RADIOLOGICAL CRITERIA FOR CONTROLS ON THE RADIOACTIVITY OF BUILDING MATERIALS

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1 ABSTRACT

The BSS Directive (Council Directive 96/29/Euratom) sets down a framework for controlling exposures to natural radiation sources arising from work activities. Title VII of the BSS applies to work activities within which the presence of natural radiation sources lead to significant increase in the exposure of workers or the members of the public. The Member States shall identify work activities which may be of concern and apply requirements of the BSS to them, as appropriate. Production of and trade in building materials causing significant public exposures may be considered a work activity in the meaning of the BSS.

The European Commission has published technical guidance, prepared by the Article 31 Group of Experts (Euratom Treaty), for harmonising controls on the radioactivity of building materials within the European Union (Publication: Radiation Protection Nr. 112). Despite that the guidance establishes proposals for common approaches for establishing controls, lot of flexibility has been left for the Member States to consider national circumstances. In addition to flexibility in the basic dose criterion (0,3 - 1 mSv a^{-1}) for controls, also possible differences in methodologies and underlying parameter values used for assessing the dose might lead to significant variety in requirements and controls within the Member States.

The purpose of this paper is to discuss the dose criteria used for setting up controls on the radioactivity building materials, as well as, the methodologies and underlying parameters used for assessing the exposure caused by building materials to the members of the public.

2 INTRODUCTION

Controls on the radioactivity of building materials might have significant economical consequences and can also have an effect on free movement of these products between the Member States. Such harms could be minimised by applying a harmonised approach for controls. Trade in and production of building materials causing significant public exposures are considered in many Member States a work activity falling under Title VII of the BSS Directive (1). The European Commission has published technical guidance (2), prepared by the Article 31 Group of Experts (Euratom Treaty), for harmonising controls on the radioactivity of building materials within the European Union. The purpose of the guidance is to aid the Member States in implementing the BSS Directive, and essentially also the requirements of the Constructions Products Directive (3), regarding the natural radioactivity of building materials.

Despite that the guidance establishes proposals for common approaches for establishing controls, lot of flexibility has been left for the Member States to consider national circumstances. In addition to flexibility in the basic dose criterion (0,3 - 1 mSv a^{-1}), also possible differences in methodologies and underlying parameter values used for assessing the dose might lead to significant variety in requirements and controls in the Member States.

The purpose of this paper is to discuss dose criteria used for setting up controls on building materials, as well as, methodologies and underlying parameters used for assessing the exposure caused by building materials to the members of the public. Some other challenges in establishing controls on the radioactivity of building materials have been discussed in an earlier paper (4).

3 RADIOLOGICAL CRITERIA AND INVESTIGATION LEVELS

Building materials cause human exposure by direct gamma radiation and by radon (^{222}Rn) released from building materials into indoor air. The relative importance of the pathways vary a lot, but hardly ever either of them can be considered insignificant compared to the other when expressed in terms of effective dose. Therefore, both pathways need to be considered in establishing radiological criteria for building materials.

The technical guidance (2) considers primarily external radiation in establishing criteria for controls and exemption. It is recommended that controls should be based on a dose in the range 0.3 – 1 mSv a^{-1}. The radon pathway is considered indirectly by effectively limiting the amount of radium (^{226}Ra) in a building material so that that the indoor radon concentration cannot rise above the design level of 200 Bq/m^3 (5) even under unfavourable conditions. In addition, the guidance recommends that building materials causing less than 0.3 mSv a^{-1} should be exempted from all restrictions concerning their radioactivity.

Investigation levels are derived for practical monitoring purposes. Because more than one radionuclide contribute to the dose, it is practical to present them in the form of an activity concentration index. The following activity concentration index (*I*) has been presented in the technical guidance (2):

$$I = \frac{C_{Ra}}{300\ Bq\ kg^{-1}} + \frac{C_{Th}}{200\ Bq\ kg^{-1}} + \frac{C_K}{3000\ Bq\ kg^{-1}} \qquad (1)$$

where C_{Ra}, C_{Th}, C_K are the radium, thorium and potassium activity concentrations (Bq kg^{-1}) in the building material. The activity concentration index shall not exceed the following values depending on the dose criterion and the way and the amount the material is used in a building (2):

Dose criterion	0.3 mSv a^{-1} (Exemption)	1 mSv a^{-1}
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.	$I \leq 2$	$I \leq 6$

4 EXPOSURE SCENARIOS AND PARAMETER VALUES

The activity concentration index is used as a screening tool for identifying materials which might be of concern. However, any actual decision on restricting the use of a material should be based on a separate dose assessment. It is also recommended in the technical guidance (2) that such assessment should be based on scenarios where the material is used in a typical way for the type of material in question and scenarios resulting in theoretical, most unlikely maximum doses, should be avoided.

The effect of different exposure scenarios and parameters are discussed below in form of demonstrations. In all the cases, an occupancy time of 7000 h a^{-1} is assumed and a value of 0.7 Sv Gy^{-1} is used for the dose conversion from absorbed dose in air to effective dose for all the natural gamma emitters in question. Further, it is assumed that activity concentrations of 'average' concrete are 40, 30 and 400 Bq kg^{-1} for thorium (^{232}Th), radium (^{226}Ra) and potassium (^{40}K), respectively. These activity concentrations are also assumed representative for soil and are used for calculating the background dose rate outdoors.

Background

When assessing the dose caused by building materials it must be clearly defined as to what extent the exposure caused by background is included. Building materials cause some excess external gamma exposure due solely to their influenced exposure geometry when compared with that of the undisturbed Earth's crust. It needs to be defined whether this contribution to dose is considered excess caused by building materials or a part of normal background. This is demonstrated in the example further on. Essentially, there are three different ways how the background dose can be defined. It can be the average dose received outdoors, the average dose of existing stock of buildings or the average dose received in a house built from materials originating from earth's curst with ‘typical’ activities. The reason why the two latter cases are different is that in the existing stock of buildings the exposure geometry is not, on the average, such extreme since e.g. ceiling structures are often made of light materials which are not giving significant rise to exposure. The effect of different ways of subtracting the background in a dose assessment is demonstrated in Table 1.

The demonstration shows that results of dose assessment may vary by a multiplier of 3, solely depending on the way the background is defined. More worrying is that the dose estimates lie clearly on both sides of 0.3 mSv a^{-1}, the exemption level and the lower end of the dose criterion range recommended in the technical guidance (2). Thus a material can either be accepted or rejected, and both with a clear margin, in different countries seemingly applying the same dose criterion. At the upper end of the range, at 1 mSv a^{-1}, this effect is relatively less important; only about 25% differences in dose estimates, depending on the definition of the background.

It should be noted that all the three 'average values' discussed above actually depend also on the geographical area in question, i.e. these values vary from region to region and from country to country. Therefore, the definition of a representative geographical area (average of a region, one Member State, or the whole EU?) is an additional cause of variation in assessment results among different countries.

Table 1. Excess dose caused by building materials in a house made of concrete having activity concentrations of 40, 40, and 600 Bq kg^{-1} for radium, thorium and potassium, respectively. These concentrations are very typical, but slightly higher than those used for 'average concrete' (see values in text). The methodology of assessment is presented in reference (6).

	Background subtraction option		
	Average outdoors	**Average indoors**	**House made of 'average concrete'**
Background dose rate	0.05 μGy h^{-1}	0.07 μGy h^{-1}	0.10 μGy h^{-1}
Total annual dose	0.61 mSv a^{-1}	0.61 mSv a^{-1}	0.61 mSv a^{-1}
Background dose (to be subtracted)	0.26 mSv a^{-1}	0.34 mSv a^{-1}	0.49 mSv a^{-1}
Excess dose	**0.38 mSv a^{-1}**	**0.27 mSv a^{-1}**	**0.12 mSv a^{-1}**

Combined and minor use of materials

The investigation level (Equation 1) has been derived on the basis of some simplifying assumptions, e.g. 1) a building is made of one material or different materials all having the same activity concentrations, and 2) the mass-thickness of structures are such that they absorb all radiation originating from the earth's crust under the building and from its surroundings. In practice, however, all buildings are made of different types of materials having different activity concentrations and also the mass-thickness of structures vary significantly.

The radiological importance of a material depends, not only on its activity concentrations, but also crucially on the amount it is used in a building. A block of flats made of concrete is perhaps the only case were a building can be considered, from the radiological point of view, comprising only one material. In this case, dose assessments and comparison of its results with the radiological criteria set for building materials is rather straightforward.

In most cases, however, many materials contribute to the dose and decision-making on the acceptability of a material is less unambiguous. This is demonstrated with the following fictitious building comprising three different materials: the floor and ceiling are made of concrete, and the walls are of brick. In addition, the floor and walls are covered with thin tiles. The example building is thus the same as that in Table 1, but the floor and walls are now covered with thin tiles. Results of the radiological assessment are presented in Table 2.

The results show that the total annual dose received in the building is 0.91 mSv a^{-1} of which 0.36 mSv a^{-1} is caused by concrete, 0.26 mSv a^{-1} by bricks and 0.29 mSv a^{-1} by tiles, i.e all the three materials are contributing about 1/3 of the overall dose. No background has been subtracted from these results. The background should be subtracted in order to estimate the 'excess gamma dose to that received outdoors', as defined by the technical guidance (2). The relative portions of outdoor gamma dose attenuated by the floor and walls separately is rather complicated to assess, but combining results of Tables 1 and 2, the following conclusions can be drawn:

1) The excess dose caused by concrete in a building made solely of concrete is 0.12 - 0.38 mSv a^{-1}, depending on the way the background has been defined,
2) Replacing walls made of concrete with those made of brick increases the dose roughly by (2 x 0.19 + 0.26 - 0.61) mSv a^{-1} = 0.03 mSv a^{-1},
3) Placing tiles on the floor increases the dose by (0.23 -(0.19 - 0.17)) mSv a^{-1} = 0.21 mSv a^{-1}, and
4) Placing tiles on the walls increases the dose by about (0.17/0.19)x0.06 mSv a^{-1} = 0.05 mSv a^{-1}.

The conclusion is that all three materials can be shown to comply with the general exemption level 0.3 mSv a^{-1} suggested in the technical guidance (2). Therefore, all these materials should be accepted for building purposes, for their intended use, without any restrictions. However, the overall excess dose caused by all building materials is 0.65 mSv a^{-1}. This demonstrates that it would be impossible to simultaneously apply a dose criterion for controls near to the lower edge of the recommended range 0.3 - 1 mSv a^{-1} and to comply with the general exemption criterion of 0.3 mSv a^{-1}.

Table 2. Radiological assessment of a building containing three different types of materials: concrete (floor and ceiling), bricks (walls) and tiles (on the floor and walls). The methodology of assessment is presented in reference (6).

		Floor		Walls		Ceiling
Material		Concrete	Tiles	Brick	Tiles	Concrete
Thickness of structure		20 cm	1 cm	20 cm	1 cm	20 cm
Activity concentrations, Bq/kg	^{226}Ra	40	200	80	200	40
	^{232}Th	30	200	60	200	30
	^{40}K	400	1200	1000	1200	400
Activity concentration index *I*		0.42	2.1	0.9	2.1	0.42
Dose rate indoors[1], nGy/h		34	47	54	12	39
Annual dose originating from the material in question[1], mSv a^{-1}		0.17	0.23	0.26	0.06	0.19
Total annual dose indoors = (0.17+0.23+0.26+0.06+0.19) mSv a^{-1} = 0.91 mSv a^{-1}						
Background (average outdoors):						0.26 mSv a^{-1}
Excess dose:				(0.91 - 0.26) mSv a^{-1} =		**0.65 mSv a^{-1}**

[1]Results for floor and ceiling are different because the tiles on the floor attenuate slightly the radiation originating from the concrete floor.

There are essentially two possible solutions for overcoming the above-described contradiction. One is that the dose criteria are selected so that the criterion for controls is significantly higher than the general exemption level for a single building material. For example, a combination of 1 mSv a^{-1} as the criterion for controls and 0.3 mSv a^{-1} as the general exemption level might work rather well (there are hardly ever cases where more than a few materials would simultaneously contribute to the overall dose by more than 0.3 mSv a^{-1}). In principle, the needed difference between these two quantities could also be achieved by setting the criterion for general exemption at a level well below 0.3 mSv a^{-1}, e.g. at 0.1 mSv a^{-1} or less. However, this would be impossible, from the economical and social point of view, because such doses are caused by many (or majority of?) commonly used building materials.

The only way how the criterion for exemption and that for the controls could have the same value (or values very near each another) would be an approach where the radiological specifications of all commonly used building materials should be determined and then the designer and the builder would be made responsible for designing and constructing the building in a way that the dose criterion would not be exceeded. The consequences of such an approach are discussed in more detail in reference (4).

5 CONCLUSIONS

The demonstrations presented showed that results of dose assessments concerning building materials may vary by a multiplier of at least 3, solely depending on the way the background is defined and considered in the assessment. Such non-harmonised approaches for dose assessments might lead to situations where a material can either be clearly accepted, or rejected, in different countries seemingly applying the same criterion for exemption or controls.

The adoption of the general exemption level of 0.3 mSv a^{-1} for building materials suggested in the technical guidance (2) necessitates the dose criterion for controls to be selected at a significantly higher level, i.e. at order of 1 mSv. If the criterion for exemption and that for the controls were not sufficiently apart from each other, they would incorporate mutually contradicting requirements. In this case only way to overcome such a contradiction would be to adopt a massive control programme where all building materials on the market should be specified for their natural radioactivity characteristics and radiological assessments are performed for all new buildings in their planning and construction phases.

The demonstrations presented suggest that before establishing radiological criteria and controls for building materials, thorough national assessments should be made on the actual scope and effects of such controls. This is especially important if a dose criterion significantly lower than 1 mSv a^{-1} is considered. If very stringent requirements are set, there is a severe danger that the actual scope of controls would widen intolerably from that intended, from the economical and social point of view, as knowledge and awareness of radiological characteristics of different materials, by-products and waste increase.

6 REFERENCES

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