RADIATION PROTECTION AGAINST RADON IN WORKPLACES OTHER THAN MINES

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1 ABSTRACT

The establishment and provision for the application of safety requirements and guidance on occupational radiation protection is a major component of the support for radiation safety provided by the Agency to its Member States. The objective of the Agency's Occupational Radiation Protection program is to promote an internationally harmonized approach to the optimization of occupational radiation protection, through the development and application of guidelines for restricting radiation exposures and applying current radiation protection techniques in the workplace.

A Safety Guide on *Occupational Radiation Protection in the Mining and Processing of Raw Materials* is in the process of being finalized. Acknowledging the importance of radon exposure control in other workplaces, such as waterworks, caves and closed-out mines open to visitors, underground stores and shopping-centers, spas, kindergartens, schools, factories, shops, public buildings and offices, the Agency considered it necessary to prepare a Safety Report on radiation protection in workplaces other than mines. The objective of the Safety Report is to provide practical guidance to employers whose workplaces may be affected by radon concentrations in excess of action levels defined in the Report. The Safety Report is intended to be used by those without an extensive background in radiological protection and it is also expected to be useful to regulatory authorities on establishing their own national policies in controlling high radon exposures of the non-mining workforce.

2 INTRODUCTION

Until the 1970s radon and its progeny were regarded as radiation health hazards encountered only in the mining and processing of uranium ore. This notion has dramatically changed as a result of increasing efforts made by many countries to measure radon in dwellings, mines other than uranium mines, and workplaces suspected of having high atmospheric radon levels. In temperate regions energy conservation measures in buildings have been adopted, resulting in reduced ventilation rates and increased radon concentrations, particularly in winter months. This rise in indoor air concentration of radon has been recognized as a radiation health hazard, potentially contributing to excess lung cancer. Radon thus has become a concern not only in underground mines but also in buildings located in areas with elevated levels of radon in soil gas or in buildings constructed with materials containing significant levels of radium. According to the assessment by the United Nations Scientific Committee on the

Effects of Atomic Radiation (UNSCEAR) environmental radon constitutes half the human exposure to radiation from natural sources (1).

The establishment and provision for the application of safety requirements and guidance on occupational radiation protection is a major component of the support for radiation safety provided by the Agency to its Member States. The objective of the Agency's Occupational Radiation Protection program is to promote an internationally harmonized approach to the optimization of occupational radiation protection, through the development and application of guidelines for restricting radiation exposures and applying current radiation protection techniques in the workplace. Guidance on conducting dose assessment and recommendations concerning dose limitation are given in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (hereafter referred to as the BSS)(2).

A Safety Guide on *Occupational Radiation Protection in the Mining and Processing of Raw Materials,* jointly sponsored by the IAEA and the International Labour Office, ILO, is in the process of being finalized. Acknowledging the importance of radon exposure control in other workplaces, the Agency considered it necessary to prepare a Safety Report on radiation protection in workplaces other than mines. The objective of the Safety Report, co-sponsored by the ILO, is to provide practical guidance to employers whose workplaces may be affected by radon concentrations in excess of action levels defined in the Report. The Safety Report is intended to be used by those without an extensive background in radiological protection and it is also expected to be useful to regulatory authorities on establishing their own national policies in controlling high radon exposures of the non-mining workforce.

The main content of this Safety Report, which is expected to be published in 2002, is summarized below.

3 WORKPLACES WHERE RADON MAY PRESENT A RISK

The spectrum of workplaces other than mines where radon (in this Safety Report the term radon refers to ^{222}Rn and thoron to ^{220}Rn) can present a hazard is large. While it includes below ground workplaces such as subways, tunnels, stores, show caves, closed out mines open to visitors and spas, the majority of such workplaces will be above ground. Thus a fraction of normal above ground workplaces such as factories, shops, schools and offices may be affected.

In buildings with high radon levels, the main mechanism for entry of radon is pressure driven flow of soil gas through cracks in the floor. This arises because buildings are normally at slight underpressure with respect to their surroundings. Most building materials produce some radon but certain types of building materials can act as significant sources of indoor radon. These have a combination of elevated levels of radium (the radioactive parent of radon) and a porosity that allows the radon gas to escape.

Groundwater can have high levels of radon, particularly in granite areas.

Workplaces such as laundries and kitchens in restaurants can have high radon levels resulting from the use of such water. Workplaces where large quantities of materials with elevated radium concentrations are stored or processes can have high radon levels. In general the most important exposure situation is from storage of large amounts of the material in a warehouse with little ventilation. Typical uranium and thorium content of commercially important minerals is summarized in the Report.

Underground workplaces can accumulate high radon levels in the same way as natural caves or abandoned mines. It cannot necessarily be assumed that high radon levels in underground workplaces will be limited to those parts of the country where elevated levels in above ground workplaces have been found. Therefore, all underground workplaces are potentially at risk.

Summaries of results of radon concentration measurements in the air of non-mining underground workplaces as well as in workplaces above ground in a number of countries are given in the Safety Report.

4 RADON EXPOSURE CONTROL SCHEME

Radon is ubiquitous in workplaces and dwellings but levels vary from place to place and over time. The scheme for control of occupational exposure to radon is therefore somewhat different from that for artificial sources. Regulatory authorities should arrange for surveys to obtain an overview of occupational and domestic exposures to radon in the territory for which they are responsible. Then, a radon program, adapted to the national conditions, should be defined in such a way as to include a manageable proportion of the buildings most affected by radon. In this way regulatory authorities can define those workplaces which are to be subject to control.

Employers responsible for workplaces that are subject to control should make arrangements for measurements to determine the radon levels in their workplaces. If radon concentrations are found to be above the action level (see below), the employer should institute remedial measures aimed at reducing radon concentrations below the action level.

If the remedial measures are successful, no further action other than periodic retesting is required. If all reasonable measures fail to bring radon concentrations below the action level, then the appropriate scheme of radiation protection measures applies, which, in essence, are described in the BSS. Some refinements may be needed to accommodate the particular features of radon exposure.

The BSS Glossary (2) defines the term ‘Action level’. In this publication, action level stands for the radon concentration at which remedial or protective actions should be undertaken to reduce excessive radon exposures at workplaces. It may also be regarded as the level at which the system of protection becomes applicable to the continuing control of radon exposures in the workplace. It is the responsibility of regulatory authorities to decide under which circumstances

radon exposures are considered to be occupational exposures in line with the BSS requirement. This may be for defined practices or in defined geographical areas, for example wherever a set proportion of buildings exceeds the action level.

The action level for radon in the workplace is given in the BSS (2) as a yearly average concentration of 1000 Bq m^{-3} which would, for an occupancy of 2000 hours per year, equate to an effective dose of about 6 mSv. This action level for radon in workplaces does not mark a boundary between safe and unsafe exposures and regulatory authorities are free to establish an occupational action level below the 1000 Bq m^{-3}, if national circumstances make this practicable. There are some workplaces defined as subject to radon control where members of the public spend considerable periods of time, such as schools, hospitals and residential care centres. In these buildings the action level chosen for dwellings may be considered in the interest of controlling public exposures.

A systematic and unbiased survey of radon concentrations in buildings is necessary to obtain an understanding of the variation of radon concentrations in workplaces. Geology can be used to interpolate the results of such measurements and may be useful in refining the identification of the areas involved.

In order to pursue a focused and manageable program, regulatory authorities may find it helpful to determine radon prone areas, i.e. geographical regions where the levels of radon in above ground workplaces are subject to the control regime. The countrywide distribution of radon concentrations and the value of the action level are important factors in defining radon prone areas. Caution, however, should be exercised in an over-reliance on the radon prone area concept as a radiation protection management tool. Even within a radon prone area there is likely to be in-homogeneity in radon concentrations and in some countries radon prone areas are relatively under populated and in absolute terms may contain very few workplaces.

Underground workplaces and other workplaces such as spas are not covered by the radon prone area concept. These should be considered as priorities for action unless the surveys of these places indicate that it is unnecessary.

Because of the wide diurnal and seasonal variation in radon concentrations, long-term measurements over a period of some months are preferable to short-term measurements. Many non-industrial type workplaces are unoccupied during night hours when radon levels are generally higher than during daytime, when the actual occupational exposure takes place. Many types of offices are likely to be in this category. With some detectors, however, it is possible to measure radon only during working hours. A similar question arises in the case of well ventilated workplaces with relatively low radon concentrations during daytime hours when staff numbers are high, while few people are present at night when ventilation rates are low and radon levels are high. These and other

similar situations need to be considered and addressed by the regulatory authorities, but in the majority of cases it is likely that assessments based on the long term 24-hour average radon level will ensure that, in the first instance, the majority of workers receive appropriate radiation protection.

If radon levels are found to be below the action level then no measures to reduce them are required. The regulatory authority can specify the frequency with which the buildings are retested when radon concentrations are below the action level.

If radon levels are found to be above the action level then the employer arranges for remedial measures to be undertaken. It is expected that remedial measures will normally be successful in reducing radon concentrations below the action level. Where this is the case it is advisable that the building be retested with a frequency determined by the regulatory authority. The employer has to perform regular operational checks of the remedial systems to ensure that fans and other equipment have not failed or accidentally been switched off.

In cases where the radon concentration still exceeds the action level after all practicable remedial measures have been taken, the authorities can implement the appropriate scheme of radiation protection

As part of a long term strategy aimed at reducing radon exposures in workplaces regulatory authorities should consider, in addition to remedial intervention in existing work places, adopting a cost-effective preventive approach to radon control in future workplaces.

5 PRACTICAL TECHNIQUES FOR MEASURING RADON CONCENTRATIONS

The performance and limitations of widely used radon measurement devices are described in the Safety Report. The overall goal will determine the choice of monitoring strategy and equipment. An effective quality assurance and quality control program is essential to any activity for monitoring radon and thoron.

Purposes for performing radon or progeny concentration measurements include: identification of workplaces with high radon levels; measurements in conjunction with remedial actions; and measurements for assessing worker exposure to comply with regulatory requirements.

Surveys designed to identify the distribution of radon levels in workplaces necessitate the distribution of large numbers of detectors. Cost and ease of placement of the detectors are important features to consider. The investigator must decide whether short term or long-term measurements are more appropriate. However, in view of potential seasonal influence (e.g. heating, ventilation, air conditioning) on the radon concentration, long-term measurements over a period of some months will usually be given preference. Alternatively, repeated measurements over shorter periods (of some days) may be satisfactory if adequate accuracy can be established.

If measurements are made during remedial work on a building in order to identify the source of the elevated radon concentration, short term or grab sample measurements may be necessary. After completion of the remediation process a long-term measurement is necessary to confirm that the average radon level is below the action level.

If radon levels remain above the action level and assessment of individual doses must be carried out to demonstrate regulatory compliance, an appropriate collection of data will be needed. This can be done either by monitoring the work area or by personal monitors worn by the worker. The decision on the frequency and duration of measurement, as well as on the choice of instrumentation, needs to be acceptable to the regulatory authority.

6 REMEDIAL ACTION TO REDUCE RADON LEVELS

If measurements indicate that radon concentrations exceed the action level established by the regulatory authority, the employer would undertake remedial action. The aim is to reduce radon levels by making permanent changes to the building (mitigation) or to the way that it is used.

Mitigation will take different forms depending upon circumstances. By far the most common cause of elevated radon levels in above ground workplaces is pressure driven radon entry through cracks or other openings in the floor. Other mechanisms are by diffusion from soil in contact with the building foundation, by diffusion from construction materials or, rarely, as a result of radon in the water supply. In all these cases remedial measures developed for dwellings may apply.

Subfloor depressurization: For foundations and basements in contact with soil, the most effective mitigation measure is to reduce the pressure of the soil gas in the vicinity of the foundation relative to the pressure in the structure. For buildings with extensive and complex foundations a number of such depressurization systems may be needed for effective radon control.

Subfloor ventilation: If the ground floor is not in contact with soil, an effective mitigation measure is to ventilate the space under the floor. The approach effectively reduces the amount of radon entering the structure by reducing the concentration of radon in the air beneath the floor.

Floor sealing and membranes: The cracks and other openings through which radon enters the structure may be sealed. This method is considered less effective than subfloor depressurization because it is difficult to seal all routes of entry adequately and because seals tend to deteriorate over time. If only a portion of the cracks are sealed, this method is likely to be almost totally ineffective.

Increased ventilation: Radon in indoor air may be diluted by increased ventilation of the indoor spaces with outdoor air. This method can be costly in

terms of energy loss, particularly in harsher climates. In some structures increased ventilation may actually cause an increase in indoor air radon levels if the ventilation causes an increase in the underpressure of the indoor air with respect to the subjacent soil gas. For these reasons ventilation as a method of reducing indoor radon is to be used with caution.

Subsoil removal: Elevated levels of radium in the soil underneath or surrounding a building can be the source of increased radon in the indoor air. Removal of the subsoil and subsequent replacement with uncontaminated soil has been shown to result in considerably lower radon levels indoors. Since this method represents a major undertaking, it is only used in very special circumstances.

Water treatment: If water to be used in a workplace is a significant source of radon, then treating the water with aeration or other methods (i.e. filtration with activated charcoal) to reduce radon prior to use can be effective. In municipal water treatment plants where groundwater containing high concentrations of radon is processed the aeration of the water may give rise to very high air concentrations of radon within the plant. In this case strong ventilation of the water treatment plant air spaces coupled to restricted work hours for staff can be effective.

The relative cost and effectiveness in radon reduction of the mitigation techniques are summarized in the Safety Report, which also contains an example of a guide to radon remedies for different levels of radon concentrations.

Radon spas: In the special situation of radon spas, the presence of the radon in treatment rooms or galleries is held to be necessary by the balneological–medical community to achieve the desired effect. The radon enters the air either directly from the native rock or transfers to air from spa water or both. The operating staff and maintenance staff must be protected by all available means. Separate, well ventilated areas should be provided for the staff. Pipes used to transfer radon to treatment rooms need to be well sealed to prevent leakage of radon into other rooms. Anterooms or other separation methods should be provided so that radon from the treatment rooms does not reach non-treatment areas in significant quantities. The time spent by staff in the treatment areas needs to be minimized.

Caves and show mines: Developed caves in which guides provide tours for the general public also present a unique problem. Although the presence of radon is not necessary, as it is reputed to be for radon spas, reduction of radon by reducing pressure in the source rock or sealing may not be practical. However radon may possibly be reduced by installing partitions to isolate unused cave galleys from those areas frequented by guides and the public and measured increase in ventilation. Great care is needed because forced ventilation may alter the humidity in caves and destroy or diminish the beauty of the formations that attract tourists. Partitioning and increased ventilation has been used successfully in some caves, particularly in the UK. Former mines used as tourist attractions (show mines) can be treated much the same as tourist caves.

7 CONTROL OF RADON EXPOSURES WHEN REMEDIAL MEASURE ARE NOT EFFECTIVE

If radon concentrations in a workplace exceed the action level even after remedial measures have been applied, then the broad system of radiation protection laid down in the BSS and further expounded in three Safety Guides applies (2-5). This means that dose limits must be observed and exposure reduction optimized. Estimates of individual exposures will be needed to achieve these goals, so programs of individual or workplace monitoring will be established**.** Any legal person intending to carry out such work activities should notify the regulatory authority unless the exposure from such activities or sources is excluded or the practice or source is exempted from regulatory requirement. A form of notification for the work activities should be submitted to the regulatory authority who may require the legal person to apply for an authorization depending on national policy. The workers involved will need appropriate training and health surveillance.

The BSS discusses the classification of areas where work involving radiation is carried out. There are two categories, controlled and supervised (2,3), the distinction between them being based on the degree to which special operational procedures are required. Where radon is the only radiological problem, the less stringent supervised areas will normally be adequate.
The employer is responsible for arranging for the assessment of the occupational exposure of the workers and for assuring that adequate arrangements be made with an appropriate dosimetry service under a satisfactory quality assurance program (2,4,5).

In most workplaces the radon exposures will be incidental to the work. It is unlikely that there will be a familiarity with radiation protection matters in these workplaces, even if they are large enough to have a health and safety officer. Where health or safety officers exist, a short, very basic training course will in most cases be sufficient to allow them to become informed on the basic principles of radiation protection and on the particular problem of dealing with radon in the workplace. Because only a basic training will be given to such workplace staff the regulatory authority staff is expected to possess a thorough knowledge in this area. Training of regulatory staff will be useful, in particular, in communicating and dealing with employers in small workplaces with no health or safety officer.

In facilities where radon exposure is directly related to the work, such as in the milling, handling and processing of materials containing enhanced concentrations of naturally occurring radionuclides, it is likely that radiation protection experts are already present. In such cases a training course of a few days duration on radon issues may be given to the radiation protection experts

and, where appropriate, to persons who are operating or controlling the facility. It may also be appropriate that, in such workplaces, exposed workers receive a short elementary training.

The BSS (2) also lays other duties on employers and employees in order to ensure the protection of workers and the compliance with any other relevant requirements of the Standards. To assist in the execution of these duties, experts should be available to advise on this and on the observance of the national regulatory framework. The opinion of the expert should be taken into account in the establishment of local rules and of a safety culture.

8 CONCLUSION

The generic approach presented in the Safety Report is designed to protect employees against radon exposure at workplaces not commonly associated with problems of radiation protection. The level of protection chosen will assure the workers that they will not be subjected to undue risks, provided the protective measures are applied properly by management. However, the Safety Report is generic in nature and does not address, for example, unusual site specific exposure conditions. Under exceptional circumstances regulatory authorities may consider modified approaches, taking into account sociopolitical or cultural factors, e.g., concerning the choice of action levels or countermeasures.

Further information on the IAEA radiation protection programs can be found in the web-page:
www.iaea.org/ns/rasanet/

9 REFERENCES

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