Assessment of the population exposure indoors due to natural radioactivity in building material: comparison between the EU index I and other computational methods

C.Nuccetelli[1], S.Risica[1], R.Trevisi[2]

[1]National Institute of Health (Istituto Superiore di Sanità), Technology and Health Department, Viale Regina Elena 299, 00161 Rome, Italy.
[2]Italian National Workers' Compensation Authority (INAIL), Dept Occup. Hygiene, Via Fontana Candida 1, 00040 Monteporzio C. (Rome), Italy.

Abstract

A wide database of activity concentration in building material allowed the authors to calculate the *activity concentration index I* - as defined in the EC guideline Radiation Protection 112 - for several building materials used in the European Union. This index was adopted in the draft *Euratom Basic Safety Standards Directive* (EBSSD) to harmonise the control and allow free movement of building products within the EU. Many countries developed methods to classify building materials on the base of their natural radionuclide content, some of them also taking into account radon from building materials. A short review of this *index family* was carried out. Last step was to evaluate the impact of the draft EBSSD implementation in European Member States (EU MS) where building material regulations are already in force.

The Inventory of European Building Materials

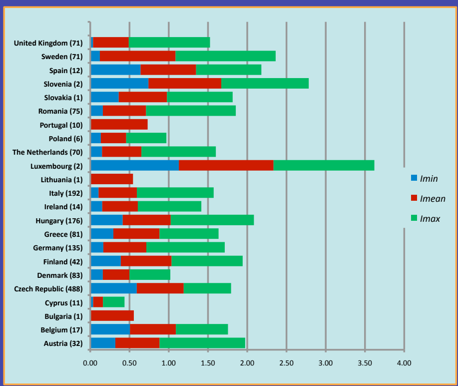

Fig. 1 Index I (RP112) in bricks in 23 EU MS (1593 samples)

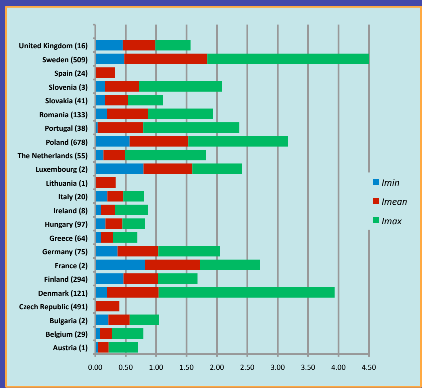

Fig. 2 Index I (RP112) in concrete in 22 EU MS (2704 samples)

The authors set up a database of activity concentration measurements of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in building material. It refers to 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 EU Member States [J. Env. Rad. 105 (2012) 11-20].

The number of non stony bulk materials (bricks, concrete, cements and gypsum: about 6900 samples) for each EU MS is low in some cases, and quite different. A wide variability of activity concentrations was high-lighted. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K is not available for all the samples: in these cases the index I could not be applied. (Fig 1,2).

Table 1. Percentage of EU bulk materials exceeding 0.3 and 1 mSvy^{-1}

Bulk Material	N of samples with complete data set	Dose criterion (mSv y^{-1})	
		0.3	1
Brick	1593	91%	5%
Concrete	2704	62%	5%
Phosphogypsum	257	98%	84%

Calculating the index I of RP112 for bulk building materials, the percentage of materials exceeding the two dose criteria – 0.3 and 1 mSv y^{-1} - was evaluated (Table 1). 91% of bricks and 62% of concrete samples exceed the dose criterion of 0.3 mSv y^{-1}, whereas only a 5% of samples exceeds 1 mSv y^{-1}.
Therefore, the goal of not exceeding 1 mSv y^{-1}, criterion chosen in the EBSSD, seems easily achievable.
On the other side a high percentage of phosphogypsum samples also exceeds 1 mSv y^{-1}, this means that its usage could undergo significant restrictions in EU MS.

Index family

In literature many methods to screen building materials were published. In Table 2 formulas of some approaches are shown. Some of them take into account the Rn contribution, in particular Austrian and Israelian formulas, already in force in relevant regulations.
A modified EC RP 112 method is here proposed to provide a tool which considers building materials as a source of both γ and Rn exposures.
These different index equations were applied to the EU building materials database. The results are shown in Table 3.

Table 2. Definition of different indexes I

Method (dose criterion)	Index equation	Comments
EC Index I method (from RP 112) (0.3 mSv/y and 1 mSv/y)	$I=\frac{C_{Ra-226}}{300\ Bq\ kg^{-1}}+\frac{C_{Th-232}}{200\ Bq\ kg^{-1}}+\frac{C_{K-40}}{3000\ Bq\ kg^{-1}}$	$I \le 1$ 1 mSv/y $I \le 0.5$ 0.3 mSv/y
Modified EC Index I method (from RP 112) (1 mSv/y + Rn contribution)	$I=(1+\alpha)\frac{C_{Ra-226}}{300\ Bq\ kg^{-1}}+\frac{C_{Th-232}}{200\ Bq\ kg^{-1}}+\frac{C_{K-40}}{3000\ Bq\ kg^{-1}} \le 1$	Where α is a factor taking into account : • outdoor ^{222}Rn background (10 Bq/m^3) • emanation, density and wall thickness • ^{222}Rn dose criterion chosen: 3 mSv y^{-1} = 100 Bqm^{-3} (ICRP 2009)
Austrian ÖNORM 2009 (1 mSv/y)	$I=(1+0.07\varepsilon\rho d)\frac{C_{Ra-226}}{880\ Bq\ kg^{-1}}+\frac{C_{Th-232}}{530\ Bq\ kg^{-1}}+\frac{C_{K-40}}{8800\ Bq\ kg^{-1}} \le 1$	Where: ε = emanation power (%) ρ = density (kg m^{-3}) d = wall thickness (m)
"Ra equivalent" Method – Ra_{eq} (1 mSv/y)	$Ra_{eq}=C_{Ra}+1.43C_{Th}+0.077C_K$ $\frac{C_{Ra}}{370\ Bq\ kg^{-1}}+1.43\frac{C_{Th}}{370\ Bq\ kg^{-1}}+0.077\frac{C_K}{370\ Bq\ kg^{-1}} \le 1$	Where: C_{Ra}, C_{Th} and C_K are the activity concentration (Bq kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K, respectively
Israelian SI 5098: 2009 (0.3 mSv/y)	$I=\frac{C_{Ra-226}}{A_1}(1-\varepsilon)+\frac{C_{Ra-226}}{A_2}\varepsilon+\frac{C_{Th-232}}{A_3}+\frac{C_{K-40}}{A_4} \le 1$	Where: ε = emanation power (%); it differs depending on build. material A_x= coefficients depending on nuclide, density and thickness (Bq kg^{-1})

Table 3. Percentages of samples exceeding different indexes I

	RP112	RP112	RP112+Rn	Raeq	Ö-NORM2009	SI 5098 2009
Dose criterion (mSv/y)	≤0.3	≤1	≤ 1 γ; ≤ 3 ^{222}Rn	≤ 1	≤ 1	≤ 0.3
Background (mSv/y) from outdoors	0.25	0.25	0.25 γ; 0.3 ^{222}Rn	-	1.2	
Background (mSv/y) from indoors						0.25 γ; 0.85 ^{222}Rn
Bricks	**91%**	**5%**	**8%**	**0%**	**0%**	**8%** (ε=0.07)
Concrete	**62%**	**5%**	**8%**	**4%**	**3%**	**50%** (ε=0.12)

Conclusions

In all cases – except RP 112 criterion of 0.3 mSv/y - the percentage of concrete samples exceeding the screening methods chosen is ≥ than the percentage of bricks, particularly when Rn emanation is considered. This may be due to the fact that in some countries concrete samples have high Ra concentration (> 300 Bq/kg).

When Rn contribution is accounted for, the application of the RP 112 doesn't change the results dramatically, i.e. the percentage of concrete and brick samples increases from 5% to 8%. Therefore the application of such a formula is feasible and represents the exposure situation more accurately from a radiation protection point of view.

As regards phosphogypsum, only the RP 112 index was applied, resulting in most of samples exceeding the 0.3 mSv y^{-1} and the 1 mSv y^{-1} dose criteria, therefore its usage could undergo strong restrictions in EU MS.

Presenting author, e-mail: cristina.nuccetelli@iss.it