas in equilibrium with its progeny (i.e. $5x10^{-4}$ WLM^{-1}), which is approximately twice the value previously used by the Commission in Publication 65 (ICRP 1993).

2. CHARACTERISTICS OF RADON EXPOSURE

Radon exposure situations have the characteristics of existing exposure situations since the source is unmodified concentrations of ubiquitous natural activity in the earth's crust. Human activities may create or modify pathways increasing indoor radon concentration compared to outdoor background. These pathways can be controlled by preventive and corrective actions. The source itself, however, cannot be modified and then already exists when a decision on control has to be taken. Some workplaces, however, may be deemed to be planned exposure situations from the outset by national authorities. Such workplaces may include uranium mines associated with the nuclear fuel cycle.

Radon is not likely to give rise to an emergency exposure situation even though the discovery of very high concentrations in a place may require the prompt implementation of protective actions. The philosophy of *Publication 103* (ICRP, 2007) compared to *Publication 60* (ICRP, 1991) is to recommend a consistent approach for the management of all types of exposure situations. This approach is based on the application of the optimisation principle implemented below appropriate constraints or reference levels.

Several characteristics of radon exposure in dwellings (and in many other locations) are similar to those of exposures arising from other existing exposure situations such as exposures to NORM or exposures in a long-term contaminated area after a nuclear accident or a radiation emergency. Radon exposure affects nearly all living places of a population. The ubiquity and the variability of radon concentration result in a very heterogeneous distribution of exposures. Day to day life or work inevitably leads to some exposure to radon. The persistence or reduction of the risk is mainly dependant on individual behaviour. Domestic radon exposure management should address several considerations such as environmental, health, economic, architectural, educational, etc. A large spectrum of parties is concerned. The role of self-help protective actions is also crucial.

Control of indoor radon exposure poses many challenges. As a given individual can move from place to place in the same area, the radon policy should provide consistency in the management of the different locations in an integrated approach. As the radon risk is mainly due to domestic exposure, the radon policy should address primarily exposure in dwellings in a public health perspective. As the radon concentration in many buildings is above the level at which the risk has been demonstrated, a real ambition is needed to both reduce the overall risk for the general population and the highest individual exposures. Radon policy should not be in contradiction with the raising role of energy saving policies. It should be as simple as possible, properly scaled with other health hazards, supported and implemented on a long term basis and involving all the concerned parties.

A national radon policy has also to address many challenges in terms of legal responsibilities, notably the responsibility of the individual householder towards her/his family, of the seller of a house or a building towards the buyer, of the landlord towards the tenant, of the employer toward the employee, and generally speaking of the responsible person for any building towards its users. The degree of enforcement of the actions that are warranted is very much related to the degree of legal responsibility for the situation.

3. A REALIST, INTEGRATED, GRADED AND AMBITIOUS APPROACH

The responsibility dimension calls clearly for the need of a graded approach in defining and implementing a radon policy. Such a graded approach should be based on realism, effectiveness and ambition. Any radon policy should thus aim to maintain and/or reduce radon concentration as low as reasonably achievable in an effective way keeping in mind that it is not possible to totally eliminate indoor radon concentration.

3.1. Application of the principles

The Commission considers that a national radon protection strategy appears to be justified since radon is a significant source of radiation exposure (second cause of lung cancer after smoking), radon exposure can be controlled and a radon policy has positive consequences on other public health policies (indoor air quality or anti-smoking policies). The Commission considers that radon strategies should address together both smokers and non-smokers.

It is the responsibility of the appropriate national authorities, as with other sources, to establish their own national reference levels, taking into account the prevailing economic and societal circumstances and then to apply the process of optimisation of protection in their country. The objective is both to reduce the overall risk of the general population and, for the sake of equity, the individual risk in particular the risk of the most exposed individuals. In both cases the process is implemented through the management of buildings and should result in radon concentrations in ambient indoor air as low as reasonably achievable below the national reference level.

According to the characteristics of radon exposure (control by actions on pathways, benefit for individuals due to the use of buildings, general information provided to enable individuals to reduce their doses), the appropriate reference level should therefore be set corresponding to an annual dose in the range 1 mSv to 20 mSv (see table 5 of Publication 103: ICRP, 2007). Further, the value of 10 mSv, which is the middle of this range, should remain the upper value of the dosimetric reference level for radon exposure as set in Publication 65 (ICRP, 1993).

Reference levels for radon are typically set in terms of the measurable quantity, Bq m^{-3}. Because an upper value of the reference level for radon gas in dwellings of 100 Bq m^{-3} is not always possible, the Commission still recommends the upper value of 300 Bq m^{-3} (see its Statement on Radon approved in November 2009: ICRP, 2010, part 2) even though the corresponding dose seems to be more than 10 mSv using reference biokinetic and dosimetric models (to be confirmed by the publication of the revised dose coefficients). However, the Commission recommends to set a national reference level as low as reasonably achievable in the band of 100 to 300 Bq m^{-3}. The measurement should be representative of the annual mean concentration of radon in a building or location.

For the sake of simplicity, considering that a given individual going from place to place in the same area along the day should be protected on the same basis whatever the location, the Commission recommends to use in mixed-use buildings (with access for both members of the public and workers) *a priori* the same upper value as set for dwellings.

Within a graded approach the radon protection strategy should start with a programme aiming at encouraging relevant decision makers to enter in a process of self-help protective actions such as measurement and, if needed, remediation, with more or less incentive and helping provisions and, if judged necessary, even requirements. Then the degree of enforcement of these various actions would be increasing depending on the degree of legal responsibility for the situation and the ambition of the national radon protection strategy.

3.2. Specific graded approach for workplaces

A specific graded approach should be implemented in workplaces. Where workers' exposures to radon are not considered as occupational exposures, i.e. when workers exposures to radon cannot reasonably be regarded as being the responsibility of the

operating management (typically office buildings), the first step is to reduce concentration of radon-222 as low as reasonably achievable below the same reference level as set for dwellings (even though the corresponding level in dose is lower because the conditions of exposure in workplace are different than those in dwellings). If difficulties are met in the first step, a more realistic approach is recommended as the second step. It means optimising exposure on the basis of a dose reference level of 10 mSv per year taking into account the actual parameters of the exposure situation.

In workplaces, if despite all reasonable efforts to reduce radon exposure, the exposure remains durably above the dose reference level of 10 mSv per year, and/or where workers' exposure to radon can reasonably be regarded as being the responsibility of the operating management (e.g. some underground workplaces, spas…), the workers should be considered as occupationally exposed. In such cases, the Commission recommends applying the optimisation principle and the relevant requirements for occupational exposure.

The dose limit should apply when the national authorities consider that the radon exposure situation should be managed like a planned exposure situation. In any case, using either the occupational dose limit or a reference level, the upper value of the tolerable risk for occupational exposure (on the order of 20 mSv per year, possibly averaged over 5 years) should not be exceeded.

3.3. National action plan

A national radon action plan should be established by national authorities with the involvement of relevant stakeholders in order to frame the implementation of the national radon protection strategy in dwellings, places open to the public and workplaces. The action plan should establish a framework with a clear infrastructure, determine priorities and responsibilities, describe the steps to deal with radon in the country and in a given location, identify concerned parties (who is exposed, who should take actions, who could provide support), address ethical issues (notably the responsibilities) and provide information, guidance, support as well as conditions for sustainability.

To be efficient, the national radon protection strategy should be established on a long term perspective. The process to reduce the radon risk of the general population significantly is rather a matter of several decades than several years. The national action plan should be periodically reviewed, including the value of the reference level.

The Commission considers now that for the sake of clarification, when dealing with existing exposure situations, the distinction should be made between prevention aiming at maintaining exposure as low as reasonably achievable under the prevailing circumstances and mitigation aiming at reducing exposure as low as reasonably achievable.

As a consequence, a radon protection strategy should include a prevention part. Whatever the indoor location is, the category of individuals inside and the type of exposure situation, it is possible to optimise radon exposure by taking into account the issue of radon exposures during the planning, design and construction phase of a building. Preventive actions mean land-planning and building codes for new buildings and for renovation of old buildings. They also mean the integration of the radon protection strategy consistently with other strategies concerning buildings such as indoor air quality or energy saving in order to develop synergies and avoid contradictions.

The mitigation part of a national radon protection strategy concerns mainly existing buildings or locations. Then the control of exposure should be ensured as far as possible through the management of the building (or location) and the conditions of its use, whatever the category of individuals inside. The main steps are measurement and; when needed, corrective actions. The actions plan should also deal with radon measurement techniques and protocols, national radon surveys to identify radon prone areas, methods for mitigating the radon exposure and their applicability in different situations, support policy including information, training and involvement of concerned parties as well as assessment of effectiveness. The issues of buildings with public access and workplaces, with specific graded approaches, should also be addressed.

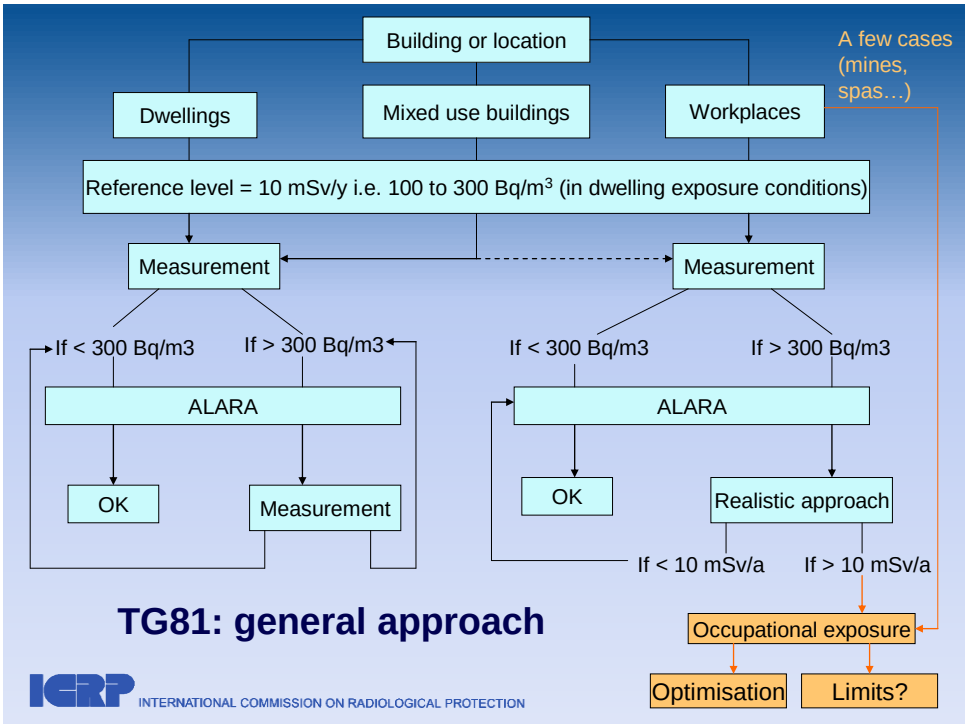

Fig. 1. General approach for the management of radon exposure

4. CONCLUSION

People are exposed to radon at home, in workplaces and in mixed-use buildings. The detriment-adjusted nominal risk coefficient recommended by the Commission is now approximately twice the value previously used in Publication 65 (ICRP 1993). Radon exposure situations are existing exposure situations since the source is unmodified concentrations of ubiquitous natural activity in the earth crust. Only pathways can be controlled.

Radon exposure has key characteristics: it is mainly due to domestic exposure (public health perspective); radon concentration in many buildings is above the level at which the risk has been demonstrated; radon policy may be in contradiction with other policies such as energy saving policy; the persistence or reduction of the risk is mainly dependant on individual behaviour (self-help protective actions); efficiency can only be achieved in a long term perspective; exposure in workplaces may be adventitious (cannot reasonably be regarded as being the responsibility of the operating management) and not occupational.

The justification of launching a national radon strategy (national action plan) is decision by the national authorities. The radon strategy should be simple and realist (same approach for smokers and non-smokers), integrated (consistent for all buildings), graded (according to the situation and the legal responsibilities) and ambitious (choice of the reference level; addressing both highest exposures and the global risk). The radon strategy should include both preventive (new buildings) and corrective (existing buildings) actions.

The management of radon exposure is mainly based on the application of the optimisation principle below an appropriate reference level. The Commission recommends 10 mSv per year as an appropriate dosimetric reference level for radon exposure. The upper value of the reference level (RL) recommended in dwellings is 300 $Bq.m^{-3}$ (annual mean concentration) with an incitation to choice a national reference level in the band of 100 to 300 Bq m^{-3}. For the sake of simplicity, the same value is recommended for mixed-use buildings.

A specific graded approach is recommended in workplaces: 1) application of the same RL in concentration as for dwellings (although the corresponding dose is below 10 mSv/y mainly because of the time of exposure); 2) application of the dosimetric RL (10 mSv/y) taking into account the actual conditions of exposure 3) application of the relevant

requirements for occupational exposure when, despite all reasonable efforts, the exposure remains above 10 mSv/y (quantitative criterion) or when the work activity is in a national positive list of radon prone work activities (qualitative criterion).

The dose limits may be applied when the national authorities consider that the radon exposure situation should be managed like a planned exposure situation.

5. REFERENCES

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