

# Radon in air Passive detectors

**Laboratory of Environmental Radiactivity, University of Cantabria**

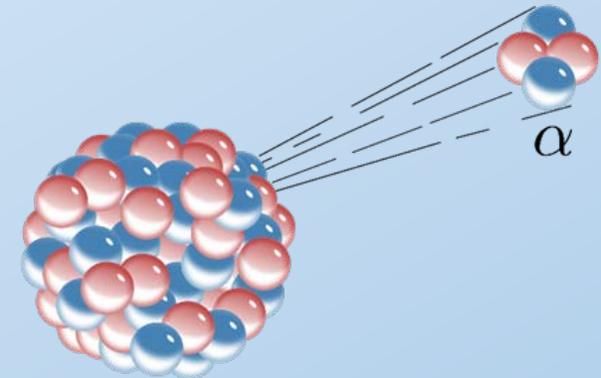
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# Introduction

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- 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

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

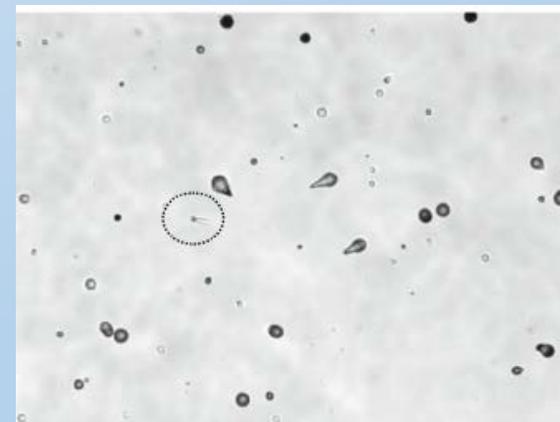
# Passive Detectors



CR-39 track detector



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



# Passive Detectors

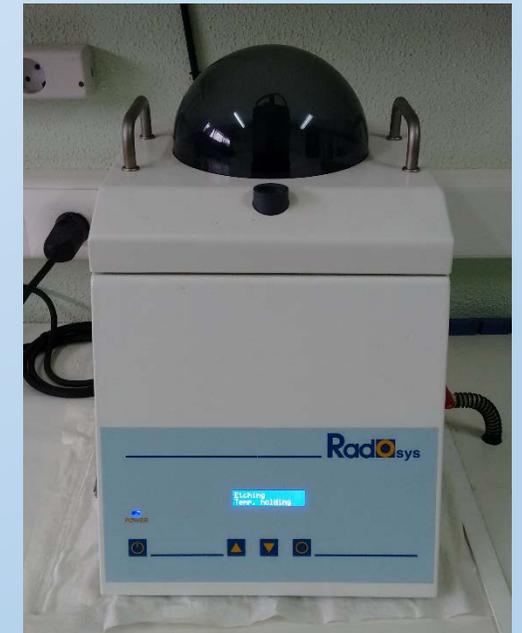
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Two phases to obtain the detectors track density

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

# Passive Detectors

- **1st: Chemical etching**
- **Materials:**
  - NaOH (sodium hydroxide)
  - Distilled water
  - Acetic acid
  - RadoBath



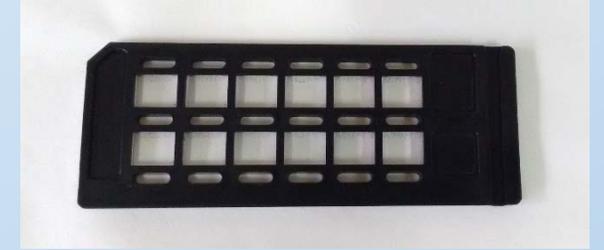
**RadoBath**

# Passive Detectors

## 1st: Chemical etching

- Process:
  - “Solution prepare”
    - Add 1 kg NaOH + 4 L water
    - Temperature reaches 90 °C
  - “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

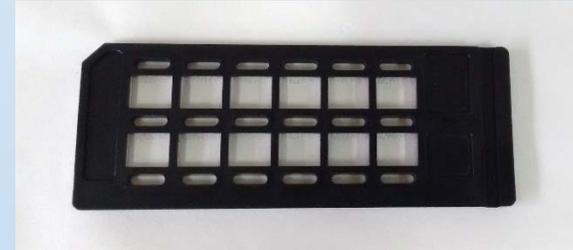
RadoBath



# Passive Detectors

## 2nd: Reading

- 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

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## 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 ( $\sim 500 \text{ kBq m}^{-3} \text{ h}$ )
- 12 detectors for a high exposure ( $\sim 1500 \text{ kBq m}^{-3} \text{ h}$ )
- For each manufacturer series

# Passive Detectors

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

$D$ = Track density (tracks/mm<sup>2</sup>)

$N$ = mean value of 5 measurements

$S$ = detector Surface (51,69 mm<sup>2</sup>)

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

# Passive Detectors

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

$E$ = Exposure (kBq m<sup>-3</sup> h)

$D_e$ = Track density exposed detector (tracks/mm<sup>2</sup>)

$D_f$ = Track density background detectors (tracks/mm<sup>2</sup>)

$CF$ = Calibration factor (kBq m<sup>-3</sup> h / tracks/mm<sup>2</sup>)

# Calibration of Passive Detectors

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

*Manufacturer*

*or*

*Radon chamber in the lab.*

$CF$ = Calibration factor (kBq m<sup>-3</sup> h / tracks/mm<sup>2</sup>)

$E$ = Exposure (kBq m<sup>-3</sup> h)

$D$ = Track density (tracks/mm<sup>2</sup>) [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<sup>3</sup>
- 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<sup>-1</sup>
- Air exchange with exterior controlled with a pump

# Calibration of Passive Detectors

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## 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

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## 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<sup>3</sup>): initial radon concentration

$\phi$  (Bq/h): radon emission rate from source

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



$\lambda_{\text{Rn}}$  : Rn decay constant (0,0076 h<sup>-1</sup>)

$\lambda_e$  : Reflects air exchange rate per hour

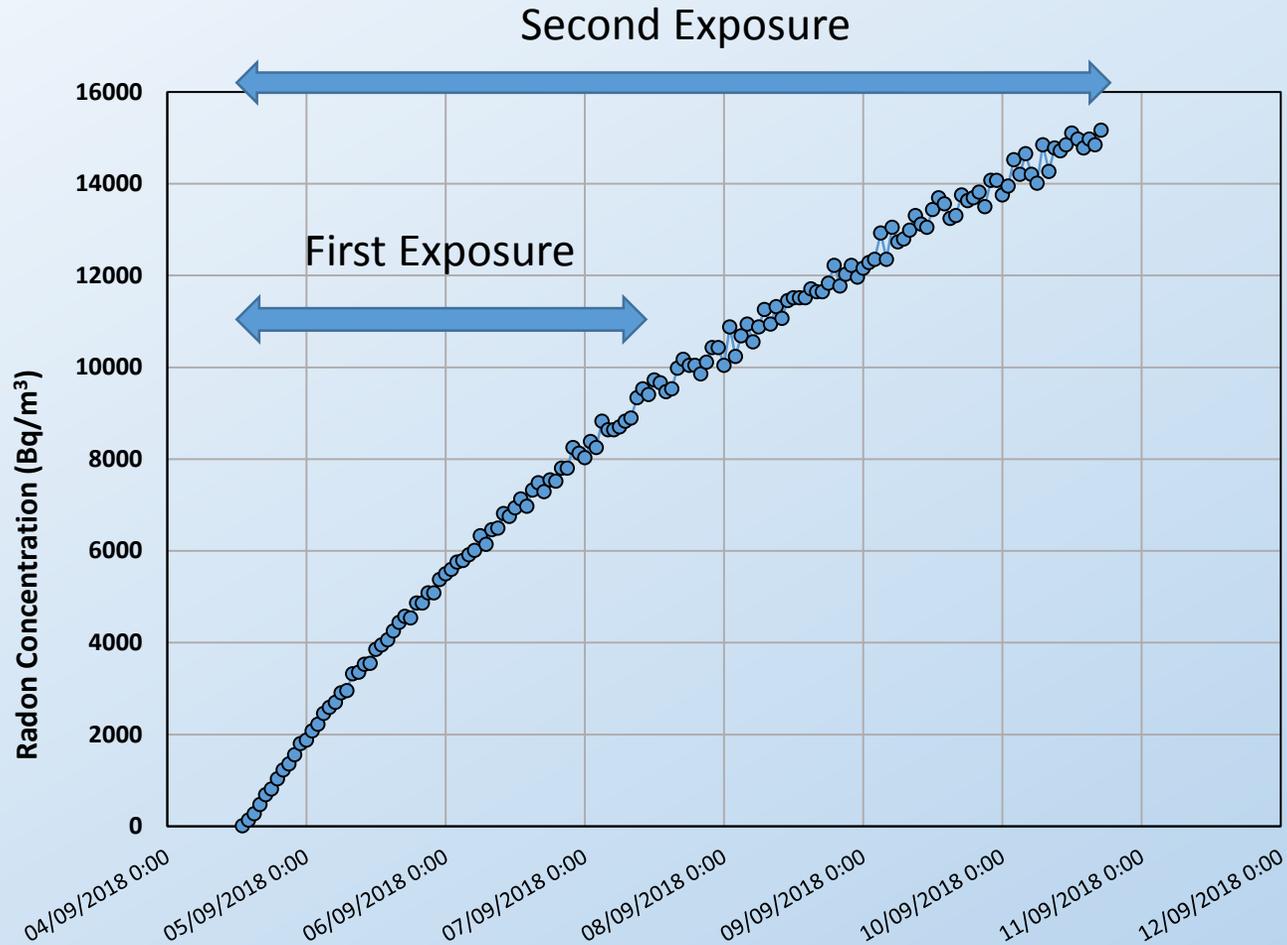


$$\lambda_e = \frac{F}{V}$$

$F$  : 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 <sup>-3</sup> h)	426	1338

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

**12 detectors in each exposure**

# Calibration of Passive Detectors

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

← *Radon monitor*

← *Etching + Track reading*

$CF$  = Calibration factor (kBq m<sup>-3</sup> h / tracks/mm<sup>2</sup>)

$E$  = Exposure (kBq m<sup>-3</sup> h)

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

# Passive Detectors

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$D_e$ = Track density exposed detector (tracks/mm<sup>2</sup>)

$D_f$ = Track density background detectors (tracks/mm<sup>2</sup>)

$CF$ = Calibration factor (kBq m<sup>-3</sup> h / tracks/mm<sup>2</sup>)