Construction and Building Materials 49 (2013) 448–454

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

# Screening tools to limit the use of building materials with enhanced/elevated levels of natural radioactivity: Analysis and application of index criteria

Rosabianca Trevisi [a,*], Cristina Nuccetelli [b], Serena Risica [b]

[a] Italian National Workers' Compensation Authority (INAIL), Department of Occupational Hygiene, Via Fontana Candida 1, 00040 Monteporzio Catone (Rome), Italy
[b] Italian National Institute of Health (Istituto Superiore di Sanità ISS), Technology and Health Department, Viale Regina Elena 299, 00161 Rome, Italy

## HIGHLIGHTS

- Database of natural radionuclide content in EU building materials.
- Various methods available to evaluate effective dose due to building materials.
- We applied different approaches to the database.
- Based on the RP112 Index, a new index is hereby proposed.
- The results obtained with different indexes are compared.

## ARTICLE INFO

*Article history:*
Received 25 March 2013
Received in revised form 1 August 2013
Accepted 29 August 2013

*Keywords:*
Natural radioactivity
Building materials index
Effective dose

## ABSTRACT

Until now various methods have been developed in several countries to evaluate and classify building materials on the basis of their natural radioactivity. Some of them also account for the contribution of radon to the annual effective dose. In this paper the authors review these methods and apply some of them to the contents of a database of natural radioactivity of building materials in the European Union, that was established by the authors. Based on the activity concentration index introduced by the EC Radiation Protection 112 guidance, $I_{RP112}$, a new index is also proposed, that accounts for the radon contribution to the effective dose indoors. The results obtained with different indexes are compared in order to evaluate the impact of the new Basic Safety Standards Directive implementation in the EU Member States, particularly in Countries where radioactivity in building materials is already regulated. Moreover, some non EU screening tools were considered to provide suggestions for possible future improvements of the EC $I_{RP112}$.

© 2013 Elsevier Ltd. All rights reserved.

## 1. Introduction

Building materials can cause significant gamma dose indoors, due to their natural radionuclide content. Moreover, they can also be a source of indoor radon: building materials contribution is estimated to be up to 30% [1]. A large database of activity concentration measurements of natural radionuclides ($^{226}Ra$, $^{232}Th$ and $^{40}K$) in building material has been set up in the last years [2], through a large review of scientific literature and personal communications from some experts. Since in some publications only the average values for activity concentration were available, in order to make data comparable the authors decided to use only the arithmetic means (source data set) for each material reported in each paper. For this reason, the variability of activity concentration is underestimated.

The database refers to about 10,000 samples of both bulk material (bricks, concrete, cement, natural-gypsum and phospho-gypsum, sedimentary and igneous bulk stones) and superficial material (igneous and metamorphic stones) used in most Member States of the European Union (MS). The number of non-stony bulk materials (bricks, concrete, cements and gypsum: about 6900 samples) for each MS is quite different – in some cases very small – and activity concentrations vary widely [2]. The database contents have been used for the calculation of the *activity concentration index I* ($I_{RP112}$) – as defined in the EC guideline Radiation Protection 112 [3], for some of these non-stony bulk materials [4]. This is an important starting point for a discussion at the European level on the consequences of future legislative requirements, since this index was adopted in the *Proposal for a COUNCIL DIRECTIVE laying down basic safety standards for protection against the dangers arising*

* Corresponding author. Tel.: +39 0694181264.
*E-mail address:* r.trevisi@inail.it (R. Trevisi).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.08.059

*from exposure to ionising radiation* (ECBSS), as a screening tool to harmonise the control, and allow the free transportation and trade of building products within the EU [5].

Aim of this paper was to analyse the various indexes reported in the literature, apply them to the contents of the database, and compare the results in terms of the materials that could possibly be excluded from the market.

## 2. Review of the main methods for screening building materials from the radiological protection point of view

Numerous methods have been published in the literature to screen building materials from the radiological protection point of view. Several of them estimate effective dose indoors from gamma radiation, and some of them also account for the contribution from radon exhaled by such materials. This is the case with Austrian, Czech, Dutch and Israeli indexes, which have long been in force as national regulations. These methods were reviewed and are summarized in the following, in order to evaluate the impact of the new Basic Safety Standards Directive implementation in the EU Member States. The non EU country screening tools, like the Israeli index and the former Yugoslavia method, were considered to provide suggestions for possible future improvements of the EC $I_{RP112}$.

### *2.1. The general approach to an index I*

In general, an index is introduced and used as a screening tool to limit gamma exposure from building materials; it consists of the sum of the contributions of the natural radionuclides to the gamma dose. In order that the material complies with the screening, the index should not generally exceed the value of 1 (see Eq. (1)).

$$I = C_{Ra\text{-}226}/A_{Ra\text{-}226} + C_{Th\text{-}232}/A_{Th\text{-}232} + C_{K\text{-}40}/A_{K\text{-}40} \leqslant 1 \quad (1)$$

where $C_x$ is the measured activity concentration (Bq kg$^{-1}$) and $A_x$ is the fixed parametric values (Bq kg$^{-1}$).

The $A_x$ parametric values are calculated after assuming a dose criterion to be complied with and a background to be subtracted. These values also depend on the geometric and structural characteristics of the indoor environment and the dose coefficients per unit activity concentration used, i.e. the chosen room model. For this reason, $A_x$ values may significantly vary from country to country. Frequently, the assumptions account for the radionuclide concentrations of typical materials of each country, due to the socio-economic consequences of banning the use and trade of these materials.

### *2.2. Index $I_{RP112}$*

The guideline Radiation Protection 112 [3] chose the values 300 Bq kg$^{-1}$, 200 Bq kg$^{-1}$ and 3000 Bq kg$^{-1}$ for $A_{Ra\text{-}226}$, $A_{Th\text{-}232}$ and $A_{K\text{-}40}$, respectively, for bulk building material, therefore the $I_{RP112}$ index is defined in the following way

$$I_{RP112} = C_{Ra\text{-}226}/300\ \text{Bq kg}^{-1} + C_{Th\text{-}232}/200\ \text{Bq kg}^{-1} + C_{K\text{-}40}/3000\ \text{Bq kg}^{-1} \quad (2)$$

The index derives from the consideration that "Within the European Union, doses exceeding 1 mSv year$^{-1}$ should be taken into account from the radiation protection point of view". This means that the $A_x$ values were obtained assuming: (i) a dose criterion of 1 mSv year$^{-1}$ – as the excess to the average background originating from the Earth's crust – (ii) an occupancy factor of 7000 h year$^{-1}$, and (iii) a conversion coefficient 0.7 Sv Gy$^{-1}$. The background dose rate, corresponding to an average value outdoors in Europe, was assumed to be 50 nGy h$^{-1}$. With the cited hypotheses, 50 nGy h$^{-1}$ correspond to about 0.25 mSv year$^{-1}$. The other data used to calculate the $A_x$ values of Eq. (2) were: a room of $4 \times 5 \times 2.8$ m$^3$, with walls, ceiling and floor made of concrete with 0.2 m thickness and 2350 kg m$^{-3}$ density.

RP112 also considers a second dose criterion of 0.3 as an exemption level – i.e. the level below which "building materials should be exempted from all restrictions concerning their radioactivity" – and provides the relevant $A_x$ values: 121 Bq kg$^{-1}$, 101 Bq kg$^{-1}$and 1390 Bq kg$^{-1}$ for radium, thorium and potassium, respectively. However, instead of changing the $A_x$ values, it prefers to change the limit value of the index concluding that "...the same activity concentration index can be used if its limit value is set at 0.5 instead of 1".

It is worth highlighting that RP112 states very clearly that "the activity concentration index should be used only as a screening tool for identifying materials which might be of concern", but "any actual decision on restricting the use of the material should be based on a separate dose assessment".

The RP112 guide [3] was the basis for the $I_{RP112}$ screening tool adopted in the new ECBSS [5]. However, at present this draft is still under discussion and significant modifications could be introduced before the new ECBSS is issued.

Lastly, the guideline also considers how to screen materials to be used superficially, but this is not discussed in this paper.

In 2002, Denmark [6] adopted this index for the exemption of building materials (dose criterion 0.3 mSv year$^{-1}$ and $I \leqslant 0.5$).

### *2.3. Index I in Austria*

In 1995 Austrian legislation established an index *I* that accounts for exposure from both gamma radiation and radon exhalation from building materials [7].

$$I = (1 + 0.15k)C_{Ra\text{-}226}/1000\ \text{Bq kg}^{-1} + C_{Th\text{-}232}/600\ \text{Bq kg}^{-1} + C_{K\text{-}40}/10{,}000\ \text{Bq kg}^{-1} \leqslant 1 \quad (3)$$

where *k* is a constant which depends on some characteristics of the materials, i.e. density, thickness and radon emanation power. The dose criterion used to calculate the $A_x$ is 2.5 mSv year$^{-1}$.

In 2009 a new regulation was issued, which improved the radon contribution estimate to the excess indoor effective dose [8], changing the index definition in this way:

$$I = (1 + 0.07\varepsilon\rho d)C_{Ra\text{-}226}/880\ \text{Bq kg}^{-1} + C_{Th\text{-}232}/530\ \text{Bq kg}^{-1} + C_{K\text{-}40}/8800\ \text{Bq kg}^{-1} \leqslant 1 \quad (4)$$

where $\varepsilon$ is the radon emanation power, $\rho$ the wall density, *d* the wall thickness and 0.07 is a constant, expressed in (m$^2$ kg$^{-1}$), resulting from the exposure model applied [8]. Where specific information is not available, $\varepsilon$ can be set at 10%, *d* at 0.3 m and $\rho$ at 2000 kg m$^{-3}$.

These parameters affect only the contribution of the radon term, and the estimation of the excess gamma dose remains independent of the density of the material and geometry of the room. The dose criterion used to calculate the $A_x$ is 1 mSv year$^{-1}$, and the assumed outdoor background dose is 1.2 mSv year$^{-1}$ [9].

### *2.4. Index I in Israel*

In 2009, Israel also adopted a similar approach and issued the standard SI 5098 for building materials radioactivity [10]. It should be pointed out, however, that this is not a screening tool, but a *standard*, actually the third version of it: the first SI 5098 Standard was issued in 2002 and a revised Standard in 2007. The 2009 standard accounts for both gamma radiation and radon exhalation

Download English Version:

https://daneshyari.com/en/article/6724859

Download Persian Version:

https://daneshyari.com/article/6724859

Daneshyari.com