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Natural radioactivity in building materials in the European Union: a database of activity concentrations, radon emanations and radon exhalation rates

C. Nuccetelli, S. Risica, S. Onisei,
F. Leonardi, R. Trevisi

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Natural radioactivity in building materials in the European Union: a database of activity concentrations, radon emanations and radon exhalation rates

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2017, 70 p. Rapporti ISTISAN 17/36

A database of activity concentration measurements of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in European building materials is presented. It contains about 23000 samples of bulk materials – bricks, concrete –, their constituents – cement, aggregates, NORM (Naturally occurring Radioactive Material) residues, etc. – and superficial materials used in the construction industry in most European Union Member States and some European Countries. In addition, density and radon emanation and/or exhalation rate information related to approximately 1500 samples of building materials or their components have been collected and organized in one table.
Key words: Building materials; Natural radioactivity; Activity concentration; Radon emanation and exhalation

Istituto Superiore di Sanità
Radioattività naturale nei materiali da costruzione nell'Unione europea: un database di concentrazioni di attività, emanazioni di radon e rateo di esalazione di radon.
Cristina Nuccetelli, Serena Risica, Silviana Onisei, Federica Leonardi, Rosabianca Trevisi
2017, 70 p. Rapporti ISTISAN 17/36 (in inglese)

Viene presentato un database di misure di concentrazione di attività di radionuclidi naturali (^{226}Ra, ^{232}Th e ^{40}K) nei materiali da costruzione utilizzati dall'industria edile nei paesi membri dell'Unione Europea (UE) e in alcuni paesi europei non UE. Il database contiene dati su circa 23000 campioni di materiali strutturali – mattoni, calcestruzzo, ecc. –, dei loro componenti – cemento, aggregati fini e grossolani, residui NORM (Naturally occurring Radioactive Material), ecc. – e di materiali superficiali – mattonelle, pietre. Sono state inoltre raccolte e organizzate in una tabella le informazioni su densità ed emanazione e/o esalazione del radon relative a circa 1500 campioni di materiali da costruzione o di loro componenti.
Parole chiave: Materiali da costruzione; Radioattività naturale; Concentrazione d'attività; Emanazione ed esalazione del radon

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DATABASE DESCRIPTION

Due to their natural origin radionuclide content, building materials can cause significant gamma dose indoors and contribute to the indoor radon concentration. A first database of the activity concentrations of ^{238}U(^{226}Ra), ^{232}Th and ^{40}K in about 10000 samples of building materials used in 25 of 27 European Union Member States (EU MS) was already collected (1) by a wide review of the relevant literature. That database accounted for previous databases. In particular, the 1996 European Commission (EC) publication (2) and a study on Italian building materials conducted in 1999 (3) were considered.

The 1996 EC publication (2) was the data source for the elaboration of the EC technical guidance for the regulatory control of building materials RP112 (4). In the Euratom Basic Safety Standards Directive (5) the RP112 guidance approach and results were the bases to introduce the regulatory control and screening of building materials of radiological concern.

From 2012 to 2017 the database has been significantly enriched. Indeed, now it contains radiological data on 23500 samples from 26 of 28 MS and also radon emanation/exhalation rate information for a subset of samples (about 1100). The collection of data has been further extended to 2 EU candidate countries and 2 non EU countries increasing of about 400 the total number of considered samples.

This new database comprises measurements of natural radionuclide activity concentrations (^{226}Ra[a], ^{232}Th and ^{40}K) of about 23900 samples used in 26 of 28 EU MS, in 2 EU candidate countries (the former Yugoslav Republic of Macedonia and Turkey) and in 2 non EU countries (Norway and Switzerland) (Table A). Where available, radon emanation/exhalation rate information concerning about 1120 building material samples have been also collected (see Table A). Moreover, for other 370 samples without data concerning activity concentrations only information related to radon emanation/exhalation rate were collected.

The updating procedures have been carried out through a broad review of international and some national literature, including peer reviewed papers, reports and personal communications (*see* Database references).

All data have been carefully checked and validated, mainly in order to avoid mis-classification and multiple counting of identical sets of sample information reported in different papers.

This database includes activity concentration measurements of several categories of building materials, in particular:

- products (bricks, concrete, cements) – about 8400 samples;
- aggregates (sand, gravel, etc.) about 3600 samples
- natural raw materials (tuff, lime, clay, gypsum, etc.) – about 2100 samples – used in bulk amounts and for some superficial application
- industrial by-products: by-product gypsum (434 samples), coal ashes (5908 samples), metallurgical slags (774 samples) and bauxite residues/red mud (71 samples); total about 7190 samples;
- others such as wood, tiles, etc. (about 1550 samples) and natural stones used as superficial products (about 610 samples).

The total number of samples, as already described in a previous paper (1), is certainly an underestimation. Indeed, in some publications only the activity concentration average values are reported, without specifying the number of samples analysed. In these cases, the value 1 was assigned to the number of samples *N*.

[a] In the database ^{238}U activity concentration is considered as equivalent to ^{226}Ra one and *vice versa.*

Table A. Summary of all data collected

Country	Total data	Data with activity concentration		Data with only emanation/ exhalation rate data
		total	with emanation/ exhalation rate	
Austria	126	126		
Belgium	250	249	40	1
Bulgaria	42	42		
Cyprus	99	99		
Czech Republic	6745	6745		
Denmark	326	326	69	
Estonia	16	16		
Finland	530	530	20	
France	104	104	73	
Germany	1042	711	27	331
Greece	1455	1454	198	1
Hungary	1511	1511		
Ireland	57	57		
Italy	1112	1105	285	7
Latvia	3	3		
Lithuania	9	9		
Luxembourg	126	126		
Netherlands	269	269	124	
Poland	5729	5729	58	
Portugal	145	128	78	17
Romania	635	635	4	
Slovakia	2148	2148	29	
Slovenia	7	7		
Spain	426	426		
Sweden	648	648		
United Kingdom	249	249	17	
Total EU MS	**23809**	**23469**	**1022**	**340**
Macedonia	30	30		
Norway	219	206	10	13
Switzerland	86	86	86	
Turkey	86	86		
Total	**24230**	**23860**	**1118**	**370**

It is important to underline that measurements published in literature and collected in the database were generally performed for radiation protection purposes on samples of materials presumed to be among the most active ones, without claim to be representative at national level. Therefore, these data cannot contribute to elaborate a representative snapshot of building materials in the Europe.

In this report, the data on activity concentrations are organized in 30 tables, one for each country. In each table data are divided into categories of building materials and their constituents, with particular attention to the industrial by-products residues (in *italic* in the following list), generally called NORM (Naturally occurring Radioactive Material) residues:

- Brick;
- Concrete;
- Cement;
- Aggregates;
- Tiles;

- Natural raw materials;
- Natural covering stones;
- *Ashes (fly and bottom);*
- *Bauxite residues/red mud;*
- *Byproduct Gypsum;*
- *Metallurgical slag*.

Table 31 presents radon emanation and radon exhalation rate data of about 1500 samples from countries with available data. Due to the scarcity of data, this lay out was considered more appropriate. Information about sample density and thickness are also present when reported in the relevant reference. Data in Table 31 are referred both to samples with information on activity concentration in Tables from 1 to 30 (fourth column in Table A), both to a sub set of samples with only information on radon emanation and exhalation rate (fifth column in Table 5). In Tables from 1 to 30 samples with emanation/exhalation rate data in Table 31 are marked with "^". However, for these samples only values about ^{226}Ra are reported in Table 31, since it is the significant activity concentration information regarding radon.

Considered the huge amount of data, in order to reduce the table sizes abbreviations have been introduced to shorten sample names and categories of information reported. In Table B the legend of abbreviations is shown.

Table B. Legend of abbreviations

Abbreviations	Extended term
BA	Bottom Ash
BFS	Blast Furnace Slag
d	Sample Thickness
FA	Fly Ash
N.	Number Of Samples
PZL	Pozzolana
PFA	Pulverized Fuel Ash
PHG	Phosphogypsum
PTL	Portland
RM	Red Mud

References

1. 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 Radioact* 2012;105:11-20.
2. European Commission. *Radiation Protection 96. Enhanced radioactivity of building materials*. Luxembourg: European Commission; 1997.
3. Risica S, Bolzan C, Nuccetelli C. Radioactivity in building materials: experimental methods, calculations and an overview of the Italian situation, 1999. *Workshop "Radon in the Living Environment" (Athens, 19-23 April 1999)*, p. 415-428 (CD-ROM).
4. European Commission. *Radiation Protection 112. Radiological protection principles concerning the natural radioactivity of building materials.* Luxembourg: European Commission; 1999.
5. Council of the European Union. Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. 2014. *Off J European Union* L 13/1, 17.1.2014.

Tables of activity concentrations of building materials used in 30 European countries

Table 1 Austria
126 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	32	38	71	20	45	112	16	635	880	520	AU1
Concrete											
Concrete	1	15	21	7	14	57	3	164	382	***16***	AU1
Cement											
Cements	18	27	49	11	14	26	10	210	286	89	AU1
Aggregates											
Sand gravel	6	14	18	6	15	67	2	171	433		AU1
Tiles											
Tiles	5	48	91	18	56	135	13	528	819	343	AU1
Natural raw materials											
Limestones	4	9	19	2	3	5	1	34	63		AU1
Others											
Plasters	7	33	50	10	19	33		288	431	12	AU1
Accessories *(glass,asbestos,asphalt, binders etc.)*	3	8	12	5	2	4		14	17	5	AU1
Natural covering stones											
Granites	22	55	117	10	25	186	16	911	1320	383	AU1
Basalts	4	23	30	14	30	37	18	307	496	150	AU1
Marbles	8	7	26	1	2	5		27	166		AU1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
By-products Gypsum											
Chemical gypsum	16	48	315	6	5	12	3	151	226		AU1

Numbers in Bold Italic= MDA (minimum detection level)

Table 2 Belgium
249 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Facade bricks	13	41	73	31	36	44	26	569	810	400	BE1
Building block	4	47	62	40	47	50	43	815	980	650	BE1
Brick^	14	32	85	15	33	52	15				BE2
Brick	47	34	85	15	32	63	16				BE3
Concrete											
Casted concrete	13	21	28	14	18	26	13	280	460	170	BE1
Concrete blocks	3	15	23	***7***	9	15	***6***	115	160	80	BE1
Argex block	3	42	58	***22***	42	53	***22***	490	550	430	BE1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Areated concrete	4	6	7	5	5	6	5	85	170	30	BE1
Concrete	1	24	30	16	27	40	13				BE2
Concrete blocks	5	31	58	***10***	34	72	***10***				BE3
Cellular concrete	2	***11***			***11***						BE2
Cement											
Cement	2	62	81	44	76	130	22				BE2
Cement p50	1	37			22			190			BE1
Cement p40	1	53			31			110			BE1
Cement hk40	1	64			51			250			BE1
Cement ppz30	1	51			43			470			BE1
Cement	20	47	163	***10***	54	148	***10***				BE3
Aggregates											
Sand-lime ballast	1	15			12			140			BE1
Broken rubble	1	5			7			160			BE1
Rolled rubble	1	14			16			310			BE1
Porphyry rubble	1	18			7			170			BE1
Sand o/2	1	9			10			340			BE1
Sand o/5	1	10			12			380			BE1
Sand, gravel	3	19	24	13	21	27	13				BE3
Slag aggregate	1	81			37						BE2
Natural raw materials											
Stone (11 out of 14 limestone)	14	19	50	5	16	84	5	240	1020	10	BE1
Limestone	1	21			5						BE3
Gypsum	1	***10***			***10***						BE3
Gypsum plasterboard^	14	***11***			***11***						BE2
Gypsum board	1	10			30			5			BE1
Gypsum plaster	6	13	43	6	5	5	5	80	120	20	BE1
Natural covering stones											
Schist	1	33			47						BE3
Phorphyry	1	27			32						BE3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Byproduct gypsum											
Sulphogypsum	3	25	40	***10***	38	39	***10***				BE3
Sulphogypsum powder	1	41			37						BE2
PHG	27	442	848	333	***10***						BE3
PHG board^	22	430	520	330	***11***						BE2
PHG powder	7	420	480	370	***11***						BE2
Metallurgical slag											
BFS	2	85	91	79	41	44	38				BE3

Numbers in Bold Italic= MDA (minimum detection level)

^ Data on emanation and/or exhalation of a subgroup of samples are reported in Table 31

Table 3 Bulgaria
42 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	1	42			43			600			EU2
Concrete											
Concrete	1	19			17			200			EU2
Cement											
Cement	1	29			19			160			EU2
Aggregates											
Concrete ballast	1	30			30			700			EU2
Tiles											
Wall Tiles	1	110			52			140			EU2
Stone Tiles	1	19			9			100			EU2
Natural raw materials											
Clay	1	30			50			180			EU2
Gypsum	17	10	14	6	5	20	1	40	61	15	EU1
Gypsum	1	7			2						EU2
Natural covering stones											
Marble	11	11	26	1	4	24	1	177	1400	13	EU1
Marble	1	2			2			1			EU2
Granite	1	90			60			1100			EU2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal ash and slag	1	120			60			500			EU2
Byproduct Gypsum											
From phosphate rocks	1	400			9			5			EU2
From apatite	1	18			25			1			EU2
Mineral sand											
Mineral sand	1	60			36			700			EU2

Table 4 Cyprus
99 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Grey clay (Per Xorio)	1	28			8			321			CY1
Grey clay (Tseri)	2	13			4			230			CY1
Grey clay brick (Tseri/Ayia Varnara)	1	***0.2***			6			293			CY1
Mixture of red and grey clay for bricks	1	***0.2***			5			192			CY1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Mixture of red and grey clay for bricks	1	4			4			165			CY1
Red clay (Levkara)	1	***0.1***			2			59			CY1
Red clay (Levkara/ Lythrondonta)	1	14			4			102			CY1
Red clay brick (Kornos)	2	***0.1***			3			66			CY1
Cement											
EN 197-1 Cem I 42.5 R	1	23			9			161			CY1
EN 197-1 Cem I 52.5 N	1	4			8			92			CY1
EN 197-1 Cem II A/L 42.5 N	1	24			5			4			CY1
EN 197-1 Cem II/A-M (L-S) 42.5 R	1	37			12			209			CY1
EN 197-1 Cem II/A-M (L-S) 52.5	1	33			10			151			CY1
EN 197-1 Cem II/A-P 42.5 N	1	25			11			194			CY1
EN 197-1 Cem II/B-M (L-S) 32.5 R	1	20			10			207			CY1
EN 197-1 Cem II/A-P 42.5 N	1	32			12			199			CY1
Aggregates											
Sand (Mitsero)	1	6			0			41			CY1
Tiles											
Red clay (Xylofagou) for tiles	1	34			16			377			CY1
Cement tile Mantonella-Lydia	1	12			2			4			CY1
Natural raw materials											
Sandstone calcareous (Kellia)	3	40			4			73			CY1
Limestone calcareous (Szomenos)	1	31			6			147			CY1
Limestone Yfalogenous (Xylofagou)	4	7			1			5			CY1
Chalk (Kalo Xorio)	1	34			6			119			CY1
Limestone (Androlykou)	1	21			0.3			7			CY1
Gypsos (Toxni) (for cement)	1	60			3			40			CY1
Chalk (Kalavasos) (for cement)	1	12			7			92			CY1
Limestone (Armenoxori) (for cement)	1	37			1			8			CY1
Marl (Vasiliko) (for cement)	1	48			7			289			CY1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural covering stones											
Diabase rock (Stavrovouni)	6	0.8			0.3			61			CY1
Diabase rock (Pelendri)	3	***0.1***			0.6			138			CY1
Diabase rock (Sia)	3	1			0.7			110			CY1
Diabase rock (Vasa)	2	3			0.5			113			CY1
Diabase rock (Pareklissia)	2	3			1.0			42			CY1
Diabase rock (Mosfiloti)	1	4			1.1			69			CY1
Diabase rock (Pyrga)	1	5			0.5			56			CY1
Granite (imported)	28	77	588	1	149	906	17	1215	1606	50	GR6
Granite (imported)	8	60	215	0.2	92	260	2	1141	1576	350	CY1
Marble (imported)	10	26	79	0.1	0.6	2	0.1	16	66	0.2	CY1

Numbers in Bold Italic= MDA (minimum detection level)

Table 5 Czech Republic

6745 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Brick	209	46			49			616			CZ1
Refractory brick	28	113			86			312			CZ1
Clay brick	279	49			48			567			CZ1
Concrete											
Concrete	491	33			24			495			CZ1
Areated concrete	1221	88			54			455			CZ1
Concrete-BA	16	30			44			268			CZ1
Concrete-BA	28	936			72			459			CZ1
Cement											
Clinker	10	31			20			193			CZ1
Cement	496	46			19			237			CZ1
Aggregates											
Aggregates	1240	48			42			664			CZ1
Sand	383	22			21			624			CZ1
gravel	154	21			21			519			CZ2
Natural raw materials											
Limestone	27	9			5			76			CZ1
Zircon sand	2	3692			1344			62			CZ1
Lime	73	15			7			90			CZ1
Clay	312	72			58			527			CZ2
Shale	37	174			131			493			CZ1
Gypsum	34	19			12			168			CZ1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
BA	159	219			87			491			CZ1
FA	1378	146			86			669			CZ1
Silica fume											
Silica fume	42	27			36			1443			CZ1
Byproduct Gypsum											
PHG	22	115			31			95			CZ1
Metallurgical slag											
Metallurgical slag	104	110			28			154			CZ1

Table 6 Denmark

326 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay Bricks	79	42	86	23	34	58	21	630	900	340	DK1
White Bricks (sand-lime)	4	8	11	6	6	11	4	280	340	160	DK1
Bricks^	1	42									DK1
Concrete											
Ready mix concrete	6	16	24	13	13	17	9	360	420	280	DK1
Aereated+Alum Shale	2	670			53			1190			DK1
Light weight aggregate	3	40	43	36	45	51	37	910	1000	860	DK1
Aereated	3	15	25	9	10	12	8	280	320	230	DK1
Concrete (5% FA-cement)^	1	10									DK2
Concrete (10% FA-cement)^	1	11									DK2
Concrete (15% FA-cement)^	1	12									DK2
Concrete (20% FA-cement)^	1	13									DK2
Concrete (25% FA-cement)^	1	14									DK2
concrEte (30% FA-cement)^	1	14									DK2
Concrete (25% FA-PTL cement)^	1	15									DK2
Concrete^	1	35									DK2
Cement											
Cement	6	20	30	9	12	21	***4***	90	140	***20***	DK1
Cement (5% FA)^	1	28			22			140			DK2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Cement PTL (25% FA)	1	65			52			240			DK2
Aggregates											
Concrete ballast (fine+coarse aggregates)	107	19	95	***4***	13	56	***4***	360	1150	240	DK1
Sand^	1	7			6			160			DK2
Granite chippings^	1	59									DK2
Gravel	1	9			10			190			DK2
Natural raw materials											
Lime stone	5	6			***4***			***20***			DK1
Gypsum	12	8	13	***4***	***4***	6	***4***	***20***	35	***20***	DK1
Others											
Insulation Material	5	***40***			***40***			***190***			DK1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal ash^	15	140	180	120	78	88	66	570	670	480	DK2
Coal ash^	16	170	200	130	160	190	120	290	430	190	DK2
Coal ash^	14	160	190	130	130	160	100	520	840	260	DK2
Coal ash ^	12	150	170	120	79	93	77	710	910	270	DK2
Coal ash	12	153	210	140	127	170	90	413	660	200	DK2
FA	1	150			81			640			DK2
Ash	10	150	210	110	90	160	74	730	1030	190	DK1

Numbers in Bold Italic= MDA (minimum detection level)
^ Data on emanation and/or exhalation are reported in Table 31

Table 7 Estonia
16 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Aseri brick	3	20	21	20	30	31	30	440	449	436	EST1
Misso Light brick	1	13			13			145			EST1
Misso Dark brick	1	18			19			207			EST1
Ash blocks	1	27.3			14			308			EST1
Concrete											
Concrete	1	35			11			207			EST1
Cement											
Kunda cement	1	47			21			587			EST1
Tiles											
Grosso 311 floor tile	1	64			82			344			EST1
Pronto 147 floor tile	1	49			86			285			EST1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural raw materials											
Clay (Siimusti)	1	69			82			678			EST1
Clay (finnish)	1	54			59			748			EST1
Clay (german)	1	36			55			447			EST1
Stone (Kolumbia)	1	26			28			480			EST1
Gypsum board	1	4			0.8			7			EST1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Ash blocks	1	27			14			308			EST1

Table 8 Finland

530 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay bricks	38	80	134	37	62	92	38	986	1185	780	FIN2
White bricks (sand-lime)	4	23	25	20	21	29	15	622	699	537	FIN2, FIN3
Concrete											
Concrete	15	53	70	36	38	53	28	838	960	791	FIN2
Concrete^	1	42									FIN2
Concrete^	1	49									FIN2
Concrete ^	1	60									FIN2
Concrete ^	1	66									FIN2
Concrete^	1	60									FIN2
Concrete ^	1	63									FIN2
Siporex-exp. concrete	2	49	53	45	36	40	31	359	385	333	FIN2
Concrete^	11	33	43	18	34	48	20	800	1010	490	FIN3, FIN4
Slag aggregates concrete^	1	75			59			400			FIN2, FIN3
Cement											
Cement	11	40	84	15	20	55	9	251	336	169	FIN2
Aggregates											
Concrete ballast	266	34	146	8	39	225	10	964	1856	394	FIN2
Natural raw materials											
Stones	1	68	210	***10***	93	370	***10***	1188	1700	250	EU2
Gypsum	1	7			2			25			FIN2
Others											
Insulation wool	8	16	31	4	7	14	2	157	275	90	FIN2
Wood	2	0.4	0.5	0.3	0.7	2	0.2	10	12	8	FIN2
Natural covering stones											
Anorthosite	1	8			8			310			FIN1
Diabase	1	2			4			86			FIN1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Gabro	1	21			19			400			FIN1
Gneiss	1	25			68			860			FIN1
Granite	13	94	170	12	141	380	23	1418	1690	860	FIN1
Granodiorite	1	44			37			1320			FIN1
Migmatite	1	33			94			1700			FIN1
Migmatite	1	20			22			650			FIN1
Soap stone	1	17			2			20			FIN1
Soap stone	1	1			1			27			FIN1
Soap stone	1	2			4			14			FIN1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal ash	25	130			78			600			FIN4
Peat ash	33	120			46			390			FIN4
Byproduct Gypsum											
By-product gypsum^	17	306	830	24	23	118	3	17	30	7	FIN2
By-product gypsum	61	470			23			19			FIN4
Metallurgical slag											
BFS	5	117	129	105	78	102	32	176	209	97	FIN2

Numbers in Bold Italic= MDA (minimum detection level)
^ Data on emanation and/or exhalation of 2 samples of this group are reported in Table 31

Table 9 France
104 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks^	3	***54***	58	50	***44***	45	43				FR1
Hollow brick^	5	***42***	44	40	***37***	37	36				FR1
Bricks	1	99			96			58			FR2
Clay hollow brick	1	133			106			118			FR2
Clear solid brick	1	61			99			21			FR2
Refractory brick	1	24			18			40			FR2
Concrete											
Concrete^	5	***13***	13.4	12.6	***13***	15	12				FR1
Concrete^	3	13			12						FR1
Concrete hollow blocks^	2	***8***	12	***5***	***4***						FR1
Concrete block	1	13			***10***			14			FR2
Cellular concrete^	4	***9***			***7***	8	6				FR1
Siporex	1	26			24			20			FR2
Cement											
Cement	1	32			21			24			FR2
Cement tile	1	111			109			52			FR2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Aggregates											
Sand	1	13			11			22			FR2
Tiles											
Tile (ardesia)^	2	***36***	39	34	***48***	48	47				FR1
Tile (faience)^	3	***113***	114	112	***69***	70	67				FR1
Tile (faience)	1	189			88			89			FR2
Tile (faience)	1	208			56			18			FR2
Tile (faience)	1	104			70			40			FR2
Tile (faience)	1	218			101			48			FR2
Tile (green marble)^	3	**1**			**2**						FR1
Tile (limestone)	1	**6**			**4**			2			FR2
Tile (natural stone)	1	**10**			**5**			1			FR2
Tile (sandstone)	1	176			69			68			FR2
Tile (stoneware)^	5	***141***	142	139	***68***	69	66				FR1
Tile (stoneware)^	4	***68***	74	62	***59***	54	63				FR1
Tile (terracotta)^	2	***61***	67	54	***66***	69	62				FR1
Tile (terracotta)^	2	***49***	52	46	***66***	68	64				FR1
Tile (terracotta)	1	76			80			63			FR2
Tile (terracotta)	1	86			90			17			FR2
Tile (white marble)^	4	**2**			**2**						FR1
Tile (white marble)	1	**5**			**4**			**1**			FR2
Natural raw materials											
Gypsum	1	15			8			8			FR2
Natural covering stones											
Stone slab^	3			***3.4***	**2.7**	2.7	2.6				FR2
Granite^	13	**370**	380	360	**672**	570	773				FR1
Ardesia	1	69			115			91			FR2
Ardesia artificial	1	54			29			7			FR2
Others											
Plaster^	2	***3***			***2***						FR1
Plaster^	6	**11**	14	8	***2***						FR1
Plaster^	2	**4.9**	5,1	4.6	***3***						FR1
Plaster	1	***9***			***6***			2			FR2
Rockwool	3	121	136	106	65	93	50	23	27	16	FR2
Glass wool IBR	1	340			59			21			FR2
Glass wool Glasco	1	34			***19***			17			FR2
Glass wool Thermolan	1	30			***22***			25			FR2
Mortar	1	16			***4***			2			FR2

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation of a subgroup of samples are reported in Table 31

Table 10 Germany

711 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay bricks	1	50	200	10	52	200	12	700	2000	100	GE3
Hollow brick	1	40	59	15	25	52	4	320	800	60	GE3
Bricks	132	96			96			592			EU3
Lime sand bricks	3	8	10	4	6	7	3	115	180	35	GE1
Bricks	27	48	63	38	57	98	37	719	1200	470	GE1
Red-slime bricks	23	281			233			333			EU3
Bricks^	1	68			37						GE2
Concrete											
Concrete	1	30	92	7	23	71	4	450	1300	50	GE3
Areated concrete	1	15	80	6	10	60	1	200	800	40	GE3
Light-weight concrete	1	30	90	***20***	30	80	***20***	1100	1600	700	GE3
Light-weight concrete with Pumice stone	1	80	200	20	90	300	30	900	2000	500	GE3
Light-weight concrete with Expanded clay	1	30	80	***20***	30	60	***20***	400	700	40	GE3
Light-weight concrete with Slag	1	100	700	20	100	200	20	500	1000	300	GE3
Light-weight concrete with crashed bricks	1	40	70	30	60	100	30	500	600	400	GE3
Light-weight concrete	7	62	98	27	49	83	28	845	850	710	GE1
Aerated concrete	10	18	26	8	12	19	5	193	350	97	GE1
Concrete	69	67			63			555			EU3
Areated concrete^	5	19			30						GE2
Heavy weight concrete^	5	52			15						GE2
Cement											
Clinker	1	50	200	10	52	200	12	700	2000	100	GE3
Cement	1	97	330	23	20	37	11	320	500	110	GE3
PTL cement	1	30	50	10	20	40	10	200	700	100	GE3
BFS cement	1	60	100	20	80	200	30	100	200	***40***	GE3
Alluminium cement	1	200	200	100	200	200	100	***40***			GE3
Cement	19	44			44			192			EU3
Cement and mortar	11	22	35	11	15	21	11	230	380	135	GE1
Azbest cement	1	***20***	40	***20***	***20***	40	11	100	300	***40***	GE3
Aggregates											
Sand, gravel	1	15	39	1	16	64	1	380	1200	***3***	GE3
Sand, gravel	50	***15***			***19***			259			EU3
Tiles											
Wall tiles	1	50	100	15	55	130	25	560	1000	250	GE3
Tiles and ceramics	5	88	110	67	62	97	39	429	620	295	GE1
Stove tiles	1	74			70			310			GE3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural raw materials											
Clay (Schamotte)	1	60	100	20	70	200	40	400	600	200	GE3
Tuff	1	100	200	***20***	100	300	30	1000	2000	500	GE3
Tuff (Porphyritic)	1	47	52	44	206	239	133	720	1700	22	GE3
Chalk sludge	1	9			2			26			GE3
Lime, hydrated lime	1	30	60	***20***	41	93	2	150		20	GE3
Gypsym, anhydrite	1	10	70	2	***5***	100	2	60	200	7	GE3
Clay (caolin)	1	90	200	30	100	200	70	600	1000	200	GE3
Gypsum product	5	8.6	13	4	3	6	2	51	120	***20***	GE1
Limestone^	5	9			15						GE2
Gypsum ^	1	10			7						GE2
Gypsum^	1	41			15						GE2
Gypsum ^	1	37			18						GE2
Limestone and marble	20	***19***			***19***			37			EU3
Pumice^	1	48			30						GE2
Pumice^	1	107			96						GE2
Pumice^	1	48			22						GE2
Pumice^	1	63			96						GE2
Pumice stone	20	111			126			1073			EU3
Sandstone^	1	11			7						GE2
Clay, slit	1	***40***	90	***20***	60	200	18	1000	2000	300	GE3
Natural covering stones											
Granite	1	100	500	30	120	311	17	1000	4000	600	GE3
Granite	34	96			81			1221			EU3
Granodiorite	1	56	73	40	44	104	37	850	990	380	GE3
Syenite	1	30			31			670			GE3
Dolerite	1	20	29	10	30	44	8	290	380	22	GE3
Diabase	1	16	25	10	8	12	4	170	210	100	GE3
Basalt	1	26	36	6	29	37	9	270	380	190	GE3
Phonolite	1	56			104			1270			GE3
Quartzoporphyry	1	54	56	15	77	98	53	1300	2100	1000	GE3
Quarrystone (porphyry)^	1	44			44						GE2
Ortophyre	1	17			22			1300			GE3
Lamprophyre	1	17	30	6	12	21	7	270	330	130	GE3
Augite porphyrite	1	55	61	46	67	79	57	1100	1300	1000	GE3
Lava	1	42	70	20	42	60	25	720	890	490	GE3
Granulit	1	10	16	4	6	11	2	360	730	9	GE3
Amphibolite	1	8			9	9	8	260	310	180	GE3
Serpentinite	1	3			7			180			GE3
Schist (hornblende)	1	13			14			380			GE3
Schist (fruct-phycides)	1	38	45	34	59	73	56	780	930	760	GE3
Marble-limestone	1	24	41	4	5	100	2	90	240	***40***	GE3
Marble-limestone	20	19			19			37			EU3
Graywacke	1	41	51	26	35	46	13	760	780	700	GE3
Oolite	1	19			31			580			GE3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Travertine	1	4			19			20			GE3
Sandstone-quartzite	1	20	70	13	25	70	15	500	1100	***40***	GE3
Flint stone	1	6			1			1			GE3
Augite	1	65			51			970			GE3
Others											
Mortars	7	27	53	11	19	31	6	226	310	120	GE1
Mineral wool	7	35	80	16	22	64	5	155	350	49	GE1
Plaster	19	8	22	2	6	31	1	75	220	12	GE1
Natural Plaster	23	***19***			***11***			74			EU3
Floor screed mortars	5	15	26	11	17	34	11	213	295	210	GE1
Ceramic raw materials	15	46	115	15	54	135	20	664	1700	65	GE1
Wood-wool board	1	21	25	19	12	14	11	210	360	50	GE3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Lignite filter ash	1	82	200	4	51	150	6	147	610	12	GE3
FA	1	200	400	80	100	300	60	700	1450	300	GE3
Boiler slag	1	68	110	24	54	120	7	200	330	20	GE3
FA	28	211			130			703			EU3
Byproduct gypsum											
From apatite	1	60	70	40	***20***						GE3
From apatite	2	56			***19***			***37***			EU3
From phosphorite	1	600	1000	300	20	160	4	110	300	***40***	GE3
From phosphorite	39	592			***15***			111			GE3
Unknown origin	7	***19***			***26***			74			EU3
From desulfur.flue gas	1	20	70	20	***20***			20			EU3
Metallurgical slag											
Copper slag (old)	1	1500	2100	860	48	78	18	520	730	300	GE3
Copper slag (new)	1	770	940	490	52	60	41	650	760	530	GE3
Nickel slag	1	52			78			76			GE3
Nickel-manganese slag	1	311			37			710			GE3
Aluminium slag	1	14	16	12	8	9	6	750	960	360	GE3
Iron-chrom.-silicon slag	1	9			6			10			GE3
Tin slag	1	1100	1200	1000	300	340	230	330			GE3
Slagstone^	1	78			37						GE2
Siemens-martin slag	1	20			7			22			GE3
Lead slag	1	270			36			200			GE3
Sulphur dross	1	12	15	8	***10***			58	85	30	GE3
Steel slag	1	13			7			21			GE3
Cupola slag	1	110			47			210			GE3
Bessemer slag	1	1000	1100	980	290	310	260				GE3
Refining slag	1	19	23	17	6	5	8	20	34	10	GE3
BFS	1	100	200	4	100	300	30	500	1000	200	GE3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Bauxite residues/red mud											
RM	1	200	800	***20***	400	1000	50	400	1000	***20***	GE3
RM	1	122	1600	20	183	1000	50				GE4
RM	1	190			370			***30***			GE5
Other residues											
Waste rock - mining	1	700	5900	36	70	100	27	700	1200	49	GE3
Phosphorus slag	1	53	86	32	74	82	65	170	270	58	GE3
Process residues	1	170	310	9	84	250	3	130	280	1	GE3

Numbers in Bold Italic= MDA (minimum detection level)

^ Data on emanation and/or exhalation of a subgroup of samples are reported in Table 31

Table 11 Greece

1454 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay bricks^	13	**37**	48	25	**42**	56	27	**686**	895	476	GR1
Bricks^	3	36	83	25	52	65	35	732	1058	539	GR13
Red brick	6	49	80	20	24	33	17	668	968	383	GR2
Brick^	3	52			41			551			GR3
Brick^	1	93			41			640			GR3
Brick^	1	81			42			704			GR3
Brick^	1	48			41			860			GR3
Brick^	1	63			42			659			GR3
Brick^	1	63			41			644			GR3
Clay bricks^	50	35	66	18	45	79	5	710	1050	10	GR4
Brick ^	1	42									GR10
Brick ^	1	46									GR10
Brick ^	1	41									GR10
Brick ^	1	53									GR10
Brick ^	1	45									GR10
Pumice stone brick^	1	48									GR1
Concrete											
Concrete - Thessaloniki	5	46	73	24	7	11	4	246	330	153	GR2
Concrete^	20	14	41	7	3	5	1	70	96	57	GR11
Concrete block^	3	85			4			43			GR3
Concrete block^	1	41			5			32			GR3
Concrete block^	1	25			3			23			GR3
Concrete block^	2	37			5			35			GR3
Concrete block^	3	30			3			25			GR3
Concrete block^	3	26			4			30			GR3
Concrete block^	3	22			3			25			GR3
Concrete block^	4	48			6			96			GR3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Concrete block^	2	37			4			33			GR3
Concrete block^	1	30			3			26			GR3
Concrete block^	1	48			5			41			GR3
Concrete block^	15	35	54	8	17	25	10	383	650	150	GR4
Concrete slab (cement with FA)^	1	140									GR1
Concr. block cement Kamari 0%PFA^	1	7									GR10
Concr. block cement Thessaloniki 0%PFA^	1	8									GR10
Concr. block cement Kamari 10%PFA^	1	11									GR10
Concr. block cement Thessaloniki 10%PFA^	1	11									GR10
Concr. block cement Kamari 20%PFA^	1	17									GR10
Concr. block cement Thessaloniki 20%PFA^	1	11									GR10
Cement											
Cement	4	64	77	38	15	16	11	457	553	330	GR2
PTL cement	2	40	48	32	14	17	11	195	210	180	GR10
Cement black	83	**88**	147	29	**22**	30	13	**252**	331	172	GR1
Cement white	10	**20**	26	14	**10**	13	7	**36**	67	5	GR1, GR9
Cement^	5	218	218	96	11			330			GR3
Cement^	4	215			26			222			GR3
Cement^	2	96			22			200			GR3
PTL cement 6% PFA	2	71			19			240			GR10
PTL cement 10% PFA	4	89	100	78	18	19	16	195	210	180	GR10
PTL cement 17% PFA	2	99			41			320			GR10
PTL cement 20% PFA	4	160	118		19	19	19	245	260	230	GR10
PTL 3% PZL	8	20	25	15	13	16	8	247	320	140	GR4
PTL 20% PZL	22	92	140	34	31	46	14	310	390	218	GR4
Pozzolanic cement	18	111	142	80	19	27	16	244	291	218	GR5
Cement white	18	28	48	19	16	22	11	32	79		GR5
Clinker	2	60	87	32	15	19	11	180	210	150	GR10
Clinker	1	15			14			141			GR5
Aggregates											
Sea sand	6	**10**	13	7	**12**	16	8	**224**	302	145	GR1, GR9
Sand	15	18	27	10	17	26	8	367	656	170	GR4
Gravel	15	11	22	2	12	30	1	140	260	5	GR4
Sand	20	12	15	7	3	10			60		GR5
Pearlite	1	46			56			1048			GR1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Rock sand (limestone, sand)^	2	**45**	81	9	**8**	11	4	**71**	100	41	GR3
Sand	13	**3**	5	1	3			**19**	37	1	GR1
Tiles											
Wall Tile	1	58			46			409			GR1
Tile	5	81	98	52	34	46	26	483			GR2
Tile^	2	89			41			885			GR3
Tile^	1	26			56			133			GR3
Tile^	2	78			15			804			GR3
Tile^	1	26			52			130			GR3
Ceramic tile	8	63	174	25	37	47	29	506	786	411	EU1
Mosaic	7	**3**	4	1	**2**	3	1	23			GR1
Granite tile^	26	67	195	2	95	450	1	1200	3800	50	GR4
Natural raw materials											
Sandstone	1	21			28			250			GR10
Limestone	20	14	21	2	2	2			25		GR5
Limestone	2	10	14	6	4	7	0	65	110	20	GR10
Gypsum	6	**6**	17	6	10			**23**	40	5	GR1, GR9
Gypsum	2	19	27	11	5	6	3	70	80	60	GR10
Gypsum	1	109			11			24			GR2
Lime (quicklime)	2	**21**	32	9	1						GR2
Pumice stone	5	**462**	874	50	**57**	60	54	**1103**	1158	1048	GR1
Gypsum	1	7									GR5
Natural covering stones											
Granite	13	42	91	4	42	70	15	630	1302	24	EU1
Granite	16	68	170	2	86	354	30	1175	1592	49	GR7
PZL	2	87	135	39	107	180	33	510	710	310	GR10
Marble Powder	20	1.8	3		2	3	1		***25***		GR1,GR5, GR9
Marble	18	16	108	1	13	142	0.4	171	986	9	EU1
Schist	1	36			31			490			GR10
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA (Thessaloniki)	4	330			53			190			GR10
FA (Kamari)	4	800			53			290			GR10
FA	7	747	850	590	67	73	58				GR12
FA	1	1041			55			462			GR5
FA (Megalopolis Unit I)	35	807			55			449			GR19
FA (Megalopol. Unit III)	35	845			56			502			GR19
FA	42	904			53			454			GR8
FA^	12	929	1176	663							GR8
FA	156	912			54			460			GR8
FA	350	**825**	1377	273	**53**	65	41	**402**	661	143	GR1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
FA	36	366	605	142	50	68	27	297	382	204	GR14
FA (Megalopolis Unit I)	2	1038	1056	1020	58	59	57	450	453	447	GR15
FA (Megalop. Unit III)	2	1046	1063	1028	59	60	58	442	445	438	GR15
BA (Megalopolis Unit I)	1	767			51			412			GR15
BA (Megalopolis Unit III)	1	831			50			451			GR15
BA (Megalopolis Unit I)	35	546			44			406			GR19
BA (Megalopolis Unit III)	35	587			44			423			GR19
BA	42	662			44			405			GR8
BA^	2	617	654	580							GR8
BA	60	**423**	743	102	**35**	49	20	**296**	480	111	GR1
Bauxite residues/red mud											
RM	1	379			472			21			GR16
RM	1	232			344			45			GR17
RM	3	122	185	13	276	412	15	105	160	72	GR18
Byproduct Gypsum											
PHG	1	642			8			26			GR2
PHG	2	547	570	524	2	4					GR10
Metallurgical slag											
Pyrite slag	1	15			1			20			GR10

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 12 Hungary

1511 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	176	57	200	30	48	67	33	666	925	444	H3
Concrete											
Concrete	95	15	22	7	13	24	7	234	407	148	H3
Cement											
PTL I	25	27			23			172			H2
PTL II	25	8			15			213			H2
PTL III	25	11			13			133			H2
PTL III S-54	25	8			16			248			H2
PTL IV	25	38			16			167			H2
PTL IV S-54	25	28			13			131			H2
PTL V	25	17			16			192			H2
PTL cement-FA I 350/10	25	55			49			383			H2
PTL cement-FA I 350/20	25	55			53			402			H2
PTL cement-FA II 350/10	25	14			19			261			H2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
PTL cement-FA IV 350/10	25	34			14			95			H2
PTL BFS cement III 350/20	25	22			18			228			H2
PTL BFS cement III 350/40	25	40			19			229			H2
PTL BFS cement V 450	25	16			19			211			H2
PTL BFS cement V 350/20	25	23			53			201			H2
PTL BFS cement V 350/40	25	61			23			226			H2
Clinker I	25	22			21			143			H2
Clinker II	25	10			14			285			H2
Clinker III	25	14			15			105			H2
Clinker IV	25	21			11			132			H2
Clinker V	25	11			15			181			H2
Aggregates											
Sand	50	17	25	9	37	49	25	509	686	331	H2
Natural raw materials											
Clay	125	18	26	4	36	53	10	497	709	186	H2
Limestone I	25	9			3			10			H2
Limestone II	25	0.6									H2
Limestone III	25	6			3			12			H2
Limestone IV	25	9			7			20			H2
Limestone V	25	2			0.6						H2
Gypsum	125	6	16	1	4	15	1	56	187		H2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal slag (Ajka)	35	1962	2893	578	42	81	16	198	386	45	H1
Coal slag (Tatabanya)	35	1912	2407	843	83	119	50	352	468	257	H1
Coal slag (Tatabanya)	35	298	523	160	40	37	48	273	333	227	H1
FA I	25	9			199			273			H2
FA II	25	92			70			423			H2
FA IV	25	228			75			610			H2
Bauxite residues/red mud											
RM Neszmely tailings pond A	1	300			260						H4
RM Neszmely tailings pond B	1	250			400						H4
RM Ajka	47	360	700	150	292	380	285	48	101	5	H5
RM Almásfüzitó	11	294	506	102	229	545	87	103	212	47	H5
Metallurgical slag											
BFS III	25	88			27			188			H2
BFS V	25	142			46			269			H2

Table 13 Ireland

57 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	14	42	139	7	31	50	8	482	1064	255	IRL1
Concrete											
Concrete	8	29	68	18	12	43	3	217	1100	16	IRL1
Cement											
Cement	3	60	107	27	11	15	3	131	252	66	IRL1
Aggregates											
Aggregate	9	24	75	10	16	54	1	482	1977	10	IRL1
Sand	1	8			10			443			IRL1
Sand	1	20			24			550			IRL1
Sand	1	9			***1***			12			IRL1
Tiles											
Tiles	9	76	124	44	26	36	20	671	1282	222	IRL1
Natural raw materials											
Gypsum	10	20	29	2	6	11	1	145	259	15	IRL1
Bauxite residues/red mud											
RM	1		240			460					IRL2

Table 14 Italy

1095 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Brick	10	47			51			729			IT4
Brick (sandstone)	2	6	8	3	9	12	5	277	328	225	IT12
Brick	5	36	44	20	31	42	20	711	865	509	IT12
Brick	2	55	81	29	99	148	49	717	883	550	IT11
Brick	1	14			20			282			IT17
Brick duplex	4	32	63	8	21	34	3	750	892	577	IT12
Bricks^	124	40			40			710			IT2
Bricks	12	39			45			696			IT6
Bricks^	1	110			97			380			IT13
Bricks^	1	96			90			160			IT13
Bricks^	1	20			25			410			IT13
Bricks^	1	35			36			560			IT13
Bricks^	1	34			40			680			IT13
Bricks^	1	76			33			590			IT13
Bricks^	1	32			39			530			IT13
Clay brick	8	47	56	32	50	65	40	694	959	365	IT8
Hollow brick	10	39	67	10	28	45	9	879	1169	638	IT12
Hollow brick (poroton)	6	27	56	3	22	44	12	844	1117	637	IT12

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Lekablock	4	22	28	15	16	26	9	524	869	253	IT12
Ytong	1	4			5			198			IT12
Concrete											
Concrete	7	19			24			457			IT6
Concrete (brick)	1	17			3			58			IT17
Concrete (cement +FA)	1	23			16			277			IT4
Concrete (PTL cement)	10	23			16			290			IT4
Concrete B** (cement+15% FA South Africa)^	1	18									IT2, IT2.A
Concrete B** (cement +15% FA US)^	1	13									IT2, IT2.A
Concrete B** (cement +26% FA South Africa)^	1	19									IT2, IT2.A
Concrete B** (cement +26% FA US)^	1	13									IT2, IT2.A
Concrete B** (cement +40% FA South Africa)^	1	19									IT2, IT2.A
Concrete B** (cement +40% FA US)^	1	15									IT2, IT2.A
Concrete B** (cement +5% FA South Africa)^	1	17									IT2, IT2.A
Concrete B** (cement +5% FA US)^	1	13									IT2, IT2.A
Concrete B**^	1	16									IT2, IT2.A
Concrete brick	1	15			17			474			IT12
Concrete-cement PZL325	1	21			38			200			IT10.A
Concrete^	1	18			12			230			IT13
Concrete^	1	13			20			390			IT13
Siporex	1	7			10			192			IT17
Cement											
Cement	1	24			28			445			IT17
Cement	4	21	25	10	18	27	9	243	266	208	IT12
Cement	1	78			167			707			IT18
Cement	1	73			156			747			IT18
Cement	1	33			46			318			IT18
Cement	1	63			123			846			IT18
Cement (special use)	2	44			11			183			IT4
Cement (with FA)	1	51			53			255			IT4
Cement 245	1	43			39			228			IT10.A
Cement 325	1	77			61			211			IT10.A
Cement powder	12	21			16			253			IT6
Cement PTL	9	16			14			205			IT4
Cement PTL	1	**30**	40	20	**50**	80	20	**125**	150	100	IT3
Cement PTL 325	1	16			11			213			IT4

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Cement PTL 425	1	51			51			279			IT10.A
Cement PTL 425	1	16			27			270			IT18
Cement PTL 425	1	13			10			199			IT4
Cement PTL 425	1	48			31			247			IT10.A
Cement PTL 425	1	53			108			314			IT10.A
Cement PTL 425 ARF	1	11			10			206			IT4
Cement PTL 525	1	**17**	17	17	**28**	29	27	**262**	270	253	IT11
Cement PTL 525	1	10			10			193			IT4
Cement PTL^	31	26			18			210			IT2
Cement PZL	1	**77**	81	72	**168**	172	164	**637**	667	607	IT11
Cement PZL	1	**75**	100	50	**85**	150	20	**425**	700	150	IT3
Cement PZL	1	83			137			662			IT4
Cement PZL	1	72			164			667			IT18
Cement PZL 325	1	61			126			480			IT10.A
Cement PZL 325	1	69			136			551			IT10.A
Cement PZL 325	1	78			149			735			IT10.A
Cement PZL 325	1	75			137			753			IT10.A
Cement PZL 325	1	98			240			788			IT10.A
Cement PZL 425	1	26			43			267			IT10.A
Cement PZL^	21	49			45			390			IT2
Cement^	7	38	40	12	22			218			IT15
Cement^	78	33			26			270			IT2.A
Aggregates											
Gravel	8	21			13			248			IT4
River gravel	1	13			15			145			IT18
River gravel	1	11			16			100			IT11
River gravel	1	14			14			134			IT11
Sand	1	16			4			34			IT17
Sand	1	15			10			334			IT17
Sand	4	21			24			477			IT4
Sand	14	24	113	1	27	88	1	528	1362	30	IT8
Sand	2	**10**	11	8	**17**	20	13	**442**	491	393	IT11
Sand	23	18			24			539			IT6
Sand	2	23			**17**	27	6	**611**	750	472	IT12
Sand & gravel^	61	15			17			390			IT2
Sand and gravel	1	20	27	13	18	26	9	403	638	168	IT3
Silicic sand	6	9			9			156			IT15
Tiles											
Facing tile	15	55			18			783			IT6
Paving tile	8	54			56			1026			IT6
Paving tile	5	64			68			680			IT4
Roofing tile (red clay)	1	23			30			540			IT13
Roofing tile (red clay)	1	24			36			590			IT13
Tile (ceramic glazed)	1	48			42			460			IT13

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Tile (ceramic glazed)	1	56			43			440			IT13
Tile (glazed-double fired)	1	79			66			890			IT14
Tile (glazed-single fired)	1	58			52			830			IT14
Tile (gres)	16	31			35			474			IT12
Tile (gres)	1	230			76			650			It13
Tile (gres)	1	50			59			520			IT14
Tile (gres)^	1	150			56			410			IT13
Tile (terracotta)	1	12			9			150			IT13
Natural raw materials											
Clay	2	**46**	55	38	**30**	33	28	**1077**	1158	995	IT12
Clay	3	29			31			412			IT4
Clay	5	45	52	38	49	54	46	687	767	600	IT8
Clay (caolin)	1	316			537			2521			IT5
Clay^	7	34	42	21	38			513			IT15
Gypsum	1	16			3			104			IT9
Gypsum	2	10	16	4	2	3	1	59	104	15	IT8
Gypsum	1	9			1			118			IT12
Gypsum (brick)	1	7			5			56			IT17
Gypsum - gypsum compound	3	8			2			62			IT4
Gypsum board	8	10	16	3	4	8	2	197	277	128	IT12
Gypsum^	5	6	13	0.6	2			32			IT15
Lime	1	7			8			300			IT4
Lime	1	17			12			84			IT17
Lime, hydrated lime	3	10	15	7	7	8	6	305	312	301	IT12
Lime, hydrated lime^	13	10			2			77			IT2
Limestone^	27	11	30	0.4	2			22			IT15
Limestone^	1	65			6			46			IT13
Limestone^	1	76			8			47			IT13
Limestones^	4	9	29	1	3.0			45			IT15
Limestone golden-yellow	1	12			0.7			5			IT1,IT7
Limestone-Vicenza stone	1	12			0.8			5			IT1,IT7
PZL	1	33			53			374			IT5
PZL	1	123			184			1113			IT5
PZL	1	191			309			1170			IT5
PZL	1	168			305			1490			IT5
PZL	15	210			250			1660			IT2
PZL	1	238			481			1888			IT11
PZL (Campania)	3	184	230	106	121	135	108	1840	2310	1330	IT8
PZL (Latium)	6	352	510	176	324	481	170	1641	1980	878	IT8
Sandstone^	1	33			32			530			IT13
Sandstone^	1	14			13			230			IT13
Stone	5	25	38	5	2	4	1	11	29	4	IT8
Tuff	1	273			241			1259			IT16
Tuff	26	160			200			1640			IT2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Tuff	8	296	550	160	309	404	163	1659	2370	937	IT8
Tuff	3	150	220	101	99	120	85	2033	2250	1900	IT8
Tuff	1	236			326			2229			IT4
Tuff (Avellino)	1	79			106			1387			IT17
Tuff (black)	1	316			387			2161			IT5
Tuff (black)	1	210			341			2180			IT5
Tuff (brick)	1	26			4			55			IT17
Tuff (compact yellow)	1	12			17			453			IT17
Tuff (friable yellow)	1	67			80			1414			IT17
Tuff (green)	1	61			93			1625			IT17
Tuff (grey)	1	90			102			1945			IT17
Tuff (grey)	1	107			121			1740			IT17
Tuff (grey)	1	243			542			1925			IT11
Tuff (lithoid red)	1	277			344			1822			IT5
Tuff (Neaples yellow)	1	73			86			2031			IT17
Tuff (red+black scales)	1	138			468			1641			IT18
Tuff (red)	1	185			302			1245			IT5
Tuff (red)	1	136			505			1468			IT11
Tuff (volcanic)^	1	92			138			1200			IT13
Tuff (volcanic)^	1	190			210			1900			IT13
Tuff (volcanic)^	1	280			270			1900			IT13
Tuff (yellow)	1	68			99			1589			IT17
Tuff (yellow)	1	164			363			2335			IT5
Natural covering stones											
Antigorio (serizzo)	2	27			41			775			IT3
Basalt	1	126			242			1973			IT5
Basalt	1	113			175			2030			IT5
Basalt	1	494			733			2354			IT1,IT7
Basalt	1	41			26			340			IT13
Basalt	1	131			261			1749			IT16
Beola ghiadonata	1	68			66			1208			IT1,IT3, IT7
Beole green	1	34			82			1891			IT1,IT3, IT9
Beole grey	1	101			28			1431			IT1,IT3, IT7
Beole white	1	49			14			1199			IT1,IT3, IT7
Bianco sardo	1	47			90			1173			IT7
Black gabbro^	1	11.7			19			240			IT13
Ceppo	1	64			1			***3***			IT1,IT3, IT7
Gneiss (S.Vigilio)	1	80			12			1480			IT12
Gneiss	1	126			112			1276			IT1
Gneiss granodiorite	1	30			86			1285			IT1,IT3, IT7
Gneiss luserna stone	1	125			114			1276			IT1,IT7

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Gneiss tonalite	1	29			25			498			IT1,IT3, IT7
Gneiss (Monte Bianco)	1	166			87			832			IT1,IT7
Granite	1	27			41			927			IT1
Granite	1	40			61			942			IT1
Granite	1	38			58			974			IT1
Granite	1	44			60			974			IT1
Granite	1	38			62			1029			IT1
Granite	1	37			58			1039			IT1
Granite	1	48			95			1137			IT1
Granite	1	29			87			1170			IT1
Granite	1	24			44			1181			IT1
Granite	1	72			72			1258			IT1
Granite	1	28			36			1258			IT1
Granite	1	85			77			1281			IT1
Granite	8	145			159			1560			IT4
Granite (green)^	1	57			49			260			IT13
Granite (pink)^	1	147			200			1200			IT13
Granite (pink)^	1	33			44			1000			IT13
Granite (pink)^	1	61			79			1200			IT13
Granite (red)^	1	153			360			1600			IT13
Granite (serizzo)	1	29			37			652			IT3
Granite (serizzo)	1	29			40			763			IT1
Granite (serizzo)	1	35			33			912			IT1
Granite (serizzo)	1	32			53			1014			IT1
Granite (syenite Balma)	4	360	384	324	330	358	305	1255	1390	1191	IT3
Granite (white)^	1	37			42			830			IT13
Granite pink (Limbara)^	1	42									IT1
Granite multicolor	1	29			89			1170			IT1,IT3, IT7
Granite pink-Porrino 0.2 water content^	1	88									IT1
Granite pink-Porrino 0.3 water content^	1	88									IT1
Granite pink-Porrino^	1	88									IT1
Granite (serizzo)	2	27	42	11	33	54	12	513	626	440	IT3
Lapillo (PZL)	1	73			110			1582			IT5
Lapillo (PZL)	1	64			152			653			IT5
Lava	1	400			750			2350			IT18
Lava (Etna)	3	79	85	71	36	40	32	426	487	378	IT8
Lava (Vesuvio)	2	704	709	699	70	77	63	2169	2180	2159	IT8
Lava (Vesuvio)	1	438			93			2163			IT17
Marble	2	2			1			24			IT4
Marble	1	2			***0.2***			***2***			IT7
Marble^	8	4	10	0.6	0.9			16			IT15
Marble (Botticino)	1	13			***0.2***			***2***			IT1,IT3, IT7

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Marble (Carrara white)	1	4			***0.4***			4			IT1,IT7
Marble (Morter)	1	0.7			0.6			18			IT12
Marble (Nuvolera)	1	2			***0.3***			***3***			IT1,IT3, IT7
Marble (Portoro)	1	4			***0.3***			5			IT1,IT3, IT7
Marble (Ratschings)	1	2						14			IT12
Marble (red)	1	1			4			20			IT13
Marble (South Tirol)	1	0.7			0.7			***0.1***			IT12
Marble (sparkling white)	1	4			***0.3***			***2***			IT1,IT7
Marble (veined white)	1	1			***0.2***			5			IT1,IT7
Marble (Verona red)	1	1			3			14			IT1,IT3, IT7
Marble (white, statuary)	1	1			***0.3***			5			IT1,IT7
Peperino	1	109			166			1312			IT5
Peperino	4	169	233	127	165	176	155	1329	1518	1167	IT8
Peperino	6	160			190			1420			IT2
Peperino	1	164			231			1790			IT5
Peperino	1	168			224			2118			IT16
Peperino (grey)	1	242			152			1500			IT9
Peperino (grey)	1	123			162			1340			IT1,IT7
Peperino (pink)	1	125			164			1351			IT1,IT7
Peperino (pink)^	1	167									IT1
Peperino (red)	1	256			158			1483			IT9
Porfido (grey)	1	25			45			1549			IT12
Porphyry (red)	1	28			47			1633			IT12
Porphyritic schist	1	**389**	477	300	**47**	51	43	**858**	900	815	IT9
Porphyry	1	41			55			1164			IT1,IT3, IT7
Porphyry	1	51			71			1476			IT1,IT3, IT7
Porphyry^	1	40			48			950			IT13
Porphyry^	1	41			57			1050			IT13
Rosa baveno	2	57	62	51	69	75	62	1168	1225	1100	IT3
Schist^	3	52	86	19	50			925			IT15
Schist^	3	39	42	34	54			766			IT15
Syenite	1	270			175			1181			IT1
Syenite	1	241			187			1206			IT1
Syenite	1	354			195			1210			IT1
Syenite	1	366			251			1264			IT1
Syenite (polished)^	1	334									IT1
Syenite (unpolished)^	1	334									IT1
Slate	1	46			47			942			IT1,IT3, IT7
Trachytes	1	41			41			1100			IT13
Trachytes (veined yellow)	1	36			52			1154			IT1,IT3, IT7

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Travertine	1	0.1			***0.1***			***1***			IT4
Travertine	1	0.5			***0.2***			***2***			IT1,IT7
Travertine	1	0.8			0.3			5			IT13
Travertine	1	0.6			***0.2***			***2***			IT1,IT7
Travertine	1	0.4			***0.2***			***2***			IT1,IT7
Travertine	1	***0.2***			***0.2***			***2***			IT1,IT7
Travertine	1	2			0.9			9			IT1,IT7
Travertine	1	***0.2***			***0.2***			***2***			IT7
Travertine	1	***1***			***1***			7			IT5
Travertine	1	***1***			***1***			18			IT5
Travertine (veined light)	1	0.5			***0.2***			***2***			IT1,IT7
Volcanic ash	1	108			67			2000			IT9
Others											
Plaster	1	7			11			155			IT10.A
Mortar	1	10			19			80			IT10.A
Mortar for injection	1	19			25			161			IT10.A
Mortar^	1	22			25			490			IT13
Mortar^	1	7			8			130			IT13
Mortar^	1	13			15			400			IT13
Lime mortar^	1	16			21			400			IT13
Plaster coat^	1	22			23			470			IT13
Plaster coat^	1	34			2			25			IT13
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA (US)^	71	170			130			470			IT2
FA (Sud Africa)^	70	170			150			330			IT2
BA^	10	130			100			470			IT2
Bauxite residues/red mud											
RM	1	97			118			15			IT19
Metallurgical slag											
BFS	1	70			30			97			IT4

Concrete A*: limestone as aggregates
Concrete B**: sand and gravel as aggregates
Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation of a subgroup of samples are reported in Table 31

Table 15 Latvia
3 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Cement											
Cement	1	**28**	51	5	**48**	93	3	**175**	320	29	LV1
Aggregates											
Sand, gravel	1	**15**	19	10	**13**	21	4	**430**	460	400	LV1
Natural covering stones											
Granite	1	**78**	150	5	**114**	210	18	**905**	1290	520	LV1

Table 16 Lithuania
9 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	1	40			32			754			LT1
Bricks	1	31	84	10	20	60	5	522	1140	228	LT2
Concrete											
Concrete	1	32			17			426			LT1
Concrete	1	37	142	6	25	110	4	480	1220	63	LT2
Cement											
Cement	1	70	465	4	30	211	3	268	1510	2	LT2
Aggregates											
Sand and gravel	1	24	67	2	14	64	1	464	926	1	LT2
Natural raw materials											
Clay	1	55	114	9	52	191	7	884	1280	225	LT2
Expanded clay	1	85	100	63	62	77	47	1135	1310	809	LT2
Natural covering stones											
Granite	1	37	292	5	30	141	3	870	1620	220	LT2

Table 17 Luxembourg
126 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	2	83	93	72	147	164	129	597	988	206	L1
Bricks Poroton	1	53			58			1013			L1
Concrete											
Concrete	2	93	98	88	92	93	90	110	146	73	L1
Cellular concrete	1	4			6			153			L1
Light concrete (pumice)	2	163	180	146	99	99	99	707	730	684	L1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Tiles											
Tile	12	100	202	31	74	117	45	669	1058	87	L1
Terre cuite	1	70			58			620			L1
Natural raw Materials											
Stone	1	90			52			916			L1
Natural covering stones											
Granite	61	58	160	3	76	262	1	1156	2040	44	L1
Marble	2	12	19	4	0.5	0.5	0.4				L1
Marble	2	22	34	***10***	29	48	***10***	115	209	***20***	L1
Marble	1	6						1			L1
Sandstone	1	31			37			560			L1
Stone (pierre de pawn)	1	106			2			30			L1
Stone (pierre Rosal)	1	23			1			28			L1
Stone (pierre Mirabelle)	1	5			1			3			L1
Stone (Pierre bleu)	1	65			2			7			L1
Schiste Pitangui	1	1691			77			53			L1
Others											
Plaster	25	52	310	1	37	240	1	29	65	2	L1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Metallurgical slags											
BFS	1	7	128	142	117	152	185	135	190	234	L1

Numbers in Bold Italic= MDA (minimum detection level)

Table 18 Macedonia

30 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural raw Materials											
Gypsum	22	32	67	5	70	188	***0.5***	144	264	22	EU1
Natural covering stones											
Marble	8	12	46	1	6	32	0.4	165	945	11	EU1

Numbers in Bold Italic= MDA (minimum detection level)

Table 19 Netherlands

269 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Brick (Fire clay light-weight - Poriso)	1	71	72	71	74	74	73	1020	1030	1010	NL2
Bricks (fire clay)	14	39	47	29	41	49	35	560	655	415	NL2, NL3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick, 20% FA^	1	76									NL3, NL4
Brick Porous 20% FA	6	72	80	67	73	76	71	1030			NL3, NL4
Bricks	1	41			49			415			EU2
Bricks (clay)	1	43	77	35	42	84	34	540	637	393	EU2
Bricks (sand-lime)	1	8	9	7	8	10	7	280	300	260	NL2
Bricks (sand-lime)	1	8	18	7	8	14	5	150	211	121	EU2
Bricks^	1	39									NL4
Bricks (sand-lime)^	22	10	17	4	9	13	3	230	360	70	NL1
Bricks (clay)^	16	39	45	27	41	50	36	500	630	300	NL1
Bricks (clay)^	5	74	75	71	82	84	79	720	750	690	NL1
Concrete											
Aereated concrete	1	21	13	9	6	8	7	150	229	111	EU2
Aereated concrete^	14	11	16	6	8	12	5	170	210	120	NL1
Aereated concrete block	4	21	24	18	6	7	6	150			NL3
Aereated concrete ^	1	22									NL4
Aereated concrete ^	1	18									NL4
Aereated concrete-FA^	1	58			47			511			EU2, NL4
Concrete	1	22	29	15	22	23	14	150	150	72	EU2
Concrete	3	14	17	11	16	23	10	130			NL3
Concrete^	28	24	36	11	18	31	6	160	230	120	NL1
Concrete (bims-pumice)	2	115	123	107	132	133	130	870			NL3
Concrete (BFS+FA)^	1	19									NL4
Concrete (PTL+phopshoslag)^	1	710									NL4
Concrete A (PTL)^	1	10			10			111			NL3, NL4
Concrete B (BFS cement)^	1	16			22			137			NL3, NL4
Concrete C (FA cement)	1	14			15			140			NL3, NL4
Concrete D (sintered FA grains)^	1	55			38			328			NL3, NL4
Concrete Portand/FA	1	15			15			141			EU2
Concrete PTL-Lytag	1	67			41			283			EU2
Concrete Slag cement	1	19			27			164			EU2
Concrete Slag cement Lytag	1	78			74			305			EU2
Cement											
PTL cement	6	27	49	10	19	28	14	230			NL3
BFS cement	6	82	116	49	120	223	43	260			NL3
PTL/FA cement	4	60	77	41	44	51	36	290			NL3
Aggregates											
Coarse aggregate	1	10	10	10	12	13	11	140	175	100	NL2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Sand	4	8	8	8	11	12	10	200			NL3
Gravel	4	10	10	10	13	14	11	140			NL3
Lytag aggregate (sintered FA grains)	3	121	145	90	77	81	74	460			NL3
Aardelite (artificial gravel, 50-75% FA)	1	90			81			274			EU2
Tiles											
Tiles	8	61	87	36	66	80	51	600			NL3
Roof tiles	1	49	54	43	55	59	52	580	630	530	NL2
Roof tiles	6	43	54	30	43	57	20	480			NL3
Natural raw materials											
Limestone	1	28			2			35			EU2
Sand-lime stone	10	8	9	7	8	9	7	280			NL3
Sandstone	1	30			41			1020			EU2
Gypsum panels	1	3	3	2	***3***			17	20	13	NL2
Gypsum blocks	1	18	30	5	28	54	1	31	80	11	NL2
Gypsum board	5	4	6	2	4			20			NL3
Gypsum blocks	4	7	10	5	6			28			NL3
Gypsum^	1	10									NL4
Gypsum^	1	5									NL4
Gypsum^	1	2									NL4
Gypsum^	1	6									NL4
Gypsum^	1	4									NL4
Gypsum^	10	8	14	3	2	6	0.6	10	17	3	NL1
Natural covering stones											
Granite	1	32			35			990			EU2
Basalt	1	19			29			350			EU2
Others											
Wood	2	10	11	9	4			19			NL3
Glass/rock wool	3	34	37	31	78	81	76	130			NL3
Mortar^	6	12	18	7	9	14	6	150	190	100	NL1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal FA	14	181	316	112	150	277	88	730			NL3
Byproduct Gypsum											
By-prod. gypsum (board)^	3	450	700	320	8.7	10	5.7	120			NL3
Gypsum block (Kolafosf.)	3	28	30	26	48	52	40	16			NL3
PHG (possible)^	1	26									NL4
Phospogypusm^	1	103									NL4
Phospogypusm ^	1	330									NL4
Phospogypusm ^	1	700									NL4
Gypsum plaster	13	200	600	4	19	53	0.4	25			NL3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Other residues											
Phosphorous slag	1	1200			60			100			EU2

Numbers in Bold Italic= MDA (minimum detection level)
^ Data on emanation and/or exhalation are reported in Table 31

Table 20 Norway
206 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	18	63			74			1136			NW2
Bricks	1	104			63			1037			EU2
Concrete											
Concrete	137	28	37	11	36	54	21	650	884	355	NW2
Concrete	1	26			37			741			EU2
Aereated	12	52			56			811			NW2
Light weight	1	46			47			638			EU2
Cement											
Cement^	5	**32**	33	30	**20**	22	18	**269**	278	260	EU2, NW3
Cement	1	30			19			259			EU2
FA cement^	1	85			59			296			EU2, NW3
Clinker	1	96			59			815			EU2
Natural raw materials											
Gypsum	1	11			4			11			EU2
Natural covering stones											
Red Rock	12	160	550	44	4000	12000	170	150	600		NW1
Rauhaugite	4	130	290	20	560	7000	160	190	430	20	NW1
Sovite	6	310	1400	10	310	780	10	380	1600	10	NW1
Fenite	1	7			185			***1***			NW1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA (imported)^	4	174	222	126	136	215	93	622			NW3

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 21 Poland

5729 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Red clay bricks^	3	**20**	22	19	**33**	44	22	**825**	944	707	PL4
Silicon-sand-lime bricks^	3	**11**	15	7	**6**	7	***4***	**204**	278	130	PL4
Concrete											
Concrete light weight cellul.	640	80	200	22	54	220	***1***	492	893	183	PL3
Concrete	37	65	171	14	36	65	18	500	974	179	PL3
Concrete	1	200			127			1005			PL2
Cement											
Cement	339	48	154	4	20	38	***1***	204	430	***1***	PL3
Cement^	4	19	26	***7***	**39**	67	11	**246**	304	189	PL4
Clinker	85	37	115	13	14	41	2	190	534	7	PL3
Cement	1	154			138			608			PL2
Aggregates											
Sand	72	8	17	1	9	76	1	231	446	34	PL3
Tiles											
Ceramics	1190	52	190	***1***	49	120	***1***	724	1410	60	PL3
Natural raw materials											
Lime	88	24	47	1	3	13	1	46	331	1	PL3
Marl	24	21	36	12	14	27	5	257	396	128	PL3
Clay	35	48	160	22	49	427	25	624	938	161	PL3
Limestone	97	17	34	***1***	3	23	***1***	74	540	***1***	PL3
Sand	17	12	32	3	5	13	***1***	105	295	24	PL3
Chalk	104	15	54	1	5	30	1	84	279	13	PL3
Gypsum	1	64			30			279			PL2
Gypsum	88	24	47	1	3	13	1	46	331	1	PL3
Natural covering stones											
Marble	9	4	10	***1***	2	7	***1***	30	51	7	PL3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA	1524	127	329	4	82	181	6	676	1180	58	PL3
FA	278	241			93			636			PL1
FA	106	**337**	611	63	**178**	322	33	**1082**	1778	385	PL4
FA^	33	96	144	63							PL4
BA-boiler Slag	476	95	275	2	58	121	1	491	1018	***1***	PL3
Byproduct Gypsum											
PHG	23	358	620	19	15	48	4	109	680	1	PL3
PHG	17	61			7			41			PL1
Byproduct gypsum^	4	512	736	26	**28**	44	11	**65**	119	11	PL4

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Metallurgical slag											
Metallurgical Slag	160	110	351	33	30	102	12	170	825	44	PL3
Copper Slag	23	295	336	237	45	76	26	902	1251	615	PL3
Slag	42	**239**	459	19	**307**	592	22	**1227**	2227	226	PL4
Slag^	11	67	144	37							PL4
Slag	282	511			52			844			PL1

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 22 Portugal

128 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks^	10	**64**	90	37	**52**	72	31	**786**	1098	473	POR1
Concrete											
Concrete block^	11	**53**	98	8	**47**	86	7	**404**	529	278	POR1
Cement											
Cement^	7	**40**	59	21	**23**	34	11	**235**	250	220	POR1
Cement	1	22			15			276			POR2
Aggregates											
Aggregates	27	62	167	1	50	152	1	761	1450	11	POR2
Washed sand Company D	1	6			8			490			POR2
Washed sand Company E	1	10			10			148			POR2
Sand	1	96			81			1213			POR2
Sand powder	1	135			93			1253			POR2
Sand^	32	**102**	2	202	**83**	4	161	**1132**	123	2140	POR1
Gravel^	11	**70**	10	130	**29**	2	56	**380**	190	569	POR1
Natural covering stones											
Granite	1	258			96			1342			POR2
Slate (ardesia)	1	33			36			817			POR2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA	1	14	75	171	8	157	169	5	69	338	POR2
Byproduct Gypsum											
PHG^	7	166	705	12	6	12	***2***	40	90	***2***	POR1
Artificial gypsum	2	**489**	568	410	**6**	7	5				POR2

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 23 Romania

635 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Red brick	5	48	105	22	66	108	40	669	760	588	RO1
Red Brick	32	36	100		32	59		493	833		RO2
ACC brick	3	8	12	5	12	14	11	264	279	233	RO1
Brick (clay, red refractory)	1	50			52			652			RO3
Brick (slate and burnt)	1	37			51			1038			RO4
Coal-cinder bricks	11	139			57			196			RO3, RO4
Clinker bricks	23	52			56			531			RO3, RO4
Concrete											
Concrete	16	28	79		20	39		201	452		RO2
Concrete: ballast, pumice,foamed, aerated and light weight, heavy	43	69			77			918			RO3, RO4
Areated alum schist concrete	1	118			556			615			RO3
Blast furnace cinder concrete	1	106			91			477			RO4
Autoclaved aereated concrete	7	17	32		16	37		163	277		RO2
Autoclaved cellular concrete, white	32	114			115			357			RO4
Autoclaved cellular concrete, grey	35	95			90			485			RO4
Cement											
Cement dust	2	***4***	4	4	16	16	16	421	633	209	RO1
Alumina cement	1	178			206			133			RO3
Asbestos-cement	3	7	9	4	12	14	11	50	57	47	RO1
Asbestos-cement	1	44			14			79			RO3
Cement	25	34	66		18	97		152	504		RO2
Cement^	1	27			22			228			RO5
Cement with FA 50%^	1	154			76			315			RO5
Cement with FA 33%^	1	107			52			298			RO5
Cement with FA 11%^	1	58			39			295			RO5
Cement PA	21	74			27			281			RO3, RO4
Aggregates											
Sand	5	7	12	2	22	32	14	507	662	370	RO1
Sand, gravel	14	8	30		27	92		557	870		RO2
Tiles											
Tiles	4	46	59	30	58	67	50	792	892	706	RO1
Natural raw materials											
Lime	8	13	41		8	19		68	167		RO2
Gypsum	14	18	43		10	27		103	277		RO2
Gypsum	1	41			40			199			RO3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural covering stones											
Tufa (travertino)	1	11			10			180			RO1
Others											
Mortar	4	6	8		6	12		426	611		RO2
Wood	3	***5***	***7***	***3***	2	3	2	75	140	41	RO1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA	18	155	219		89	126		569	945		RO2
Ash from CFPPs	1	224			80			646			RO3
FA	120	276	460	140	244	501	79	547	1265	170	RO4
FA	2	118	122	114	87	97	77	673	729	617	RO1
FA I Oradea	4	160	246	72	85	175	38	475	520	384	RO5
Escaping FA	34	380	558	149	114	360	41	660	1390	205	RO4
(Slag) BA	76	94	121	21	49	129	15	514	1100	280	RO4
Slag from CFPPs	1	122			62			394			RO3
Byproduct Gypsum											
PHG	54	702	970		23	42		113	116		RO2
PHG	1	634			9			44			RO3
Metallurgical slag											
Blast furnace ash	1	110			62			438			RO3
Blast furnace cinders	1	181			50			270			RO3

Numbers in Bold Italic= MDA (minimum detection level)
^ Data on emanation and/or exhalation are reported in Table 31

Table 24 Slovakia

2148 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Bricks	1	49	64	28	44	70	22	695	820	477	EU2
Bricks	25	71	265	12	80	252	13	590	887	72	SK3
Bricks+ slate	137	**129**	247	11	**132**	252	11	**627**	1181	72	SK1
Concrete											
Concrete	1	42	71	8	36	61	6	392	557	171	EU2
Concrete (B7.5 325R)^	3	10			6			247			SK2
Concrete (B20 325R)	3	10			6			238			SK2
Concrete (B35 325R)^	3	13			7			250			SK2
Concrete (B7.5 325HS)	3	10			7			266			SK2
Concrete (B20 325HS)	3	10			7			240			SK2
Concrete (B35 325HS)^	3	11			5			251			SK2
Concrete (B7.5 250LL)	3	10			7			245			SK2
Concrete (B20 250LL)	3	12			10			254			SK2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Concrete (B35 250LL)	3	15			11			270			SK2
Concrete with broken bricks BBC/325HS^	2	46			39			653			SK2
Concrete with broken bricks BBC/325R^	2	44			40			644			SK2
Concrete with broken bricks BBC/325LL	2	45			41			664			SK2
Cellular concrete SS^	3	16			8			214			SK2
Cellular concrete SE^	3	50			41			372			SK2
Cellular concrete BA^	1	69			38			347			SK2
Concrete	29	60	127	10	36	70	5	336	652	96	SK2
Concrete	80	**107**	207	6	**37**	74	1	**328**	651	4	SK1
Concrete	1	42	71	8	36	61	6	392	557	171	EU2
Cement											
Cement	1	23	36	12	15	20	7	198	295	104	EU2
Cement 250 LL	3	47			19			253			SK2
Cement 325 R	1	42			19			190			SK2
Cement 325 HS	1	28			18			251			SK2
Cement	288	**61**	118	4	**39**	77	1	**215**	425	5	SK1
Cement	88	42	116	16	21	37	12	249	352	161	SK3
Clinker	1	57	91	20	67	113	34	613	819	435	EU2
Aggregates											
Aggregates (fine and coarse)	348		252			115		**1713**	3426	1	SK1
Gravel	1	10	15	4	13	18	3	152	271	152	EU2
Gravel	2	6			3			189			SK2
Sand	3	9			5			282			SK2
Sand	1	8	15	3	9	15	7	193	328	65	EU2
Sand	14	28	258	4	21	142	1	339	912	5	SK3
Sand	141	**21**	41	1	**33**	67	0.3	**516**	1030	2	SK1
Tiles											
Ceramics	1	31	41	20	37	41	19	507	770	271	EU2
Natural raw materials											
Limestone	1	10	14	5	4	8	2	63	137	28	EU2
Azbestos	1	9	13	5	14	19	7	191	230	118	EU2
Stone	96	16	106	1	16	133	1	342	2441	2	SK3
Stone	286	**67**	132	2	**198**	395	0.3	**1221**	2441	1	SK1
Natural covering stones											
Granites	1	58	101	10	59	137	17	680	1043	383	EU2
Pearlites	1	53	67	39	76	87	66	1149	1172	1125	EU2
Marbles	1	13	15	11	5	8	3	137	165	103	EU2
Marble	7	14	41	1	37	95	0	590	887	72	SK3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
FA	1	83	129	38	68	109	32	496	832	194	EU2
FA	92	102	318	34	70	159	21	458	937	33	SK3
FA	133	**185**	336	34	**90**	159	21	**1353**	2685	22	SK1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Metallurgical slag											
Slag	17	86	158	44	64	106	39	287	575	149	SK3
Dross	5	163	257	75	37	51	14	295	650	76	SK3
Slag+dross	43	**233**	436	10	**33**	56	10	**363**	650	76	SK1

Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 25 Slovenia

7 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mea	max	min	mea	max	min	mea	max	min	
Brick											
Clay red brick	1	69			72			454			SLO1
Coal ash brick	1	93			101			898			SLO1
Concrete											
Concrete brick	1	20			11			105			SLO1
Aereated concrete	1	22			10			143			SLO1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal-ashes plaster	1	190			33			360			SLO1
Coal ash aggregate	1	309			40			406			SLO1
Byproduct Gypsum											
PHG plaster	1	500			10			41			SLO1

Table 26 Spain

426 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Brick	1	34			99			666			SP2
Brick	3	55			44			747			SP3
Brick	8	73			60			292			SP3
Concrete											
Concrete	24	30			32			204			SP3
PC Concrete	4	21	29	16	18	22	11	283	363	221	SP4
CAC Concrete	5	38	42	10	23	27	20	246	456	176	SP4
Cement											
Cement	1	48	135	5	32	90	5	316	651	31	EU2
Cement	1	75			30			239			SP2
Cement I	3	25			20			59			SP3
Cement II	7	422			266			599			SP3
Cement III	5	95			67			44			SP3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Cement IV	4	23			19			85			SP3
Cement V	5	52			41			403			SP3
Cement VI	6	36			30			204			SP3
Cement VII	7	54			38			275			SP3
Cement - Albasete	1	32			31			315			SP3
Cement - Alicante	8	31			23			245			SP3
Cement - Almeria	3	73			45			287			SP3
Cement - Asturias	5	60			30			408			SP3
Cement - Barcelona	18	46			37			273			SP3
Cement - Cantabria	5	56			30			378			SP3
Cement - Cordoba	1	74			19			341			SP3
Cement - Guipuzcoa	6	56			31			315			SP3
Cement - Huelva	3	28			27			234			SP3
Cement - Huesca	3	92			41			330			SP3
Cement - Jaen	5	44			35			382			SP3
Cement - Leon	3	93			42			509			SP3
Cement - Lugo	2	29			45			439			SP3
Cement - Malaga	6	56			47			357			SP3
Cement - Mallorca	1	29			43			302			SP3
Cement - Madrid	9	39			26			330			SP3
Cement - Murcia	8	57			35			305			SP3
Cement - Navarra	6	43			31			350			SP3
Cement - Sevilla	2	24			16			170			SP3
Cement - Tarragona	4	33			15			290			SP3
Cement - Toledo	8	43			31			338			SP3
Cement - Valencia	11	32			23			285			SP3
Cement - Vizcaya	10	54			40			272			SP3
Cement - Zaragoza	4	75			33			387			SP3
CEM I 52,5 R	1	37			25			245			SP4
CEM II/BL 32,5 N	1	27			13			211			SP4
CEM III/A 42,5 N/SR	1	109			38			240			SP4
CEM IV/B (V) 32,5 N	1	97			41			373			SP4
CAC Electroland molins	1	75			128			22			SP4
CAC Aluminite	1	84			136			44			SP4
CAC Ciment Fondu Lafarge	1	98			128			30			SP4
CAC Secar 51 Lafarge	1	208			220			95			SP4
CAC Gorkal 70 Gorka	1	7			2			12			SP4
Aggregates											
Sea sand	6	6			4			56			SP3
Sand I	4	30			28			31			SP3
Sand II	7	7			3			12			SP3
Sand	1	14			17			267			SP2
Gravels	1	23						47			SP3

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Natural raw materials											
Gypsum	1	3			9			224			SP2
Gypsum	3	10			4			56			SP3
Gypsum	5	36			26			155			SP3
Gypsum	7	51			34			167			SP3
Gypsum	5	11			7			70			SP3
Natural covering stones											
Granite	1	87	282	7	44	133	2	1021	1869	234	EU2
Granite	1	74			97			1378			IT1
Granite Avila	2	86	113	60	68	75	62	1206	1309	1104	SP3
Granite Badajoz	23	66	144	7	41	107	3	958	1362	234	SP3
Granite Caceres	10	78	104	37	44	133	9	997	1236	629	SP3
GraniteLa Coruña	3	92	114	78	65	101	44	1329	1424	1225	SP3
Granite Huelva	1	33			2			337			SP3
Granite Huesca	1	282						712			SP3
Granite Lugo	6	93	169	42	33	63	11	951	1324	454	SP3
Granite Madrid	13	91	172	44	42	60	11	976	1283	567	SP3
Granite Orense	5	78	98	43	43	81	12	1251	1869	754	SP3
Granite Pontevedra	12	112	198	36	45	124	6	1112	1394	453	SP3
Granite Salamanca	3	61	82	44	38	54	26	1112	1180	1022	SP3
Granite Segovia	3	127	166	90	58	67	49	1049	1123	1007	SP3
Granite Sevilla	1	30			111			790			SP3
Granite Toledo	1	191			74			1253			SP3
Granite Zamora	3	74	95	59	47	74	2	987	1318	578	SP3
Marble	1	33			***1***			10			IT1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
Coal FA	1	160			62			459			SP4
Ashes (Asturias)	68	91	106	80	89	104	77	1059	1223	895	SP1
Ashes (Galicia)	1	90			91			1039			SP1
Metallurgical slag											
BFS	1	167			48			232			SP4

Numbers in Bold Italic= MDA (minimum detection level)

Table 27 Sweden

648 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Brick	21	96			126			925			EU3
Brick	12	96	152	41	127	178	100	960	1090	560	S3
Brick (clay)	35	98	164	40	116	180	71	888	1108	548	S1
Brick (sand-limestone)	3	10	15	7	7	10	4	162	440	22	S1
Concrete											
Concrete	19	46	63	31	74	127	46	714	932	573	S1
Concrete°	1	52	67	44	74	89	59	630	670	590	S2
Concrete°	1	44	159	8	63	389	6	696	1225	115	EU2
Concrete iron ore ballast	2	26			32			68			S1
Concrete-hoforsit ballast	3	3			6			32			S1
Concrete-hoforsit ballast	1	3			3			20			S1
Concrete for radiation shielding	1	8			14			133			S1
Aereated+light weight concrete	4	551	2200	14	100	190	15	734	1100	260	S2
Aereated concrete (sand based)	36	42	132	3	49	157	4	276	505	21	S1
Aereated concrete (alum shale)°°	70	1300	2620	620	67	115	30	770	1062	618	S3
Heavy concrete	15	48			85			703			EU3
Aerated with alum shale	22	56			70			333			EU3
Aerated with alum shale	13	425	559	272	31	39	24	506	566	445	S1
Cement											
Cement	1	56	190	22	72	110	33	196	370	22	S2
Cement	1	56	185	22	48	74	33	233	370	22	EU2
Cement	20	44	168	21	41	92	24	235	378	21	S1
Cement	8	56			56			233			EU3
Aggregates											
Gravel	157	44	78	15	56	463	21	820	1206	180	S1
Shingels	113	52	99	22	89	178	29	821	1199	311	S1
Macadam ballast	57	52	167	7	86	283	3	814	1317	137	S1
Lightweight aggregate	10	144			159			999			EU3
Concrete Ballast	1	**54**	56	52	**80**	93	67	**720**	740	700	S2
Natural raw materials											
Gypsum plaster	1	3			***1***			22			EU3
Gypsum	2	10			21			170			S1
Gypsum board	8	4	9	2	4	12	***1***	28	68	***3***	S1
Natural covering stones											
Balmoral Red Granite	1	154			289			1265			IT1

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Baltic Bronze Granite (Granodiorite)	1	69			74			1305			IT1
Swedish blackGabro	1	4			4			335			IT1
Imperial Red Granite	1	128			184			1301			IT1
Diorite	1	1			***0.2***			55			IT1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Byproduct Gypsum											
Byproduct gypsum	3	22			55			24			S1
Metallurgical slag											
Slag	2	118			148			141			S1

° calculated from ballast (sand, gravel) and cement assuming mixing ratio 79:14:7 for ballast:cement:water. IN RP 96
°° no production since 1975
Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum

Table 28 Switzerland

86 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay brick^	18	47	62	32							SW1
Concrete											
Concrete brick^	2	**12**	12	11							SW1
Aerated concrete^	2	**19**	28	9							SW1
Pumice concrete^	5	149	249	28							SW1
Cement											
Cement^	10	20	29	11							SW1
Tiles											
Gravel^	12	25	50	9							SW1
Sand^	22	20	56	9							SW1
Rhenice pumice^	5	237	415	121							SW1
Natural raw materials											
Lime^	3	**17**	22	11							SW1
Sand-lime stone^	2	**13**	15	11							SW1
Gypsum^	5	15	18	13							SW1

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum
^ Data on emanation and/or exhalation are reported in Table 31

Table 29 Turkey
86 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Red brick	11	31	49	25	37	51	27	776	1092	587	TR1
White brick	4	70	75	66	70	79	53	923	1080	723	TR1
Lightweight brick	3	9	13	4	10	17	6	208	326	148	TR1
Concrete											
Concrete	5	16	27	7	9	22	1	151	465	45	TR1
Light concrete	6	17	24	12	25	37	14	527	879	405	TR1
Cement											
Grey cement	37	40	82	18	26	49	8	317	476	169	TR1
White cement	5	33	38	28	16	23	8	99	128	62	TR1
Sulphate resistant cement	7	22	33	15	14	18	11	176	230	147	TR1
Natural raw materials											
Gypsum	7	5	15	1	5	18	1	59	186	2	TR1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Bauxite residues/red mud											
RM	1	210			539			112			TR2

Table 30 United Kingdom
249 samples

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Brick											
Clay brick	23	52			44			620			GB2
Granite brick (reformite)	3	11			13			590			GB2
Granite brick	7	89			81			1000			GB2
Calcium silicate (rock aggregate) brick	3	52			4			790			GB2
Calcium silicate brick (gravel aggregate)	5	7			3			350			GB2
Calcium silicate brick (flint aggregate)	5	2			5			12			GB2
Clay brick^	6	65			48						GB1
Silica brick^	1	33			15						GB1
Flint brick^	1	70			52						GB1
Oil shale brick^	1	76			43						GB1
Crushed granite bricks and blocks^	3	40			39						GB1
Expanded clay blocks^	2	94			57						GB1
Concrete											
Concrete	4	74			30			519			EU2

BUILDING MATERIALS	N.	Ra-226 (Bq kg^{-1})			Th-232 (Bq kg^{-1})			K-40 (Bq kg^{-1})			Ref.
		mean	max	min	mean	max	min	mean	max	min	
Concrete blocks - PFA	3	66			37			433			GB2
Aereated concrete	2	89			13			650			GB2
Light weight concrete	10	59			26			370			GB3
Concrete block^	1	18			42						GB1
Building blocks - PFA^	2	54			43			490			EU2
Cement											
Cement	6	22			18			160			GB2
Cement-natural gypsum	2	**109**	210	7	**28**	55					GB2
Aggregate											
Sand and gravel	10	4			7			33			GB2,GB3
Natural raw materials											
Gypsum	73	22			7			148			GB3
Natural covering stones											
Granite	7	89			81			111			GB3
Vermiculite	1	93			0			1400			GB2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS											
Ashes											
PFA	1	89			68			900			EU2
Byproduct gypsum											
PHG	6	790			17			62			GB2
PHG from carbonatite	1	120			23						GB2
PHG	60	629			19			41			GB3

Numbers in Bold underline= average from minimum and maximum

^ Data on emanation and/or exhalation are reported in Table 31

Table of radon emanation and exhalation rate of building materials used in 15 European countries

Table 31 Data on radon emanation and exhalation rate of building materials used in European countries.

Numbers in Bold Italic= MDA (minimum detection level)
Numbers in Bold underline= average from minimum and maximum

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
BELGIUM (40 samples from TABLE 2 + 1 sample with only emanation/exhalation rate data)								
Brick								
Brick [b]	4			0.7 (0.1-2)	35 (22-72)	mBq m^{-2} h^{-1}	59 (40-85)	BE2
		6		0.1	22	mBq m^{-2} h^{-1}	85	BE2
		6		0.1	22	mBq m^{-2} h^{-1}	70	BE2
		5		0.3	22	mBq m^{-2} h^{-1}	40	BE2
		9		2	72	mBq m^{-2} h^{-1}	40	BE2
Natural raw materials								
Plasterboard	14	0.9			28	mBq m^{-2} h^{-1}	***11***	BE2
Gypsum blocks	1				24	mBq m^{-2} h^{-1}		BE2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
By-products Gypsum								
PHG board	22[c]			14	1548	mBq m^{-2} h^{-1}	430 (330-520)	BE2
DENMARK (69 samples from TABLE 6)								
Brick								
Bricks	1			0.2	0.6	mBq kg^{-1} h^{-1}	42	DK2
Concrete								
Concrete (5% FA-cement)	1			11	9	mBq kg^{-1} h^{-1}	10	DK2
Concrete (10% FA-cement)	1			10	9	mBq kg^{-1} h^{-1}	11	DK2
Concrete (15% FA-cement)	1			9	8	mBq kg^{-1} h^{-1}	12	DK2
Concrete (20% FA-cement)	1			8	8	mBq kg^{-1} h^{-1}	13	DK2
Concrete (25% FA-cement)	1			9	9	mBq kg^{-1} h^{-1}	14	DK2
Concrete (30% FA-cement)	1			8	9	mBq kg^{-1} h^{-1}	14	DK2
Concrete (25% FA-PTL cem.)	1			9	10	mBq kg^{-1} h^{-1}	15	DK2
Concrete	1			6	17	mBq kg^{-1} h^{-1}	35	DK2
Cement								
Cement (5% FA)	1			0.7	15	mBq kg^{-1} h^{-1}	28	DK2
Aggregates								
Sand	1			5	25	mBq kg^{-1} h^{-1}	7	DK2
Granite chippings	1			2	10	mBq kg^{-1} h^{-1}	59	DK2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
Coal ash	15			0.5	5	mBq kg^{-1} h^{-1}	140 (120-180)	DK2
Coal ash	16			0.4	49	mBq kg^{-1} h^{-1}	170 (130-200)	DK2
Coal ash	14			0.4	49	mBq kg^{-1} h^{-1}	160 (130-190)	DK2
Coal ash	12			0.9	10	mBq kg^{-1} h^{-1}	150 (120-170)	DK2

[b] Exhalation rate measured on 4 out of 14 samples
[c] Emanation and exhalation rate refer to unknown number of samples

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
FINLAND (20 samples from TABLE 8)								
Concrete								
Slag aggregate concrete	1[d]	15	1800		11067 (10000-12000)	mBq m^{-2} h^{-1}	75	FIN2, FIN3
Concrete	1	20			19700	mBq m^{-2} h^{-1}	42	FIN2
Concrete	1	20			21700	mBq m^{-2} h^{-1}	49	FIN2
Concrete	1	20			22200	mBq m^{-2} h^{-1}	60	FIN2
Concrete	1	18			27000	mBq m^{-2} h^{-1}	66	FIN2
Concrete	1	15			23200	mBq m^{-2} h^{-1}	63	FIN2
Concrete	1[e]							FIN2
		20			31500	mBq m^{-2} h^{-1}	60	FIN2
		15			24000	mBq m^{-2} h^{-1}	60	FIN2
		10			15900	mBq m^{-2} h^{-1}	60	FIN2
		2.5			1900	mBq m^{-2} h^{-1}	60	FIN2
Concrete	11	15	2350		0.4	Bq m^{-2}h^{-1} /Bq kg^{-1}	33 (18-43)	FIN3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
By-product gypsum								
By-product gypsum	1	6.7			13900	mBq m^{-2}h^{-1}	319	FIN2
By-product gypsum	1[f]							FIN2
		20			42300	mBq m^{-2}h^{-1}	482	FIN2
		15			31200	mBq m^{-2}h^{-1}	482	FIN2
		10			20300	mBq m^{-2}h^{-1}	482	FIN2
		7.5			18600	mBq m^{-2}h^{-1}	482	FIN2
		5			10100	mBq m^{-2}h^{-1}	482	FIN2
		2.5			4700	mBq m^{-2}h^{-1}	482	FIN2
FRANCE (73 samples from TABLE 9)								
Bricks								
Bricks	3				245	mBq m^{-2} h^{-1}	**54** (50-58)	FR1
Hollow brick	5				184	mBq m^{-2} h^{-1}	**42** (40-44)	FR1
Concrete								
Concrete	5				1130	mBq m^{-2} h^{-1}	**13** (12.6-13.4)	FR1
Concrete	3				1883	mBq m^{-2} h^{-1}	13	FR1
Concrete hollow blocks	2				1105	mBq m^{-2} h^{-1}	**8** (***5***-12)	FR1
Cellular concrete	4				254	mBq m^{-2} h^{-1}	***9***	FR1
Tile								
Tile (ardesia)	2				194	mBq m^{-2} h^{-1}	**36** (34-39)	FR1
Tile (faience)	3				122	mBq m^{-2} h^{-1}	**113** (112-114)	FR1
Tile (green marble)	3				108	mBq m^{-2} h^{-1}	***1***	FR1

[d] 3 measurements of the same sample
[e] 4 measurements of the same sample with 4 different thickness
[f] 6 measurements of the same sample with 6 different thickness

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Tile (stoneware)	5				119	mBq m^{-2} h^{-1}	**141** (139-142)	FR1
Tile (stoneware)					94	mBq m^{-2} h^{-1}	**68** (62-74)	FR1
Tile (terracotta)	2				281	mBq m^{-2} h^{-1}	**61** (54-67)	FR1
Tile (terracotta)	2				112	mBq m^{-2} h^{-1}	**49** (46-52)	FR1
Tile (white marble)	4				119	mBq m^{-2} h^{-1}	***2***	FR1
Natural covering stones								
Granite	13				49	mBq m^{-2} h^{-1}	**370** (360-380)	FR1
Stone slab	3				259	mBq m^{-2} h^{-1}	***3***	FR2
Other								
Plaster	2				130	mBq m^{-2} h^{-1}	***3***	FR1
Plaster	6				497	mBq m^{-2} h^{-1}	**11** (8-14)	FR1
Plaster	2				248	mBq m^{-2} h^{-1}	**5** (4.6-5.1)	FR1
GERMANY (27 samples from TABLE 10 + 331 samples with only emanation/exhalation rate data)								
Bricks								
Bricks	180			1.3 (0.01-15)				GE3
Sandstone bricks	7			12				GE3
Bricks	1	10-15	2200	0.7	180	mBq m^{-2}h^{-1}	68	GE2
Concrete								
Areated concrete	3			11(6-20)				GE3
Areated concrete	1				1000	mBq m^{-2}h^{-1}		EU2
Areated concrete	5		520	24	972 (432-1836)	mBq m^{-2}h^{-1}	19	GE2
Concrete	1				1100	mBq m^{-2}h^{-1}		EU2
Concrete	63			14 (4-41)				GE3
Heavy weight concrete	5		2300	4	1260 (180-1980)	mBq m^{-2}h^{-1}	52	GE2
Precast concrete	20			33 (11-40)				GE3
Cement								
Cement	9			2 (0.8-3)			97 (23-330)	GE3
Aggregates								
Sand, gravel	24			13 (7-41)				GE3
Natural raw materials								
Pumice	4	10-15			2.6 (0.6-6.3)	Bq m^{-2}h^{-1}		GE2
			1350	6			48	
			1020	5			107	
			800	7			48	
			1340	2			63	
Gypsum	4	10-15			2.8 (0.2-18.4[g])	Bq m^{-2}h^{-1}		GE2
			850	5			10[h]	GE2

[g] This value is referred to chemical gypsum
[h] In table 10 are reported as a single sample for a total of 3 samples

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
			1280	5			10[g]	GE2
			900	3			41	GE2
			1250	14			37	GE2
Limestone	5	10-15	1840	28	4.8 (1.3-10.8)	Bq m^{-2}h^{-1}	9	GE2
Limestone/ marble	10			10 (1- 29)				GE3
Sandstone	1	10-15	2200	19	936	mBq m^{-2}h^{-1}	11	GE2
Natural covering stones								
Marble	1				180	mBq m^{-2}h^{-1}		GE2
Quarrystone (porphyry)	1	10-15	2700	16	2052	mBq m^{-2}h^{-1}	44	GE2
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
Fly ash	9			2 (0.06-11)				
Slag	3			0.4 (0.3-0.4)				
Slagstone	1		1930	2	648	mBq m^{-2}h^{-1}	78	GE2
GREECE (253 samples from Table 11 + 1 sample with only emanation/exhalation rate data)								
Bricks								
Brick	3			51			52	GR3
Brick	1			67			93	GR3
Brick	1			65			81	GR3
Brick	1			17			48	GR3
Brick	1			54			63	GR3
Brick	1			52			63	GR3
Brick	3			3 (0.5-12)	8 (1.3-35)	mBq kg^{-1}h^{-1}	36 (25-83)	GR13
Brick (Alatini)	1				1	mBq kg^{-1}h^{-1}	45	GR10
Brick (Dragofina)	1				4	mBq kg^{-1}h^{-1}	41	GR10
Brick (Kalochori)	1				2	mBq kg^{-1}h^{-1}	53	GR10
Brick (Kokkinogenis)	1				27	mBq kg^{-1}h^{-1}	42	GR10
Brick (Lamia)	1				6	mBq kg^{-1}h^{-1}	46	GR10
Clay brick	13	20			360	mBq m^{-2}h^{-1}	37 (25-48)	GR1
Clay brick	13[i]	20		3 (max 8)	210 (max 420)	mBq m^{-2}h^{-1}	35 (18-66)	GR4
Pumice stone brick	1				2880	mBq m^{-2}h^{-1}	48	GR1
Concrete								
Concrete	20			13	12 (4-24)	mBq kg^{-1}h^{-1}	14 (7-41)	GR11
Concrete block	3			85			85	GR3
Concrete block	1			75			41	GR3
Concrete block	1			73			25	GR3
Concrete block	2			82			37	GR3
Concrete block	3			76			30	GR3
Concrete block	3			70			26	GR3
Concrete block	3			75			22	GR3
Concrete block	4			75			48	GR3
Concrete block	2			81			37	GR3

[i] Radiometric measure on 50 samples

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Concrete block	1			82			30	GR3
Concrete block	1			14			48	GR3
Concrete block	15	15-20		14 (10-20)	3.5 (1-6.7)	Bq m^{-2}h^{-1}	35 (8-54)	GR4
Concrete block cement Kamari 0% PFA	1				10	mBq kg^{-1}h^{-1}	7	GR10
Concrete block cement Kamari 10% PFA	1				23	mBq kg^{-1}h^{-1}	11	GR10
Concrete block cement Kamari 20% PFA	1				38	mBq kg^{-1}h^{-1}	17	GR10
Concrete block cement Thessaloniki 0% PFA	1				18	mBq kg^{-1}h^{-1}	8	GR10
Concrete block cement Thessaloniki 10% PFA	1				72	mBq kg^{-1}h^{-1}	11	GR10
Concrete block cement Thessaloniki 20% PFA	1				30	mBq kg^{-1}h^{-1}	11	GR10
Concrete slab (FA cement)	1				17.6 (13-22.3)	Bq m^{-2}h^{-1}	140	GR1
Cement								
Cement	5			56			218	GR3
Cement	4			53			215	GR3
Cement	2			55			96	GR3
Aggregates								
Rock sand (limestone, sand)	2			63			45 (9-81)	GR3
Tile								
Tile	2			50			89	GR3
Tile	1			36			26	GR3
Tile	2			43			78	GR3
Tile	1			50			26	GR3
Granite tile	1				10.8	Bq m^{-2}h^{-1}		GR1
Granite tile	26	1		8 (max 13)	1240 (max 3540)	mBq m^{-2}h^{-1}	67 (2-195)	GR4
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
Fly ash	12				176 (43-421)	mBq kg^{-1}h^{-1}	929 (663-1176)	GR8
BA	2				176 (133-220)	mBq kg^{-1}h^{-1}	61 (580-654)	GR8
ITALY (285 samples from Table 14 + 7 sample with only emanation/exhalation rate data)								
Brick								
Bricks	30[j]			2	5	mBq kg^{-1} h^{-1}	40	IT2
Bricks	1			2	137	mBq kg^{-1}h^{-1}	110	IT13
Bricks	1			2	16	mBq kg^{-1}h^{-1}	96	IT13
Bricks	1			18	28	mBq kg^{-1}h^{-1}	20	IT13
Bricks	1			4	70	mBq kg^{-1}h^{-1}	35	IT13
Bricks	1			2	8	mBq kg^{-1}h^{-1}	34	IT13
Bricks	1			3	9	mBq kg^{-1}h^{-1}	76	IT13
Bricks	1			2	7	mBq kg^{-1}h^{-1}	32	IT13

[j] Radiometric measure on 124 samples
Concrete A*: white limestone as aggregate

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Concrete								
Concrete	1			7	9	mBq $kg^{-1}h^{-1}$	18	IT13
Concrete	1			16	16	mBq $kg^{-1}h^{-1}$	13	IT13
Concrete A*	1	10			11	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+5%FA South Africa)	1	10			9	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+15% FA South Africa)	1	10			12	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+26% FA South Africa)	1	10			13	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+5% FA US)	1	10			8	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+15% FA US)	1	10			11	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete A* (cement+26% FA US)	1	10			10	mBq $kg^{-1}h^{-1}$		IT2.A
Concrete B**	1	10			20	mBq $kg^{-1}h^{-1}$	16	IT2
Concrete B** (cement+5% FA South Africa)	1	10			20	mBq $kg^{-1}h^{-1}$	17	IT2
Concrete B** (cement+15% FA South Africa)	1	10			22	mBq $kg^{-1}h^{-1}$	18	IT2
Concrete B** (cement+26% FA South Africa)	1	10			24	mBq $kg^{-1}h^{-1}$	19	IT2
Concrete B** (cement+40% FA South Africa)	1	10			26	mBq $kg^{-1}h^{-1}$	19	IT2
Concrete B** (cement+5% FA US)	1	10			21	mBq $kg^{-1}h^{-1}$	13	IT2
Concrete B** (cement+15% FA US)	1	10			21	mBq $kg^{-1}h^{-1}$	13	IT2
Concrete B** (cement+26% FA US)	1	10			24	mBq $kg^{-1}h^{-1}$	13	IT2
Concrete B** (cement+40% FA US)	1	10			25	mBq $kg^{-1}h^{-1}$	15	IT2
Cement								
Cement	7		1400-1600	15	**10** (4.1-16)	Bq $m^{-2}h^{-1}$	38 (12-40)	IT15
Cemento ptl	21[k]			5	8	mBq $kg^{-1}h^{-1}$	26	IT2
Cement -pz	15[l]			9	32	mBq $kg^{-1}h^{-1}$	49	IT2
Cement	37[m]			7	18	mBq $kg^{-1}h^{-1}$	33	IT2.A
Aggregates								
Sand & gravel	31[n]			8	8	mBq $kg^{-1}h^{-1}$	15	IT2
Natural raw materials								
Clay	7		2000-2700	4	**5** (2.7-7.4)	Bq m^{-2} h^{-1}	34 (21-42)	IT15
Limestone	27		1100-2000	23	**11.1** (0.2-22)	Bq m^{-2} h^{-1}	11 (0.4-30)	IT15
Limestone	4		1100-2400	23	**13.2** (0.4-26)	Bq m^{-2} h^{-1}	9 (1-29)	IT15

[k] Radiometric measure on 31 samples
[l] Radiometric measure on 21 samples
[m] Radiometric measure on 78 samples
[n] Radiometric measure on 61 samples

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Lime, hydrated lime	6[o]			9	4	mBq kg^{-1} h^{-1}	10	IT2
Limestone	1			7	36	mBq kg^{-1} h^{-1}	65	IT13
Limestone	1			6	34	mBq kg^{-1} h^{-1}	76	IT13
Sandstone	1			6	14	mBq kg^{-1} h^{-1}	33	IT13
Sandstone	1			9	10	mBq kg^{-1} h^{-1}	14	IT13
Tuff (volcanic)	1			6	41	mBq kg^{-1} h^{-1}	14	IT13
Tuff (volcanic)	1			7	103	mBq kg^{-1} h^{-1}	25	IT13
Tuff (volcanic)	1			8	170	mBq kg^{-1} h^{-1}	34	IT13
Gypsum	5		2000-2400	8	**2.1** (0.2-4.1)	Bq m^{-2} h^{-1}	6 (1-13)	IT15
Natural covering stones								
Granite Limbara Pink	1	3			468	Bq m^{-2}h^{-1}	42	IT1
Peperino Pink	1	3			482	Bq m^{-2}h^{-1}	167	IT1
Sienites (unpolished)	1	3			846	Bq m^{-2}h^{-1}	334	IT1
Sienites (polished)	1	3			526	Bq m^{-2}h^{-1}	334	IT1
Granite pink- Porrino	1	3			695	Bq m^{-2}h^{-1}	88	IT1
Granite pink- Porrino 0.2 water content	1	3			850	Bq m^{-2}h^{-1}	88	IT1
Granite pink- Porrino 0.3 water content	1	3			1253	Bq m^{-2}h^{-1}	88	IT1
Marble	8		2400-3000	0.5	130 (10-250)	mBq m^{-2}h^{-1}	4 (0.6-10)	IT15
Schist	3		2600-3000	2	12.3 (8.7-16)	Bq m^{-2} h^{-1}	52 (19-86)	IT15
Schist	3		2600-3000	2	3.5 (2.9-4.1)	Bq m^{-2} h^{-1}	39 (34-42)	IT15
Granite (green)	1			19	82	mBq kg^{-1} h^{-1}	57	IT13
Granite (red)	1			21	250	mBq kg^{-1} h^{-1}	153	IT13
Granite (pink)	1			2	129	mBq kg^{-1} h^{-1}	147	IT13
Granite (pink)	1			5	12	mBq kg^{-1} h^{-1}	33	IT13
Granite (pink)	1			15	69	mBq kg^{-1} h^{-1}	61	IT13
Granite (white)	1			2	4	mBq kg^{-1} h^{-1}	37	IT13
Black gabbro	1			7	7	mBq kg^{-1} h^{-1}	12	IT13
Porphyry	1			2	7	mBq kg^{-1} h^{-1}	40	IT13
Porphyry	1			12	38	mBq kg^{-1} h^{-1}	41	IT13
Other						mBq kg^{-1} h^{-1}		
Mortar	1			9	15	mBq kg^{-1} h^{-1}	22	IT13
Mortar	1			23	12	mBq kg^{-1} h^{-1}	7	IT13
Mortar	1			13	13	mBq kg^{-1} h^{-1}	13	IT13
Lime mortar	1			3	4	mBq kg^{-1} h^{-1}	16	IT13
Plaster coat	1			10	17	mBq kg^{-1} h^{-1}	22	IT13
Plaster coat	1			1	3	mBq kg^{-1} h^{-1}	34	IT13
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
FA (USA)	10[p]			2	23	mBq kg^{-1} h^{-1}	170	IT2

[o] Radiometric measure on 13 samples
Concrete A*: white limestone as aggregate
Concrete B**: sand and gravel as aggregate
[p] Radiometric measure on 71 samples

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
FA (Sud Africa)	19[q]			1	16	mBq kg^{-1} h^{-1}	170	IT2
BA	5[r]			3	24	mBq kg^{-1} h^{-1}	130	IT2
NETHERLANDS (124 samples from Table 19)								
Brick	1	10	1680	1	290	mBq m^{-2}h^{-1}	39	NL4
Brick (clay)	16	**10**	1670 (1370-2000)	0.3 (0.03-1)	4 (0.1-4)	mBq kg^{-1}h^{-1}	39 (27-45)	NL1
Brick (clay)	5	10	1370 (1350-1390)	0.2 (0.07-0.3)	4 (0.4-1)	mBq kg^{-1}h^{-1}	74 (71-75)	NL1
Brick (sand-lime)	22	**10**	1820 (1720-1910)	10 (6-15)	8 (3-14)	mBq kg^{-1}h^{-1}	10 (4-17)	NL1
Brick 20% FA	1	7	1490	0.7	200	mBq m^{-2}h^{-1}	76	NL3,NL4
Concrete								
Aereated concrete	14			13 (5-17)	10 (5-22)	mBq kg^{-1}h^{-1}	11 (6-16)	NL1
Aereated concrete	1	10	570	18	850	mBq m^{-2}h^{-1}	22	NL4
Aereated concrete	1	10	790	22	1200	mBq m^{-2}h^{-1}	18	NL4
Aereated concrete with FA	1	10	810	21	3800	mBq m^{-2}h^{-1}	58	EU2, NL4
Concrete	28			14 (6-26)	25 (4-40)	mBq kg^{-1}h^{-1}	24 (11-36)	NL1
Concrete (BFS+FA)	1		2300	9	1510	mBq m^{-2}h^{-1}	19	NL4
Concrete (PTL+ phopshoslag)	1		2390	1	6200	mBq m^{-2}h^{-1}	710	NL4
Concrete A (PTL)	1	10	2360	26[s]	2350[s]	mBq m^{-2}h^{-1}	10[s]	NL3, NL4
Concrete B (BFS cement)	1	10	2360	26[s]	3550[s]	mBq m^{-2}h^{-1}	16[s]	NL3, NL4
Concrete C (FA cement)	1	10	2330	17[s]	2500[s]	mBq m^{-2}h^{-1}	14[s]	NL3, NL4
Concrete D (sintered FA grains)	1	10	1900	6[s]	2350[s]	mBq m^{-2}h^{-1}	55[s]	NL3, NL4
Natural raw materials								
Gypsum	1	7	960	13	340	mBq m^{-2}h^{-1}	10	NL4
Gypsum	1	7	990	9	130	mBq m^{-2}h^{-1}	5	NL4
Gypsum	1	1	760		***50***	mBq m^{-2}h^{-1}	2	NL4
Gypsum	1	1	910	19	33	mBq m^{-2}h^{-1}	6	NL4
Gypsum	1	1	820		***20***	mBq m^{-2}h^{-1}	4	NL4
Gypsum	10	1-10	900 (700-1200)	13 (5-17)	6 (4-10)	mBq kg^{-1}h^{-1}	8 (3-14)	NL1
Others								
Mortar	6	4	1830 (1740-1890)	26 (20-34)	25 (11-47)	mBq kg^{-1}h^{-1}	12 (7-18)	NL1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
By-product gypsum								
PHG	1	7	960	18	4800	mBq m^{-2}h^{-1}	103	NL4
PHG	1	7	960	19	15800	mBq m^{-2}h^{-1}	330	NL4
PHG	1	1	840	13	2500	mBq m^{-2}h^{-1}	700	NL4
PHG (possible)	1	7	900	3	200	mBq m^{-2}h^{-1}	26	NL4
Chemical gypsum (board)	3	7		7	9.6	Bq m^{-2}h^{-1}	450 (320-700)	NL3

[q] Radiometric measure on 70 samples
[r] Radiometric measure on 10 samples
[s] Average value between data from NL3 e NL4

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
NORWAY (10 samples from Table 20 + 13 samples with only emanation/exhalation rate data)								
Concrete								
Concrete	7				4 (3-6)	mBq h^{-1} /Bq kg^{-1}		NW3
Concrete with FA	3				61 (50-71)	mB qh^{-1}		NW3
Concrete without FA	3				91 (84-102)	mB qh^{-1}		NW3
Cement								
Cement	5			2-5			30-33	EU2, NW3
FA cement	1			2			85	EU2, NW3
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
FA (imported)	4			0.5-1.5			174 (126-222)	NW3
POLAND (58 samples from Table 21)								
Bricks								
Red clay bricks	3							PL4
		9		2.2			19	
		9		2.3			19	
		9		5			19	
Silicon (sand-lime) bricks	3							PL4
		9		16			7	
		9		3			7	
		9		0.8			15	
Cement								
Cement	4							PL4
Cement		9		***5***			***9***	
Cement		9		4			24	
Cement		9		0.8			26	
Cement		9		9			19	
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
Ashes								
Fly ash	33			0.5 (0.2-1.2)			96 (63-144)	PL4
By product gypsum								
By product gypsum	4							PL4
		9		4			26	
		9		13			699	
		9		21			736	
		9		20			585	
Metallurgical Slags								
Slag	11	9		0.7 (0.2-1.5)			67 (37-144)	PL4
PORTUGAL (78 samples from Table 22)								
Bricks								
Bricks	10				**6.1**(1.8-10.4)	Bq m^{-2}h^{-1}	**64** (37-90)	POR1
Concrete								
Concrete block	11				**7** (1.1-13)	Bq m^{-2}h^{-1}	**53** (8-98)	POR1

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Cement								
Cement	7				**2.5** (1.8-3.2)	Bq m^{-2}h^{-1}	**40** (21-59)	POR1
Aggregates								
Sand	32				**61.4** (0.4-122)	Bq m^{-2}h^{-1}	**102** 2-202	POR1
Gravel	11				**3.6** (0.4-6.8)	Bq m^{-2}h^{-1}	**70** (10-130)	POR1
INDUSTRIAL BY-PRODUCTS IN BUILDING MATERIALS								
By-product gypsum								
PHG	7				18.2 (4-74.2)	Bq m^{-2}h^{-1}	166 (12-705)	POR1
ROMANIA (4 samples from Table 23)								
Cement								
Cement	1	15	1700		520	mBq m^{-2}h^{-1}	27	RO5
Cement-FA 50%	1	15	1700		2970	mBq m^{-2}h^{-1}	154	RO5
Cement-FA 33%	1	15	1700		2070	mBq m^{-2}h^{-1}	107	RO5
Cement-FA 11%	1	15	1700		1120	mBq m^{-2}h^{-1}	58	RO5
SLOVAKIA (29 samples from Table 24)								
Concrete								
Concrete b7.5/325R	3	7.5	2210	3	3	mBq kg^{-1}h^{-1}	10	SK2
Concrete b7.5/325R+2mm plaster	3	7.5	2210		1	mBq kg^{-1}h^{-1}	10	SK2
Concrete b35/325 R	3	7.5	2295	9	9	mBq kg^{-1}h^{-1}	13	SK2
Concrete b35/325 R+2mm plaster	3	7.5	2295		5	mBq kg^{-1}h^{-1}	13	SK2
Concrete b35/325 HS	3	7.5	2200	4	3	mBq kg^{-1}h^{-1}	11	SK2
Concrete b35/325 HS+2 mm plaster	3	7.5	2200		3	mBq kg^{-1}h^{-1}	11	SK2
Concrete with broken bricks BBC/325HS	2		1600	4	3	mBq kg^{-1}h^{-1}	46	SK2
Concrete with broken bricks BBC/325R	2		1545	6	6	mBq kg^{-1}h^{-1}	44	SK2
Cellular concrete SS	3	7.5	535	9	10	mBq kg^{-1}h^{-1}	16	SK2
Cellular concrete SE	3	7.5	500	12	49	mBq kg^{-1}h^{-1}	50	SK2
Cellular concrete BA	1	7.5	580	11	57	mBq kg^{-1}h^{-1}	69	SK2
SWITZERLAND (86 samples from Table 28)								
Brick								
Clay brick	18			3 (0.4-16)	11 (0.7-49)	mBq kg^{-1}h^{-1}	47 (32-62)	SW1
Concrete								
Concrete brick	2			**6** (2-10)	**6** (2-9)	mBq kg^{-1}h^{-1}	**12** (11-12)	SW1
Aerated concrete	2			**6** (3-10)	**6** (5.8-6.5)	mBq kg^{-1}h^{-1}	**19** (9-28)	SW1
Pumice concrete	5			5 (3-22)	49 (18-87)	mBq kg^{-1}h^{-1}	149 (28-249)	SW1
Cement								
Cement	10			15 (2-50)	22 (4-69)	mBq kg^{-1}h^{-1}	20 (11-29)	SW1
Aggregates								
Gravel	12			20 (3-47)	33 (5-150)	mBq kg^{-1}h^{-1}	25 (9-50)	SW1

BUILDING MATERIALS	N.	d (cm)	Density (kg m^{-3})	Emanation (%)	Exhalation rate value	Exhalation rate unit	^{226}Ra (Bq kg^{-1})	Ref.
Sand	22			19 (2-63)	31 (1-146)	mBq kg^{-1}h^{-1}	20 (9-56)	SW1
Rhenice pumice	5			1 (0.4-2)	21 (9-35)	mBq kg^{-1}h^{-1}	237 (121-415)	SW1
Natural Raw Materials								
Lime	3			**15** (3-26)	**14** (5-21)	mBq kg^{-1}h^{-1}	**17** (11-22)	SW1
Sand-lime stone	2			**35** (34-36)	**34** (32-37)	mBq kg^{-1}h^{-1}	13 (11-15)	SW1
Gypsum	5			24 (14-40)	26 (18-87)	mBq kg^{-1}h^{-1}	15 (13-18)	SW1
UNITED KINGDOM (17 samples from Table 30)								
Brick								
Clay brick	6			0.5	50	mBq m^{-2}h^{-1}	65	GB1
Silica brick	1			3	180	mBq m^{-2}h^{-1}	33	GB1
Flint brick	1			0.9	133	mBq m^{-2}h^{-1}	70	GB1
Oil shale brick	1			8	1166	mBq m^{-2}h^{-1}	76	GB1
Crushed granite bricks and blocks	3			11	1800	mBq m^{-2}h^{-1}	40	GB1
Expanded clay blocks	2			0.8	14	mBq m^{-2}h^{-1}	94	GB1
Concrete								
Building blocks with PFA	2				610 (160-1480)	mBq m^{-2}h^{-1}	54	EU2
Concrete block	1			4	324	mBq m^{-2}h^{-1}	18	GB1

DATABASE REFERENCES

[AU1] Sorantin H, Steger F. Natural Radioactivity of building materials in Austria. *Radiat Prot Dosim* 1984;7(1-4):59-61.

[BE1] Poffijn A, personal communication from FANC Report in Dutch.

[BE2] Poffijn A, Bourgoignie R, Marijins R, Uyttenhove J, Janssens A, Jacobs R. Laboratory measurements of radon exhalation and diffusion. *Radiat Prot Dosim* 1984;7(1-4):77-9.

[BE3] Poffijn A, Marijins R, Vanmarcke H, Uyttenhove J. Results of a preliminary survey on radon in Belgium. *Sci. Tot. Environ.* 1985. 45, 335-342.

[CY1] Michael F, Parpottas Y, Tsertos H. Gamma radiation measurements and dose rates in commonly used building materials in Cyprus. *Radiat Prot Dosimetry* 2010;142(2-4):282-91. I dati coincidono con: Panicos Demetriades, Personal communication.

[CZ1] Breda M. "Prirodni radioakivita ve stavebnictvì" 1990

[DK1] Ulbak K. Radioaktive stoffer i danske byggematerialer. SIS, State Institute of Radiation Hygiene & The National Health Service of Denmark, p.6+app. (1980). Partially translated in: Ulbak K. Natural radioactivity in building materials in Denmark. In: Proceedings of the *"Seminar on the radiological burden of man from natural radioactivity in the countries of the European Communities".* 4-6 December 1979, Le Vesinet, Paris, France 1979.

[DK2] Ulbak K. En stralehygiejnisk vurderin af brufen af flyveaske i byggeindustrien. SIS, State Institute of Radiation Hygiene & The National Health Service of Denmark, p. 13 1984.

[EST1] Lust M, Realo E. Assessment of natural radiation exposure from building materials in Estonia. Proceedings of the "*Estonian Academy of Sciences",* 2012, 61, 2, 107–112 doi: 10.3176/proc.2012.2.03

[EU1] Krstic D, Nikezic D, Stevanovic N, Vucic D. Radioactivity of some domestic and imported building materials from South Eastern Europe. *Radiat Meas* 2007;42:1731-6.

[EU2] European Commission. *Enhanced radioactivity of building materials. Radiation Protection 96.* Luxembourg: European Commission; 1997.

[EU3] United Nations. *Sources and effects of ionizing radiation. united nations scientific committee on the effects of atomic radiation. Report to the General Assembly, with annexes*. New York: United Nations; 1977.

[FIN1] Turtiainen T, Weltner A. Assessment of dose during the life cycle of natural stone production. *Radiation Protection Dosimetry* 2007;124(2):167-71.

[FIN2] Mustonen R. Natural radioactivity in and radon exhalation from Finnish building materials. *Health Phys* 1984;46(6):1195-203.

[FIN3] Mustonen R. Methods for Evaluation of radiation from building materials. *Rad Prot Dos* 1984;7(1-4):235-8.

[FIN4] Mustonen R. *Building materials as sources of indoor exposure to ionizing radiation. STUK-A105*. Helsinki Finnish centre for Radiation and Nuclear Safety; 1992.

[FR1] Dupuis M, Ameon R, Alcalde G, Diez O. *Les matériaux de construction, source secondarie de radon dans les batiments.* Fontanay-aux-Roses: Institut de Radioprotection et de Surete Nucleare; 2008 (IRSN/DEI/SARG/2008-008).

[FR2] Pasquier JL, Lemaitre N. *Radioprotection et materiaux de construction.* Le Vésinet: Office de Protection contre les Rayonnements Ionisants; 1999. **(**Rapport O.P.R.I – 22/06/99.

[GB1] Cliff KD, Green BMR, Miles JCH. The levels of radioactive materials in some common UK building materials. *Sci Total Environ* 1985;45:181-6.

[GB2] Cliff KD, Miles JCH, Brown K. *The incidence and origin f radon and its decay products in buildings.* Chilton: National Radiological Protection Board; 1984. (NRPB-R159)

[GB3] O'Riordan MC, Hunt GJ. Radiological controls for construction materials. In: Proceedings of the *4th International Congress of IRPA*, 24-30 April 1977, Paris, France, vol. 3, p. 1053-6.

[GE1] Gehrcke K, Hoffmann B, Schkade Y, Schmidt V, Wichterey K. Radiation exposure from the use of NORM in building materials in Germany. IAEA Library Cataloguing in Publication Data Naturally occurring radioactive material (NORM VI): proceedings of the "S*ixth International Symposium on naturally occurring radioactive material"* organized by the Hassan II University of Mohammedia and the Cadi Ayyad University of Marrakesh in cooperation with the International Atomic Energy Agency and held in Marrakesh, Morocco, 22-26 March 2010. Vienna: International Atomic Energy Agency, 2011. p. 443-53.

[GE2] Folkerts KH, Keller G, Muth H. An experimental study on diffusion and exhalation of ^{222}Rn and ^{220}Rn from building materials. *Radiation Protection Dosimetry* 1984;9(1):27-34.

[GE3] Lehman R. Strahlenbelastung durch naturliche Radionuklide in Baumaterialen, fossilen Brennstoffen und Dungemitteln. In: Siehl A. (Hrsg.) Umweltradioaktivitat. Ernst & Sohn Verlag, Berlin, Germany, 1996,135-156.

[GE4] Von Philipsborn H, Kuhnast E. Gamma spectrometric characterisation of industrially used African and Australian bauxites and their red mud tailings. *Radiat Prot Dosim* 1992;45(1-4 Suppl.):741-3.

[GE5] Döring J, Beck T, Beyermann M, Gerler J, Henze G, Mielcarek J, Schkade UK. Exposure and radiation protection for work areas with enhanced natural radioactivity. In: *Proceedings of the Fifth International Symposium on Naturally Occurring Radioactive Material.* Seville, 19-22 March 2007. 399-407. IAEA, Vienna 2008.

[GR1] Petropoulos NP, Anagnostakis MJ, Simopoulos SE. Photon attenuation, natural radioactivity content and radon exhalation rate of building materials. *J Environ Radioact* 2002;61:257-69.

[GR2] Papastefanou C, Manolopolou M, Charalambous S. Exposure from radioactivity in building materials. *Health Phys* 1984;47:775-83.

[GR3] Pakou AA, Assimakopoulos PA, Prapidis M. Natural radioacitivty and radon emanation factors in building material used in Epirus (north-western Greece). *Sci Total Environ* 1994;144:255-60.

[GR4] Stoulos S, Manolopolou M, Papastefanou C. Assessment of natural radiation exposure and radon exhalation from building materials in Greece. *J Environ Radioact* 2003;69:225-40.

[GR5] Papaefthymiou H, Gouseti O. Natural radioactivity and associated radiation hazards in building materials used in Peloponnese, Greece. *Radiat Meas* 2008;43:1453-7.

[GR6] Tzortzis M, Tsertos H, Christofides S, Christodoulides G. Gamma radiation measurements and dose rates in commercially-used natural tiling rocks (granites). *J Environ Radioact* 2003;70:223-35.

[GR7] Pavlidou S, Koroneos A, Papastefanou C, Christofides G, Stoulos S, Vavelides M. Natural radioactivity of granites used as building materials. *J Environ Radioact* 2006;89:48-60.

[GR8] Karangelos DJ, Petropoulos NP, Anagnostakis MJ, Hinis EP, Simopoulos SE. Radiological characteristics and investigation of the radioactive equilibrium in the ashes produced in lignite-fired power plants. *J Environ Radioact* 2004;77:233-46.

[GR9] Louizi A, Proukakis C, Petropoulos NP, Simopoulos SE. Natural radioactivity content and radon exhalation rates of Greek building materials. In: Morawska L, Bofinger ND, Maroni M (Ed.). *Indoor air – an integrated approach*. Oxford: Elsevier; 1995. p. 131-5.

[GR10] Siotis I, Wrixon AD. Radiological consequences of the use of fly ash in building materials in Greece. *Radiat Prot Dosim* 1984;7:101-5.

[GR11] Savidou A, Raptis C, Kritidis P. Natural radioactivity and radon exhalation from building materials used in Attica region, Greece. *Radiat Prot Dosim* 1995;59(4):309-12.

[GR12] Maraziotis EA. Gamma activity of the fly ash from Greek power plant and properties of fly ash cement. *Health Phys* 1985;49(2):302-3.

[GR13] Savidou A, Raptis C, Kritidis P. Study of Natural Radionuclides and Radon Emanation in Bricks used in the Attica Region, Greece. *J Environ Radioact* 1996;31:21-8.

[GR14] Papastefanou C. Escaping radioactivity from coal-fired power plants (CPPs) due to coal burning and the associated hazards: a review. *J Environ Radioact* 2010;101:191-200.

[GR15] Papaefthymiou H, Symeopoulos BD, Soupioni M. Neutron activation analysis and natural radioactivity measurements of lignite and ashes from Megalopolis basin, Greece. *J Radioanal Nucl Chem* 2007;274:123-30.

[GR16] Pontikes Y, Vangelatos I, Boufounos D, Fafoutis D, Angelopoulos GN. Environmental aspects on the use of Bayer's process bauxite residue in theproduction of ceramics. *Adv Sci Technol* 2006;45:2176-81.

[GR17] Papatheodorou G, Papaefthymiou H, Maratou A, Ferentinos G. Natural radionuclides in bauxitic tailings (red-mud) in the Gulf of Corinth, Greece. *Radioprotection* 2005;40:S549-S555.

[GR18] Samouhos M, Taxiarchou M, Tsakiridis PE, Potiriadis K. Greek "red mud" residue: a study of microwave reductive roasting followed by magnetic separation for a metallic iron recovery process. *J Hazard Mater* 2013;254-255:193-205.

[GR19] Simopoulos SE, Angelopoulos MG, Natural radioactivity releases from lignite power plants in Greece, *J. Environ. Radioact.* 1987. 5(5), 379-389.

[H1] Somlai J, Jobbágy V, Németh C, Gorjánácz Z, Kávási N, Kovács T. Radiation dose from coal slag used as building material in the Transdanubian region of Hungary. *Radiat Prot Dosim* 2006;118(1):82-7.

[H2] Gallyas M, Torok I. Natural radioactivity of raw materials and products in the cement industry. *Radiat Prot Dosim* 1984;7(1-4):69-71.

[H3] Toth A, Feher I, Novotny Lakatos S, Koszorus L, Keszthely B. Distribution of natural radioactive isotopes concentrations and emanation factors measured on concrete and brick samples produced in Hungary. In: *Proceedings of Symposium "Natural Radiation Environment III".* April 1978, Houston Springfield, NTIS, 1980. p.1396-406.

[H4] IBES, International Bureau for Environmental Studies. Final report INTAILRISK (assessment of environmental risk for use of radioactively contaminated industrial tailings); 2011.

[H5] Jobbágy V, Somlai J, Kovács J, Szeiler G, Kovács T. Dependence of radon emanation of red mud bauxite processing wastes on heat treatment. *Journal of Hazardous Materials* 2009;172:1258-63.

[IRL1] Lee EM, Menezes G, Finch EC. Natural radioactivity on building materials in the Republic of Ireland. *Health Phys* 2004;86(4):378-83.

[IRL2] Organo C, Fenton D. *Radiological assessment of NORM Industries in Ireland – Radiation doses to workers and members of the public*. Dublin: Radiation Protection Institute of Ireland; 2008.

[IT1] Carrera G, Garavaglia M, Magnoni S, Valli G, Vecchi R. Natural Radioactivity and Radon Exhalation in Stony Materials. *J Environ Radioact* 1997;34(2):149-59.

[IT2] Battaglia A, Capra D, Queirazza G, Sampaolo A. Rn exhalation rates from building materials and fly ash-containing concretes. In: *Proceeding of IRPA 8*, Montreal 1992. p. 1578-81.

[IT2.A] Battaglia A, Capra D, Queirazza G, Sampaolo A. Emanazione di radon da ceneri di carbone e da materiali edili. In: *Atti del "XXVII Congresso Nazionale AIRP",* 16-18 settembre 1991, Ferrara, Italia, 1991. p. 533-41.

[IT3] Bonetti R, Capra L, Facchini U, Valli G, Carreri V, Anversa A, Blanco G, Gualdi R, Sgorbati G, De Crescenzo S. Development of Radon Surveys in Lombardia, Italy. In: *Proceedings of "Indoor Air '90",* 29 July-3 August 1990, Toronto, Canada,1990. p. 53-8.

[IT4] Trotti F, Lanciai M, Lucchese R, Mozzo P, Predicatori F, Tacconi A. Radioattività naturale nei materiali da costruzione utilizzati in provincia di Verona. In: *Atti del "XXVII Congresso Nazionale AIRP",* 16-18 settembre 1991, Ferrara, Italia,1991. p. 597-604.

[IT5] Orlando P, Massari P, Paolelli C, Trenta R, Trevisi R, Amici M, Benvenuti F, Altieri A, Catano F. La radioattività nei materiali da costruzione nel Lazio. In: *Rapporti ISTISAN 98/3, Atti del Convegno nazionale "Aria '96",* 12-14 giugno 1996, Roma, Italia. 1998. p. 303-13.

[IT6] Battaglia A, Bazzano E, Bonfanti G. Indoor dose in Milano (Italy). *Sci Total Environ* 1983;45:365-71.

[IT7] Valli G, Vecchi R, Piardi S, Gregorini E. Concentrazione di radioelementi naturali in materiali lapidei usati nell'edilizia. In: *Atti del Convegno nazionale "La qualità dell'aria negli ambienti interni, Aria '92",* 28-29 ottobre 1992, Pisa, Italia. 1992. p. 60-66.

[IT8] Sciocchetti G, Scacco F, Baldassini PG, Monte L, Sarao R. Indoor measurements of airborne natural radioactivity in Italy. *Radia. Prot Dosim* 1984;7(1-4):347-51.

[IT9] Sciocchetti G, Clemente GF, Ingrao G, Scacco F. Results of a survey on radioactivity of building materials in Italy. *Health Phys* 1983;45(2):385-8.

[IT10] Campos Venuti G, Esposito A, Grisanti A, Grisanti G, Pelliccioni M, Risica S. Studio della radioattività naturale in rocce e cementi, ai fini della costruzione del laboratorio del Gran Sasso dell'INFN. In: *atti del XXIII congresso nazionale dell'associazione italiana di protezione contro le radiazioni (AIRP)*. Capri 5-8 ottobre 1983

[IT10.A] Campos Venuti G, Esposito A, Grisanti A, Grisanti G, Pelliccioni M, Risica S. *Studio della radioattività naturale in rocce e cementi, ai fini della costruzione del laboratorio del Gran Sasso dell'INFN*. Frascati: Istituto Nazionale di Fisca Nucleare; 1982. (LNF-82/78(R)).

[IT11] Campos Venuti G, Colilli S, Grisanti A, Grisanti G, Monteleone G, Risica S, Antonini A, Borio R, Gobbi G, Leogrande MP. Methodology and Results of a Natural Radioactivity Assessment in a Region of Central Italy. In: *Proceedings of the "6th International Congress IRPA*", May 7-12 1984, Berlin, Germany, 1984. p. 84-87.

[IT12] Minach L, Brunner P. Radioattività nei materiali da costruzione (in Alto Adige). In: *Misurazioni della radioattività in Alto Adige.* Bolzano: Provincia Autonoma di Bolzano; 1990. P. 48-53.

[IT13] Righi S, Bruzzi L. Natural radioactivity and radon exhalation in building materials used Italian dwellings. *J Environ Radioact* 2006;88:158-70.

[IT14] Bruzzi L, Baroni M, Mazzotti G, Mele R, Righi S. Radioactivity in raw materials and end products in the Italian ceramics industry. *J Environ Radioact* 2000;47:171-81.

[IT15] Rizzo S, Brai M, Basile S, Bellia S, Hauser S. Gamma activity and geochemical features of building materials: estimation of gamma dose rate and indoor radon levels in Sicily. *Applied Radiation and Isotopes* 2001;55:259-65.

[IT16] Ianni A, Cavariani F, Lucci F, Morgia A, Nobili C, Sandri S, Vasselli R. Natural radiation in building materials from the volcanic area of the Italian Lazio region - Occupational Safety. In: Peter J, Schneider G, Bayer A (Ed). *Proceedings of "High levels of natural radiation and radon areas: radiation dose and health effects". Munich (Germany); 4-7 Sep 2000*. Salzgitter: Bundesamt fuer Strahlenschutz; 2002. p. 351-4.

[IT17] Sabbarese C, Inglima I, D'Onofrio A, Roca V, Ermice A, Lubritto C, Terrasi F, Plamieri A, Casa G, Migliore G. Radioattività nei materiali da csotruzione utilizzati nella regione Campania. In: *atti del convegno AIRP "La radioattività nel contesto degli studi ambientali"* Isola del Giglio 9-10 maggio 2002

[IT18] Grisanti G. *Data on radioactivity concentration in Italian building materials* (data not published). Rome: Istituto Superiore di Sanità; 1990

[IT19] Trotti F, Zampieri C, Nuccetelli C and Risica S. Review of Italian NORM industries with specific reference to their environmental impact. In: *Proceeding of ''EAN NORM workshop – European ALARA network for NORM''* 20–22 November 2007 Dresden – Germany; 2007.

[LT1] Pilkyte L, Butkus D, Morkunas G. Assessment of the external dose indoors in Lithuania. *Radiat Prot Dosim* 2006;121(2):140-7.

[LT2] Butkus D, Morkunas G, Pilkyte L. Ionising radiation in buildings: situation and dealing with problems. *J Environmental Engineering and Landscape Managements* 2005;13(2):103-7.

[L1] Harpes N, Lecomte M. Radiation Protection Division, Ministry of Health, Luxembourg. Personal communication.

[LV1] Riekstina D, Berzins J, Veveris O. Assessment of natural radionucldes level in building materials. Personal communication.

[NL1] de Jong P, van Dijk W, van der Graaf ER, de Groot TJH. National survey on the natural radioactivity and ^{222}Rn exhalation of building materials in the Netherlands. *Health Phys.* 2006. 91 (3), 200-210.

[NL2] Hogeweg B, Bosnjakovic BFM, Willart WMAJ. Radiation aspects of indoor environments and related radioecological problems: a study of the situation in the Netherlands. *Radiat Prot Dosim* 1984;7(1-4):327-31.

[NL3] Ackers JG, den Boer JF, de Jong P, Wolschrijn RA. Radioactivity and radon exhalation rates of building materials in the Netherlands. *Sci Total Environ* 1985;45:151-6.

[NL4] van Dijk W, de Jong P. Determining the ^{222}Rn exhalation rate of building materials using liquid scintillation counting. *Health Physics* 1991;61(4):501-9.

[NW1] Stranden E, Strand T. Natural gamma radiation in a Norwegian area rich in thorium. *Radiat Prot Dosim* 1986;16(4):325-8.

[NW2] Stranden E. Radioactivity of building materials and the gamma radiation in dwellings. *Phys Med Biol* 1979;24(5):921-30.

[NW3] Stranden E. Assessment of the radiological impact of using fly ash in cement. *Health Phys* 1983;44(2):145-53.

[PL1] Mamont-Ciesla K, Gwiazdowski B, Biernacka M, Zak A. Radioactivity of building materials in Poland. In: *Proceedings of the "Second Special Symposium on natural radiation environment",* Bhabha Atomic Research Centre, 19-23 January 1981, Bombay, India. 1981. p. 551-6.

[PL2] Skowronek J, Dulewski J. NORM in polish industry. In: *Proceedings of the "NORM III congress"*, 17-21 September 2001, Brussels, Belgium.

[PL3] Zak A, Biernacka M, Jagielak J, Lipinski P. Investigations of radioactivity of building raws and materials. *Nukleonika* 1993;38(4):51-70.

[PL4] Pensko J, Stipezynska Z, Blaton-Albicka K. Emanating power of radon-222 measured in building materials. In: Lowder WM, Gesell TF (Ed*.). Proceedings of Symposium "Natural Radiation Environment III". Houston, Texas, April 23-28, 1978*. Oak Ridge: U.S. Dept. of Energy; 1980. p. 1407-14.

[POR1] Faisca MC, Teixeira MMR. Different studies on building materials. In: *Proceedings of the "Radon in the Living Environment",* 19-23 April 1999, Athens, Greece. p. 935-42.

[POR2] Oliveira C. *Data on radioactivity concentration in Portugal building materials (data not published)*. Lisbon: Instituto Tecnològico e Nuclear, 2009.

[RO1] Pantelica A, Georgescu II, Murariu-Magureanu MD, Margaritescu I, Cincu E. Thorium determination in intercomparisons samples and in some Romania building materials by gamma ray spectrometry. *Radiat Prot Dosim* 2001;97(2):187-91.

[RO2] Gheorge R, Milu C, Gheorge D, Modoran G. Exposure due to phosphogypsum and fly-ash used as building materials. In: *Proceeding of the "5th International Conference on high levels of natural radiation and radon areas: Radiation dose and health effects*", 4-7 September 2000, Munich, Germany. 2002, p. 331-4.

[RO3] Botezatu E, Iacob O, Miron C, Gradinaru M. Increased indoor radiation exposures-consequences of NORMs contained in building materials. In: *Proceeding of the "5th International Conference on high levels of natural radiation and radon areas: Radiation dose and health effects",* 4-7 September 2000, Munich, Germany. 2002, p. 355-8.

[RO4] Botezatu E, Grecea C, Iacob O. Is coal ash and slags any useful or unloaded wastes? In: *Proceeding of the "European IRPA congress",* October 8-11 2002, Florence, Italy.

[RO5] Mocsy I, Onitiu T, Gorcea L. Radioactivity of the new building materials from Romania. In: *Proceedings of "Indoor Air '93",* July 4-8 1993, Helsinki, Finland. 1993, p. 527-32.

[SK1] Cabáneková H. Building materials as the source of radiation load of Slovak population. In: Seliga M, Sebesta (Ed.). *Proceedings of the 10. Banska Stiavnica Days 2008. Peaceful use of atomic energy. Application of nuclear technologies and determination of radionuclides in the environment. Environmental load and municipal wastes. Banska Stiavnica (Slovakia); 8-10 Oct 2008*. Bratislava: Slovak Nuclear Society; 2008. p. 53-6.

[SK2] Holy K, Sykora I, Chudy M, Polaskova A, Fedja J, Hola O. Radionuclide content in some building materials and their radon exhalation. *J. Radioanal Nucl Chem Letters* 1995;199(4):251-63.

[SLO1] Križman M. Exposure to natural radiation in dwellings and problems of high concentrations of ^{222}Rn. In: Culibrk R (Ed.). *Proceedings of the Symposium on "Influence of Building Materials to the Microclimate of Residental Spaces"*, November 1990, Kanjiža (Serbia). Beograd: Yugoslavian Chamber of Economy; 1990. p. 24-40.

[SP1] Cruz Alvarez M, Garzon L. Assessment of radiological emission from Spanish coal power plants: radioactive releases and associated risks. *Health Phys* 1989;57(5):765-9.

[SP2] Garzon L, Fontenla P, Suarez A. Radioactivity of building materials- Adsorbed Doses. In: *Proceedings of the "Second Special Symposium on natural radiation environment",* Bhabha Atomic Research Centre, 19-23 January 1981, Bombay, India. 1981, p. 544-6.

[SP3] Martín Matarranz JL. *Concentraciones de radón en viviendas españolas. Otros estudios de radiación natural*. Madrid: Consejo de Seguridad Nuclear; 2004. (Colección Informes Técnicos 13.2004).

[SP4] Chinchon-Paya S, Piedecausa B, Hurtado S, Sanjuan MA, Chinchon S. Radiological impact of cement concrete and admixtures in Spain. *Radiation Measurements* 2011;46:734-5.

[S1] More H. *Radoiaktiva amnen I byggnadsmaterial*. Stockholm: Statens stralskyddsinstitut; 1985. (SSI-rapport 85-08).

[S2] Swedjemark GA. *The ionizing radiation in dwellings related to the building materials.* Stockholm: National Institute of Radiation Protection; 1977. (SSI: 1977-004).

[S3] Mjones L. Gamma radiation in Swedish dwellings. *Radiat Prot Dosim* 1986;15(2):131-40.

[SW1] Schuler Ch, Cramieri R, Burkat W. Assessment of the indoor Rn contribution of Swiss building materials. *Health Phys* 1991;60(3):447-51.

[TR1] Turhan S, Baykan UN, Sen K. Measurement of the natural radioactivity in building materials used in Ankara and assessment of external doses. *J Radiol Prot* 2008;28:83-91.

[TR2] Akinci AN, Artir R. Characterization of trace elements and radionuclides and their risk assessment in red mud. *Mater Charact* 2008;59(4):417-21.

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