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**European Commission Services considerations with regard to
natural radiation sources in BSS Directive**

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PREAMBLE

The Commission is currently in the process of recasting five Council Directives: Basic Safety Standards Directive (96/29/Euratom), Medical Directive (97/43/Euratom), Directive on High Activity Sealed Sources (2003/122/Euratom), Directive on Outside Workers (90/641/Euratom), Directive on Public Information (89/618/Euratom). The aim is to merge the five Directives into one while keeping as much of the present texts as possible. The recast procedure does however leave room for certain parts to be revised and the Commission is taking this opportunity to clarify and strengthen legal requirements, based on the new ICRP Recommendations published in 2007 (ICRP Publication 103) and on experience gained by Member States and the Commission since the present Basic Safety Standards Directive was adopted in 1996. The revision of the EU BSS is timely as it coincides with the IAEA revision process of the international BSS. The Commission participates actively in this revision process in order to achieve a high degree of harmonisation between different international standards.

Working towards enhanced transparency, the publication of this document is part of the Commission's policy of involving the organisations, authorities and industries affected by the Directive. In this way the Commission wishes to achieve a better understanding and acceptance of the new ideas.

The article 31 Group of Experts has set up a number of Working Parties to examine different parts of the regulatory framework. One of the Working Parties was dedicated to the management of natural radiation sources.

The WP Natural Sources worked in three steps, taking into account existing Commission Recommendations and earlier guidance. First step was to look into present requirements for natural radiation sources and to suggest adjustments. Second step related to radon in dwellings, taking Commission Recommendation 90/143/Euratom into account. Third step was to set up new requirements for building materials containing natural radioactivity. Each step resulted in a report providing background information and motivation for the proposed requirements.

This document is based on the reports provided by the WP Natural Sources, which have in full or in parts been endorsed by the article 31 Group of Experts. It should be emphasised that the content of the document reflect the views of the Commission services and not necessarily the final point of view of the article 31 Group of Experts. It will serve as background material for the ongoing process regarding the recasting of the five Directives. The Commission wishes to express its gratitude to the article 31 Group of Experts, in particular the members of the WP Natural Sources, for their contribution to the three reports.

The Commission welcomes comments from stakeholders on the rationale of the proposed approach for natural radiation sources, on its adequacy, and on the impact of the requirements on the regulatory bodies and industries. Comments should be sent in a concise form to the mailbox TREN-LUX-H4-BSSRECAST@ec.europa.eu before 20 April 2009. The Commission commits to taking good note of the comments and will report to the article 31 Group of Experts on the results of this consultation. The results will also be reflected in an Impact Assessment document which is part of the decision making process.

1. THE EURATOM BASIC SAFETY STANDARDS OF TODAY

The Euratom Basic Safety Standards (EU BSS) for the protection of the health of workers and the general public against the dangers arising from ionizing radiation (Directive 96/29/Euratom) set out the framework for radiation protection within the European Union and Member States are obliged to transpose the requirements into national legislation. When the present EU BSS was issued in 1996 it included for the first time special provisions concerning exposure to natural radiation sources (Title VII of the Directive). Some exposures to natural sources were however excluded from the scope of the Directive, such as exposure to radon in dwellings and the natural level of radiation, i.e. to radionuclides contained in the human body, to cosmic radiation at ground level or to aboveground exposure to radionuclides in the undisturbed earth crust.

Title VII addresses the concept of a “*significant increase in exposure due to natural radiation sources*”. There are no specific activity concentrations or dose levels defined above which exposures are regarded as of regulatory concern, instead title VII introduces a stepwise system where the Member States are required to identify work activities of concern, set up appropriate means for monitoring exposures in these work activities and as necessary apply radiation protection measures to reduce exposures (articles 40 and 41). The work activities indicated in Title VII are specified as:

- a. *"work activities where workers and, where appropriate, members of the public are exposed to thoron or radon decay products or gamma radiation or any other exposure to radiation in workplaces such as spas, caves, mines underground workplaces and aboveground workplaces in identified areas;*
- b. *work activities involving operations with, and storage of, materials, not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of workers and, where appropriate, members of the public;*
- c. *work activities which lead to the production of residues not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of members of the public and, where appropriate, workers ;*
- d. *aircraft operation."*

2. REASONS FOR A REVISION OF TITLE VII

When adopting the present EU BSS the European Community opted for a flexible approach to natural radiation sources, thus leaving considerable room for interpretation. This has led to different approaches by the Member States, occasionally resulting in different conclusions on which materials should be subject to regulatory control. Some of the products including NORM or residues from NORM industries intended for recycling are subject to trade between Member States. Therefore harmonisation is also needed from the point of view of trade.

Since 1996 the Member States have gained considerable knowledge in the field of natural radiation sources by national studies, inventories and assessments. Knowledge has improved through a number of conferences on this topic and case studies. Guidance material has been published by international organisations and bodies, such as the International Atomic Energy Agency (IAEA). An international safety standard on the concepts of exclusion, exemption and

clearance has also been published, see IAEA Safety Guide RS-G-1.7. The knowledge gained provides, along with the new Recommendations from the ICRP (ICRP Publication 103), a firm basis for introducing more binding requirements on natural radiation sources.

The Commission therefore envisages incorporating a comprehensive approach to the management of natural radiation sources within the overall set of requirements of the new EU BSS. The requirements will reflect the distinction made in ICRP Publication 103 between planned and existing exposure situations. However, bearing in mind that ICRP has introduced a coherent radiation protection system across all exposure situations, it does not really matter under which heading the requirements are spelled out.

The natural radiation sources that will explicitly be incorporated in the new BSS are:

- naturally occurring radioactive materials used or processed in specific industries (NORM-industries) or used as building materials
- indoor exposure to radon¹ in dwellings and workplaces
- exposure of aircrew and space crew to cosmic radiation.

With regard to radon in dwellings, the new requirements will reflect the recommendations laid down in Commission Recommendation 90/143/Euratom but essential requirements will become binding under the new Directive.

With regard to aircrew, the current requirements laid down in the present BSS (Directive 96/29/Euratom) proved effective and will be maintained. Since the exposure of space crew is a rather exceptional situation, it is not addressed in detail but the general provisions for exceptionally authorised occupational exposure will apply.

3. REQUIREMENTS FOR NORM INDUSTRIES

3.1. Identifying exposure situations

The regulatory framework for NORM industries should essentially be the same as for other practices dealing with "artificial" radionuclides. In the new BSS NORM industries are considered planned exposure situations and have therefore been integrated in the regulatory system as practices. However, as is shown further down, specific requirements will still be made for NORM based on the fact that natural radiation sources are ubiquitous in the environment. In the case of NORM it is also most unlikely that severe radiological accidents would occur and the existence of other industrial hygiene controls should be taken into account. Nevertheless, the system of protection can be made the same. A graded approach was considered a suitable way to proceed with notification as a first step, then registering or licensing depending on expected doses to workers or the public and the effectiveness of control measures. This approach is intended for all practices not only NORM industries.

As was previously mentioned, the present Title VII requires Member States to ensure the identification of work activities which may be of concern, leaving the Member State to decide what is considered of concern. For clarification, but also as a step towards harmonisation of the regulatory framework for NORM, a specific list of industrial activities of concern is

¹ Radon refers here to isotope Rn-222. While Thoron (Rn-220) can also be cause of concern, it is not explicitly addressed in the new BSS.

introduced in the new EU BSS. The list² covers industrial activities known to require regulatory consideration and is to a large extent similar to the work activities listed by IAEA:

- Extraction of rare earths from monazite
- Production of thorium compounds and manufacture of thorium-containing products
- Processing of niobium/tantalum ore
- Oil and gas production
- TiO₂ pigment production
- Thermal phosphorus production
- Zircon and zirconia industry
- Production of phosphate fertilisers
- Cement production, maintenance of clinker ovens
- Coal-fire power plants, maintenance of boilers
- Phosphoric acid production,
- Primary iron production,
- Tin/lead/copper smelting
- Ground water treatment

The proposed list of industrial activities is a so-called positive list specifying what activities may be subject to notification. If a NORM industry is not on the list the idea is that it is exempted from notification. Member States may however add industrial activities to the list if the national authorities identify other activities requiring regulatory attention.

3.2. Materials of concern

As a starting point, the following dose criteria for the exemption of NORM industries from regulatory control: 1 mSv/y for workers or 0.3 mSv/y for members of the public, are proposed. Above these values protective actions should be considered to reduce the doses, bearing in mind that as for all other practices the principle of optimisation should always be applied.

Assessing doses from NORM activities can be complicated, in particular doses to members of the public. Exemption levels based on activity concentrations are therefore proposed, see table 1. According to UNSCEAR 2000 and ICRP Publication 75 workers or members of the public will generally not receive doses higher than 1 or 0.3 mSv/y respectively if the activity concentrations are lower than the values in table 1, except for particular situations such as exposure due to building materials containing natural radionuclides. If a NORM industry on the positive list produces residues used in building materials there is always a requirement on notification, irrespective of the levels of concentration of the radionuclides.

Table 1: Values for natural radionuclides in secular equilibrium in solid materials³

Natural radionuclides from the U-238 series	1 Bq/g
Natural radionuclides from the Th-232 series	1 Bq/g
K-40	10 Bq/g

² Uranium mining and uranium milling are part of the nuclear fuel cycle and require licensing

³ Values in Table 1 has been proposed in IAEA Safety Guide RS-G-1.7 on the concept of exclusion, exemption and clearance, and are based essentially on the distribution of concentrations in the earth's crust

Some individual elements in the decay chain, e.g. Po-210 or Pb-210, may warrant the use of values significantly higher than those in Table 1, by up to two orders of magnitude. Numerical values for segments of the decay chain can be found in EC guidance Radiation Protection 122, part II⁴.

3.3. A graded approach to occupational exposure

If, at any point in the industrial process, the activity concentration in any materials exceeds the values indicated Table 1, the regulatory authorities should be notified by the undertaking. The notification should include information on the materials processed, radionuclide concentrations, products, by-products and residues. Based on this information the authorities will decide on the level of regulatory control and can impose requirements for the initial assessment of the exposure of workers. When the assessed exposure of workers is expected to be less than 1 mSv/y, the practice may be exempted from further regulatory control. If the assessed exposure of workers in a group of identical industrial processes is consistently less than 1 mSv/y, these processes could be exempted on a generic basis.

If the exposure of workers can exceed 1 mSv/y but is less than 6 mSv/y, Member States shall consider authorisation, i.e. either registration or licensing, or consider if circumstances indicate that the practice shall be exempted from further regulation. Member States shall require the employers to regularly assess whether doses could effectively be further reduced and whether there is a potential for doses to increase over time or as a result of changes in the work practice. Where appropriate, the authorities shall request a formal implementation of the principle of optimisation as it would for any other practice. Subsequent controls on monitoring occupational doses shall be commensurate with the magnitude of the exposures. Furthermore, designated members of the staff should be trained in radiation protection. For this purpose the competence and human resources of a Health and Safety department within the undertaking can be used. Where appropriate, a radiation protection expert should be responsible for the training and for further advice on protective measures.

When the exposure of workers exceeds or is likely to exceed 6 mSv/y in normal operations, Member States shall require that the practice is licensed.

3.4. Control of public exposure from discharges and disposal of waste and residues

Doses to members of the public from industrial facilities discharging liquid and gaseous effluents containing NORM are generally below 0.3 mSv/y, see chapter 3.2. Operational values in terms of Bq/y could also be used, see e.g. EC guidance Radiation Protection 135.

In particular situations authorisation should be required, for instance when drinking water resources are likely to be affected by discharges from NORM industries. The authorisation may include discharge limits and requirements on monitoring discharges.

Reuse and recycling of residues from any authorised practice is subject to authorisation. The recycling of residues for the manufacture of building materials may warrant lower values than those proposed in Table 1, see also chapter 5.

⁴ The approach followed in RP part II was based on scenarios used to check compliance with the dose criteria.

For some residues from identified and listed NORM industries the optimised solution may be to mix the residues with other inert materials. It is however clearly pointed out that this may only be permitted in specific justified cases.

4. REQUIREMENTS RELATED TO RADON EXPOSURE

4.1. General requirements within EU BSS for national Action Plans

The COM Recommendation from 1990 (90/143/Euratom) addresses the protection of the public against indoor exposure to radon, but exposures to radon in dwellings are excluded from the present EU BSS directive, while a flexible approach on radon in workplaces was adopted in that directive. Therefore the policy for reducing radon exposures relies mainly on Member States willingness to address the issue.

The Commission proposes to strengthen the legal framework with requirements on Member States to enhance their national strategies for reducing radon exposures in dwellings and in workplaces, and to set reference levels in the range indicated in the new directive. One of the main requirements in the proposal for new text in the EU BSS is the demand for an Action Plan on how to manage long term radon exposure both in dwelling and in workplaces for any source of radon, including soil, building materials and drinking water. The Action Plan should cover the issues specified in an Annex to the BSS. It should be placed under the responsibility of the Member State and be periodically updated.

The Action Plan should include:

- goals and targets, in terms of reduction of lung cancer risk ;
- criteria and available data used for the delimitation of radon prone areas ;
- the basis for choosing and establishing reference levels in accordance with the EU BSS ;
- identification of stakeholders and contributors, assignment of responsibilities, and co-ordination of national authorities and resources;
- strategies, methods and tools for measuring radon levels, and for taking remedial actions, particularly in dwellings ;
- audits and reviews of the implementation of the plan ;
- strategy for communication to increase public and local decision maker's awareness of the risks of radon and its relation to smoking.

Regarding reference levels, the choice of a reference level has to be done at national level depending on national circumstances such as number of buildings and dwellings affected. This choice is complex, depending not only of the level of exposure but also on the likely scale of action which has economic implications for the community and for individuals. Therefore an upper bound is proposed rather than a range of values, leaving the Member State the option to set its own reference level below that upper bound.

It is the responsibility of appropriate national authorities to establish 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. When setting reference levels, the national authority should consult interested parties. The levels should be chosen such that the resulting activities are seen to be practicable and manageable.

On the basis of

- the link between exposure to radon and lung cancer established by pooled analyses of residential case-control studies⁵ ;
- the convergence of international recommendations from WHO, ICRP and IAEA, on the national strategies to be set both for radon in dwellings and in workplaces ;
- the present COM Recommendation (90/143/Euratom) on the protection of the public against indoor exposure to radon ; and
- the objectives to reduce the level of exposures to radon within Europe and to improve the harmonisation between Member States of the protection of workers and population against the risk of lung cancer due to radon exposures ;

the Commission proposes that Member States shall establish national reference levels not exceeding (as an annual average):

- 200 Bq/m³ for new buildings;
- 400 Bq/m³ for existing dwellings
- 400 Bq/m³ for buildings with a high occupancy of the public⁶;
- 1000 Bq/m³ for existing workplaces and other public buildings.

4.2 Technical requirements for reducing radon exposures

4.2.1 Radon surveys and mapping of radon-prone areas

Radon-prone areas should be defined as a geographic area or administrative region defined on the basis of surveys indicating that the percentage of dwellings expected to exceed the national reference level is significantly higher than in other parts of the country.

When undertaking a national survey there are two principal considerations:

- (1) There is a need to estimate the average exposure of the population to radon, and the range of exposures occurring, for comparison with exposures from other sources of ionizing radiation.
- (2) There is a need to identify areas where higher than average radon concentrations are likely to be found. This can be achieved by carrying out a geographically-based survey. The results can be used to develop radon risk maps and to identify radon-prone areas.

With careful consideration a single survey can be designed to address both issues simultaneously. On the basis of this survey, the national authority shall define radon-prone

⁵ Darby, S., Hill, D., Auvinen, A., et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. *Br. Med. J.* 330 (7485): 223 (2005).

Darby, S., Hill, D., Deo, H., et al. Residential radon and lung cancer – detailed results of a collaborative analysis of individual data on 7148 persons with lung cancer and 14208 persons without lung cancer from 13 epidemiologic studies in Europe, *Scand. J. Work Environ. Health* 32 (Suppl. 1): 1-84 (2006).

Krewski, D., Lubin, J.H., Zielinski, J.M., et al. Risk of lung cancer in North America associated with residential radon. *Epidemiology* 16(2): 137-145 (2005).

Krewski, D., Lubin, J.H., Zielinski, J.M., et al. A combined analysis of North American case-control studies of residential radon and lung cancer. *J. Toxicol. Environ. Health Part A* 69 (7-8): 533-598 (2006).

⁶ For instance nursery homes, schools and prisons

areas within its territories and consider specific measures for reducing radon exposures to be applied within these areas.

4.2.2 Measurements in workplaces and in public buildings

Within radon-prone areas, the proposed new requirements demand in principle that radon measurements should be made for all workplaces, including workplaces that are both public buildings and workplaces like libraries and museums. This requirement also applies to buildings with a high occupancy of the public such as schools, nursing homes and prisons. There is however flexibility for Member States to define their own strategy for conducting surveys of indoor radon concentrations, and indications other than radon prone areas may be used to identify the workplaces.

For specific workplaces identified by the Member States, such as underground workplaces, spas and NORM industries of concern, measurements of radon shall be mandatory, whether the workplaces are within a radon prone area or not. The term underground workplaces comprises workplaces such as mines, show caves, underground transport systems, laboratories or storage facilities, whereas workplaces close to ground level such as car parks or basement workplaces are not automatically included.

4.2.3 Remedial actions

The national Action Plan should specify what actions should be taken, and by whom, in situations where the radon concentration is found to exceed the applicable reference level set by the national authority. Those actions should be aimed at reducing the radon concentration to a level at which protection can be considered to be optimized and should be designed to be reasonable. For instance, it would not be reasonable to expect that a detailed optimization exercise be carried out for existing individual homes.

For certain workplaces, despite making all reasonable efforts to reduce the radon concentration, the concentration may still remain above the reference level set by the national authority. In such cases, exposure of workers to radon should, along with any other occupational exposures, be subject to the normal requirements for radiation protection such as compliance with the relevant dose limit. The recorded occupational exposure should not include radon exposure below 400 Bq/m³. The Commission proposes a fixed threshold in order to ensure consistency between Member States in the recording of occupational exposure to radon for monitoring and record keeping purposes.

4.2.4 Planning and construction requirements

The national authority should consider the cost-effectiveness of radon preventive measures for new dwellings either in all areas or only in radon-prone areas. The national authority should develop building codes and construction practices that limit the ingress of radon into new dwellings. Compliance with these codes should be mandatory, especially in radon-prone areas.

5. REQUIREMENTS FOR BUILDING MATERIALS CONTAINING NATURAL RADIATION SOURCES

The present EU BSS do not include specific requirements related to radionuclide concentrations in building materials. By introducing such requirements in the new EU BSS, the Commission on the one hand complements the Council Directive on constructions products (89/196/EEC), on the other pursues further harmonisation of the regulatory approaches by Member States to allow free movement of building products within the European Union.

Exposure from natural radioactivity in building material will be regarded as an existing exposure situation.

5.1 List of building materials and components

The Member States will be required to insert in their legislation a list of the different types of building materials which need to be controlled with regard to their emitted gamma radiation. When setting up this list, the list in an Annex to the BSS shall be taken into account.

Proposal for content of Annex:

1. Natural materials

- Alum-shale
- Building materials or additives from natural igneous origin, such as
 - Granite,
 - Basalt,
 - Tuff,
 - Pozzolana,
 - Lava.

2. Materials incorporating by-products or residues from NORM industries such as

- Fly ash
- Phospho-gypsum
- Phosphorus slag
- Tin slag
- Copper slag
- Red mud (residue from aluminium production)

The requirements will offer the possibility for Member States to add or withdraw certain categories of materials when there is evidence of them being a cause for concern or not being of concern. For instance materials which the Member State has assessed to be of concern in the national action plan for radon, see chapter 4, should be added to the list.

Having identified certain materials Member States should ensure that the radiological implications of using these materials in building applications in their countries are assessed by

- a) determining the activity concentration index and, if necessary
- b) determining the doses resulting from the different types of use.

5.2 Measurements and activity concentration index

For the materials of concern the industries placing such materials on the market will be required to measure the three radionuclides indicated in an Annex. The activity concentration index (I), as defined in EC guidance RP 112, has to be calculated⁷. The industry is required to provide information to the national authority on the results of the measurements and of the corresponding activity concentration index (I).

The activity concentration index is a screening tool for identifying materials that might be of concern. It should be noted that the activity concentration index applies to the building material, not to its constituents. For application of the index to residues from NORM industries recycled into building materials an appropriate mixing factor needs to be applied.

5.3 Reference level and classification

A reference level of 1 mSv per year is proposed for indoor external exposure from building materials. This is in excess of the background outdoor external exposure. When assessing compliance with the reference level the doses from the exposure to local prevailing activity concentrations in the undisturbed earth's crust should, where appropriate, be subtracted.

If the building material is found to give doses not exceeding the reference level, then the material should be exempted from requirements at national level, except for appropriate further monitoring of activity concentrations if so required. If the material is liable to give doses exceeding the reference level the authority should consider appropriate control measures ranging from registration and general application of relevant building codes, to specific restrictions on the use of such material.

Building materials not exceeding the reference level shall be exempted from any restrictions with regard to placing them on the market in the European Union. Building materials are often imported or exported, consequently some form of classification of the material would be beneficial for harmonising the regulatory approach regarding materials crossing borders. The activity concentration index could be used as a tool for identifying materials that may be subject to restrictions in other Member States.

Two groups of building materials should be considered:

- materials used in bulk amounts;
- superficial and other materials with restricted use.

For this purpose the activity concentration index I could be used for the classification of the materials into four classes leading to two categories of building materials (A and B):

⁷ $I = C_{\text{Ra226}}/300 \text{ Bq/kg} + C_{\text{Th232}}/200 \text{ Bq/kg} + C_{\text{K40}}/3000 \text{ Bq/kg}$

where C_{Ra226} , C_{Th232} and C_{K40} are the activity concentrations in Bq/kg of the corresponding radionuclides in the building material. For practical purposes the measurement of Th-232 can be replaced by that of Ra-228 which is more readily measured.

Use	Category (corresponding default dose)	
	A (≤ 1 mSv)	B (> 1 mSv)
(1) materials used in bulk amounts	A1 $I \leq 1$	B1 $I > 1$
(2) superficial and other materials with restricted use.	A2 $I \leq 6$	B2 $I > 6$

The distinction of materials into (1) or (2) should be defined by the national authority and based on national building codes.

The information relevant to the implementation of building codes should be made available before the materials are placed on the market. Relevant information includes radionuclide concentrations, activity concentration index and corresponding classification.

ANNEX – International framework

The annex presents the main documents forming the international framework for natural radiation sources. The content does not claim to be comprehensive, for instance UNSCEAR reports are not described.

1 NORM

1.1 ICRP Recommendations and guidance

The new recommendations from ICRP (ICRP Publication 103, 2007), *The 2007 Recommendations of the International Commission on Radiological Protection*, distinguish between three types of exposure situations when implementing the system of radiological protection of humans: planned, emergency and existing. Exposures to radon in dwellings and naturally occurring radioactive materials (NORM) are mentioned as examples of existing exposure situations. For existing exposure situations the ICRP recommends that reference levels, set in terms of individual doses, should be used in conjunction with the implementation of optimisation, not ignoring doses below the reference level. ICRP also indicates that the feasibility of controlling the situation and the past experience are the main factors to be considered for setting reference levels for existing exposure situations.

The ICRP Publication 104 (2007), *Scope of radiological protection control measures*, takes into account the IAEA Safety Guide RS-G-1.7 (see below), pointing out that industries handling NORM with activities not higher than these criteria (1 Bq/g for uranium and thorium series radionuclides and 10 Bq/g for K-40) could be excluded by the legislator from the scope of regulatory control. In addition, it could be recommended that, in situations where the activity concentration values are exceeded, the regulatory body, before automatically imposing regulatory requirements, needs to decide whether to exempt on a case-by-case basis, using an approach based on dose. A dose of 1 mSv/y could serve as a suitable criterion for this approach.

1.2 IAEA Safety Standards and Safety Guides

The IAEA Safety Series No. 115 *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (1996), which is presently being revised, apply equally to exposures to both natural and artificial sources of radiation, but provides no specific requirements for NORM other than to say that activities involving enhanced exposure to NORM are included within the practices to which the Basic Safety Standards apply. Mines and mills processing uranium or thorium ores as part of the nuclear fuel cycle are singled out as requiring to be authorized by way of a licence. The Standards also provide dose coefficients for radionuclides of natural origin.

Several Safety Guides that have been published subsequent to the Safety Series No. 115, or are still in preparation, provide coverage of NORM issues. Taken together with the Standards and other documents providing requirements on levels, these documents provide a reasonably complete framework of standards covering the conduct of practices involving exposure to NORM and the remediation of NORM residues. The Safety Guides are supported by Safety Reports that provide further information for assisting in implementation of the Standards. In particular, IAEA has published a safety guide (RS-G-1.7) on the application of the concepts

of exclusion, exemption and clearance⁸, which also contains a table of activity concentration levels for natural radionuclides.

The IAEA Safety Guide RS-G-1.7 has introduced a set of values below which it is usually unnecessary to regulate, irrespective of the quantity of material or whether it is in its natural state or has been subject to some form of processing:

- 1 Bq/g for uranium and thorium series radionuclides ;
- 10 Bq/g for K-40.

These values were not determined on the basis of dose. The values applicable to these types of radionuclides were derived using a pragmatic approach that places greater emphasis on optimisation of protection, including optimisation of regulatory resources. This involved consideration of worldwide distribution of the concentration of radionuclides of natural origin present in material that is found in the environment. Furthermore, in keeping with the approach adopted for the exemption levels in BSS 115, the values were specified only to the nearest order of magnitude, since a higher precision (e.g. 0.5 Bq/g instead of 1 Bq/g) could not be justified. However, the RS-G-1.7 quotes that “there are situations (such as the use of some building materials containing natural radionuclides) for which exposures from materials due to radionuclides with activity concentrations below these values necessitate consideration by the regulatory body for some types of regulatory control”.

The values of activity concentrations provided in RS-G-1.7 are not intended to be applied to the control of radioactive discharges of liquid and airborne effluents from authorised practices, or to radioactive residues in the environment.

A graded approach to regulation is one of the key principles embodied in the BSS 115, which state that the application of the requirements for practices, including NORM industries, “shall be commensurate with the characteristics of the practice or source and with the magnitude and likelihood of the exposures”. For situations involving exposure to NORM, it implies that the regulatory body will go beyond just establishing that the activity concentration values (included in the safety guide RS-G-1.7) are exceeded. The regulatory bodies will consider particular types of operation, process and material in more detail, including some form of exposure or dose assessment in order to determine the optimum regulatory approach.

Experience with industrial activities involving exposure to NORM indicates that the dose received by a member of the public living near the industrial facility concerned is generally no more than a few microsieverts per year (exceptionally of the order of 100 $\mu\text{Sv/y}$)⁹, and is consequently only a small fraction of the dose that could be received by a worker. Therefore, a decision not to impose regulatory requirements can generally be made on the basis of the worker dose not exceeding 1–2 mSv in a year, in the knowledge that under such circumstances the dose received by a member of the public living nearby is likely to be lower by at least an order of magnitude.

⁸ IAEA Safety Guide No. RS-G-1.7, *Application of the concepts of exclusion exemption and clearance*, 2004

⁹ See *Sources and Effects of Ionizing Radiation, Volume I: Sources*, United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes, United Nations, New York (2000).

1.3 European Commission guidance

Since the EU BSS (Council Directive 96/29/Euratom) entered into force, the European Commission has published several reports in its Radiation Protection series to assist Member States in regulating natural radiation sources and to stimulate further harmonisation between Member States¹⁰.

Radiation Protection 88 (RP88) identifies industrial processes which may be of concern from a radiation protection point of view. It introduces a framework for the protection of workers based on annual doses of 1 mSv and 6 mSv. It also specifically addresses exposure to aircrew.

Radiation Protection 95 (RP 95) provides reference levels for identifying industries where workers exposure should require regulatory control. The reference levels are specified in terms of activity concentrations of the input material. The exposure scenarios are based on a review of relevant industries within the EU and consider normal and unlikely, or extreme, situations. The reference levels have been defined in relation to "marker points" in terms of annual effective dose (1 mSv and 6 mSv per year).

Using calculations from certain pathways, including inhalation from radon, these dose levels can be converted to activity concentration, so called screening levels. For screening purposes it is reasonable to assume a fixed radionuclide composition in the specific work situation and characterise the activity of the material from its most significant radionuclide. Having done so, the screening levels indicate in which band the material/work activity belongs and thus an indication on how to proceed. Should this initial assessment fall within one of the bands requiring action, an analysis of the radionuclide composition should be made. This would allow for a more precise classification of the process using specific reference levels indicated in the report.

Radiation Protection 112 (RP 112) provides guidance for natural radioactivity in building materials and its content is described in 3.2 of the Annex.

Radiation Protection 122 part II (RP 122 part II) gives guidance on the concepts of exemption and clearance for natural radiation sources, in particular for materials arising from industries that mine or process ores or other materials for which the presence of naturally occurring radionuclides are of concern. It proposes to set the criteria for exemption and clearance for such work activities at an annual effective dose increment of 0.3 mSv/y, in addition to background exposure from natural radiation sources. Based on this, exemption-clearance levels for NORM were calculated with different scenarios (transport, storage, disposal on a heap, etc.). Levels were rounded to 0.5 Bq/g for uranium and thorium in secular equilibrium on the basis that "this is in the upper range of concentrations usually found in ores and thus ensures that regulatory control is practicable".

Radiation Protection 135 (RP 135) identifies which NORM industries may be of concern and proposes screening levels in GBq per year for NORM discharges to the sea, river or air. These screening levels correspond to dose criteria of 10, 100 and 300 μ Sv per year to members of the public.

¹⁰ Reports can be found at http://ec.europa.eu/energy/nuclear/radiation_protection/publications_en.htm

2 RADON

2.1 ICRP

2.1.1 Radon in dwellings

In ICRP Publication 60 (1991), *1990 Recommendations of the International Commission on Radiological Protection*, the Commission singled out radon in dwellings for special attention, because of the magnitude of individual and collective doses. It deals with the occupancy of dwellings only in the context of intervention, not as a practice. Intervention would involve modifications to the dwellings or to the manner in which occupants are using a dwelling. The Commission recommended the use of action levels to help in deciding when to require or advise remedial action in existing dwellings. The choice of an action level is complex, depending not only on the level of exposure, but also on the likely scale of action, which has economic implications for the community and for individuals, and the Commission recommends that the best choice “may well be that level which defines a significant, but not unmanageable, number of houses in need of remedial work. It is then not to be expected that the same action level will be appropriate in all countries”. The Commission concluded that for owner-occupied dwellings general guidance may be adequate, but in countries with substantial numbers of rented dwellings, it may be desirable to establish firm action levels. Guides or codes for the construction of new dwellings in certain areas can be selected, resulting in exposures in these dwellings below some chosen reference level.

In ICRP Publication 65 (1994), *Protection Against Radon-222 at Home and at Work* the Commission presents a series of recommendations for action levels in existing dwellings, new dwellings and workplaces, as well as for identifying radon-prone areas, and applying remedial and preventive actions. For intervention in dwellings, the ICRP concludes that some remedial measures against radon in dwellings are almost always justified above a continued annual dose of 10 mSv. For simple remedial measures, a somewhat lower figure could be considered, but a reduction by a factor five or ten would reduce the action level to below the natural background dose. Thus, the choice of action level is limited to the range of 3-10 mSv, which corresponds with rounded concentration levels of 200-600 Bq/m³ (occupancy 7000 h/y; equilibrium factor 0.4).

ICRP Publication 82 (2000), *Protection of the Public in Situations of Prolonged Radiation Exposure*, provides guidance on the application of the system of radiation protection to controllable exposure to natural sources and long-lived radioactive residues, affecting members of the public. The Commission concludes that the recommendations of ICRP 65 remain valid and are fully applicable for controlling prolonged exposure to radon in dwellings. For existing buildings, the Commission emphasizes that intervention should take place to protect the more highly exposed individuals. The cost and effectiveness of the protective actions are likely to vary locally, and national authorities are best placed to adapt their policies to their particular circumstances. Actions needed to reduce the radon concentration are usually fairly simple and moderate expensive. The recommended range of 200-600 Bq/m³ for dwellings relates only to simple measures. More severe actions, such as relocation, would not be appropriate unless the irreducible concentrations were an order of magnitude higher.

2.1.1 Radon in workplaces

Concerning workplaces, and specifically for workers who are not regarded as being occupationally exposed to radiation, ICRP recommends in ICRP 65 action levels in the range of 500-1500 Bq/m³, simply by multiplying the range for members of the public by the ratio of occupancy factors and by the ratio of dose conversion coefficients. The ICRP recommends that when selecting action levels for dwellings and workplaces, authorities should choose values that are similarly located within the two ranges. ICRP also points out that for workplaces with a high occupancy of members of the public, such as hospitals, residential homes, schools, etc, the premises should be treated as dwellings for the purpose of setting action levels.

2.1.3 Requirements on new buildings

According to ICRP 65, there are two aims in imposing restrictions on the construction of new dwellings in radon-prone areas, namely to keep the radon concentrations in finished buildings as low as can reasonably be achieved and secondly, to provide for the easy introduction of further remedial measures if the initial construction fails to achieve concentrations below the action level for existing buildings. ICRP concludes that these aims are best achieved by issuing guidance on construction practices. Construction codes and building guides should be devised that will consistently achieve low concentrations of radon in the completed buildings.

Particular consideration should be given when buildings are planned on made-up ground, if there are indications of radium-bearing material used as landfill. A thorough quantitative assessment will then be needed, possibly supported by measurements in a temporary structure on the proposed site.

To achieve the aims, there are two approaches to modify the foundations of buildings to prevent radon entering the building. One is to change the foundation design and the construction to prevent radon in the soil gas by passive means. Such a radon resistant approach may require quite a change in the design, but when it is effective, it has no further costs. The second approach is a ready-remedy approach, in which a low-resistance fill layer with low radium content is provided under the floor slab so that the radon may be extracted. The approach favoured by national authorities will depend on local building styles, the severity of the problem and the regulatory regime.

2.1.4 New recommendations (ICRP 103)

In the new recommendations from ICRP (ICRP 103, 2007), both radon in dwellings and workplaces as well as NORM are included in a new Chapter 6.3 “Existing exposure situations”. For these situations, ICRP recommends applying a source-related restriction for controlling exposure by a reference level which represents the level or risk above which it is judged to be inappropriate to allow exposure to occur, and below which optimisation of protection should be implemented to assure that all exposures are kept ALARA. The source related restriction for radon exposure is the reference level.

The ICRP has, up till now, had the view that radon risk assessment should be based on epidemiological studies of miners. Given the wealth of data on domestic exposure to radon, the ICRP now recommends that the estimation of risk from domestic radon exposure be based on the results of pooled residential case-control radon studies. However, there is still great

value in the miner epidemiology studies for investigating dose response relationships and confounding effects of smoking and exposure to other agents. The current available epidemiological evidence indicates that risks other than lung cancer from exposure to radon and its decay products are likely to be small.

It is the responsibility of 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. ICRP also maintains the view that there is merit in defining radon-prone areas in which the concentration of radon in buildings is likely to be higher than is typical of the country as a whole. This allows action to be concentrated to where it is most likely to be effective.

Responsibility for taking action against radon in houses and other premises will often fall on the individual owners, who cannot be expected to carry out a detailed optimisation exercise for each property. Therefore, in addition to reference levels, national authorities may also wish to specify levels at which protection against radon-222 can be considered optimised, i.e. where no further action is needed.

Even though the nominal risk per Sv has changed slightly, for the sake of continuity and practicality the ICRP retains the relationship between the upper value of 10 mSv (per year) for the individual dose reference level and the corresponding activity concentration given in ICRP 65. This means that the radon upper values remain at 1500 Bq m⁻³ for workplaces and 600 Bq m⁻³ for domestic dwellings.

The ICRP states that the IAEA has in the interest of international harmonisation established a single action level value of 1000 Bq/m³, to define where to start applying occupational safety standards. For the same reasons, the ICRP considers that such a value might be used globally to define the entry point for occupational protection requirements.

2.2 IAEA

The IAEA publication *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (IAEA Safety Series No. 115, 1996), jointly sponsored by the FAO, IAEA, ILO, OECD/NEA, PAHO and WHO, sets out the international standards that include requirements for exposure to radon¹¹. Those requirements and supporting guidance from IAEA Safety Guides, which are summarized below, are consistent with the recommendations in ICRP Publication 65.

2.2.1 Normal situations

With certain exceptions, exposure to radon in buildings and workplaces is subject to the requirements for intervention. The following requirements apply to “situations requiring remedial action to reduce or avert chronic exposure”:

- Remedial actions shall be undertaken whenever they are justified.

¹¹ The IAEA is presently in the process of revising Safety Series No. 115.

- The form, scale and duration of any such remedial action shall be optimized so as to produce the maximum net benefit, understood in a broad sense, under the prevailing social and economic circumstances.
- Remedial actions are not normally likely to be necessary unless the relevant action level is exceeded. The IAEA Safety Guide on *Occupational Exposure* (IAEA Safety Standards Series No. RS-G-1.1, 1999), jointly sponsored by the IAEA and ILO, recommends that, in determining whether the action level is exceeded in workplaces, the possibility of large variations in space and time of the concentration of radon and its progeny should be taken into account.
- The action level shall be justified and optimized, taking into account: the individual and collective exposures; the radiological and non-radiological risk; and the financial and social costs, the benefits and the financial liability for the remedial actions.
- Optimized action levels are expected generally to fall within the following guidelines established by international consensus: a yearly average radon concentration in dwellings of 200–600 Bq/m³ in air and a yearly average radon concentration in workplaces of 1000 Bq/m³ in air.
- These values are based on an assumed equilibrium factor of 0.4. Safety Guide RS-G-1.1 advises that there is practical advantage in adopting a single value for the action level which applies to all situations irrespective of the equilibrium factor, but that other action levels may be appropriate if the equilibrium factor is significantly different from 0.4.
- For new workplaces, Safety Guide RS-G-1.1 recommends that the regulatory body should establish a basis for identifying in advance those workplaces in which radon concentrations are likely to exceed the action level. The design and construction should then include preventive features and the action level applied after construction of the workplace as a check on the effectiveness of the preventive measures.
- The decision on whether remedial actions for exposure to radon in dwellings shall be mandatory or advisory shall be taken by the regulatory body or the intervening organization. The decision shall take into account the social and legal circumstances that apply, noting that the recommendations of the ICRP emphasize the role of national authorities in deciding the levels of funding for general reduction in radon levels or other aspects of housing improvements.

2.2.2 *Exceptional situations*

In the following exceptional situations, the standards treat exposure to radon in buildings and workplaces as subject to the requirements for practices:

- (a) Public exposure to radon delivered by effluent discharges or the disposal of radioactive waste arising from a practice involving natural sources, unless the exposure is excluded or the practice or source is exempted;
- (b) Occupational exposure to radon “required by or directly related to” the work, unless the exposure is excluded or the practice or source is exempted. Safety Guide RS-G-1.1 advises that this refers to situations where the exposure to radon is not

- adventitious, and is thus intended to cover exposures of workers to radon in workplaces involving the mining and processing of uranium ore.
- (c) Occupational exposure to radon “incidental to the work” where the action level for workplaces is exceeded, unless the exposure is excluded or the practice or source is exempted. Safety Guide RS-G-1.1 advises that this refers to situations where:
- the regulatory body has identified or determined, by means of a survey or otherwise, the workplace to have a radon concentration above the action level;
 - consideration has been given to whether the concentration can be reasonably reduced to below the action level (in terms of the requirements for intervention, see above);
 - a sufficient reduction in the concentration could not reasonably be achieved.
- In such situations, the numerical value of the action level is no longer used as the basis for a decision on intervention. It is instead used as the basis for a decision to consider the radon exposure to be arising from a practice.

In these situations, exposure to radon is treated in exactly the same way as any other exposure arising from a practice.

2.3 WHO recommendations and guidelines

For the World Health Organization (WHO), the prevention of lung cancers caused by radon has been an issue for many years. Earlier activities of the WHO Regional Office for Europe resulted in 2005 in the WHO International Radon Project (IRP)¹². Scientists and radon experts from more than 35 countries worldwide have been involved in this project. An important aspect of the IRP work is related to advocacy for radon health risk and to development of risk communication tools. WHO has also carried out an international survey on national radon activities.

One of the main outputs of the IRP is the WHO radon handbook, focusing on indoor radon exposures emphasizing its importance from public health point of view. The goal of the handbook is to give a current and authoritative overview of all major aspects of radon and health, with particular emphasis on issues that are relevant for the planning, implementation and evaluation of national radon programs. In particular, countries that plan to develop or extend their radon activities should find this handbook useful. It gives an overview of radon related health risks and describes radon measurement and mitigation approaches. In addition, it gives guidance on how to do cost-effectiveness studies in order to compare alternative risk reduction strategies and summarize risk communication issues and approaches. The launching of the WHO radon handbook is scheduled for late 2008.

The upper reference level for radon concentration in dwellings recommended by WHO in this handbook is a maximum of 400 Bq/m³. Under optimal condition the value should be around 100 Bq/m³. The concentration levels were derived by applying UNSCEAR's dose-conversion factor to an annual dose between 3 and 10 mSv.

With regard to radon in new buildings, the IRP has concluded that radon issues should be addressed in national building codes. Countries should consider developing cost-effective national policies on testing and mitigation. They should explore ways to reduce radon risks in

¹² See www.who.int/ionizing_radiation/env/radon/en/

a cost-effective manner, considering both the installation of preventive measures in new buildings and remediation of existing buildings. Where appropriate, countries should build capacity within the public and/or private sectors to provide testing, mitigation and radon-resistant new construction.

Actions to reduce radon in new buildings should not be taken in isolation. They should be part of a program to improve the whole indoor environment, including damp, moulds, dust, etc. that can cause respiratory health problems.

The WHO Radon Handbook is planned to address the subject and proposes a maximum reference level for radon concentrations in new buildings of 200 Bq/m³ (preliminary information from WHO – to be confirmed).

2.4 EU legislation and guidance

The European Commission (EC) stated already in 1990 in its *Recommendation on the protection of the public against indoor exposure to radon (90/143/Euratom)* that indoor radon is controllable in the physical and engineering sense. Member States should therefore develop guidelines for remedial actions in existing building where the level of radon concentrations exceed specified reference levels. Design and construction specifications should be developed in order to prevent radon concentrations above a certain reference level in future buildings. Lower reference levels for new buildings than for existing buildings are justified. The reference level¹³ for consideration of remedial action for radon in existing buildings is set to 400 Bq/m³. Where remedial actions are considered necessary, the public concerned should be informed on the radon levels it is exposed to and to the remedies available to reduce such levels. For future constructions a design level is set at 200 Bq/m³ to aid the relevant authorities in establishing regulations, standards or codes of construction practices for circumstances under which the design level might otherwise be exceeded. Information should be provided to those involved in the construction of new buildings on possible radon exposure levels and on preventive measures that could be taken. When remedial or preventive measures are being determined, the principles of optimisation should be applied in accordance with the Community basic safety standards. Furthermore, criteria should be developed for identifying regions, sites and building characteristics likely to be associated with high indoor radon levels.

The EC report *Radiation Protection 88 (RP 88)*, published shortly after the *Council Directive 96/29/Euratom on Basic Safety Standards (EU BSS)* was issued, gives technical guidance and recommendations for the implementation of Title VII of the Directive. Although the EU BSS does not apply to radon exposure in dwellings, the report concludes that domestic and occupational exposures to radon, as well as any programme of control implemented in line with the Commission Recommendation 90/143/Euratom, are likely to be related. Action Levels and Radon Prone Areas are concepts which national authorities may find useful in controlling both domestic and occupational radon exposures.

¹³ The terminology has changed since 1990. The new ICRP Recommendations (ICRP 103) uses "reference level" in parallel to the term "dose constraint", where the latter is used for planned exposure situations and the former is used for existing or emergency exposure situation. The meaning is the same for both terms: a level of dose which is as low as reasonably achievable, economic and societal factors being taken into account. SANT!?!?

RP 88 points out that the directive brings exposure to natural sources within the same general framework as other exposures. Member States should set up a system where attention is concentrated on the highest exposures and where action is most likely to be effective. National authorities must ensure representative surveys of radon exposure in different types of workplaces. Surveys of radon-prone areas (geographically or in underground workplaces) should be based on long-term measurements (one year or more). Geological information may prove useful, but a high concentration in soil and earth crust does not automatically lead to high levels in buildings.

RP 88 defines an action level as a concentration of radon gas above which national authorities require (in case of dwellings, recommend) that action is taken. Occupational exposure above a certain action level will be subject to regulatory control. The action level should not exceed the dose level for protection of category A workers (annual doses higher than 6 mSv). For workplaces within the EU the action levels should be set in the range 500 – 1000 Bq/m³. When appropriate, Member States may select lower levels if they will not lead to impracticalities. For workplaces with a high occupancy of the public the action levels may have to be adjusted.

Existing workplaces are likely to need to be measured if they are underground. Member States should ensure that undertakings and relevant business sectors receive adequate information and advice on remedial actions. Should radon concentration still be too high even after reasonable measures are taken, the principles in the rest of BSS should be applied (monitoring, defining controlled areas and dose limits).

3 BUILDING MATERIALS

In many countries, the most important source of indoor radon is the underlying soil, but in some countries the building materials are significant, or even dominant, contributors. Building materials contain various amounts of natural radionuclides. Materials derived from rock and soil mainly contain radionuclides of the U-238 and Th-232 series, and K-40. In the U-238 series, the decay chain segment starting from Ra-226 is the most important from a radiation protection point of view. Decay of Ra-226 produces Rn-222, which will be exhaled from the building materials in the walls, ceiling and walls. This leads to an indoor concentration of radon causing internal exposure by inhalation.

In most cases the main part of indoor radon on the upper floors of a building originates from building materials. Typical excess indoor radon concentrations due to building materials are 10-20 Bq/m³, but occasionally it may raise up to 1000 Bq/m³ or more.

3.1 ICRP

ICRP 65 addresses natural radionuclides in building materials only marginally, when it deals with its policy for limiting radon concentrations in new buildings.

ICRP 82 elaborates on the presence of natural radionuclides in building materials. Concerned national authorities and, as appropriate, relevant international organizations should derive standardized intervention exemption levels for activity concentrations of specific radionuclides in building materials, taking into account the recommendations for commodities containing radioactive substances. It is not likely that several types of commodities would be simultaneously sources of high prolonged exposure to any given individual. On the basis of

this presumption, the ICRP recommends a generic intervention level of around 1 mSv for a dominant type of commodity, such as some building materials.

ICRP 82 refers to the recommendations of ICRP 65, recalling that they remain valid and applicable to control of exposure to radon in dwellings. For new buildings, it will usually be feasible to avoid the use of building materials with elevated levels of radioactivity. The establishment of standardized intervention exemption levels for activity concentrations in building materials should help to solve many practical problems.

The new recommendations from ICRP (ICRP 103) distinguish between three types of exposure situations when implementing the system of radiological protection of humans: planned, emergency and existing. Exposures to radon in dwellings and naturally occurring radioactive materials (NORM) are mentioned as examples of existing exposure situations, thus making exposure from natural radioactivity in building material an existing exposure situation. For existing exposure situations the ICRP recommends that reference levels, set in terms of individual doses, should be used in conjunction with the implementation of optimisation, not ignoring doses below the reference level. ICRP also indicates that the feasibility of controlling the situation and the past experience are the main factors to be considered for setting reference levels for existing exposure situations.

3.2 IAEA

The IAEA Basic Safety Standards do not currently recommend or require any limitation on radioactivity concentration in building material. Safety Guide RS-G-1.7 provides guidance that can be applied to all commodities other than foodstuffs and drinking water. As regards the application of these values it is specified that “It is usually unnecessary to regulate radioactive material in activity concentration below the value given in the table. However, there are some situations (such as the use of some building materials containing natural radionuclides) for which exposures from materials due to radionuclides with activity concentrations below those given in the table would necessitate consideration by the regulatory body for some types of regulatory control. Regulatory bodies should retain the authority to investigate such situations and to take whatever action is considered necessary”.

3.3 EC Directive and Guidance

In 1989, a European Council Directive related to construction products (89/196/EEC) stated in its annex 1 that “the construction work must be designed and built in such a way that it will not be a threat to the hygiene or health of the occupants or neighbours, in particular as a result of... the presence of dangerous particles or gases in the air [or] the emission of dangerous radiation [etc.]” There is no doubt that both radionuclides in building materials and radon indoors originated by them are covered by these definitions, even if the Directive devotes no detailed discussion to the problem, nor does it suggest limits for radioactivity, or for other pollutants. Such limits are not yet available, but the European Commission states¹⁴ that for the preparation of a “horizontal standard on the measurement of radiation from construction products ... the principles described in the European Commission publication ...Radiation Protection 112 (1999) shall be taken into account”.

¹⁴ European Commission. Horizontal Complement to the Mandates to CEN/CENELEC concerning the Execution of Standardisation Work for the Development of Horizontal Standardised Evaluation Methods for Harmonised Approaches relating to Dangerous Substances under the Construction Products Directive. Emission to indoor air, soil, surface water and ground water. June 2004.

In guidance report *Radiological protection principles concerning the natural radioactivity of building materials* (RP 112, 1999) the radiation protection principles are described that should be used for the purpose of limiting the exposure due to the radioactivity of building materials. These principles are based on the following considerations:

- Small unavoidable exposures need to be exempted from control. A uniform exemption level would allow free movement of most building materials.
- Restricting the use of certain building materials might have significant economical, environmental or social consequences locally and nationally. Such consequences should be assessed and considered when establishing national regulations.
- The radium concentration should be restricted to a level where it is unlikely that it could be a major cause for exceeding the design level of 200 Bq/m³ for indoor radon, as recommended by the European Commission.
- A gamma dose due to building materials exceeding 1 mSv/y is exceptional within the European Union and cannot be disregarded from a radiation protection point of view. By limiting the gamma dose to 1 mSv/y, the radium concentration in building materials is limited, in practice, to a level unlikely to cause an indoor radon concentration exceeding 200 Bq/m³.

This leads to the following radiological criteria:

- a) Dose criterion for controls
Controls should be based on a dose criterion, which is established considering overall national circumstances. Within the European Union, doses exceeding 1 mSv/y should be taken into account from the radiation protection point of view. Higher doses should be accepted only in some very exceptional cases where materials are used locally. Controls can be based on a lower dose criterion if it is judged that this is desirable and will not lead to impractical controls. It is therefore recommended that controls should be based on a dose in the range 0.3-1 mSv/y. This is the excess gamma dose to that received outdoors.
- b) Exemption level
Building materials should be exempted from all restrictions concerning their radioactivity if the excess gamma radiation originating from them increases the annual effective dose of a member of the public by 0.3 mSv at the most. This is the excess gamma dose to that received outdoors.

As more than one radionuclide is involved, the European Commission recommends the use of an activity concentration index I. This index should also take into account the typical ways and amounts in which the materials are used in a building. The activity concentration index is given in the following formula:

$$I = C_{\text{Ra226}}/300 \text{ Bq/kg} + C_{\text{Th232}}/200 \text{ Bq/kg} + C_{\text{K40}}/3000 \text{ Bq/kg}$$

where C_{Ra226} , C_{Th232} and C_{K40} are the activity concentrations in Bq/kg of the corresponding radionuclides in the building material. For practical purposes the measurement of Th 232 can be replaced by that of Ra 228 which is more readily measured.

The activity concentration index shall not exceed the following values, depending on the dose criterion and the way and amount the material is used in the building:

Dose criterion	0.3 mSv/y	1 mSv/y
Materials used in bulk amounts, e.g. concrete	$I \leq 0.5$	$I \leq 1$
Superficial and other materials with restricted use: tiles, boards, etc	$I \leq 2$	$I \leq 6$

The activity index should be used only as a screening tool for identifying materials that might be of concern. Any actual decision on restricting the use should be based on a separate dose assessment, using scenarios where the material is used in a typical way for the type of material in question. Scenarios resulting in theoretical, most unlikely maximum doses should be avoided.