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The use of portable equipment for the activity concentration index determination of building materials: method validation and survey of building materials on the Belgian market

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ABSTRACT

The Euratom BSS requires that in the near future (2015) the building materials for application in dwellings or buildings such as offices or workshops are screened for NORM nuclides. The screening tool is the *activity concentration index* (ACI). Therefore it is expected that a large number of building materials will be screened for NORM and thus require ACI determination. Nowadays, the proposed standard for determination of building material ACI is a laboratory analyses technique with high purity germanium spectrometry and 21 days equilibrium delay. In this paper, the *B-NORM* method for determination of building material ACI is assessed as a faster method that can be performed on-site, alternative to the aforementioned standard method. The *B-NORM* method utilizes a $LaBr_3(Ce)$ scintillation probe to obtain the spectral data. Commercially available software was applied to comprehensively take into account the factors determining the counting efficiency. The ACI was determined by interpreting the gamma spectrum from ^{226}Ra and its progeny; ^{232}Th progeny and ^{40}K. In order to assess the accuracy of the *B-NORM* method, a large selection of samples was analyzed by a certified laboratory and the results were compared with the *B-NORM* results. The results obtained with the *B-NORM* method were in good correlation with the results obtained by the certified laboratory, indicating that the *B-NORM* method is an appropriate screening method to assess building material ACI. The *B-NORM* method was applied to analyze more than 120 building materials on the Belgian market. No building materials that exceed the proposed reference level of 1 mSv/year were encountered.

1. Introduction

On average, one stays for 80% of the time indoors. Therefore, it is relevant to assess the radiation dose a person receives from the building materials. Most building materials contain certain amounts of the naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K. Building materials of natural origin reflect the geology of their origin (Haquin, 2008). Besides this, the trend to re-use industrial by products in building material may enhance the building material activity concentration. Therefore, it is relevant to study NORM in building materials. Moreover, NORM in building materials will be legally regulated in the near future (Euratom, 2013).

The Basic Safety Standards (BSS) is a European Directive concerning (among others) the protection of the public and the workers against the dangers of ionizing radiation. It is expected that the EU member states will ratify the Directive by 2015. The new Euratom BSS, explicitly mentions natural radioactivity in building materials:

> "The competent authority shall make arrangements for the classification of identified types of building materials, as laid down in Annex 11,[1] on the basis of their intended use and *activity concentration index* I."

The article also states that the radiological information shall be published before marketing the material.

In order to determine the building material activity concentration index I, one has to determine the activity concentrations of the radionuclides ^{226}Ra; ^{232}Th and ^{40}K. Different formulas exist for the calculation of the activity concentration index; e.g. (Steger et al.,

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[1] The Annex number is likely to change in final version of the text.

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1992) but the most widespread formula is the one used in the Euratom BSS:

$$I = \frac{C\,^{226}Ra}{300} + \frac{C\,^{232}Th}{200} + \frac{C\,^{40}K}{3000} \quad (1)$$

With: C = activity concentration of the respective nuclide in secular equilibrium [Bq/kg]

The activity concentration index (ACI) of a building material, whether bulk or superficial material shall not be higher than 1. If the index is higher than 1, a dose model should be calculated in order to determine the annual excess external dose. The activity concentration index is related to the excess gamma radiation dose resulting from the use of the respective materials. It is applicable for the material as a whole and not for its constituents. The extra gamma radiation dose due to the use of building materials may not exceed the reference level of 1 mSv/a. The constants in the formula are derived for a described room and a material with a certain density (EC, 1999). If the actual room or material circumstances differ from the circumstances on which Equation (1) is based, it may not be completely accurate. This causes, among relevant parties, some discussion concerning the applicability of one formula for all different building materials.[2]

If the allowed reference level of 1 mSv/year is exceeded, the competent authority shall decide on appropriate measures ranging from registration, dosimetric study, general application of relevant building codes, to specific restrictions on the envisaged use of such materials. The requirement to determine the activity concentration index implies that in the near future, numerous gamma spectrometric analyses have to be performed on building materials.

With the *B-NORM* project, NuTeC strives for the development of an easy to operate; on-site measurement method (Bronson, 2008), that facilitates companies with gamma spectrometric measuring tools. This method is intended to be a valuable *in situ* screening tool that can be used additionally with "conventional" high resolution gamma spectrometry in a laboratory.

2. Materials and method

2.1. Materials: building materials

The current paper is focused on building materials that are available on the Belgian market. The most common types of building materials that are applied in the construction of dwellings are studied. The results are discussed per type of building materials: tiles and stones; bricks, concrete, cement and gypsum.

2.2. B-NORM method

In the *B-NORM method*, a Canberra Inspector 1000 (In1k) equipped with an intelligent stabilized 1.5″ $LaBr_3$(Ce) probe is used to obtain the spectral data. The $LaBr_3$(Ce) probe is operated at ambient temperature and has improved properties compared to NaI(Tl) probes: it has a 2.9% resolution at 662 keV (7% for NaI(Tl)); 160% relative light output and a fast decay time of 16 ns. The In1k can be set-up in any room with a reasonable low and stable background. High background radiation is detrimental, especially when measuring low activity materials. Measuring in 100 nSv/h or higher background level should be avoided.

[2] EAN-NORM round table workshop; "Transportation of NORM, NORM Measurements and Strategies, Building Materials" Nov. 29th – Dec. 1st 2011, Hasselt (Belgium).

Fig. 1. B-NORM method: setup for counting a sample.

In practice, e.g. when measuring in a supplier's warehouse, one should make arrangements with the owner so that no materials are removed or positioned near the measuring location; because these actions will alter the background radiation during the acquisition.

In a first stage, the background spectrum is acquired. This step is required for each different measurement location. Then, the sample is positioned in front of the probe and the spectrum is acquired. The spectrum acquisition itself is a "one-touch and let alone" operation that can be performed by untrained personnel. The sample geometry consists of well-positioned whole building materials, e.g. a stack of tiles, a stack of packs of tiles, a pallet of bricks or a stack of concrete testing cubes from the firm's own material testing lab. An example of an actual measurement setup is shown in Fig. 1. We carefully determine the geometry dimensions, mass, shape, material composition and detector configuration and position. This information is loaded into Canberra *In Situ Object Counting Software* (ISOCS) to determine the counting efficiency of the measurement setup. The influence of the sample size and geometry is discussed under 3.1.

Spectrum analysis is performed with Genie2000. The analysis includes (besides peak localization and net peak area calculation) a peaked background correction, efficiency correction, selection of applicable peaks from the nuclides of interest and an interference correction.

When the activity concentrations of the nuclides are determined, the ACI (Activity concentration index) is calculated. The nuclide ^{226}Ra can be assessed with the *B-NORM* method in two ways. First option is to directly determine ^{226}Ra by measuring its 186.2 keV line and correcting 57.1% for natural ^{235}U (185.9 keV). This correction is only correct if the assumption that the natural equilibrium has not been disturbed is true. The second option is to determine the ^{214}Pb and ^{214}Bi progeny of ^{226}Ra. This option will be accurate only if the secular equilibrium is not disturbed. In fact, it can not be absolutely assured that any of these assumptions will lead to the actual, accurate determination of the activity of ^{226}Ra. Since building materials are usually dense materials and the material thickness is large because we are not milling the materials, we assume the secular equilibrium condition to be met and therefore we calculate the ^{226}Ra concentration via ^{226}Ra progeny.

2.3. Method validation

The current accepted "standard" method for gamma spectrometric analysis of solid substances is to analyze the sample in a laboratory with a lead-shielded high purity germanium detector. The geometry is a precisely defined, usually relatively small sample