Radon in air
Passive detectors

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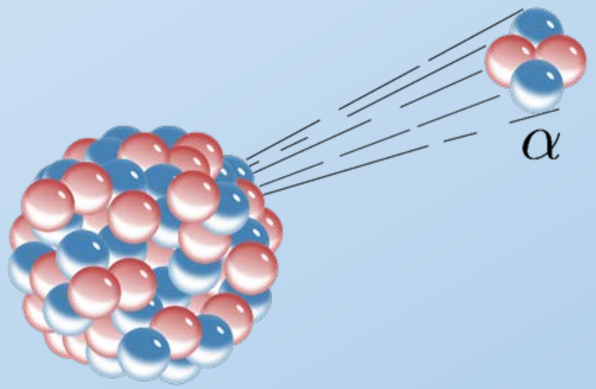
Introduction

- Most studies include radon measurements to classify the radon risk areas, to evaluate dwellings, etc.
- **Passive detectors** are commonly used to carry out long-term measurements:
  - Time-integrated concentration
- **Active detectors** are frequently used in Rn diagnostic measurement:
  - Continuous monitoring
- It is important to ensure radon measurements quality and maintain traceability to calibration standards.

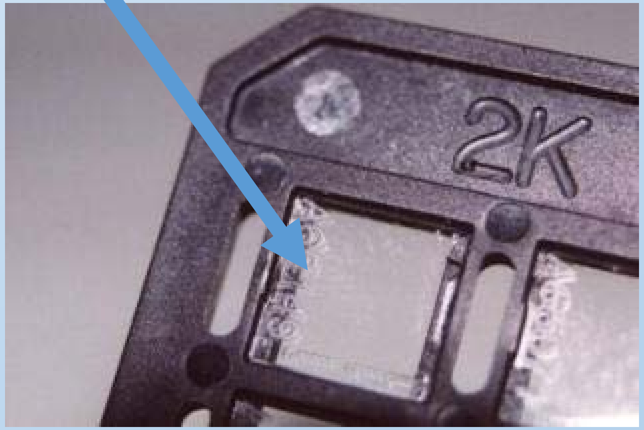


Passive Detectors

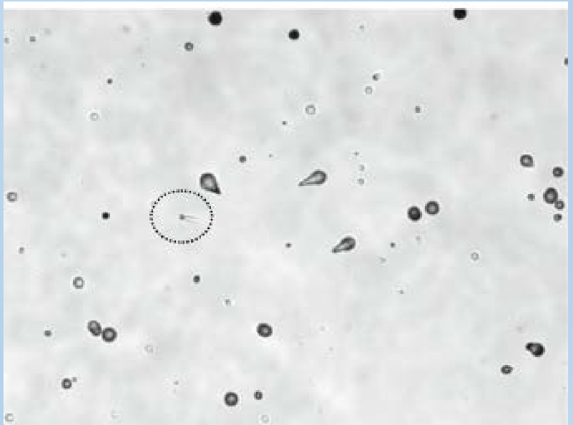
- Provide the radon concentration integrated in time
- Exposure Value *E* (Bq m^{-3} h)
- Mean Radon concentration *C* (Bq m^{-3})
  - Taking into account the exposure time

Passive Detectors

CR-39 track detector



Alpha Particles from Radon and its progeny hit with the detector and leave tracks



Passive Detectors

Two phases to obtain the detectors track density

- **1st: Chemical etching**
- **2nd: Reading with a microscope**

Passive Detectors

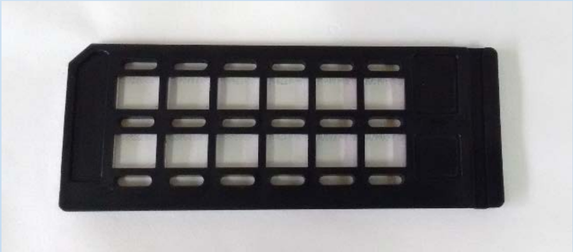
- **1st: Chemical etching**

- Materials:
    - NaOH (sodium hydroxide)
    - Distilled water
    - Acetic acid
    - RadoBath

RadoBath

Passive Detectors

RadoBath



<u>1st: Chemical etching</u>

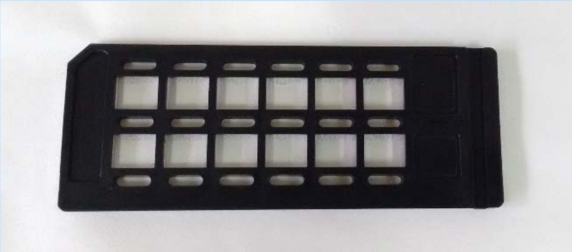
- Process:
  - “Solution prepare”
    - Add 1 kg NaOH + 4 L water
    - Temperature reachs 90 ºC
  - “Etching”
    - Introduce detectors during a stablished time according to manufactures specifications
  - “Neutralization”
    - 35 mL of Acetic acid in 3965 L of water
    - Time: 20 min.
  - Final actions
    - Detector washing with water + dry in filter paper

Passive Detectors

<u>2nd: Reading</u>

- Process:
  - Introduce the slide with 12 detector max in the Radometer
  - Carry out 5 measurements each to obtain the uncertainty/dispersion

  - Previously, background values were obtained.
    - Etching and reading is the same process



Radometer

Passive Detectors

Background Control

- From each group of 500 detectors,
  - 12 detector for background control
  - At the beginning of the use of each group

Calibration

  - 12 detectors for a low exposure (~ 500 kBq m^{-3} h)
  - 12 detectors for a high exposure (~ 1500 kBq m^{-3} h)
  - For each manufacturer series

Passive Detectors

$$D = \frac{\bar{N}}{S} F$$

D= Track density (tracks/mm^2)

N= mean value of 5 measurements

S= detector Surface (51,69 mm^2)

F= microscope factor given by the manufacturer determined conunting the tracks with other methods

Passive Detectors

$$E = (D_e - D_f)CF$$

E= Exposure (kBq m^{-3} h)

De= Track density exposed detector (tracks/mm^2)

Df= Track density background detectors (tracks/mm^2)

CF= Calibration factor (kBq m^{-3} h / tracks/mm^2)

Calibration of Passive Detectors

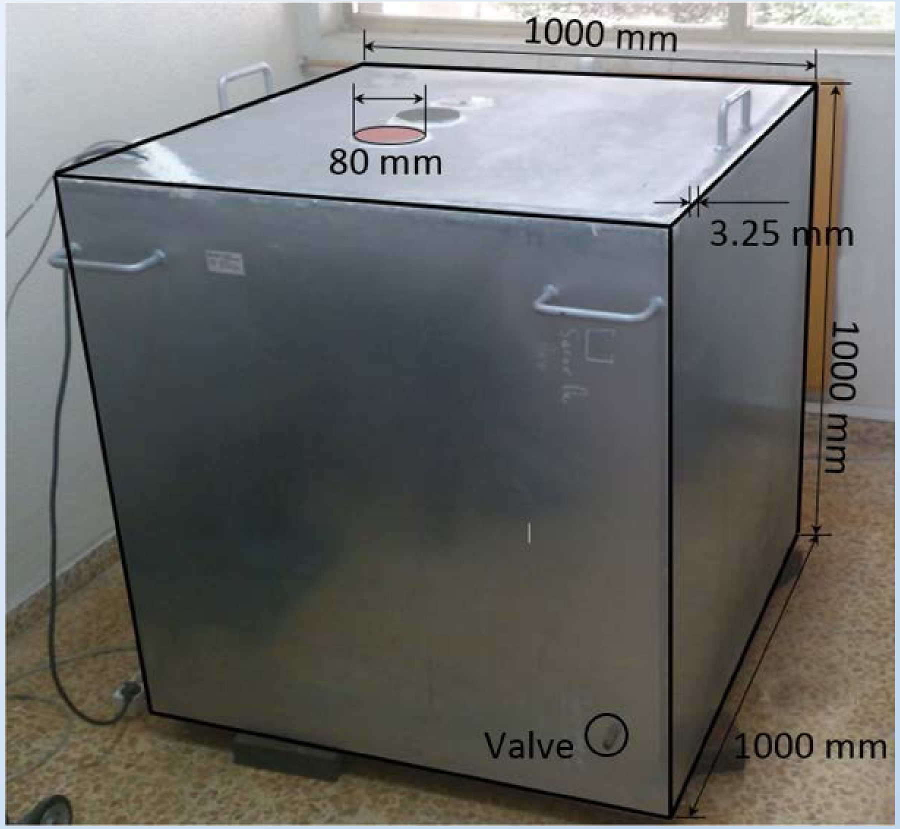
$$CF = \frac{E}{D}$$

Manufacturer
or
***Radon chamber** in the lab.*

CF= Calibration factor (kBq m^{-3} h / tracks/mm^2)
E= Exposure (kBq m^{-3} h)
D= Track density (tracks/mm^2) [removed the background]

Calibration of Passive Detectors

Radon Chamber: Laboratory of Environmental Radioactivity, University of Cantabria (Spain)



- Stainless steel radon chamber
- Thickness of 3.25 mm
- Internal volume 1 m^3
- Top face is a lid that can be removed
- 3 circular holes to insert etched track detectors

- Radon sources: from 30 to 1100 Bq h^{-1}
- Air exchange with exterior controlled with a pump

Calibration of Passive Detectors

Experimental design:

- Radon source inside the chamber
- Sealed with acrylic putty
- Air exchange with exterior/ leakages: controlled with the pump
- Radon concentration in the chamber is monitored with a reference monitor traceable to international standards

Calibration of Passive Detectors

Radon detectors:

- **AlphaGUARD** [Saphymo - Bertin Technologies SAS]
- **Atmos12** [Gammadata instruments AB]
  - **Devices traceable to international standards**

Calibration of Passive Detectors

Experimental design:

- Theoretical approach:

$$C(t) = C_0 e^{-\lambda t} + \frac{\phi}{V\lambda}(1 - e^{-\lambda t})$$

C_0 (Bq/m^3): initial radon concentration

ϕ (Bq/h): radon emission rate from source

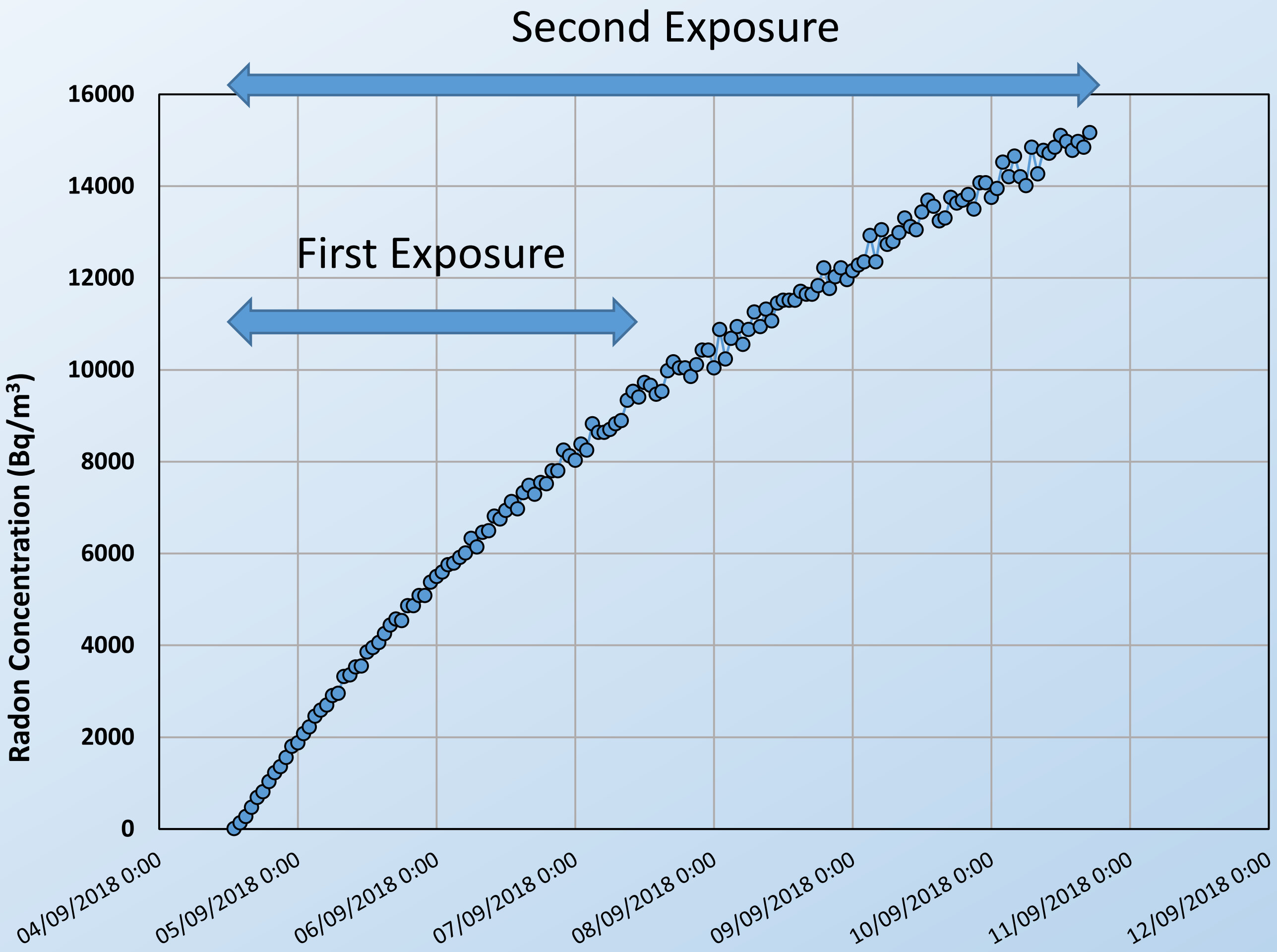
$\lambda = \lambda_{Rn} + \lambda_e$

λ_{Rn} : Rn decay constant (0,0076 h^{-1})

λ_e : Reflects air exchange rate per hour → $\lambda_e = \frac{F}{V}$

F : pump flow rate
V : Rn chamber volume

Calibration of Passive Detectors



Start Date	04/09/2018 13:00	04/09/2018 13:00
End Date	07/09/2018 17:00	10/09/2018 17:00
Exposure ($kBq\ m^{-3}\ h$)	426	1338

$$E = C \cdot \Delta t$$

12 detectors in each exposure

Calibration of Passive Detectors

$$CF = \frac{E}{D}$$

← ***Radon monitor*** (E)

← ***Etching + Track reading*** (D)

CF= Calibration factor (kBq m^{-3} h / $tracks/mm^2$)

E= Exposure (kBq m^{-3} h)

D= Track density ($tracks/mm^2$) [removed the background]

Passive Detectors

$$E = (D_e - D_f)CF$$

E= Exposure (kBq m^{-3} h)
De= Track density exposed detector (tracks/mm^2)
Df= Track density background detectors (tracks/mm^2)
CF= Calibration factor (kBq m^{-3} h / tracks/mm^2)