IRPA 12
BUENOS AIRES - ARGENTINA - 19 / 24 OCTOBER 2008
12TH INTERNATIONAL CONGRESS OF THE INTERNATIONAL RADIATION PROTECTION ASSOCIATION

NORM and Radon in Building Materials

Keynote Lecture TS III 4.4

Gustavo Haquin
Radiation Safety Division,
Soreq NRC, Yavne, Israel

שורק

Overview

- Introduction
- Radon exhalation and measurement
- Internal exposure to Radon
- Regulations
- Conclusions

Introduction

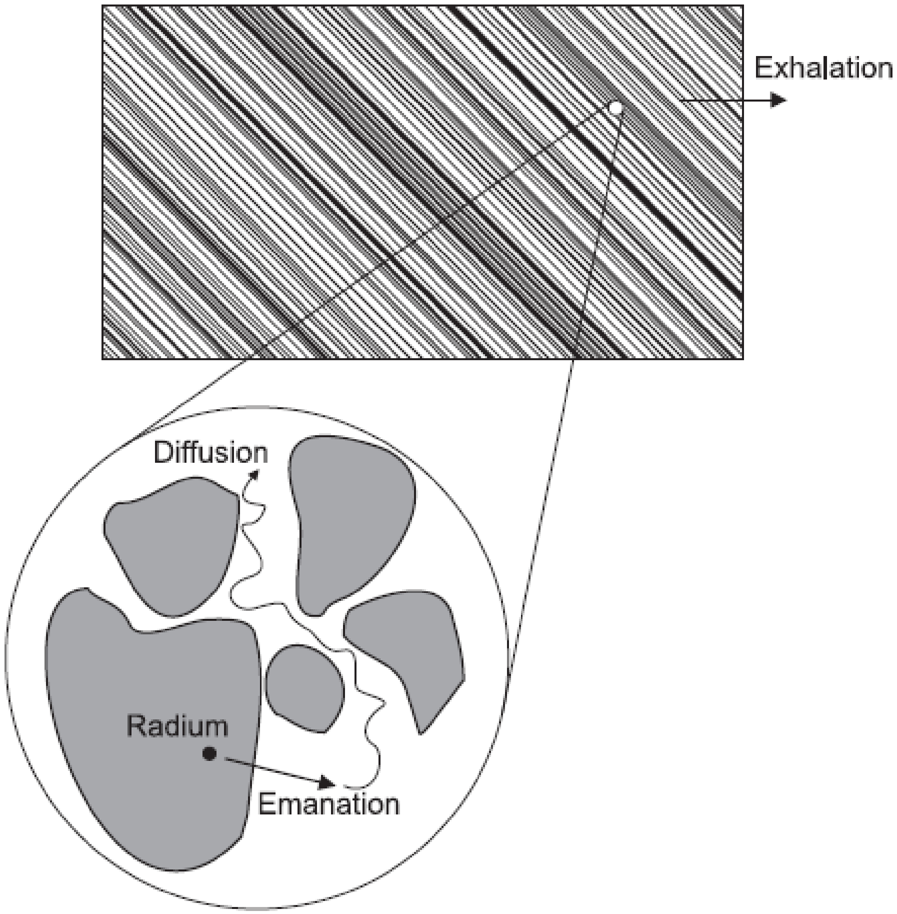
- Most building materials of terrestrial origin contain small amounts of NORM mainly radionuclides from the ^{238}U and ^{232}Th decay series and ^{40}K.
- The Earth's crust average concentration is 35, 30 and 400 Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K respectively.
- The activity concentration in building materials usually reflects the geology of their site of origin.
- Industrial by-products with TENORM e.g. coal ash, red mud, phosphogypsum, are extensively used in the construction industry.
- Their use and the increased exposure caused are the driving force for the development of standards and guidelines.

- National surveys were conducted to determine the activity concentration of raw materials, industrial by-products and building materials.
- Typical activity concentration in European concrete is estimated at 40, 30, 400 Bq/kg.
- The external radiation exposure is assessed by means of direct exposure measurements or by mathematical calculations using different approaches.
- The worldwide average indoor effective dose due to gamma rays from building materials is estimated to be about 0.4 mSv per year.

Radon exhalation from building materials

- Radon emanation power is the fraction of Rn produced in the grains that can escape into the interstitial volume.
- It ranges from 0 (no Rn escapes) to 1 (all Rn escapes).

Radon exhalation from building materials



Radon exhalation from building materials

- The Rn exhalation (E) represents the flux rate of Rn atoms from the building materials.
- It is proportional to the gradient of the Rn concentration in the internal pores

$$E = -D \cdot \left. \frac{dC}{dx} \right|_{x=l}$$

- The principal factors affecting the exhalation rate per unit activity concentration of ^{226}Ra are the porosity and density, the diffusion coefficient, water content, age and composition of the building materials.

Radon exhalation measurements

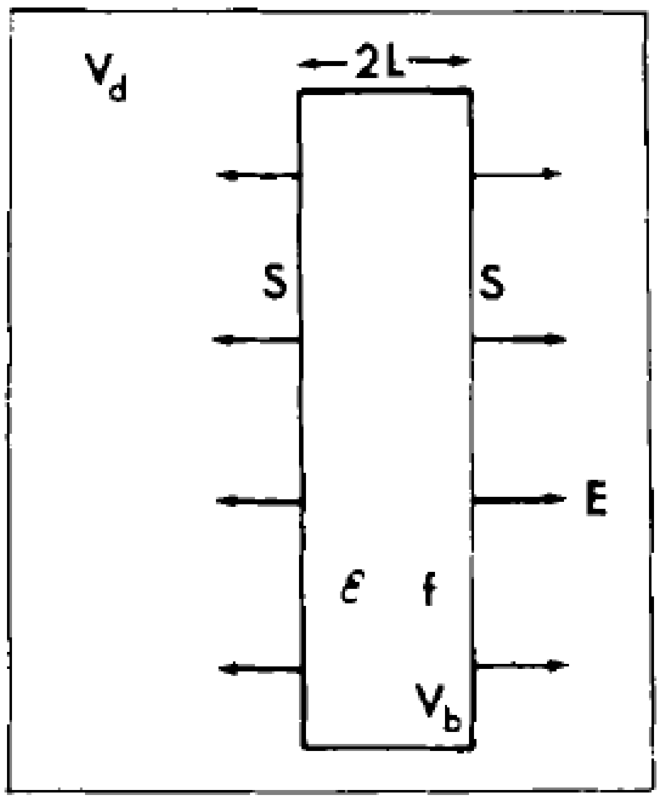
- Several methods for Rn exhalation measurements have been developed.
- The measurement methods are:
  - The closed chamber
  - Purge and trap
  - Rn flux measurements from the material surface
  - *In-situ* measurements

Closed chamber method

- Air tight chamber.
- Rn concentration in the chamber is:

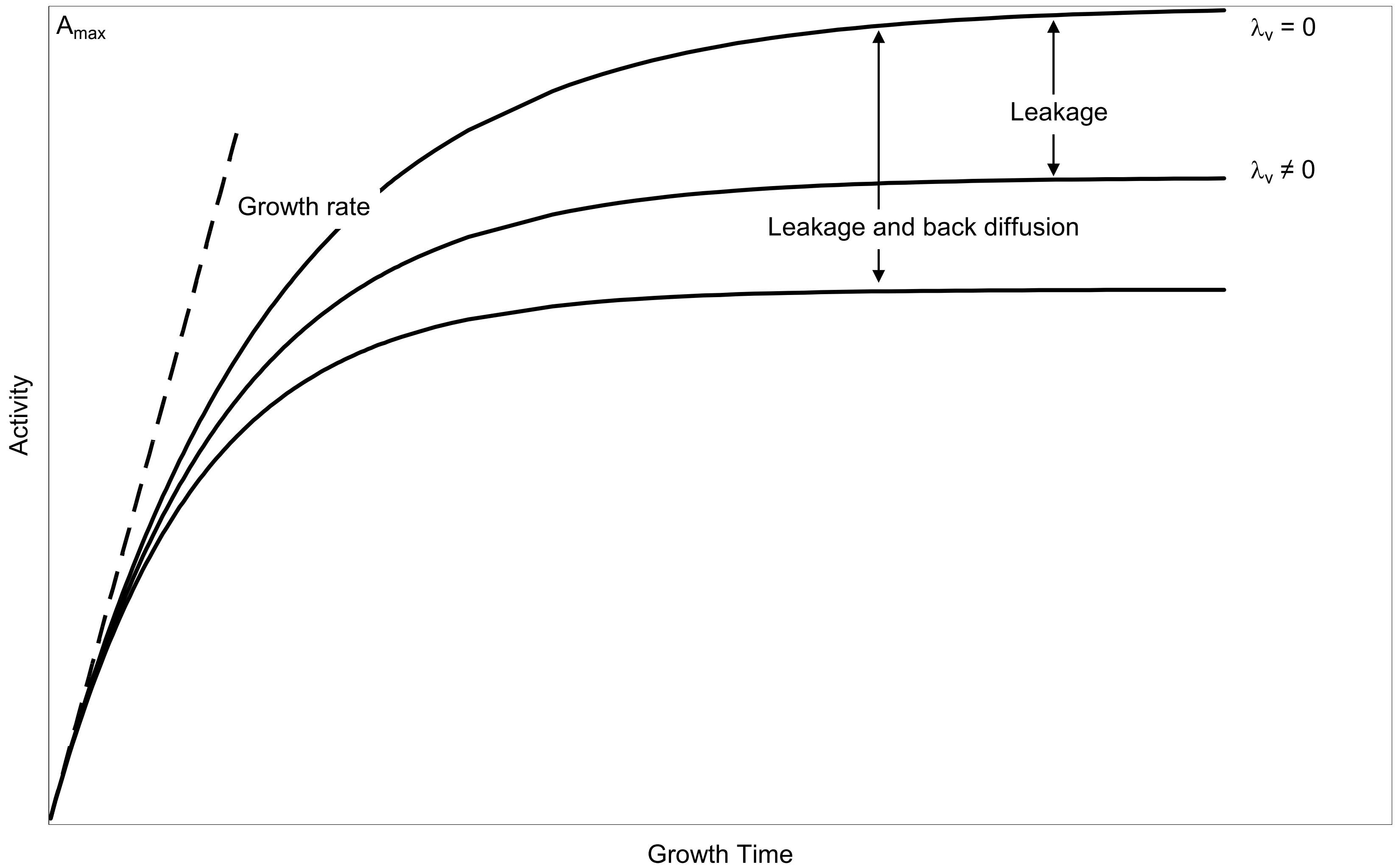
$$\frac{dN}{dt} = \frac{E}{V} - (\lambda + \lambda_v)N$$

- The Rn is then measured with a continuous radon monitor, activated charcoal, electret, etc..



(Jonassen, 1983)

שורק



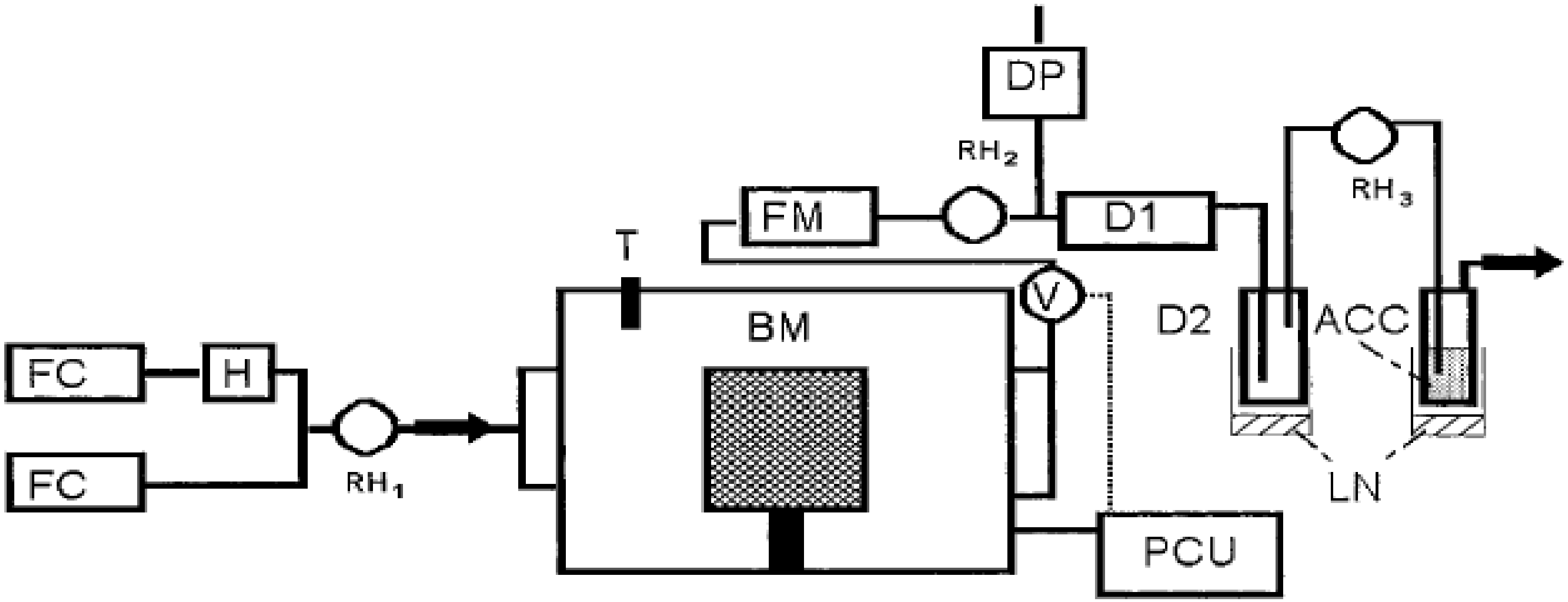
A$_{max}$
$\lambda_v = 0$
Leakage
$\lambda_v \neq 0$
Growth rate
Leakage and back diffusion
Activity
Growth Time

Purge and Trap method

- Sample enclosed in a container.
- The exhaled radon is continuously purged with nitrogen.
- To avoid back diffusion a sufficient low Rn concentration around the sample must be ensured.
- The exchange rate of the sample container has to fulfill:

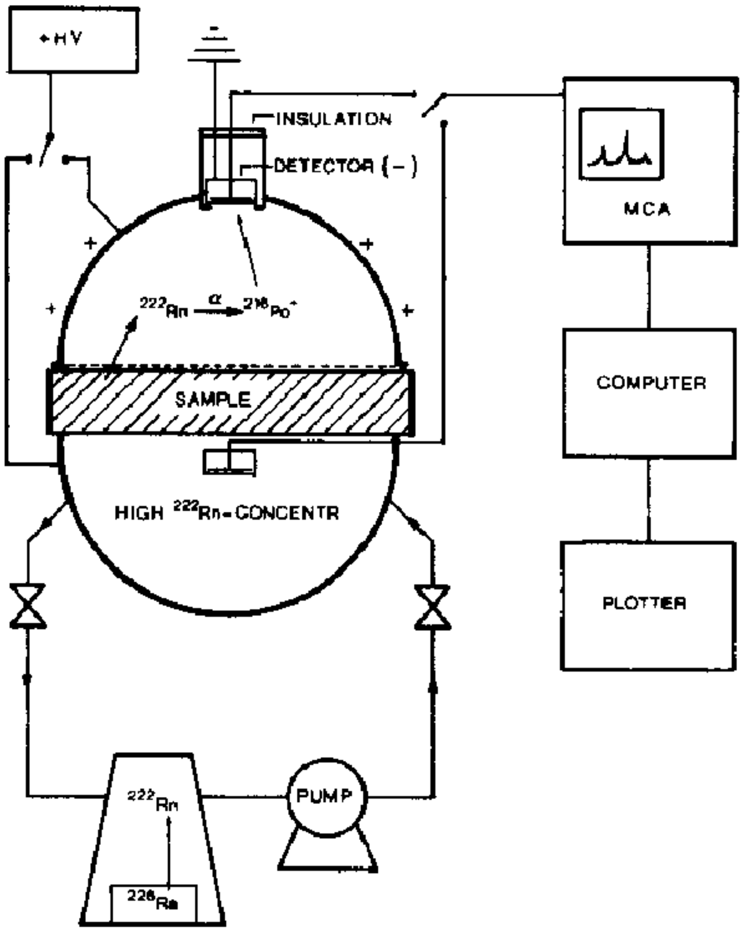
$$\frac{V_S}{V} \times \frac{\lambda}{\lambda + \lambda_v} < 0.1$$

- The nitrogen stream is directed through a Rn trapping device e.g. activated charcoal.



(Cozmuta et al, 2003)

Radon exhalation from surfaces



(Folkerts et al, 1984)

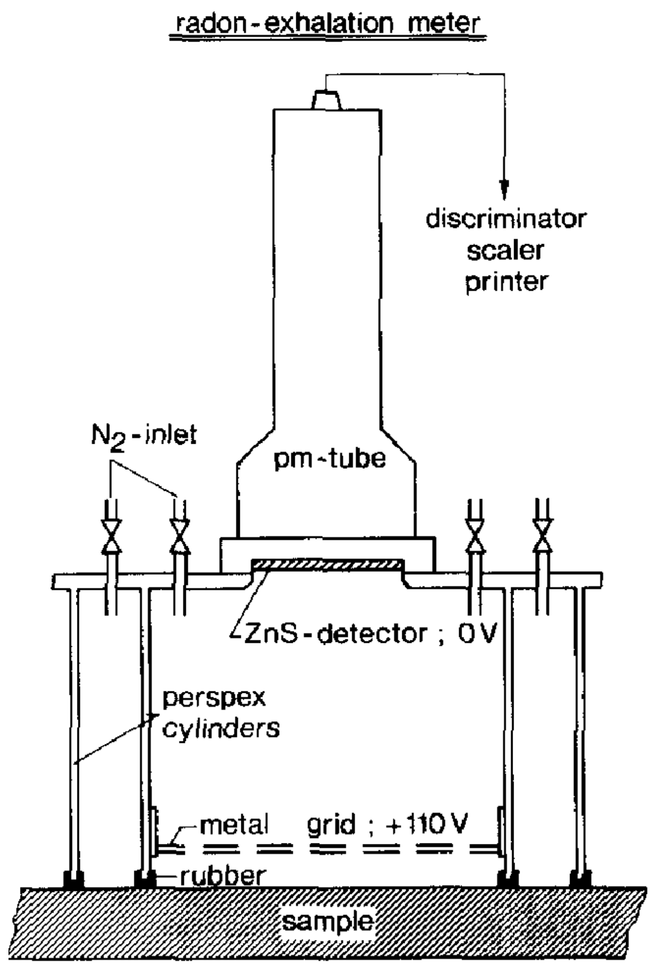
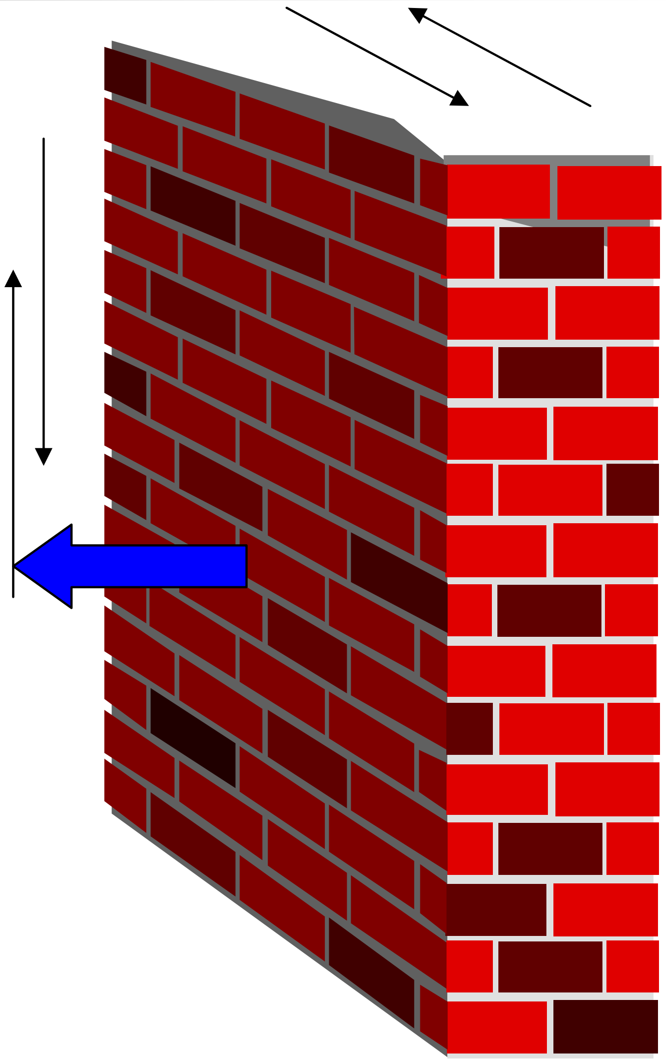


Figure 1. Design of the radon exhalation rate meter.

(Ackers, 1984)

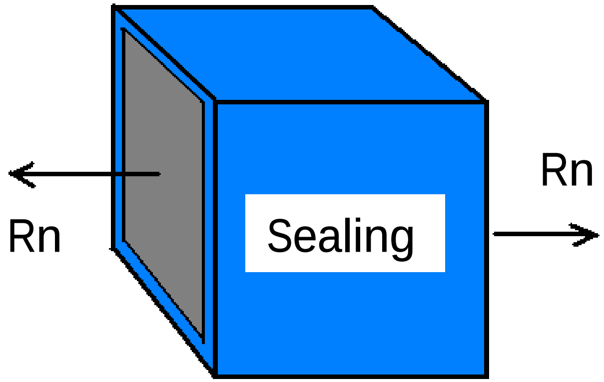
In-situ measurement

- Measurement of Rn exhaled direct from wall.
- Rn growth in an airtight room.
- Prediction by complex mathematical methods.



In-situ vs laboratory measurement

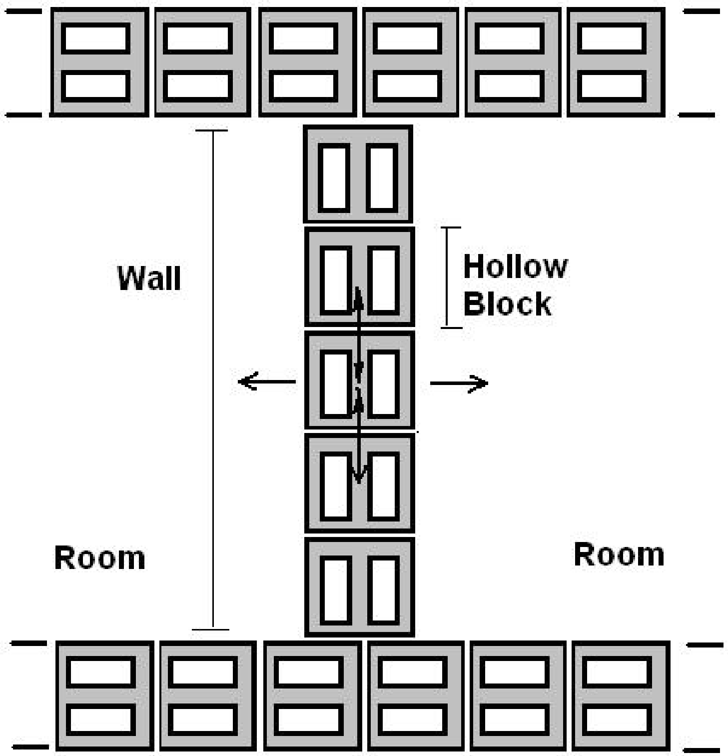
- Effects of wall covering
- Large variety of building materials types
- Simulation of wall conditions.
- No comprehensive model to explain the correlation between the measurements.



Internal exposure to Radon

- Complex task.
- Room dimensions (Surf./Vol.).
- Real ventilation rate
- Air conditioning.
- Covering layer.
- Thoron exposure only from outer layer (~1mm).
- Occupancy factor: 80%?

$$C = \frac{E \cdot S}{V \cdot (\lambda + \lambda_v)} + \frac{C_o \cdot \lambda_v}{\lambda + \lambda_v}$$



Regulations

- Introduction of TENORM by-products.
- Building materials cause prolonged exposure situations.
- “Annual doses should be restricted to a few mSv for the worst-case scenarios“ (ICRP 104).
- Existing exposure situation rather than planned.
- Controls should be based on the excess exposure caused by the building materials
- Activity index for external exposure

$$I = \frac{C_{Ra}}{A_{Ra}} + \frac{C_{Th}}{A_{Th}} + \frac{C_K}{A_K}$$

European recommendations

- RP-112 - Radiological Protection Principles Concerning the Natural Radioactivity of Building Materials.
- Doses to members of the public should be kept as low as reasonably achievable
- Control should be applied on exposure levels above background typical levels
- Controls based on dose criterion.
- Doses over 1 mSv/y should be taken into account
- Uniform exemption levels to allow free movement of most building materials within Europe

- Generalization, application to most used building materials.
- Activity concentration index (*I*) only for external exposure.

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

Dose criterion	**0.3 mSv/y**	**1 mSv/y**
Materials used in bulk amount, e.g. concrete	$I \leq 0.5$	$I \leq 1$
Superficial and other materials with restricted use: tiles, boards, etc.	$I \leq 2$	$I \leq 6$

שורק

Other national regulations

- Low background levels: choose stricter criterion, excess dose < 0.3 mSv/y.
- Some regulations consider material type

$$\frac{C_K}{10000}+\frac{C_{Ra}}{1000}\left(1+0.15\varepsilon\rho d\right)+\frac{C_{Th}}{600}\leq 1$$

$$\frac{C_K}{A_K(\rho d)}+\frac{C_{Ra}}{A_{Ra}(\rho d)}\left(1-\varepsilon\right)+\frac{C_{Th}}{A_{Th}(\rho d)}+\frac{\varepsilon\cdot C_{Ra}}{A_{Rn}(\rho d)}\leq 1$$

- Specific design of building, use of several correction factors (the Netherlands)

Country	Dose criterion	Radon meas.
Denmark	0.3 mSv/y	No
Israel	0.3 mSv/y	Yes
Netherlands		Yes
Austria	1 mSv/y	Optional
Poland	1 mSv/y	No

Radon from building materials: Intervention or control

- Limiting the ^{226}Ra in the building materials.
- Limiting the Rn exhalation rate.
- Radon from underlying soil - intervention
- Hong Kong – intervention (<150 Bq/m^3)
- Rn from building materials
    - Intervention – some contributions from other sources.
    - Intervention – consistent with national action levels for indoor radon
    - Control – dose ~ 1 mSv/y.

Conclusions

- Use of TENORM increases activity concentration in building materials.
- Several Rn exhalation measurements methods. No uniformity. Problems with intercomparisons.
- Poor correlation between laboratory measurements and *in-situ* exhalation rate.
- Control based on dose criteria and reference levels.
- Regulations need to consider economical, social and environmental consequences.
- Rn as intervention or amenable to control.
- Occupancy factor: is 80% still valid?

Some alternative solutions

Gracias por su atencion

Thank you for your attention