

Radiation Exposure from the Use of NORM in Building Materials in Germany

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Current German NORM Regulations (2001)

- Directive 96/29 EURATOM (European Basic Safety Standards)
- Radiological criterion: 1 mSv/a (in addition to natural background) to members of the public
- Systematic investigations to identify relevant processes & materials

Results:

- re-use / disposal of particular industrial residues relevant
(surface / underground disposal, road construction, building material, landfilling ...)
- Radionuclides: U-238 and Th-232 series (K- 40 considered not relevant)

Controlled Residues (Extract)

- Sludge and scale from oil and natural gas extraction,
- Impure phosphogypsum; sludges, dust, slags from the production / processing of raw phosphate,
- waste rock, sludges, sands, slags and dusts from the extraction and preparation of bauxite, columbite, copper shale, tin, ...
- Dust and sludge from the off-gas cleaning of blast furnaces in raw iron and non-ferrous metal processing.

Exemption from control: **radioactivity contents < control limits (C)**

Restrictions on Building Materials

No control necessary if

$$C_{U238_{\max}} + C_{Th232_{\max}} \leq C$$

C - 'Control limits' for building materials (houses only):

- C = 1 Bq/g (less than 20 % NORM)
- C = 0.5 Bq/g (more than 20 % NORM)

Otherwise: explicite dose estimates

Paths:

- external exposure to Gamma-radiation
- inhalation of Radon / Radon progeny

Current Practice

- obligation for NORM additions within the framework of approval procedures of building materials

- very limited use of NORM in building materials

Examples: sludge from water purification,
(brick, concrete), slag from steel industry (concrete)

no importance anymore:

- red mud (no longer used),

- phosphogypsum (not produced any more)

- ashes from coal combustion (low radioactivity contents)

Changing Framework

Revision of EU – Basic Safety Standards in RP:

Natural radioactivity in building material planned to be regulated specifically

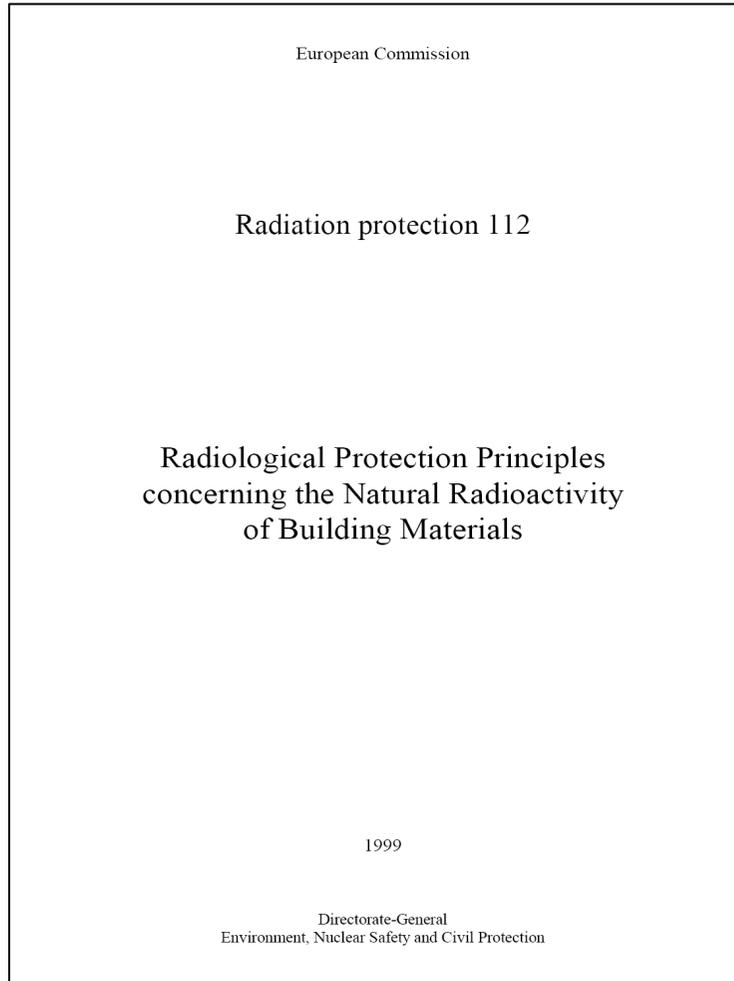
EEC Construction Products Directive (1989)

→ Standardization of measurement methods / evaluation methods (CEN/TC 351)

In either case:

EC Recommendation RP 112 (1999) basis of discussion

Radiation Protection 112



- Only external exposure considered
- Radon inhalation not considered explicitly

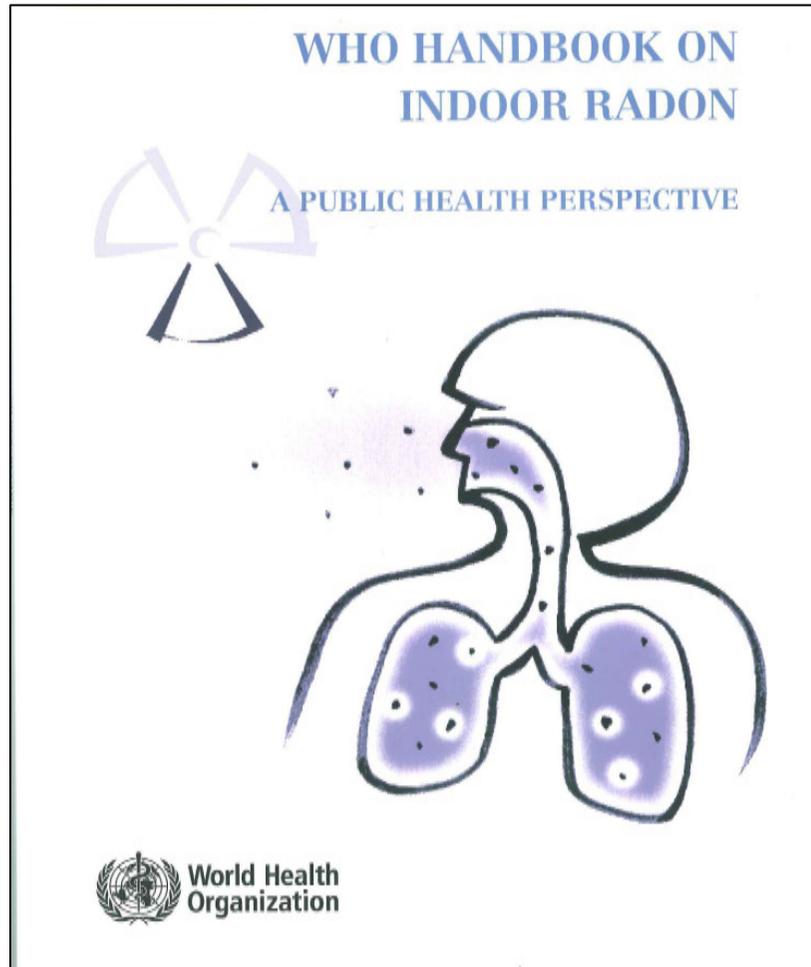
Index formula:

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

For bulk material:

$$\text{If } I > 1 \rightarrow E < 1 \text{ mSv a}^{-1}$$

WHO – Radon Handbook (2009)



Recommendation on radon concentrations in dwellings:
100 Bq/m³ .. 300 Bq/m³

Consistent with recommendation of BfS of 100 Bq/m³ as a target value

Future Requirements

Future requirements on NORM and natural radioactivity in building materials in Germany should:

- not fall short of the protection level provided by the current NORM regulations (including radon exposure!)
- be in line with RP 112 (K-40)
- be consistent with a target value of 100 Bq/m³ of Radon concentration in homes
- not impose undue restrictions on widely used building materials and the utilization of waste



Up to date overview needed!

Measurement Programme

- Cooperation with bbs (Federal Association Construction materials) → Delivery of samples
- Inclusion of some results from other accredited laboratories after quality control
- ~130 samples altogether

Selection criteria:

- Currently produced products
- Market coverage (representative samples)
- Indoor application

Measurement Methods – Gamma Spectrometry

K-40, Ra-226, Th-228 by Gamma Spectrometry;

airproof measuring vessels (Ra-226 via Bi-214, Pb-214)



Measurement / Assessment Methods – Radon

internal exposure (Rn-222-inhalation) assessed by :

- Measurement of emanation coefficient (2 different methods:
closed bottles in szintillationchamber,
open volume with filters (Alphaspectrometry)
- Calculation of exhalation rate
- Calculation of radon concentration using model room assumptions:

$$C_{Rn} = \frac{A \cdot \Phi}{V \cdot v}$$

total inner surface A: 38 m²

Volume V: 17,4 m³

Air ventilation rate v: 0.5 h⁻¹

Results: Mass Specific Activities

Products	Number of samples	Specific activity [Bq/kg]								
		K-40			Th-228			Ra-226		
		min.	max.	arithm. mean	min.	max.	arithm. mean	min.	max.	arithm. mean
Gypsum products	5	< 20	120	51	1,6	5,8	3,3	3,8	13	8,6
Lime sand bricks	3	35	180	115	2,8	7,2	6,3	4,1	10	8
Mineral wool	7	49	350	155	4,7	64	22	16	80	35
Bricks	27	470	1200	719	37	98	57	38	63	48
Cement/Mortar	11	135	380	230	11	21	15	11	35	22
Tiles/ ceramics	5	295	620	429	39	97	62	67	110	88
Ceramic raw materials	15	65	1700	664	20	135	54	15	115	46
Aerated concrete	10	97	350	193	4,8	19	12	8	26	18
Mortars	7	120	310	226	6	31	19	11	53	27
Plaster	19	12	220	75	0,9	31	6	2	22	7,7
Floor screed mortars	5	210	295	213	11	34	17	11	26	15
Lightweight concrete	7	710	850	845	28	83	49	27	98	62

Results: Ranges of Rn - Concentrations

Products	Contribution to the Radon indoor concentration [Bq/m ³]	Possible dose contribution [mSv/a]
gypsum, lime sand bricks, mortar, plaster, aerated concrete, tiles	0 - 4	≤ 0.1
floor screed mortars	0 - 8	≤ 0.2
bricks	0 - 12	≤ 0.3
lightweight concrete, concrete, cement	0 - 18	≤ 0.4

RP 112 model room, air exchange rate of 0.5 h⁻¹

diffusion coefficient: $1 \cdot 10^{-7}$ m²/s.

Material specific, realistic wall thicknesses and densities

Dose conversion coefficient of UNSCEAR 2000

Results: Dose Ranges

Products	External exposure [mSv/a]	Internal exposure by Radon-222 [mSv/a]
Gypsum products	<0.3	<0.02 – 0.02
Lime sand bricks	<0.3	0.02 – 0.05
Mineral wool	<0.3	not measured
Cement	<0.3	0.02 – 0.05
Tiles/ ceramics	<0.3	0.002 – 0.005
Aerated concrete	<0.3	0.02 – 0.15
Mortars, Plaster	<0.3	<0.02 – 0.02
Floor screed mortars	<0.3	<0.02 – 0.05
Bricks	0.3 – 0.9	0.02 – 0.30
Lightweight concrete	0.3 – 1.0	0.1 – 0.45
Concrete	0.3 – 1.0	0.1 – 0.5

Comparison of German RPO and RP 112

The German NORM regulations and the recommendations of RP 112 reflect different regulatory approaches:

- 1 mSv per year criterion referring to building material as a whole in RP 112 but to the contribution from NORM additives only in RPO;
- Radon explicitly considered and dosimetrically evaluated in the RPO – NORM regulations but taken into account only implicitly in RP 112;
- K-40 is being taken into account in RP 112, while the NORM regulations only refer to radionuclides of the Uranium-Radium- and the Thorium-decay series.

Aspects of a new regulatory approach

- RP 112 is a suitable basis to regulate external exposure
- In order not to fall short of the existing NORM regulations, radon should be considered explicitly
- Radon from building materials should be small compared to the 100 Bq/m³ target value recommended by the BfS – a max. value of 20 Bq/m³ seems adequate. It is rarely exceeded by the building materials currently in use.

Open question:

Should Radon exposure be taken into account dosimetrically?

Dosimetric interpretation of radon?

(new) ÖNORM S 5200 „Radioactivity in construction materials“ (2009, Austria):

maximal tolerable dose: 2.2 mSv/a (!)

$$I = (1 + 0.15 \cdot \varepsilon \cdot \rho \cdot d) \cdot \frac{C_{Ra-226}}{880 \text{ Bq/kg}} + \frac{C_{Th-228}}{530 \text{ Bq/kg}} + \frac{C_{K-40}}{8800 \text{ Bq/kg}}$$

Drawback (from BfS point of view):

- Contributions interchangeable
- Dosimetric evaluation may change

BfS Proposal

$$E_{\text{ext}} < 1 \text{ mSv/a} \quad \text{and} \quad C_{\text{radon}} < 20 \text{ Bq/m}^3$$

- in line with RP 112
- in line with current NORM regulation of RPO
- no conflict with recommendation of 100 Bq/m³ Radon (target value)
- no undue implication on currently used building materials