BUILDING MATERIAL WITH ENHANCED OR ELEVATED LEVELS OF NATURAL RADIOACTIVITY: ANALYSES OF THE USE OF INDEX CRITERIA FOR LIMITING THEIR USE

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THE DATABASE OF BUILDING MATERIALS IN MEMBER STATES

Dolabella and Silano arch and *Navicella* street, Rome

The Database

It contains ^{226}Ra, ^{232}Th and ^{40}K activity conc. measurements in building material

- ⟶ collected with a large review of scientific literature and personal communications
- ⟶ used in most Member States of the European Union (24 out of 27 MS)
- ⟶ data for Estonia, Latvia and Malta could not be found by the authors
- ⟶ about 10,000 samples (at least)

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Country	Number of samples
Austria	105
Belgium	218
Bulgaria	42
Cyprus	55
Czech Republic	1531
Denmark	307
Finland	439
France	44
Germany	299
Greece	1032
Hungary	849
Ireland	35
Italy	1112
Lithuania	2
Luxembourg	89
The Netherlands	219
Poland	1331
Portugal	78
Romania	737
Slovakia	60
Slovenia	6
Spain	423
Sweden	625
United Kingdom	284
Total	9922

Number of sets of data collected for each Member States in the database

Trevisi R., D'Alessandro M., Risica S., Nuccetelli C.
Natural radioactivity in building materials in the European Union: a database and an estimate of radiological significance
J. Environ. Radioactivity 2012; 105: 11-20

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The database composition

Building material	Use	N. of samples
brick and concrete	bulk	≅ 4400
cement and gypsum	bulk/superficial	≅ 2500
natural stone (igneous and metamorphic)	bulk/superficial	≅ 900
phosphogypsum	bulk/superficial	≅ 290
fly and bottom ash, typically	additives	≅ 1300
others such as wood, tiles, etc.	limited	≅ 500

REVIEW OF INDEXES/METHODS AS SCREENING TOOLS

The general approach to an index I

$$I = \frac{C_{Ra-226}}{A_{Ra-226}} + \frac{C_{Th-232}}{A_{Th-232}} + \frac{C_{K-40}}{A_{K-40}} \leq 1$$

where

C_x = measured activity concentrations (Bq kg^{-1})

A_x = fixed parametric values (Bq kg^{-1}), they

- are calculated with a dose criterion and a background to be subtracted
- depend on the geometric and structural characteristics of the indoor environment and the dose coefficients/unit activity concentration used (room model)
- vary widely from country to country

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The index I in RP112 (I_{RP112})

$$I = \frac{C_{Ra-226}}{300\ \mathrm{Bq\ kg^{-1}}} + \frac{C_{Th-232}}{200\ \mathrm{Bq\ kg^{-1}}} + \frac{C_{K-40}}{3000\ \mathrm{Bq\ kg^{-1}}}$$

Basis: "Within the European Union, doses exceeding 1 mSv y^{-1} should be taken into account from the radiation protection point of view"

- dose criterion = 1 mSv y^{-1} (excess average background)
- occupancy factor = 7000 h y^{-1}
- dose conversion coefficient = 0.7 Sv Gy^{-1}
- average background = 50 nGy h^{-1} ≅ 0.25 mSv y^{-1}

European Commission 1999. Radiation Protection 112.
Radiological protection principles concerning the natural radioactivity of building materials. Luxembourg

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The index I_{RP112} (cont.)

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

RP112: "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".

In 2002, Denmark adopted this index for the exemption of building material (dose criterion 0.3 mSv y^{-1} and $I \leq 0.5$)

The index I in Austria (Önorm S 5200)

In 1995

$$I = (1 + 0.15k)\frac{C_{Ra-226}}{1000\ Bqkg^{-1}} + \frac{C_{Th-232}}{600\ Bqkg^{-1}} + \frac{C_{K-40}}{10000\ Bqkg^{-1}} \leq 1$$

where

k depends on material density and thickness, and
Rn emanation power

In 2009

$$I = (1 + 0{,}07\varepsilon\rho d)\frac{C_{Ra-226}}{880\ Bqkg^{-1}} + \frac{C_{Th-232}}{530\ Bqkg^{-1}} + \frac{C_{K-40}}{8800\ Bqkg^{-1}} \leq 1$$

where

ε = radon emanation power
ρ = wall density
d = wall thickness

dose criterion = 1 mSv y^{-1}

outdoor background dose = 1.2 mSv y^{-1}

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The Ra equivalent (Ra_{eq})

Still used by some authors

$$Ra_{eq} = C_{Ra} + 1.43\, C_{Th} + 0.077\, C_K$$

where

C_{Ra}, C_{Th} and C_K = activity conc. of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1})

Basis: the assessment that
10 pCi g^{-1} (=370 Bq kg^{-1}) of ^{226}Ra
7 pCi g^{-1} of ^{232}Th and
130 pCi g^{-1} of ^{40}K
yield the same γ dose of 150 mrad y^{-1} (now 1.5 mGy y^{-1} ≅ 1 mSv y^{-1}) chosen as dose criterion

This condition is generally expressed in the following way:

$$C_{Ra}/10 + C_{Th}/7 + C_K/130 \leq 1\ \text{pCi/g}\ (37\ \text{Bq/kg})$$

Beretka I., Mathew P.I. Natural radioactivity of Australian building materials, waste and byproducts. Health Phys. 1985; 48: 87-95.

APPLICATION OF SOME INDEXES/METHODS TO THE DATABASE

Aureliano's **Walls, Rome**

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Index/method hypotheses

Hypotheses	Screening tools			
	I_{RP112}		Ra_{eq}	Austrian index
Limit value	0.5	1	370 Bq kg^{-1}	1
Dose criterion (mSv y^{-1})	≤0.3	≤1	≤ 1	≤ 1
Outdoor background* (mSv y^{-1})	0.25	0.25		1.2

*Outdoor γ or radon background dose - calculated with the indoor occupancy factor - subtracted from the indoor dose

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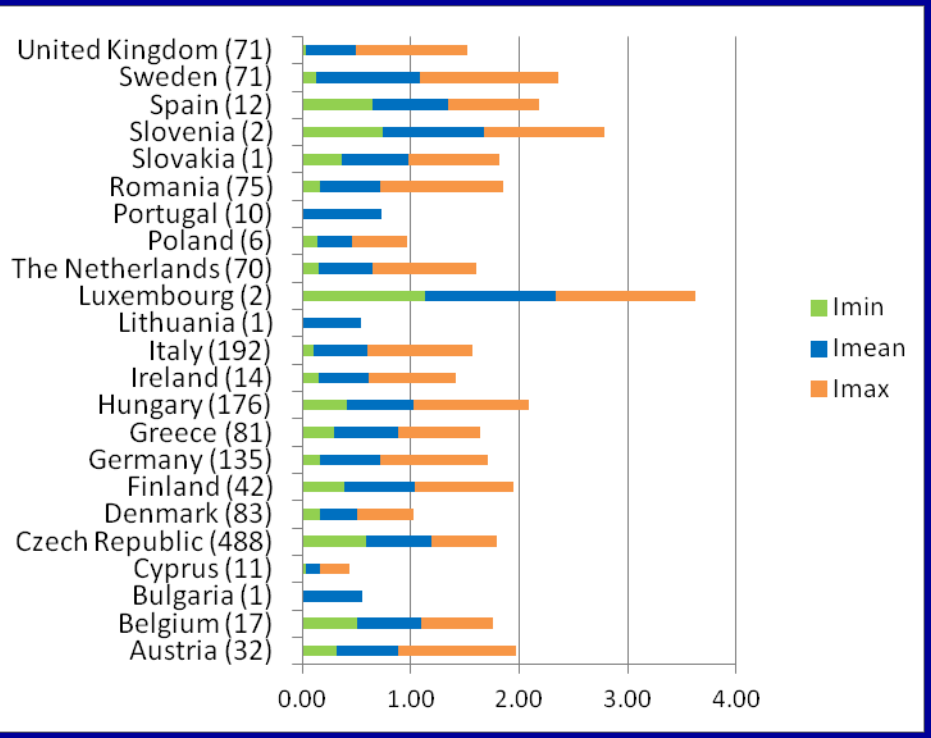
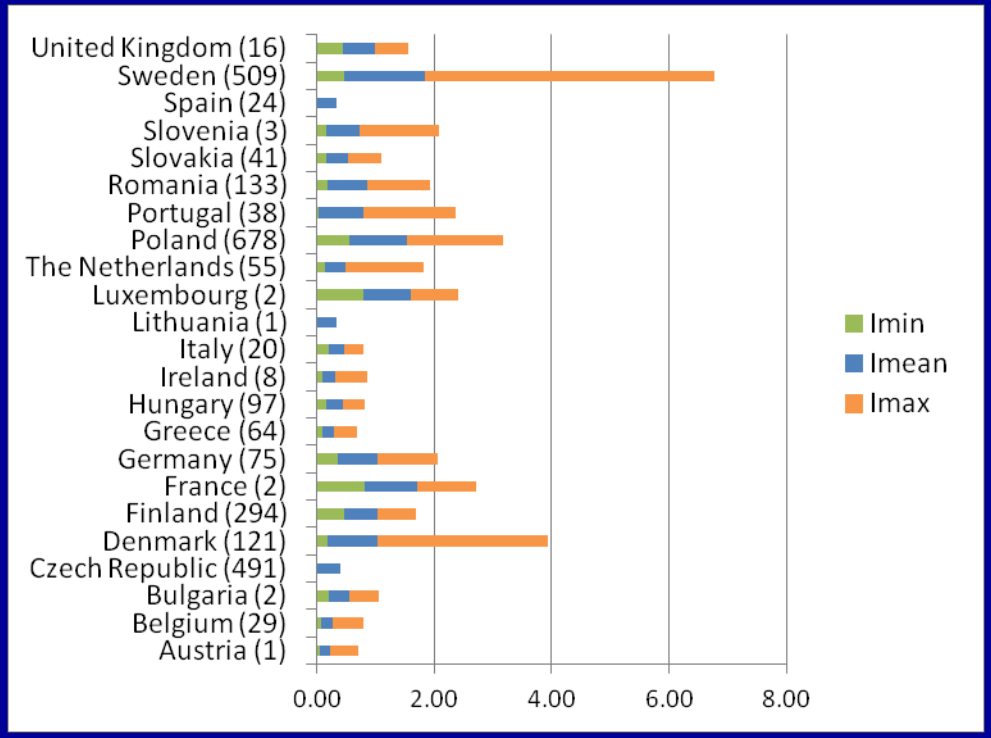
Index I_{RP112} applied to the database



bricks
(on 1593 samples out of a total of 1676)



concrete samples
(on 2704 samples out of a total of 2727)

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Percentages of samples exceeding the limits of various indexes/methods

Building material	Screening tools			
	I_{RP112}		Ra_{eq}	Austrian index
	0.3 mSv y^{-1}	1 mSv y^{-1}		
Bricks	91%	5%	0%	0%
Concrete	62%	5%	4%	3%

- generally, the percentage of concrete samples ≥ the percentage of bricks
- the reason: ^{226}Ra concentration quite high (> 300 Bq kg^{-1}) in the concrete of some countries?
- more deep analysis needed!

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The Jewish Ghetto, Rome

CONCLUSIONS AND FUTURE PROSPECTS

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- different screening tools? ⟶ different results for each material as for which materials should be excluded from the market
- no surprise: different hypotheses and methods
- other methods in literature make use of more elaborate models
- Basic Safety Standards draft (EC, 2011): "Where appropriate, actual doses for comparison with the reference level shall be assessed using more elaborate models which may also take into account the background outdoor external exposure from local prevailing activity concentrations in the undisturbed earth's crust"

- with the *room model* used in RP112 the percent variation of the γ absorbed dose rate in air vs density of walls, floor and ceiling is very significant (Risica, Bolzan, Nuccetelli, 2001)
- if each MS adapted index I to its mean background*, the exemption on materials would vary widely within the EU (Nuccetelli, Risica, Trevisi, 2012 in press)
- what about the free movement of building materials in the EU?
- the authors are continuing this type of investigation and analysis

*the background to be subtracted in I_{RP112} calculation - for which a mean value of 50 nGy h^{-1} was used - ranges from 18 nGy h^{-1} for Portugal to 84 nGy h^{-1} for Cyprus (UNSCEAR 2000, UNSCEAR 2010)

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Thank you very much for your attention

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