Radon emanation measurements in the Israeli Standard 5098

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

WEACAU-III: 11-12 December 2012

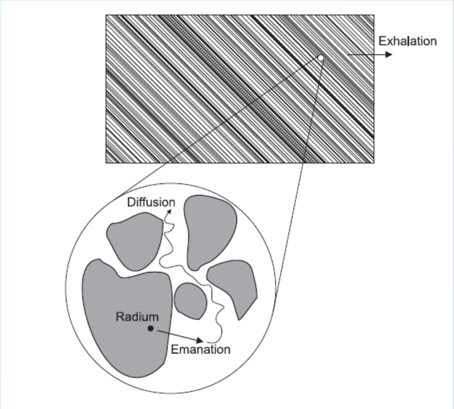
Introduction

- Most building materials of terrestrial origin contain small amounts of radionuclides from the ^{238}U and ^{232}Th decay series and ^{40}K.
- The activity concentration in building materials usually reflects the geology of their site of origin and the addition of industrial by-products as coal ash, red mud, phospho-gypsum etc..
- The radioactivity in the BM will expose the inhabitants in two pathways: externally by gamma radiation and internally by radon and radon decay products inhalation.
- The Israeli Standard 5098 is one of few National regulations worldwide which specifically request radon measurement.

Radon exhalation from BM

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

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



Factors affecting Radon release

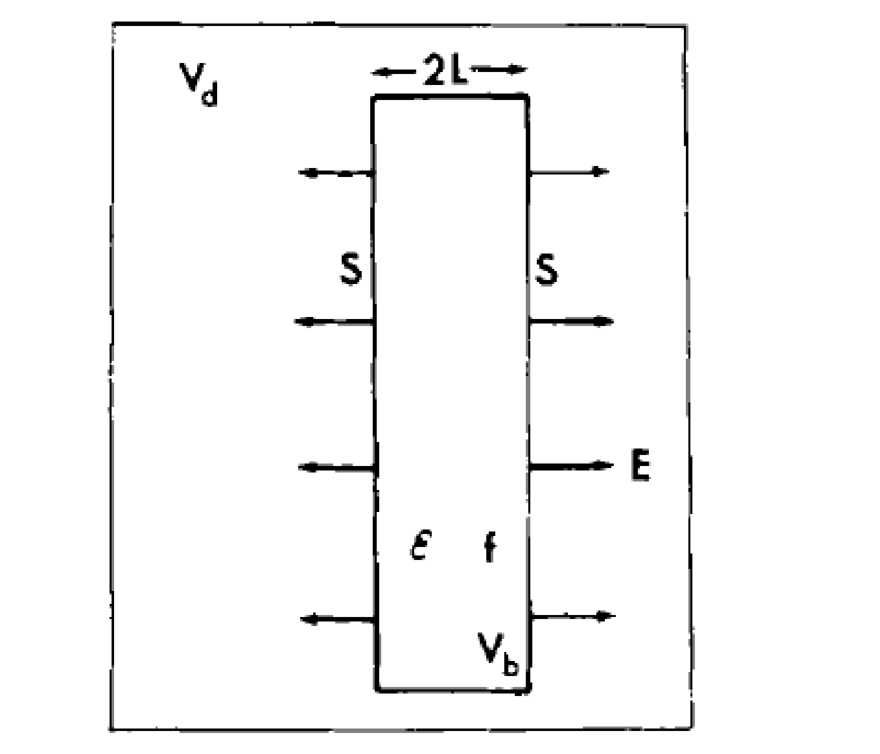
- The principal factors affecting the Rn exhalation rate per unit activity concentration of ^{226}Ra are:
  - Material porosity and density,
  - Diffusion coefficient,
  - Water content (in concrete is related to the age)
  - Raw materials
  - Curing process (related to water content and cementation process)

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)

Preliminary determinations

- Sealing capability of measuring chamber
  - To be determined using a certified radon source

$$\mathbf{T_v} = \frac{1}{\lambda_{\mathbf{v}}} > 2000 \ \mathbf{hours}$$

  - The A_{max} represents more than 94% of the Rn
- Diffusion length in sealing material
  - To be determined by measuring the effective diffusion coef.

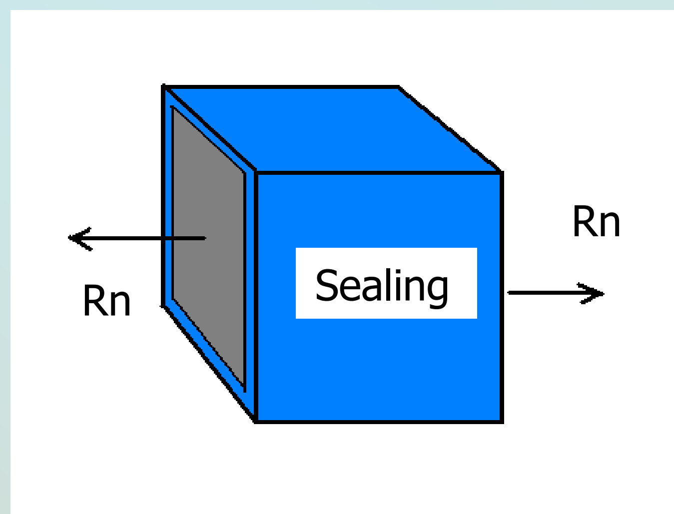
$$\mathbf{L} = \sqrt{\frac{\mathbf{D}}{\lambda}}$$

  - If d= 3L the material is “Rn tight” and can be used as sealing material

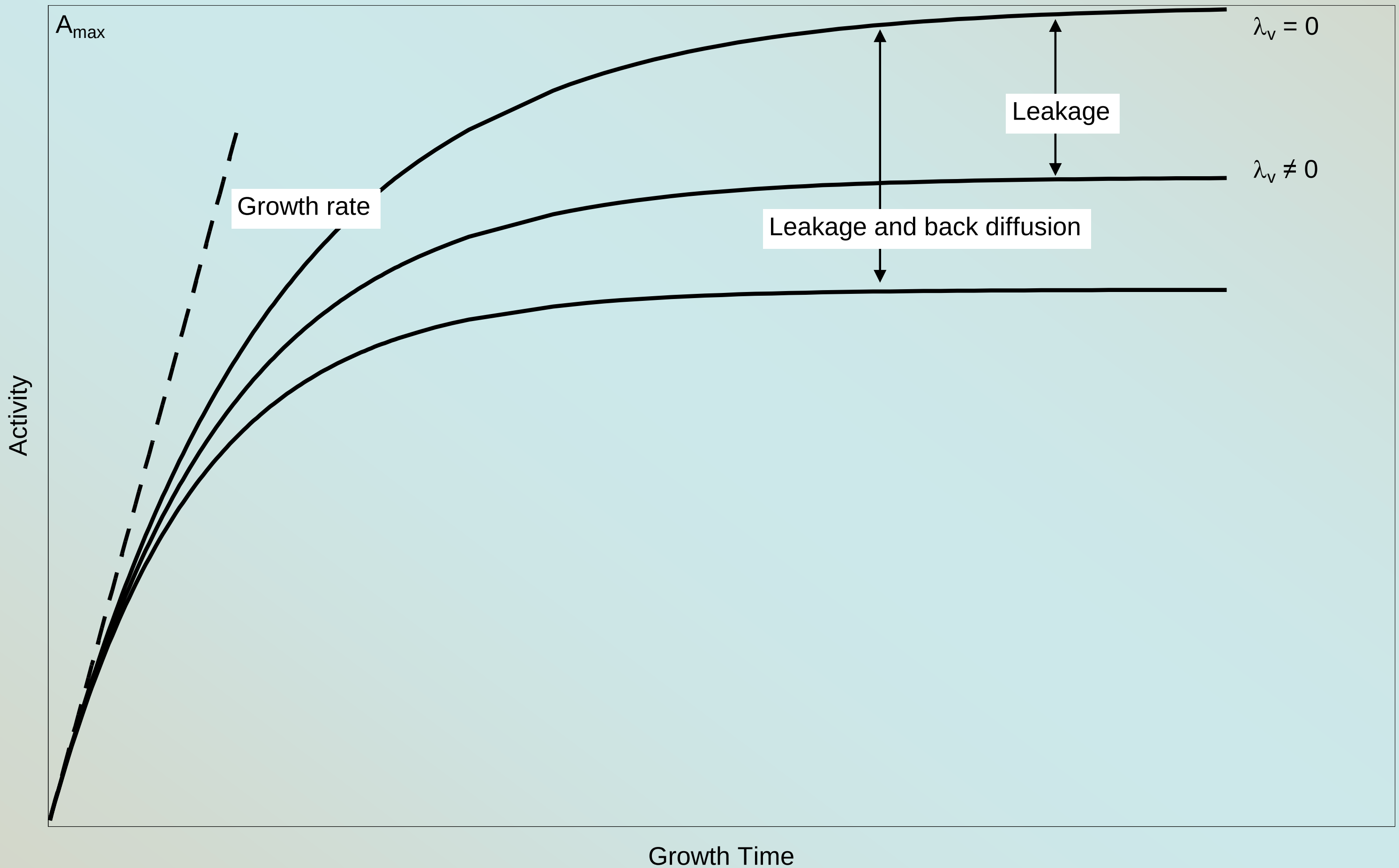
Preliminary determinations ...

- Achieve equilibrium between the BM and the environmental conditions in the laboratory
- The influence of RH and T during the Rn measurement was experimentally determined
- RH = 50 ± 20%
- T = 20 – 25 ^{o}C
- Weight gain and loses of the BM during conditioning before Rn measurement


ALPHAGUARD


Rn
Sealing
Rn

Ingrowths Rn in chamber



Exhalation rate

- The Rn concentration in the chamber is:

$$C(t) = C_0 \exp\left[-(\lambda + \lambda_v)\, t\right] + C_{\max}^{v} \left\{1 - \exp\left[-(\lambda + \lambda_v)\ t\right]\right\} \quad (1)$$

- Then

$$\mathbf{C}_{\mathbf{max}}^{\mathbf{v}} = \frac{\boldsymbol{\lambda}_{\mathbf{v}} \mathbf{C}_{\mathbf{out}} + \boldsymbol{\lambda}\, \mathbf{C}_{\mathbf{max}}^{\mathbf{0}}}{\boldsymbol{\lambda} + \boldsymbol{\lambda}_{\mathbf{v}}}$$

$$\mathbf{C}_{\mathbf{max}}^{\mathbf{0}} = \frac{\mathbf{E\,S}}{\boldsymbol{\lambda}\mathbf{V}} \quad \rightarrow \quad E = \lambda \frac{C_{\max}^{0} V}{S} \quad (2)$$

- If C_{out} and C_0 negligible
- Back diffusion is neglected

Emanation coefficient

- As defined in IS 5098:
  - The ratio between the Rn activity (at saturation) in the chamber and the Rn created in the BM (Ra activity)

$$\mathbf{e} = \frac{\mathbf{A_{Rn}}}{\mathbf{A_{Ra}}}$$

  - A_{Ra} calculated under dry conditions

Exemptions

- Average of 3 samples of the same batch
- Result of one sample and multiply by 1.25
- Use default Rn emanation
- Measurement of non-sealed material
  - Concrete – multiply the Rn activity by 0.75 (empirical from tens of measurements)
  - Blocks (hollow and massive) - use the Rn activity measured

Rn measurement

- Continuous Rn monitor
  - Use equation (1) and (2)
  - Use first hours of measurement (independent to λ_v

$$E = \left.\frac{dC}{dt}\right|_{t=0} \cdot \frac{V}{S}$$

- Activated charcoal canister

$$A_{Rn} = f\,\frac{A_{AC}(t)\left(1+\frac{V}{V_{AC}^{max}}\right)}{1-\exp(-\lambda\, t)}$$

- Electret

$$A_{Rn} = \frac{C(t)\,V}{1-\frac{1-\exp(-\lambda\, t)}{\lambda\, t}}$$

Conclusions

- Rn measurement are mandatory in IS 5098
- Measurement are performed using the close chamber method
- The measurements should be performed using:
  - Continuous Radon monitor,
  - Activated charcoal
  - Electret detectors
- Well established methods were defined for both concrete samples and blocks
- Further instructions should be established for other type of BM