PREPARING THE BUILDING INDUSTRY FOR THE NEW EURATOM BSS

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Abstract

In the proposed new Euratom Basic Safety Standards (EU-BSS), a reference level of 1 mSv/a is set for indoor external exposure to gamma rays emitted by building materials. An activity concentration index (ACI) is proposed as a conservative screening parameter for identifying building materials that may cause the reference level to be exceeded. An alternative in situ ACI determination method was developed and the validation of this method is discussed. This screening method was used to analyse numerous building materials available on the Belgian market. An attempt was made to identify building materials containing residues from naturally occurring radioactive material processing industries that pass through Belgium, by analysing results from a large scale radiological study of the container traffic in the port of Antwerp. In addition to the regulation provided on the gamma exposure from building materials, specific parts of the proposed new EU-BSS are dealing with radon issues separately. A reference level of 300 Bq/m³ for indoor radon concentration is proposed for the EU-BSS. Relationships between radon exposure and type of building material used, the airtightness of the building and the stage of construction work were determined.

1. INTRODUCTION

The European Commission is in the process of recasting the Euratom Basic Safety Standards (EU-BSS), which provide for the control of exposure of the public and workers to radioactivity [1]. The recasting process is nearing its conclusion and adoption by the Council is expected by the end of 2013.

The proposed new EU-BSS in their current form (draft version April 2013) provide for the regulation of building materials incorporating residues from NORM processing industries, such as fly ash, phosphogypsum, phosphorus/tin/ copper slag and red mud, as well as building materials with of natural origin. In the proposed new EU-BSS, the reference level for indoor external exposure to gamma emissions from building materials is 1 mSv/a. For verification of this

reference level, the following screening parameter in the form of an 'activity concentration index' (ACI) is proposed:

$$ACI = \frac{C_{Ra-226}}{0.3 \text{ Bq/g}} + \frac{C_{Th-232}}{0.2 \text{ Bq/g}} + \frac{C_{K-40}}{3 \text{ Bq/g}}$$
(1)

where $C_{\text{Ra-226}}$, $C_{\text{Th-232}}$ and $C_{\text{K-40}}$ are the concentrations (Bq/g) of ²²⁶Ra, ²³²Th and ⁴⁰K, respectively.

It is stated in the proposed new EU-BSS that the ACI relates directly to the incremental gamma dose in a building constructed from a specified building material (i.e. the dose above the dose typically received from outdoor exposure). The ACI applies to the building material, not to its constituents, except when those constituents are building materials themselves and are separately assessed as such, in which case an appropriate partitioning factor needs to be applied. The ACI is used as a conservative screening parameter. If the ACI ≤ 1 , the building material can be marketed without any restrictions associated with the radionuclide content. If the ACI > 1, a detailed dose assessment is required to demonstrate that the 1 mSv/a reference level is not exceeded. The dose assessment needs to take into account factors such as density, thickness of material and factors relating to the type of building and the intended use of the material (bulk or superficial). Once the proposed new EU-BSS is approved and becomes adopted in national legislation, cost efficient techniques for the measurement of activity concentration in an industrial context will be needed to support the building industry in the determination of the ACL

NORM residues such as fly ash produced in large quantities from coal burning, slags from steelworks and metal recycling industries, phosphogypsum from the phosphate industry and red mud from the bauxite processing industry are being investigated for use in building materials. In Table 1, a summary of European and worldwide production is given for some NORM residues that can be used as constituents of building materials. In addition, Table 1 provides a proposal for the codification of the listed NORM residues in the European Union Waste Catalogue. The use of NORM residues in the production of new types of synthetic building materials raises concerns among authorities, the public and the scientific community on the potential increase in gamma exposure of building occupants and on indoor air quality when considering radon and other chemical hazards.

Specific parts of the proposed new EU-BSS deal with indoor radon exposure separately from exposure related to gamma exposure of occupants. The proposal requires that Member States establish a national action plan addressing the management of long term risks from radon exposure in dwellings, buildings

	Source of residue	Estimated annual amount (million t)	Proposed EU Waste Catalogue codification
Fly ash	Coal fired power generation	44 (Europe) [2]	001 02 or 10 01 16
Slag and bottom ash	Coal fired power generation	8 (Europe) [2]	10 01 01 or 10 01 14
Phosphorous slag	Thermal phosphorus production		06 09 02
Phosphogypsum	Phosphoric acid production	180 (worldwide) [3]	I
Red mud	Bauxite processing (alumina production)	120 (worldwide) ^a	01 03 07
Slag	Primary iron production	260–310 (worldwide) [4]	10 02 02
Slag	Steel and lead smelting	130–210 (worldwide) [4]	10 04 01
Slag	Primary and secondary copper production	24.6 (worldwide) [5]	10 06 01
Slag	Primary and secondary tin production		
Pyro and hydrometallurgy esidues	Production of platinum group metals and rare earth elements		I
See http://www.redmud.org/L	Disposal.html (accessed on 14 May 2013).		

TABLE 1. NORM RESIDUES WITH POTENTIAL FOR USE IN BUILDING MATERIALS

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with public access and workplaces for any source of radon ingress, whether from soil, building materials or water. A reference level for indoor radon concentration of 300 Bq/m³ is proposed. If the radon concentration exceeds the reference level, the necessary technical and financial means have to be employed to reduce it.

2. MEASUREMENT EQUIPMENT AND METHODS

2.1. Portal monitor study in the port of Antwerp

A large scale radiological study of container traffic in the port of Antwerp was conducted during the period 23 April 2007 to 31 August 2010 by means of portal monitors. The alarm level of the portal monitors was set at five times the standard deviation of background variations. More details on the instrumental method used can be found in Refs [6–8].

2.2. In situ and laboratory based measurements to determine the ACI of building materials

Geometry corrected in situ measurements were performed to determine the ACI of building materials with an $LaBr_3(Ce)$ probe. The experimental method used for the analysis of the building materials is discussed in more detail in Ref. [9]. A detailed comparison of the properties of $LaBr_3(Ce)$ and NaI(Tl) probes is given in Ref. [10]. The results of the in situ method were compared with laboratory analyses of the samples using a high purity germanium (HPGe) detector for 21 days in a sealed container to achieve secular equilibrium before measurement while, for the in situ measurements with the $LaBr_3(Ce)$ probe, this was not the case.

2.3. Indoor radon measurements

A study was performed to determine the relationships between radon concentration and the type of building material, the airtightness of the building and the stage of construction work. During the winter of 2012, integrating passive radon detectors were exposed for three months and indoor radon concentrations were measured over a period of three days using a Sun Nuclear 1029 continuous radon monitor and a Sarad Radon Scout PMT. Airtightness measurements were performed with a Mineapolis blower door system and supporting Tectite software. The V50, v50 and n50 values were used to quantify the airtightness. The experimental approach is described in more detail in Ref. [9].

3. RESULTS AND DISCUSSION

3.1. Results for in situ determination of the ACI of building materials

A new industrially useful protocol for measurement of the ACI was developed to assess the applicability of newly developed materials for the European building market. The applicability of an in situ measurement methodology was investigated with the specific objective of aiding the industry in its search for cost efficient measurement techniques. An important aspect of the investigation was the validation of the so called B-NORM method that had been developed. A good correlation was found between the B-NORM in situ method and the certified laboratory based analysis using an HPGe detector (see Fig. 1). The slope of the regression line in Fig. 1 is 0.95 ($r^2 = 0.98$), indicating that the B-NORM method can provide a good estimate of the ACI for the materials within the measured range of values.

During the measurement campaign of the B-NORM investigation, the highest ACI found (for a natural stone product) was 3.65 when determined by the in situ method and 3.91 when determined by the laboratory method (see Fig. 1). This means that, on implementation of the proposed new EU-BSS in Belgium, a more detailed dose assessment will be required to determine whether the dose is below the 1 mSv/a reference level before allowing this natural stone to be put on the Belgian market for use in dwellings. A more detailed discussion of the results is given in Ref. [9].



FIG. 1. Comparison of ACI determined by the B-NORM in situ method and by the certified laboratory based HPGe method for 14 tiles, 11 natural stone products and 1 gypsum product.

3.2. Database of building materials and potential NORM constituents

Figure 2 gives a summary of the results from a large scale portal monitor study at the port of Antwerp. Alarms at the detection portals (103 600 events) were attributed to various categories of materials on the basis of the shipping information. The database was compiled during the Megaports project [6] and the NuTeC-NORM project [8] by combining several databases with in-house measurement information. All percentages considered in the discussion below refer to percentages of the 103 600 events.

Figure 2 indicates that 23% of the events were attributed to the category 'stones and tiles' that contained, among other things, bricks, slate, sandstone, natural stone, a wide variety of tiles, paving stones and marble. Since not all of these subcategories were well defined on the basis of recorded shipping information, a quantitative assessment of the subcategories was difficult. It was found that 1% of the events could be assigned to the category



FIG. 2. NORM database relating to 103 600 alarms at detection portals, classified according to shipping information, for the period 23 April 2007 to 31 August 2010.

'concrete-cement-asphalt-bitumen' and 14% of events to the category 'ceramicsrefractory materials'. Furthermore, it should be noted that about 1% of events in the category 'other' were classified as "building materials" (without further specification) and that it was unclear if these events needed to be attributed to the category 'stones and tiles' or one of the other categories. A more detailed description of the database and its different categories is given in Ref. [8] and more detailed publications are being prepared.

3.3. Indoor radon measurements

A group of six neighbouring dwellings in Neeroeteren, Belgium, were selected or this study. The soil in this area consists of moist sand. At the time of the experiment, the dwellings were at different stages of construction (see Fig. 3). This resulted in different levels of airtightness. During the study, no one entered the building. In this way, differences in radon concentration due to external parameters were excluded. In Dwelling 1, the floor screed and plastering of the walls had been completed; while in Dwellings 2 and 3, the plastering was complete but no screed had been applied. In Dwellings 4, 5 and 6, neither the plastering nor the screed had been applied.

The results are presented in Table 2. The indoor radon concentration is clearly higher in buildings with a better airtightness. Both parameters seemed to be inversely proportional, as shown in Fig. 4. These results confirm the importance of a good, functioning ventilation system, especially in dwellings with limited natural ventilation such as low energy and passive dwellings. In this way the radon risk can be minimized.



Dwelling 1

Dwelling 2,3

Dwelling 4,5 and 6

FIG. 3. Various construction stages of the dwellings.

	Dwelling						
	1	2	3	4	5	6	
Screed	Yes	No	No	No	No	No	
Plaster	Yes	Yes	Yes	No	No	No	
n50 (h ⁻¹)	3.28	8.79	9.40	31.86	27.93	29.68	
$v50 (m^3 \cdot h^{-1} \cdot m^{-2})$	3.69	8.34	9.68	32.50	26.46	33.89	
Radon concentration (Bq/m ³)	57	48	29	13	12	26	

TABLE 2. RESULTS OF INDOOR RADON MEASUREMENTS



FIG. 4. Inverse proportionality of radon concentration to airtightness.

The contribution of radon to the radiation exposure is not fully accounted for in the ACI used in the proposed new EU-BSS. It is shown in Refs [11–13] that the assessment of the radon situation in dwellings is a multidimensional problem to solve. In houses, distinguishing between radon emanation from the soil and radon from the building materials is not straightforward and therefore the

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approach of the proposed new EC-BSS in dealing with radon issues separately from exposure related to gamma exposure is supported.

4. CONCLUSIONS AND OUTLOOK

4.1. Conclusions

An alternative, in situ ACI determination method has been developed and validated. This method was used to analyse various building materials available on the Belgian market and can serve as a screening tool to support the industry when the proposed new EU-BSS are implemented.

A NORM database of building materials has been established, which gives an idea of which materials, both those of natural origin and those incorporating NORM residues, pass through Belgium. However, owing to limitations on the quality of the shipping information, a systematic investigation of such building materials could not be carried out.

In the proposed new EU-BSS, a reference level for indoor radon is established in addition to the reference level for gamma exposure from building materials. The relationship between indoor radon concentration and airtightness of buildings was investigated and confirmed the importance of a good, functional ventilation system to assure that indoor radon concentrations stay well below the reference level proposed in the EU-BSS.

4.2. Outlook

The depletion of energy resources and raw materials has a huge impact on the building market. In the development of new synthetic building materials, the use of various industrial residues becomes highly desirable. Therefore a new 'COST' network proposal has been submitted to stimulate the collaboration of scientists, industry and regulators in the development of knowledge, experience and new technology to stimulate research on the use of NORM residues in tailor made building materials in the construction sector, while considering the impact on both external gamma exposure of building occupants and indoor air quality. By improving radiological impact assessment models for the use of NORM residues in building materials, the proposed COST action aims to further stimulate justified uses of NORM residues in different types of newly developed building materials. Based on these models, the proposed COST action aims at investigating realistic legislative scenarios so that the authorities concerned can allow uses of NORM residues that are acceptable from a radiation protection point of view in accordance with the Lead Market Initiative and sustainable construction. The COST proposal is awaiting final approval in May 2013.

ACKNOWLEDGEMENTS

Funding for the research projects mentioned in this paper was provided by the Ministry of the Flemish Community (Hermesfonds: 45% of the NuTeC-NORM and B-NORM projects), EFRO (40% of the NuTeC-NORM and B-NORM projects) and LRM. In addition, the authors would like to acknowledge the contribution and support from P. Fias (Controlatom), F. Biermans and T. Peeters (Federale Overheidsdienst Financiën), M. Bruggeman (SCK-CEN), A. Poffijn and S. Pepin (FANC), S. Verhoeven, S. Schepens, P. Vannitsen, L. Hulshagen, C. Vandervelpen and T. De Clerck (XIOS Hogeschool Limburg).

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