



MANAGING EXPOSURE DUE TO RADON AT HOME AND AT WORK

Information overview prepared by the Inter-Agency Committee on Radiation Safety (IACRS)

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Key messages

- Radon occurs naturally in the environment and is the main source of exposure to ionizing radiation for many people. It is the most significant cause of lung cancer after smoking.
- Control of radon to protect people in homes and most workplaces is guided by reference levels for radon concentrations in air. However, in planned exposure situations, where dose limits are used, protection of workers requires calculation of the radiation dose due to radon exposure using a dose coefficient or dose conversion factor (DCF).
- The DCFs used internationally to calculate doses from all radionuclides for purposes of radiological protection are provided by the International Commission on Radiological Protection (ICRP). The new DCF [ICRP 2017] for occupational exposures to radon results in doses approximately twice those calculated using the DCF previously set by ICRP [ICRP 1993].
- UNSCEAR has also been evaluating the health effects of radon and has derived DCFs since the 1980s. In its recent review of the scientific evidence on lung cancer risk from inhaled radon and its progeny, UNSCEAR concluded that its DCF remains appropriate for estimating radon exposure levels in its dose assessments for public and workers [UNSCEAR 2019].
- The October 2019 IAEA Technical Meeting on the Implications of the new DCFs for radon, recommended the use of a DCF of 10 mSv per working level month (WLM) [ICRP 2017] as the default for workplaces unless a different DCF is justified by specific aerosol characteristics.
- It is up to individual national authorities to decide if and when to implement the new ICRP DCF for radon. This could be carried out immediately, but it may be practical to do so once the full set of revised ICRP DCFs for workers are available to ensure a consistent approach for all radionuclides. All revised occupational DCFs are expected to be available within a year.
- The IACRS supports the continued implementation by national authorities of the approaches reflected in the IAEA General Safety Requirements Part 3 (GSR Part 3, also referred to as the International Basic Safety Standards or simply the BSS) [IAEA 2014] for managing exposure due to radon in homes and workplaces, with emphasis on optimization of protection and the use of a graded approach.
- The IACRS will monitor further developments regarding the estimation of DCFs for radon, will evaluate the potential implications for managing exposure due to radon at home and at work and will review/update this information overview if warranted.

Purpose

This document has been prepared by the Inter-Agency Committee on Radiation Safety (IACRS¹) to summarize its current understanding of approaches for the management of exposure due to radon² for which the IACRS considers that there is a broad consensus. This document relates to a recent Information Note from the ICRP and UNSCEAR secretariat [ICRP & UNSCEAR 2020] and is linked to the implementation of the requirements that apply to radon in the IAEA General Safety Requirements Part 3 (GSR Part 3, also referred to as the International Basic Safety Standards or simply the BSS) [IAEA 2014]. It also takes into consideration the conclusions of an IAEA Technical Meeting on 1-4 October 2019³ and subsequent discussions at the IAEA's Radiation Safety Standards Committee (RASSC) on 21-23 November 2019.

National authorities and radiation protection practitioners may use this information in managing exposures due to radon at home and at workplaces.

European Union (EU) Member States are bound to comply with the obligations laid down in the legally binding Council Directive 2013/59/Euratom [EC 2013] – the Euratom Basic Safety Standards (BSS Directive). The BSS Directive had to be transposed into the national legal frameworks of all EU Member States and further implemented in practice. The BSS Directive contains detailed requirements on protection from exposure to indoor radon. While the BSS Directive's approach is generally consistent with the one given in the International BSS, there are, however, some differences (see section "Radon in Council Directive 2013/59/Euratom – the Euratom Basic Safety Standards"). For EU Member States, the legal requirements laid down in the BSS Directive prevail.

Why is this important?

This document is important and timely because ICRP has recently recommended new DCFs for radon, about twice the value previously recommended in 1993. More recently, UNSCEAR, after review of newly available scientific evidence, has confirmed that the DCF for radon, as published in its previous reports since 1982, remains appropriate for estimating radon exposure levels in its dose assessments for public and workers. This has drawn attention to the potential implications for radon policies and regulations.

Background

- Radon is a radioactive gas present in the air we breathe every day.
- While radon is generally present in low concentrations in outdoor air, it can accumulate in indoor environments such as homes and workplaces, and in underground workplaces such as mines.
- While the relative contribution to radiation exposure from the radon gas itself is low, its short-lived decay products (known as radon progeny) are the main contributors to the radiation exposure of many people throughout their lifetime.
- Radon is regarded as the most significant cause of lung cancer after smoking.

Characteristics of Exposure due to Radon

- The concentration of radon and the corresponding concentration of radon progeny are related by the 'equilibrium factor' (F).
- Where the ventilation rate is high, F is usually low. This is because, while radon may continue to be produced, the radon progeny have insufficient time to 'grow in' because of the dilution and clearing effect of the ventilation.
- Where the ventilation rate is low, F can be high. This is because the radon progeny have time to grow in and

¹European Commission (EC); Food and Agriculture Organization of the United Nations (FAO); International Atomic Energy Agency (IAEA); International Commission on Radiation Units and Measurements (ICRU); International Commission on Radiological Protection (ICRP); International Electrotechnical Commission (IEC); International Labour Organization (ILO); International Radiation Protection Association (IRPA); International Standards Organization (ISO); Nuclear Energy Agency of the Organization for Economic Co-operation and Development (NEA/OECD); Pan American Health Organization (PAHO); United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); World Health Organization (WHO).

² Throughout this document, 'radon' refers specifically to radon-222.

³ Technical Meeting on the Implications of the New Dose Conversion Factors for Radon, 1-4 October 2019, IAEA, Vienna.

approach equilibrium concentrations.

- Because radon is relatively easy to measure, radon concentration (in Bq/m³) has historically been used as a surrogate for radon progeny concentration.
- As most of the radiation dose is delivered by the radon progeny, care must be exercised when using radon concentration as the main measure for dose assessment and control.
- In planned exposure situations⁴, direct measurement of radon progeny may be preferable since uncertainties in conversion procedures could significantly affect the radiation doses received by workers.
- Unless otherwise stated, an F value of 0.4 is assumed as a default value.

Reference Levels and Dose Limits

- Control of radon to protect people in homes and most workplaces is managed through the use of reference levels for radon concentrations in air.
- Reference levels are not limits and should not be used as such. By definition, they represent levels above which it would be inappropriate to plan to allow exposures to occur over an extended period of time, and below which optimization of protection should be implemented.
- In establishing reference levels, the national authority must first understand the extent to which people are exposed (i.e. the distribution of radon concentrations from a particular source within the population) as well as the ability to reduce exposures and the associated economic and societal consequences.
- For specific workplaces with elevated concentrations of naturally occurring radionuclides (such as uranium mining and some mineral extraction industries), radon concentrations are managed as planned exposure situations and occupational dose limits apply.
- Dose limits for occupational exposure are levels of individual dose that shall not be exceeded. Annual dose limits are established in GSR Part 3, in Council Directive 2013/59/Euratom, and in the national legislation of many countries.
- In planned exposure situations, worker exposure from radon is one component of the total radiation occupational exposure (with external gamma irradiation and internal exposure from inhalation of other radionuclides being the others).

Estimating Radiation Doses from Radon

- A DCF is one of the required factors to convert a radon concentration - or radon progeny concentration - to a radiation dose.
- Control of radon to protect people in homes and most workplaces is guided by reference levels for radon concentrations in air and a DCF does not need to be applied. However, in certain situations, where dose limits are used, protection of workers requires calculation of the radiation dose due to radon exposure using a DCF.
- DCFs are used by regulators and practitioners and are integrated into the practice of radiation protection in planned exposure situations.
- Uniquely for radon and its progeny, DCFs can be derived from the results of epidemiological studies. Dosimetric studies can also be used to derive DCFs, as has been done by ICRP for all other radionuclides, including thoron (Rn-220). The derived DCFs can have large uncertainties, although those for radon are more firmly based than those for many other radionuclides.

Radon in GSR Part 3

- IAEA safety standards are developed taking into account both the scientific reports of UNSCEAR and the recommendations of ICRP.
- GSR Part 3 outlines radiation safety requirements related to the exposure due to radon, reflecting the consensus of international organizations⁵ and Member States.

⁴ Situations that arise from a planned activity that results in an exposure to radiation.

⁵ GSR Part 3 is cosponsored by EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP and WHO. Other relevant international organizations and professional bodies were consulted during its development. The Council Directive 2013/59/Euratom introduces requirements related to the exposure to radon which differ from the requirements in GSR Part 3. European Union Member States need to transpose and implement the requirements of Council Directive 2013/59/Euratom

- Reference levels in terms of indoor radon concentration have been established assuming an F value of 0.4.
- Exposure of members of the public in homes and other buildings with high occupancy rates is managed using a reference level which does not exceed an annual average activity concentration of 300 Bq/m³.
- Where indoor radon concentrations of public health concern have been identified, a radon action plan needs to be developed by the national authority(ies).
- The relevant national authorities are responsible for identifying the workplaces where radiation exposure may occur and, in consultation with the employer, develop the radiation protection measures to be applied.
- For workplaces managed as existing exposure situations, exposure of workers is controlled using a reference level which does not exceed an annual average activity concentration of 1 000 Bq/m³.⁶ This is the case for most indoor workplaces.
- Workplaces where the annual average activity concentration cannot be reduced below 1000 Bq/m³ are managed as planned exposure situations using a graded approach, and dose limits are applied. Under the ILO Convention 115, such workers are considered to be occupationally exposed to radiation and have recognized rights and duties in that regard.
- In planned exposure situations, for occupational exposure of workers over the age of 18 years, the effective dose limit is 20 mSv per year averaged over five consecutive years (100 mSv in five years) and of 50 mSv in any single year.

Radon in Council Directive 2013/59/Euratom – the Euratom Basic Safety Standards

European Union Member States are bound to comply with the obligations laid down in the legally binding Council Directive 2013/59/Euratom. The requirements on protection from exposure to indoor radon can be summarised as follows:

- As major provision with regard to the radon protection strategy, the BSS Directive requires that all EU Member States establish a national action plan addressing long-term risks from radon in dwellings, buildings with public access and workplaces for any source of radon ingress, whether from soil, building materials or water. The BSS Directive offers a detailed list of items to be considered in preparing the national action plan.
- For dwellings, the BSS Directive requires the establishment of a national reference level for indoor radon concentrations that shall not be higher than **300 Bq/m³**.
- The respective national reference level for indoor radon concentration in workplaces shall also not be higher than **300 Bq/m³** unless it is warranted by national prevailing circumstances.
- EU Member States are requested to establish programmes to carry out radon measurements in workplaces within the areas identified under the national action plan, and in specific types of workplaces also identified in the national action plan.
- Workplaces where the radon concentration continues to exceed the national reference level, despite all actions taken to optimise, need to be notified to the competent authority and the radon exposure of workers needs to be assessed.
- Based on an assessment of the radon exposure of workers, the BSS Directive introduces a graded approach offering two levels of regulatory control of the given workplace. At workplaces, where the effective dose of workers is less than or equal to 6 mSv per year, the exposures of workers need to be kept under review. Workplaces where the exposure of workers is liable to exceed an effective dose of 6 mSv per year or a corresponding time-integrated radon exposure value shall be managed as a planned exposure situation and the Member States shall determine which occupational exposure requirements of the BSS Directive are appropriate.
- It is worth noting that the BSS Directive stipulates that the dose limits for occupational exposure apply to the sum of annual occupational exposures of a worker including occupational exposure to radon in workplaces requiring notification. The limit on the effective dose for occupational exposure of workers over the age of 18 years is 20 mSv per year.
- The assessment of the radon exposure of workers requires the application of dose conversion factors for radon.

⁶ The reference level required in the Council Directive 2013/59/Euratom is provided in the information box.

Recent developments on radon DCFs

- In 2018, ICRP issued *Publication 137* which has provided a revised DCF for exposures due to radon in workplaces [ICRP 2017].
- The new DCF for exposures due to radon recommended by ICRP is 10 mSv per Working Level Month (WLM)⁷. This is approximately twice the value previously published in ICRP *Publication 65* [ICRP 1993].
- The ICRP publication also notes that in certain circumstances, e.g. where the aerosol characteristics are very different from standard assumptions, the use of a different DCF might be warranted. But in almost all situations, the new DCF is appropriate.
- ICRP has not yet published a revised DCF for radon exposure in homes but has stated that the value given will be the same value as for workplaces.
- ICRP has used biokinetic and dosimetric models to derive its new radon DCF, similar to its approach for other radionuclides, but has also taken account of values of dose conversion based on recent epidemiological data on radon and lung cancer.
- Using the new ICRP DCFs, the maximum reference levels (300 Bq/m³ for homes and 1 000 Bq/m³ for workplaces)⁵ correspond to effective doses around 13 - 14 mSv in a year.
- In 2019, UNSCEAR reviewed the most recent dosimetric and epidemiological studies of lung cancer resulting from inhalation of radon and progeny and also of the results of dosimetric models since 2006; the report is planned to be published in 2020. Given that the ranges observed in these data since 2006 were similar to those observed in previous UNSCEAR assessments and recognizing the uncertainties, UNSCEAR concluded that it was appropriate to continue to use the same DCF for radon progeny (corresponding to 5.7 mSv per WLM) for estimating radon exposure levels in its dose assessments for public and workers [UNSCEAR 2006, UNSCEAR 2019]. The UNSCEAR value of 5.7 mSv per WLM lies between the ICRP *Publication 65* DCF of 4 mSv per WLM for radon at home and 5 mSv per WLM at work [ICRP 1993] and the new ICRP value of 10 mSv per WLM for workplaces in ICRP *Publication 137* [ICRP 2017].
- In October 2019, the IAEA convened a Technical Meeting on the Implications of the New Dose Conversion Factors for Radon. The participants recommended using a DCF of 10 mSv per WLM (from ICRP *Publication 137*) as the default for workplaces in existing and planned exposure situations unless a different DCF is justified by specific aerosol characteristics, and that the same value should be used for residential dose assessments.
- It is up to individual national authorities to decide if and when to implement this new DCF for radon. This could be done immediately, but it may be practical to do so once the full set of revised DCFs for workers are available to ensure a consistent approach for all radionuclides. Alternatively, national authorities may decide to apply a DCF other than that recommended by ICRP justified by specific aerosol characteristics.

Summary

IACRS notes that national authorities consider that the requirements in GSR Part 3 for managing radon exposure in homes and workplaces continue to be appropriate and do not need to be changed at this time. IACRS emphasises the following points:

- Implementation of safety standards for radiation protection is the responsibility of each Member State.⁸
- Optimization of protection is the most important tool for managing exposures to radon.
- A graded approach is always applied, as appropriate.
- Most situations involving exposure due to radon can be managed appropriately using reference levels (in terms of indoor radon concentrations) for monitoring and controlling exposure.
- National authorities continue to implement the requirements of GSR Part 3 in relation to characterisation

⁷ For all situations of occupational exposure to thoron, the ICRP recommends the use of a DCF of 5 mSv per WLM. In existing exposure situations, thoron exposure should be managed in a manner similar to that for radon i.e. through reference levels and application of optimization. Currently there are no reference levels for thoron in GSR Part 3.

⁸ European Union Member States are required to transpose and implement the respective requirements in Council Directive 2013/59/Euratom.

and control of exposure of the public due to radon in existing exposure situations - including homes, schools, and kindergartens - by applying a reference level that does not exceed 300 Bq/m³.

- In line with GSR Part 3, for workplaces managed as existing exposure situations, worker exposure is controlled by applying a reference level that does not exceed 1 000 Bq/m³.⁹
- For exposure due to radon in homes and workplaces managed as existing exposure situations, control measures are based on the concentration of radon in indoor air and the use of a dose-conversion factor is not necessary. However, it is noted that the reference levels of 300 Bq/m³ for homes and 1000 Bq/m³ for workplaces correspond to effective doses of 13 – 14 mSv per year, consistent with the requirements of GSR Part 3 that doses should be within the band of 1 – 20 mSv and of the order of 10 mSv.
- For planned exposure situations, where worker dose assessment is required for ensuring compliance with the dose limits provided in GSR Part 3, national authorities may choose to use a DCF that most accurately reflects the actual situation in the respective workplace, in particular taking into account the most relevant equilibrium factor F and aerosol characteristics.
- When managing internal exposure, most national authorities apply the controls recommended by ICRP. ICRP is now producing an updated set of DCFs for all radionuclides. All updated DCFs for occupational exposures should be published within a year. It is a matter for each national authority to decide when to adopt the most recently published values. The new DCF for radon could be implemented immediately, or It may be practical to do so after the full set of new DCFs for occupational exposures is available to ensure a consistent approach.
- The decision to use the new DCF recommended by ICRP is particularly relevant for workplaces which are managed as planned exposure situations. Additional controls may be necessary to ensure that the occupational dose limit is not exceeded.
- UNSCEAR has provided a comprehensive review of epidemiological studies of lung cancer resulting from inhalation of radon and its progeny and also of the results of dosimetric models since 2006. Given that the ranges observed in these data were similar to those observed in previous assessments and recognising the uncertainties that apply to both, UNSCEAR concluded that it is appropriate to continue the use of the dose conversion factor of 9 nSv per h Bq m⁻³ EEC of radon-222, which corresponds to 1.6 mSv per mJ h m⁻³ (5.7 mSv per WLM) of radon progeny, for estimating radon exposure levels in its dose assessments for public and workers.
- The October 2019 IAEA Technical Meeting on the Implications of the New Dose Conversion Factors for Radon, recommended the use of a DCF of 10 mSv per WLM [ICRP 2017] as the default for workplaces unless a different DCF is justified by specific aerosol characteristics.
- As required by GSR Part 3, a radiation protection program is needed to assess and manage radon exposure in workplaces, with a key focus on optimization of protection.
- The IACRS will monitor further developments regarding the estimation of DCFs for radon, will evaluate the potential implications for managing exposure due to radon at home and at work and will review/update this information overview if warranted.

IACRS therefore supports the continued implementation by national authorities of the requirements in GSR Part 3⁸ for managing exposure due to radon in homes and workplaces, with emphasis on optimization of protection and the use of a graded approach.

References

[EC 2013] Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom available at <https://eur-lex.europa.eu/eli/dir/2013/59/oj>.

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⁹ Council Directive 2013/59/Euratom requires that the reference level for indoor radon concentrations in workplaces shall not exceed 300 Bq/m³.

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