Information Note for Participants at the IAEA Technical Meeting on the Implications of the New Dose Conversion Factors for Radon, 1-4 Oct 2019

Prepared by the International Commission on Radiological Protection (ICRP) and the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) Secretariat

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The International Commission on Radiological Protection (ICRP) recommends policies, principles and a whole a system of radiological protection that is designed to protect people and the environment from the harmful effects of exposure to ionising radiation. ICRP calculates and publishes dose coefficients for use in the implementation of the system of radiological protection.

The remit of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is to undertake broad assessments of the sources of ionizing radiation and their effects on human health and the environment. UNSCEAR assessments allow the international community to better understand and compare exposures from different sources of ionizing radiation and their effects and risks.

UNSCEAR

UNSCEAR has been evaluating the effects of radon (Rn-222) for decades and derived dose conversion factors since 1980s. In its recent review of the scientific evidence on lung cancer risk from inhaled radon-222 and its progeny, UNSCEAR confirmed its previous conclusions that inhalation of radon and its decay products is carcinogenic mainly for the lungs. UNSCEAR also concluded that conversion factors for calculating the dose from a given exposure to radon are needed for radiation protection purposes, which is in the mandate of other international bodies and for comparison purposes with other sources of radiation exposure, which is related directly to the mandate of UNSCEAR.

UNSCEAR reviewed the recent literature dealing with epidemiological studies of lung cancer risk from radon exposure published since 2006.

UNSCEAR reviewed occupational studies of miners, which were based mainly on extended follow-up of earlier cohort studies. Substantial variability in the excess relative risk estimates for lung cancer was observed in the updated occupational studies, with values ranging from 0.19 to 3.4 per 100 working level month (WLM), without adjustment for modifying factors. Based on a statistical weighting procedure, using random-effects meta-analysis with inverse-variance weighting, the combined excess relative risk estimated from the entire cohorts was 0.60 (95% confidence interval (CI): 0.34, 0.87) per 100 WLM, which is in close agreement with UNSCEAR’s previous combined estimate in 2006 of 0.59 (95% CI: 0.35, 1.0) per 100 WLM.

Lifetime risk was estimated by applying the BEIR VI exposure-age-concentration model to the combined 11 miner studies used in the BEIR VI report \(^2\), the selected Czech, Eldorado and Wismut miner studies, where information was available. The estimates of lifetime excess absolute risk were per 10,000 persons per WLM:

- 5.5 for the BEIR VI studies,
- 3.9 for the updated Czech study,
- 7.5 for the updated Eldorado study, and
- 2.4 for the newly published large Wismut study, which has the largest impact.

Thus, UNSCEAR concluded that the totality of this evidence is compatible with its previous assessments (e.g. 2006 UNSCEAR Report).

UNSCEAR also reviewed recent residential epidemiological studies of lung cancer risk from radon. The excess relative risk estimates varied from -0.13 to 0.73 per 100 Bq m\(^{-3}\) with a mean excess relative risk of 0.13 per 100 Bq m\(^{-3}\), which is also in close agreement with UNSCEAR’s previous estimate of 0.16 per 100 Bq m\(^{-3}\) published in its 2006 report \(^1\).

As the analyses of miner studies showed largely a sub-multiplicative joint effect of radon and smoking on lung cancer, UNSCEAR considered on the assumption of synergistic effect of smoking and radon that the lifetime absolute risk from radon depends on the prevalence of smoking in a population – when the prevalence decreases, the risk also decreases.

UNSCEAR further reviewed recent published dosimetry assessments for exposures in homes, indoor workplaces and mines and found that for exposures in homes the range of the assessed effective doses per unit of exposure of equilibrium equivalent concentration (EEC) of radon-222 are from 7 to 34 nSv per h Bq m\(^{-3}\) with an arithmetic mean of 18 nSv per h Bq m\(^{-3}\), and a geometric mean of 16 nSv per h Bq m\(^{-3}\). UNSCEAR concluded that these values are consistent with those previously estimated for average indoor conditions on the basis of dosimetric evaluations.

UNSCEAR concluded that since the uncertainties from both dosimetric and epidemiological studies give rise to a broad range of risk estimates and the fact that values from the current dosimetry and epidemiological reviews are consistent with those used in previous UNSCEAR 2006 report, UNSCEAR would continue to use a 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\(^{-3}\) of radon progeny, for estimating radon exposure levels in its dose assessments.

**ICRP**

ICRP develops equivalent and effective dose coefficients for radiological protection purposes, considering exposures to external sources and the inhalation and ingestion of radionuclides. For radionuclide intakes, sets of dose coefficients have been published for intakes by workers and members of the public. Uniquely, for inhalation of radon-222 and progeny, ICRP has used the epidemiological approach to calculate dose coefficients. ICRP *Publication 65* \(^3\) used a lifetime lung

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cancer risk from radon of $2.83 \times 10^{-4}$ per WLM and ICRP Publication 60\(^4\) detriment values to calculate dose conversion values of 5 mSv per WLM for workers and 4 mSv per WLM for the whole population. ICRP Publication 115\(^5\) provided an updated review of epidemiological data. A key observation was that focussing on more recent data and lower levels of exposure gave substantially higher risk estimates. A revised value for lifetime lung cancer risk of $5 \times 10^{-4}$ per WLM was obtained, nearly twice that calculated twenty years before. In a statement issued in Publication 115, ICRP took account of this change and lowered its upper reference level for radon in homes by a factor of two to 300 Bq/m\(^3\) from the value of 600 Bq/m\(^3\) given in the 2007 Recommendations (Publication 103)\(^6\). Taking account of the different lengths of time spent in homes and workplaces, a level above which the requirements of occupational protection would apply was set at 1000 Bq/m\(^3\). ICRP also indicated its intention to in future calculate dose coefficients for radon isotopes in the same way as for all other radionuclides, using biokinetic and dosimetric models.

ICRP Publication 137\(^7\) is the third part in a series of reports providing dose coefficients and associated data for occupational exposures to radionuclides, and includes radioisotopes of radon. Noting that inhaled radon-222 and progeny is a special case for which there is good epidemiology as well as dosimetry, and taking account of the two methods of calculation of dose coefficients with their associated uncertainties, ICRP recommends a single rounded value for use in most circumstances of occupational exposure of 3 mSv per mJ h m\(^{-3}\) (approximately 10 mSv per WLM), equivalent to 6.7 nSv per Bq h m\(^{-3}\) applying an equilibrium factor of 0.4. ICRP has also indicated that this value is applicable to exposures in homes. Using this dose coefficient, the reference level of 300 Bq/m\(^3\) corresponds to 14 mSv per year for homes (7000 hours). The value of 1000 Bq/m\(^3\) referred to in the IAEA Basic Safety Standards for occupational exposures corresponds to 13 mSv per year (2000 hours).

For occupational exposures to radon in which conditions such as aerosol characteristics are significantly different from the reference conditions, where estimated doses warrant more detailed consideration, and reliable data are available, it is possible to calculate site-specific dose coefficients using data provided by ICRP. A second higher value of 6 mSv per mJ h m\(^{-3}\) (approximately 20 mSv per WLM) was referred to in ICRP Publication 137 but this may be seen as an example of requirements for more specific calculations when warranted.

Dose coefficients for the inhalation of thoron (radon-220) progeny were given in Publication 137 for mines and indoor workplaces: 1.4 mSv per mJ h m\(^{-3}\) (4.8 mSv per WLM) and 1.6 mSv per mJ h m\(^{-3}\) (5.6 mSv per WLM), respectively. On the basis of these calculations, a single rounded value was recommended of 1.5 mSv per mJ h m\(^{-3}\) (5 mSv per WLM) for all situations of exposure. As in the


case of inhalation of radon-222 progeny, data are provided for site-specific calculations should these be warranted.

The final set of internal dose coefficients for occupational exposures, Occupational Intakes of Radionuclides Part 5, is expected to be published around the end of 2020.

**Summary**

ICRP develops dose coefficients for the purposes of radiological protection. Uniquely in the case of radon, account is taken of epidemiological data in addition to dosimetric data. A key epidemiological observation has been that lung cancer risk estimates based on miner studies are generally higher for lower levels of exposure (notably because of better data quality). This observation led to a change in the nominal risk coefficient used by ICRP from $2.83 \times 10^{-4}$ per WLM to $5 \times 10^{-4}$ per WLM. On this basis, ICRP recommended lower reference levels. The effective dose coefficient has also been updated to a central value of $3 \text{ mSv per mJ h m}^{-3}$ ($10 \text{ mSv per WLM}$) to apply to most circumstances of exposure in workplaces and homes, equivalent to $6.7 \text{ nSv per Bq h m}^{-3}$ using an equilibrium factor of 0.4 ($16.8 \text{ nSv per Bq h m}^{-3}$ EEC). If circumstances of occupational exposure warrant more detailed consideration and reliable alternative data are available, site-specific doses can be assessed using methodology provided by ICRP.

UNSCEAR has provided a comprehensive review of epidemiological studies of lung cancer resulting from inhalation of radon and 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 $9 \text{ nSv per h Bq m}^{-3}$ EEC of radon-222, which corresponds to $1.6 \text{ mSv per mJ h m}^{-3}$ ($5.7 \text{ mSv per WLM}$) of radon progeny, for estimating radon exposure levels in its dose assessments for public and workers. Applying UNSCEAR’s default equilibrium factors for the indoor and outdoor environment of 0.4 and 0.6 results in dose conversion factors in terms of radon concentration of $3.6 \text{ nSv per h Bq m}^{-3}$ indoors and $5.4 \text{ nSv per h Bq m}^{-3}$ outdoors.