# Radon Exhalation Measurement and Assessment of Building Material: why and how?

## - from a regulator's view -

**Bernd Hoffmann**
**Federal Office for Radion Protection**
**Berlin**


Wikipedia

# Radon

Gefällt mir


www.wienerberger.de

Peter Bossew


Bisotherm, www.chaux-de-contern.lu

Bundesamt für Strahlenschutz

# Construction Products Regulation (CPR)

4.4.2011 EN Official Journal of the European Union L 88/5

**REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL**

**of 9 March 2011**

**laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC**

**(Text with EEA relevance)**

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on tl
Union, and in particular Article

Having regard to the proposal fı

Having regard to the opinion o
Social Committee ([1]),

(4) Member States have introduced provisions, including requirements, relating not only to safety of buildings and other construction works but also to health, dura-

*ANNEX I*

**BASIC REQUIREMENTS FOR CONSTRUCTION WORKS**

Construction works as a whole and in their separate parts must be fit for their intended use, taking into account in particular the health and safety of persons involved throughout the life cycle of the works. Subject to normal maintenance, construction works must satisfy these basic requirements for construction works for an economically reasonable working life.

1. Mechanical res

The constructi
during their cc

(a) collapse o

(b) major defc

(c) damage tc
deformatic

3. Hygiene, health and the environment

The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition, in particular as a result of any of the following:

(a) the giving-off of toxic gas;

(b) the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air;

(c) the emission of dangerous radiation;

COUNCIL OF EUROPE
CONSEIL DE L'EUROPE

EUROPEAN COMMISSION
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL

Chemicals and construction
**Construction**

Brussels, 16th March 2005
**M /366 EN**

HORIZONTAL COMPLEMENT TO THE MANDATES

TO CEN/CENELEC

CONCERNING THE EXECUTION OF STANDARDISATION WORK FOR THE

**DEVELOPMENT OF HORIZONTAL STANDARDISED ASSESSMENT METHODS FOR HARMONISED APPROACHES RELATING TO DANGEROUS SUBSTANCES UNDER THE CONSTRUCTION PRODUCTS DIRECTIVE (CPD)**

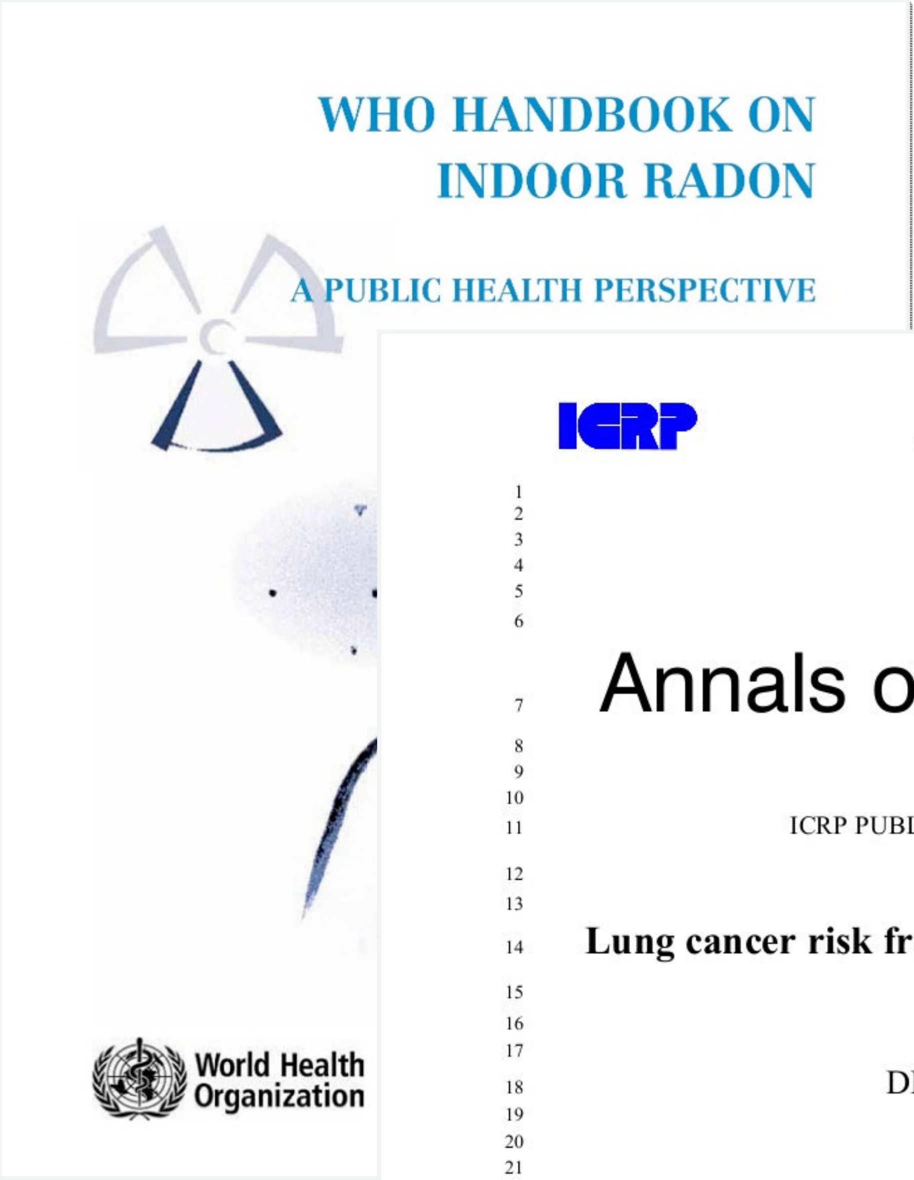
**Emission to indoor air, soil, surface water and ground water**

DESCRIPTION OF THE SPECIFIC MANDATE

*I. FOREWORD*

*This mandate details the scope of a standardisation mandate issued by the Commission to CEN/CENELEC within the context of the Council Directive 89/106/EEC of December 21, 1988 concerning construction products, hereafter referred to as "the Di[...] mandate deals with the subject of emission of dangerous substance[...] products as defined in the CPD that may have harmful impacts on h[...] environment as called for under the Essential Requirements 3 of the CP[...]*

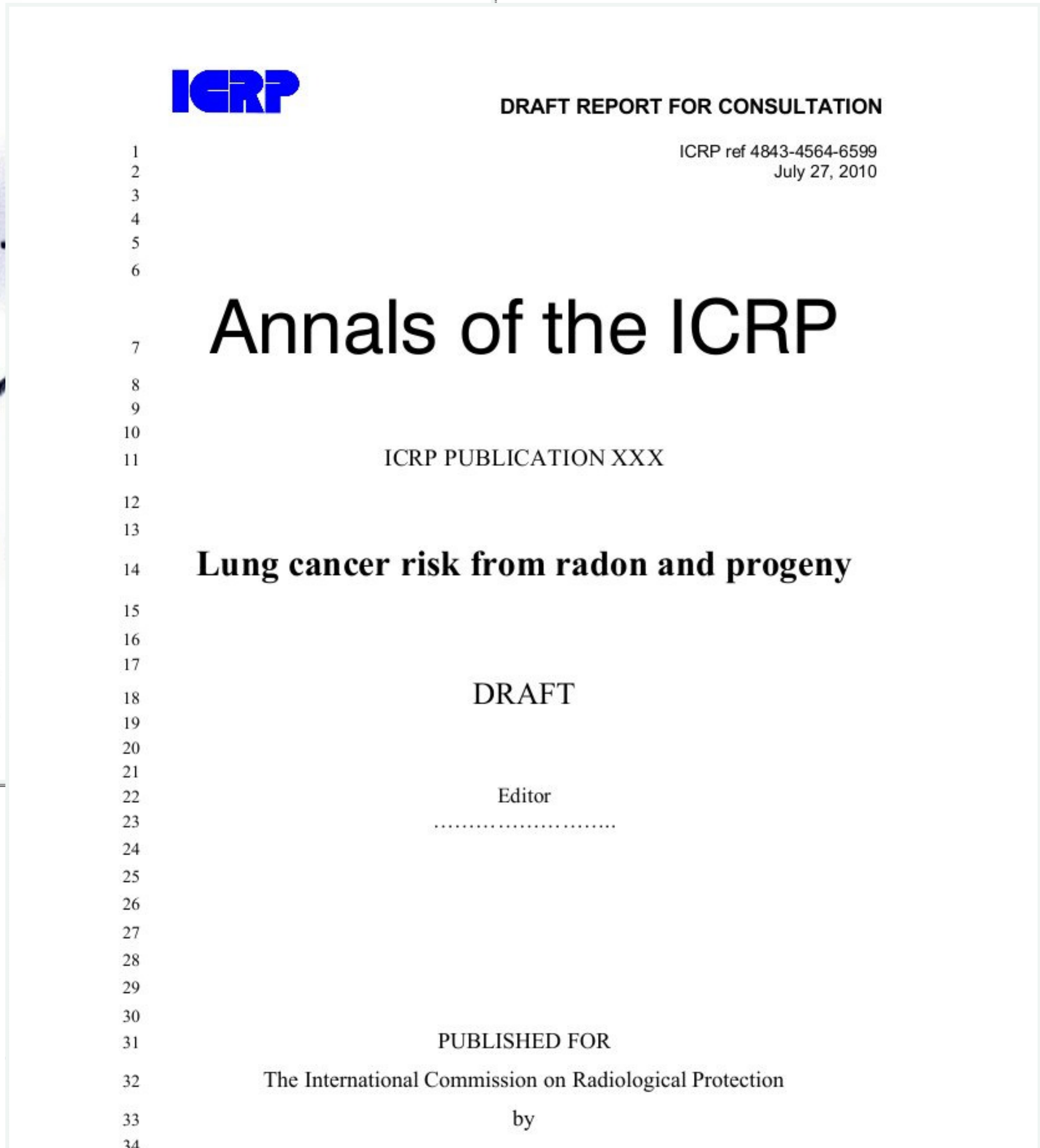
European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung


WHO HANDBOOK ON INDOOR RADON

A PUBLIC HEALTH PERSPECTIVE

World Health Organization

World Health Organization


ICRP

DRAFT REPORT FOR CONSULTATION

ICRP ref 4843-4564-6599
July 27, 2010

# Annals of the ICRP

ICRP PUBLICATION XXX

**Lung cancer risk from radon and progeny**

DRAFT

Editor
………………………

PUBLISHED FOR
The International Commission on Radiological Protection
by

ICRP

1 mSv/a □ 30 Bq/$m^3$

Bundesamt für Strahlenschutz

IAEA Safety Standards

for protecting people and the environment

Radiation Pr
Safety of Ra
International
Safety Stanc

INTERIM EDITIC

General Safety
No. GSR Part 3

IAEA
International Atomic Energy Agency

IAEA
International Atomic Energy Agency
*Atoms for Peace*

DS421
29 September 2011

IAEA SAFETY STANDARDS

for protecting people and the environment

Status: Submitted to RASSC in September 2011 for approval for submission to Member States for comment.

DRAFT

Protection of the Public Against Indoor Exposure to Natural Sources of Radiation

DRAFT SAFETY GUIDE
No. DS 421

New Safety Guide

| Verantwortung für Mensc

Bundesamt für Strahlenschutz

European Commission

# Radiation protection 112

# Radiological Protection Principles concerning the Natural Radioactivit of Building Materials

1999

Directorate-General
Environment, Nuclear Safety and Civil Protection

European Commission
Energy

Proposal for a

**COUNCIL DIRECTIVE**

**laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation**

**Draft presented under Article 31 Euratom Treaty for the opinion of the European Economic and Social Committee**

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Atomic Energy Community, and in particular Articles 31 and 32 thereof,

Having regard to the proposal from the Commission, drawn up after obtaining the opinion of a group of persons appointed by the Scientific and Technical Committee from among scientific experts in the Member States, and after having consulted the European Economic and Social Committee,

Having regard to the opinion of the European Economic and Social Committee,

Having regard to the opinion of the European Parliament,

Whereas:

(1) Article 2(b) of the Treaty provides for the establishment of uniform safety standards to protect the health of workers and the general public and Article 30 of the Treaty defines 'basic standards' for the health protection of workers and the general public against the dangers arising from ionising radiations.

(2) In order to perform its task, the Community laid down basic standards for the first time in 1959 pursuant to Article 218 of the Treaty by means of the Directives of 2 February 1959 laying down the basic standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation[9]. The Directives have been revised several times, most recently in 1996 by Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation[10] which repealed the earlier Directives.

(3) Directive 96/29/Euratom establishes the basic safety standards. The provisions of that Directive apply to normal and emergency situations and have been supplemented by more specific legislation.

**ANNEX XI**

Indicative list of types of building materials considered for control measures with regard to their emitted gamma radiation

1. Natural materials

(a) Alum-shale.

**Oil shale?**

(b) Building materials or additives of natural igneous origin, such as:

– granite,
– gneiss;
– porphyries;
– syenite;
– basalt;
– tuff;
– pozzolana;
– lava.

**Pumice?**

2. Materials incorporating residues from industries processing naturally occurring radioactive material, such as:

– fly ash;
– phosphogypsum;
– phosphorus slag;
– tin slag;
– copper slag;
– red mud (residue from aluminium production);
– residues from steel production.

## Concrete/Cement (Germany: > 30 Mio. t/a)

Portland pozzolan cement CEM II/A-P: - 35 % nat. pozzolana

Blast furnance cement CEM III/C: - 95 % slag sand

Portland shale cement CEM II/B-T: - 35 % burnt shale

Portland fly ash cement CEM II/B-V: - 35 % fly ash

Berlin, Potsdamer Platz: 100.000 t of fly ash

## ANNEX VII

Definition and use of the activity concentration index for the gamma radiation emitted by building materials

For the purposes of Article 75(2), for identified types of building materials, the activity concentrations of primordial radionuclides Ra-226, Th-232 (or its decay product Ra-228) and K-40 shall be determined.

The activity concentration index I is given by the following formula:

$$I = C_{Ra226}/300\ Bq/kg + C_{Th232}/200\ Bq/kg + C_{K40}/3000\ Bq/kg$$

where $C_{Ra226}$, $C_{Th232}$ and $C_{K40}$ are the activity concentrations in Bq/kg of the corresponding radionuclides in the building material.

The index relates directly to the gamma radiation dose, in excess of typical outdoor exposure, in a building constructed from a specified building material. It applies to the building material, not to its constituents. For application of the index to such constituents, in particular residues from industries processing naturally occurring radioactive material recycled into building materials an appropriate partitioning factor needs to be applied. The activity concentration index shall be used as a screening tool for identifying materials that may be exempted or subject to restrictions. For this purpose the activity concentration index I may be used for the classification of the materials into four classes, leading to two categories of building materials (A and B):

| | Category (corresponding default dose) | |
|---|---|---|
| Use | A (≤ 1 mSv) | B (> 1 mSv) |
| (1) materials used in bulk amounts | A1<br>I≤1 | B1<br>I>1 |
| (2) superficial and other materials with restricted use. | A2<br>I≤6 | B2<br>I>6 |

The division of materials into (1) or (2) according to their use shall be based on national building codes.

Where appropriate, actual doses for comparison with the reference level shall be assessed using more elaborate models which may also take into account the background outdoor external exposure from local prevailing activity concentrations in the undisturbed earth's crust.

Screening: RP 112,

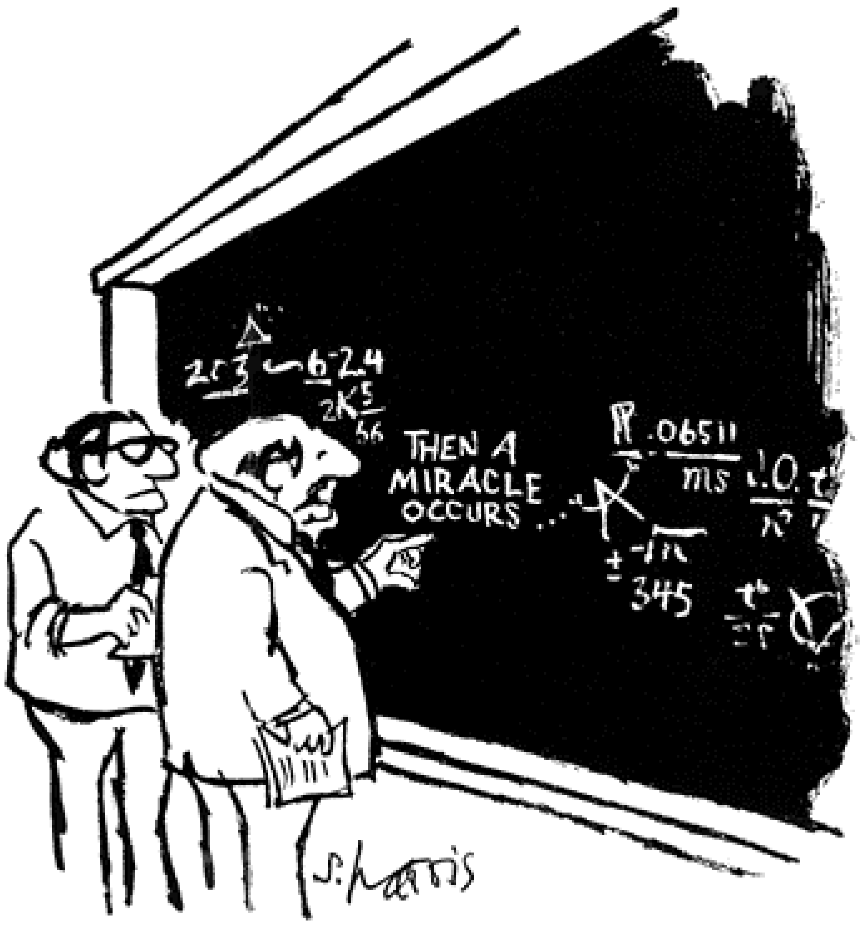
Proof < 1mSv/a with

ere appropriate, actual doses
g more elaborate models w
osure from local prevailing ac

# „more elaborate models“

- National regulations:
  - Finnland
  - Poland
  - Austria
  - Luxembourg

- IAEA
- Suggestions from industry
- CEN/TC 351 WG3
- BfS




“I think you should be more explicit here in step two.”

Sidney Harris, Science Cartoons

# „more elaborate models“

- Finnland: RP 112
- Luxembourg (Radioprotection - B. reglements d’execution)

9. L'importation, la fabrication et la vente de matériaux utilisés dans la construction de maisons ou de locaux à l'intérieur desquels séjournent des personnes sont interdites lorsque la teneur radioactive du produit fini au niveau du bâtiment dépasse les limites suivantes:

| | |
|---|---|
| K-40 | 3000 Bq/kg |
| Ra-226 | 300 Bq/kg |
| Th-232 | 200 Bq/kg |

Si tous les trois radionucléides sont contenus dans un tel matériau de construction, la formule suivante doit être respectée:

$$\frac{C\ K}{3000\ K} + \frac{C\ Ra}{300\ Ra} + \frac{C\ Th}{200\ Th} \leq I$$

avec I = 0.5 pour les matériaux utilisés en grosses quantités et I = 2 pour les matériaux utilisés de façon superficielle ou en quantités mineures.

C = concentration exprimée en Bq/kg

→ several traditional building materials I > 0.5

# „more elaborate models“

- Poland: Dzennik Ustaw 2007 nr 4 poz. 29

§ 2. 1. Zawartość naturalnych izotopów promieniotwórczych potasu K-40, radu Ra-226 i toru Th-228 w surowcach i materiałach stosowanych w budynkach przeznaczonych na pobyt ludzi lub inwentarza żywego, a także w odpadach przemysłowych stosowanych w budownictwie ustala się za pomocą:

1) wskaźnika aktywności $f_1$, który określa zawartość naturalnych izotopów promieniotwórczych, oraz
2) wskaźnika aktywności $f_2$, który określa zawartość radu Ra-226.

2. Wskaźniki aktywności, o których mowa w ust. 1, są zdefiniowane wzorami:

1) $$f_1 = \frac{S_K}{3\,000\ \mathrm{Bq/kg}} + \frac{S_{Ra}}{300\ \mathrm{Bq/kg}} + \frac{S_{Th}}{200\ \mathrm{Bq/kg}},$$

2) $f_2 = S_{Ra},$

gdzie:

$S_K$, $S_{Ra}$ i $S_{Th}$ oznaczają odpowiednio stężenia promieniotwórcze izotopów potasu K-40, radu Ra-226 i toru Th-228, wyrażone w bekerelach na kilogram (Bq/kg).

§ 3. Wartości wskaźników aktywności $f_1$ i $f_2$ nie mogą przekraczać o więcej niż 20 % wartości:

1) $f_1 = 1$ i $f_2 = 200$ Bq/kg w odniesieniu do surowców i materiałów budowlanych stosowanych w budynkach przeznaczonych na pobyt ludzi lub inwentarza żywego;

Limit for Radium → Limit for Radon

# „more elaborate models“

- Austria: ÖNORM 5200

**3.2 Gesamtstrahlenexposition durch Gammastrahlung und Inhalation des Radons und seiner Folgeprodukte**

Die nachstehende Formel, die beide Expositionen beinhaltet, beruht auf dem Richtwert von maximal 2,2 mSv für die jährliche Strahlenexposition durch natürliche Radionuklide in Baumaterialien

$$\frac{a_{\text{K-40}}}{8800} + \frac{a_{\text{Ra-226}}}{880} \cdot (1 + 0{,}07 \cdot \varepsilon \cdot \rho \cdot d) + \frac{a_{\text{Th-232}}}{530} \leq 1 \qquad (1)$$

→ sum of ext. and int. dose

→ Emanation coefficient generally 0.1 (no obligation for measurement)

→ Adjustment for thickness and density only for the radon path

# „more elaborate models“

- **IAEA**:
  Protection of the Public Against Indoor Exposure to Natural Sources of Radiation
  DRAFT SAFETY GUIDE No. DS 421

- RP 112

- with
- a) combinations of materials
- b) correction of mass per unit area of the walls

Example 2 Gamma exposure in a room where the walls are made of material with elevated Ra and Th concentrations and floor and ceiling of average concrete

The floor and ceiling of the room in Figure VII.1 are constructed of concrete that contains the worldwide population weighted average concentrations of radium, thorium and potassium in soil [VII.2] of 33 Bq kg$^{-1}$, 45 Bq kg$^{-1}$ and 420 Bq kg$^{-1}$ for $^{226}$Ra, $^{232}$Th and $^{40}$K, respectively. The walls are of brick with elevated levels of natural radionuclides. The material specifications are:

| | Floor, ceiling - concrete | Walls - brick |
|---|---|---|
| Radionuclide | Activity concentration | Activity concentration |
| $^{226}$Ra | 33 Bq kg$^{-1}$ | 200 Bq kg$^{-1}$ |
| $^{232}$Th | 45 Bq kg$^{-1}$ | 300 Bq kg$^{-1}$ |
| $^{40}$K | 420 Bq kg$^{-1}$ | 1500 Bq kg$^{-1}$ |
| Other parameters | | |
| Density of concrete | 2350 kg m$^{-3}$ | 2000 kg m$^{-3}$ |
| Thickness of concrete | 20 cm | 15 cm |

The mass per unit area of the walls is 2 000 kg m$^{-3}$ 0.15 m = 300 kg m$^{-2}$ and of the floor and ceiling it is 2 350 kgm$^{-3}$ x 0.20 m = 460 kg m$^{-2}$, thus the specific dose rates for a mass per unit area of 500 kg m$^{-2}$ in Table 1 are used. The dose rate in the room is calculated:

| Source | Calculation | Dose rate |
|---|---|---|
| $W_1$, brick | 2 x (79x200 + 91x300 + 6.4x1500) | 0.1054 µGy h$^{-1}$ |
| $W_2$, brick | 2 x (26x200 + 30x300 + 2.1x1500) | 0.0347 µGy h$^{-1}$ |
| Floor and ceiling, concrete | 2 x (350x33 + 420x45 + 30x420) | 0.0861 µGy h$^{-1}$ |
| Total dose rate in a room (cosmic radiation excluded) | | **0.2262 µGy h$^{-1}$** |
| Terrestrial gamma radiation outdoors: the concrete structures of the building shield against this source | | -0.06 µGy h$^{-1}$ |
| Excess dose rate caused by building materials | | 0.1662 µGy h$^{-1}$ |
| Excess effective dose | 0.,7 Sv Gy$^{-1}$ x 0.1662 µGy h$^{-1}$ | **0.116 µSv h$^{-1}$** |

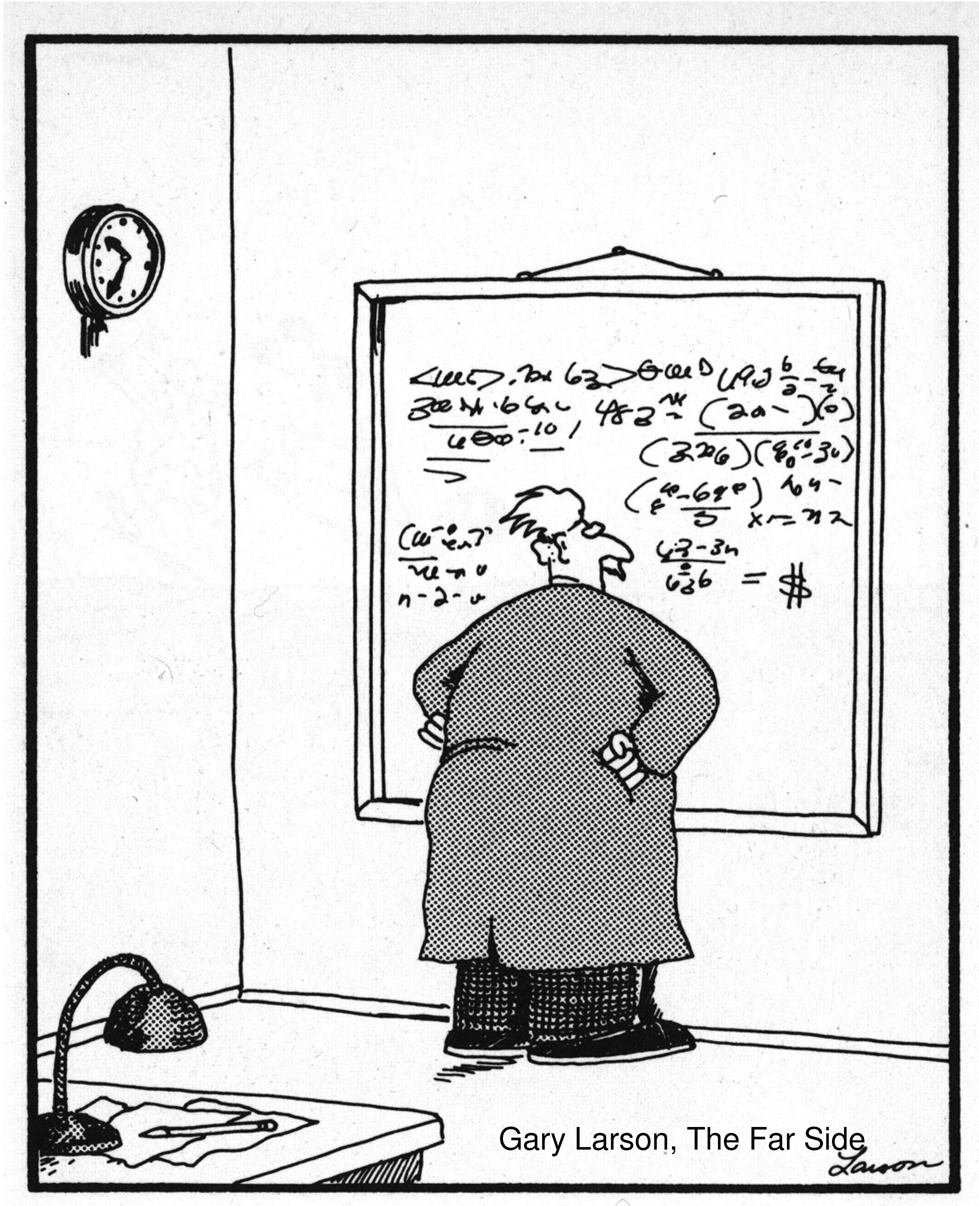
The annual excess dose to an occupant depends on the annual occupancy time:

# „more elaborate models“

- **Suggestions from Industry**:

RP112 resp. Annex VII of BSS
replaced by european standard

Or
a) only walls (not effective)
b) Correction factor (density)
→ ¼ of density ⇒ ¼ of activity
⇒ ¼ of dose
→ Almost all materials I < 1
→ no needs for regulations
(… only concrete …)



Gary Larson, The Far Side

# BfS-Criterion for Assessment

*External Exposure*

max. 1 mSv/a – in addition to the natural background

*$^{222}$Rn-Exposure*

max. 20 Bq/m$^3$ indoor Radon from building material (~ 0.3. 0.5 o. 0.7 mSv/a)

→ Consistent with EU-BSS and WHO-Handbook

But: No official "German" position

# Methods of measurement

- Gamma Spectroscopy
  - Well-established
  - Several protocolls available
  - ISO 18589-3: „Soil“, NEN ...
- Radon exhalation
  - Not a material constant, not directly related to the recipe
  - Activity flux density [Bq/m$^2$s] or
    mass related activity flux [Bq/(s kg)]
  - Germany: A. Wicke (1979), Folkerts (1983)
  - Literature 2002 – 2008: min. 9 different methods
  - NEN 5699

  → BfS: two different ways

  → DIBt/BAM: VOC-Chambers?

# Results:
# Radon exhalation

| *Products* | *Exhalation rate [Bq/m²h]* |
|---|---|
| **Gypsum, Lime Sandstone, Tiles** | 0.02 – 0.38 |
| **Mortar, Plaster** | 0.07 – 1.5 |
| **Porous Concrete** | 0.31 – 1.3 |
| **Floor Screed** | 0.50 – 1.7 |
| **Bricks** | 0.14 – 1.6 |
| **L.W. Concrete, Cement** | 0.27 – 1.9 |
| **Clay** | 2 – 22 |

$$C_{Rn} \approx A/V \cdot \nu^{-1} \cdot \Phi$$

$$C_{Rn} \approx A/V \cdot \nu^{-1} \cdot \Phi$$

RP 112: 1.6 $m^{-1}$

EnEV: 0.5 $h^{-1}$

**Measurement**

$C_{Rn} \approx A/V \cdot \nu^{-1} \cdot \Phi$

RP 112: 1.6 $m^{-1}$

EnEV: 0,5 $h^{-1}$

$C_{Rn} < 20\ Bq/m^3 \Rightarrow \Phi < 5{,}5\ Bq/m^2h = 1{,}5\ mBq/m^2s$

# Results:
# Exhalation rate and part of indoor concentration

| *Products* | *Exhalation rate [Bq/m²h]* | *Radon concentration [Bq/m³]* |
|---|---|---|
| **Gypsum, Lime Sandstone, Tiles** | 0.02 – 0.4 | <1 – 2 |
| **Mortar, Plaster** | 0.07 – 1.5 | <1 – 5 |
| **Porous Concrete** | 0.31 – 1.3 | <1 – 5 |
| **Floor Screed** | 0.50 – 1.7 | <1 – 6 |
| **Bricks** | 0.14 – 1.6 | <1 – 6 |
| **L.W. Concrete, Cement** | 0.27 – 1.9 | <1 – 7 |
| **Clay** | 2 – 22 | 6 – 80 |

## Standard Concrete?

$$C_{Rn} \approx A/V \cdot \nu^{-1} \cdot 0.5 \cdot \lambda_{Rn} \cdot \rho \cdot d \cdot \varepsilon \cdot C_{Ra}$$

RP 112: 1.6 $m^{-1}$

EnEV: 0.5 $h^{-1}$

$$C_{Rn} \approx A/V \cdot \nu^{-1} \cdot 0.5 \cdot \lambda_{Rn} \cdot \rho \cdot d \cdot \varepsilon \cdot C_{Ra}$$

RP 112: $1.6\ m^{-1}$

EnEV: $0.5\ h^{-1}$

$0.5 \cdot 0.008\ h^{-1}$

DIN: 36.5 cm

Screening: $\varepsilon = 0.1$

$$C_{Rn} \approx 1.6 \cdot 2 \cdot 0.5 \cdot 0.008 \cdot \rho \cdot 0.365 \cdot 0.1 \cdot C_{Ra}$$

RP 112: 1.6 $m^{-1}$

EnEV: 0.5 $h^{-1}$

$0.5 \cdot 0.008$ $h^{-1}$

DIN: 36.5 cm

Screening: $\varepsilon = 0.1$

$$C_{Rn} \approx 0.0005 \cdot \rho \cdot C_{Ra}$$

# Standard Concrete: $\rho$ > 2000 kg/m$^3$

$C_{Rn}$ [Bq/m$^3$] $\approx$ $C_{Ra}$ [Bq/kg]

# Results:
# spezific activity

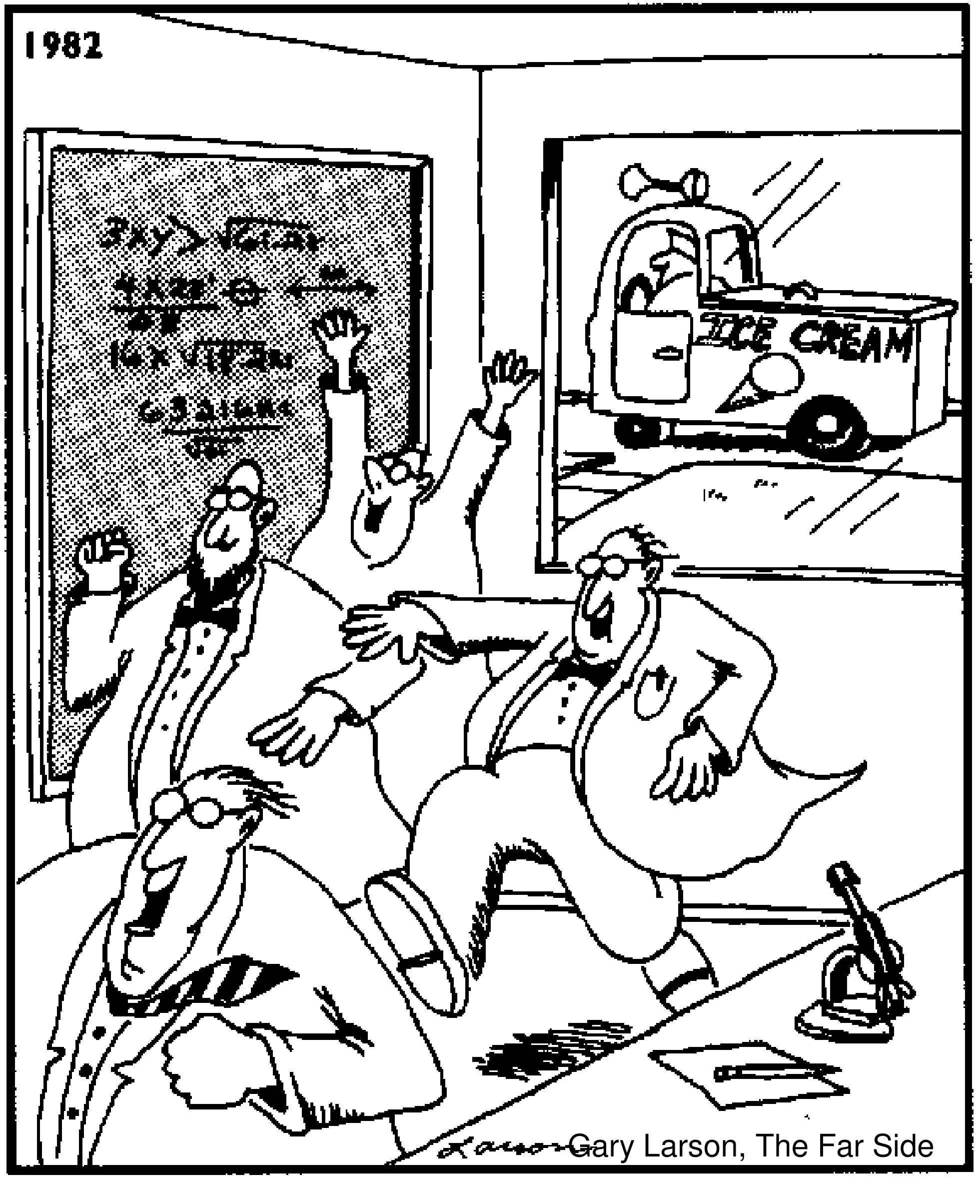
| Produkt/ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | K-40 | | | Th-228 | | | Ra-226 | | |
| | Min. | Max. | Median | Min. | Max. | Median | Min. | Max. | Median |
| Gypsum | < 20 | 120 | < 20 | 1.6 | 5.8 | 1.9 | 3.8 | 13 | 10 |
| Lime Sand | 35 | 180 | 130 | 2.8 | 8.9 | 7.2 | 4.1 | 10 | 10 |
| Por. Concrete | 97 | 350 | 170 | 4.8 | 19 | 11 | 8 | 26 | 19 |
| Bricks | 470 | 1200 | 670 | 37 | 89 | 53 | 38 | 63 | 48 |
| L.W. Concrete | 710 | 950 | 850 | 22 | 83 | 70 | 27 | 98 | 49 |
| Mortar | 120 | 310 | 250 | 6 | 31 | 13 | 11 | 53 | 20 |
| Plaster | 12 | 220 | 46 | 0.9 | 31 | 4.2 | 2 | 22 | 6.3 |
| Estriche | 210 | 295 | 260 | 11 | 34 | 14 | 11 | 26 | 15 |

# model room

| | | Surface/Volume | surface | Height | ACH |
|---|---|---|---|---|---|
| | | [$m^{-1}$] | [$m^2$] | [m] | [$m^{-1}$] |
| RP 96 | Radiation Protection | 1.6 | 5 x 4 | 2.8 | |
| RP 112 | Radiation Protection | 1.6 | 5 x 4 | 2.8 | |
| ÖNORM 5200 | Radiation Protection | 2.0 | | | 0.7 |
| DIN V ENV 13419-1 | VOC | 2.4 | 2 x 3.5 | 2.5 | 0.5 |
| DIN 1946-6 | Air Conditioning | 1.9 | 3 x 4 | 2.7 | 0.5 |
| DIN ISO 16000-9 | Indoor air quality | 2.0 | 3 x 4 | 2.5 | 0.5 |
| CEN TC 351 WG 2 | Indoor air quality | 2.0 | 3 x 4 | 2.5 | 0.5 |
| IAEA DS 421 | Radiation Protection | 1.2 | 12 x 7 | 2.8 | |

**Reality: ACH 0.1 – 0.5 $h^{-1}$**

# Thanks for your attention!




Gary Larson, The Far Side