15th GARRM

15th INTERNATIONAL WORKSHOP GARRM
(on the GEOLOGICAL ASPECTS OF RADON RISK MAPPING)

The Exhalation Bed: Facility to calibrate radon flux devices

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Overview

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  - **Design**
  - **Setup**
  - **Characterization**
- **Calibration plan**
  - **Environmental parameters**
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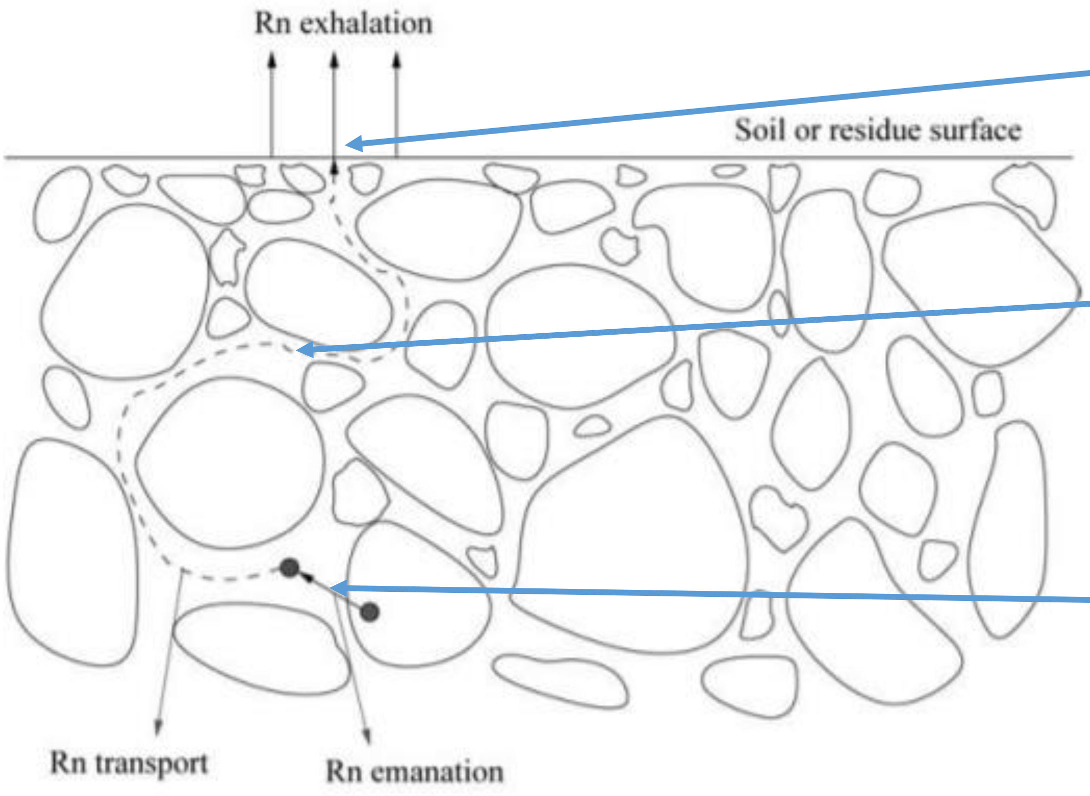
Introduction



[IAEA 2013]

Exhalation: radon atoms that have been transported to the ground surface exhale to the atmosphere. (Bq m^{-2} h^{-1})

Transport : diffusion and advective flow cause the movement of the emanated radon atoms through the residue or soil profile to the ground surface.

Emanation: radon atoms formed from the decay of radium escape from the grains (mainly because of recoil) into the interstitial space between the grains.

Introduction

Radon Exhalation or Radon flux information:

a. Determining the radon potential of a new building area

b. Monitoring the accomplishment of regulatory requirements in uranium mill tailings or phosphogypsum piles

c. Determining the radon exhalation rate of building materials. In addition, the knowledge of the spatial and temporal variability of terrestrial radon fluxes over the soil is useful for the application of the Radon Tracer Method (RTM), an approach for the indirect estimation of greenhouse gas fluxes.

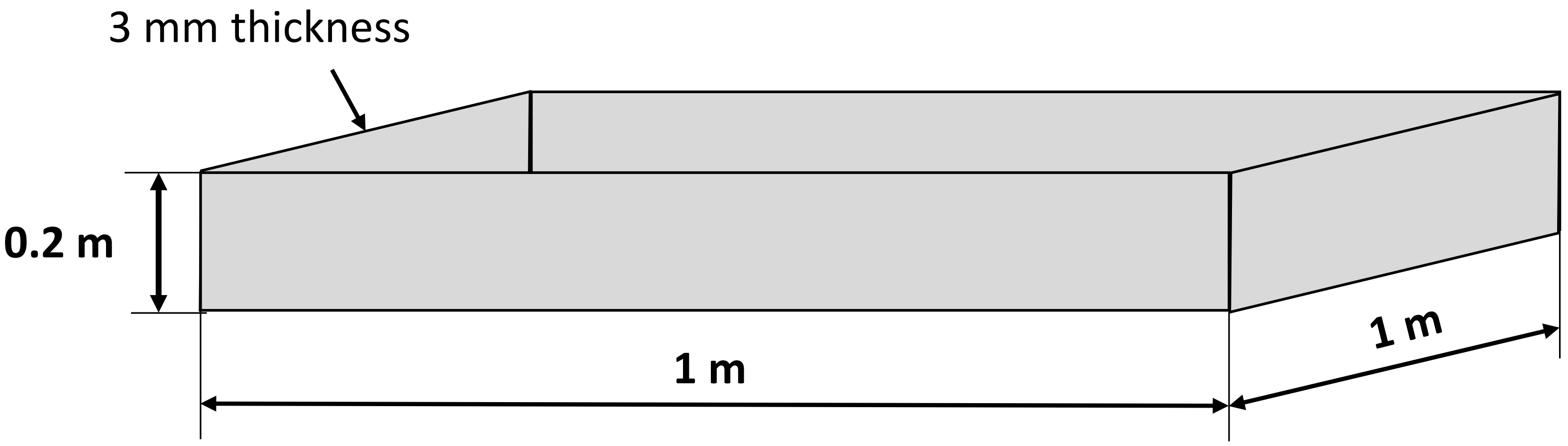
Exhalation Bed Facility

Exhalation system to calibrate radon flux devices

- Design
- Setup
- Characterization

Exhalation Bed Facility: Design

Welded Stainless Steel plates



Exhalation Bed Facility: Setup

Setup

- Soil from Fos-Bucraa mine (western Sahara) from raw material of a fertilizers factory (~ 400 kg)

- A bit higher Radium content compared to environmental values
- Extended on 30 m^2 plastic layer surface
- Sieved (Sieve Nominal Aperture 1 mm)
- Dryied (humidity ~ 2%)
- Homogenized [IAEA-TECDOC-1415]

Exhalation Bed Facility: Setup

Exhalation Bed Facility: characterization

Determination of Exhalation Rate

Theoretical

Parameters related with difussion

Experimental

Rn monitoring in a hermetically closed accumulation chamber

Characterization: Theoretical

Characterization: Theoretical Aproach

- Theoretical expression to determine the radon exhalation rate (E):

$$E = \varepsilon \cdot C_{\mathrm{Ra}} \cdot \rho \cdot L \cdot \lambda \cdot \tanh\left(\frac{z}{L}\right)$$

Approach: $z \ll L$

$$\tanh\left(\frac{z}{L}\right) \approx \frac{z}{L}$$

$$\boxed{E = \varepsilon \cdot C_{\mathrm{Ra}} \cdot \rho \cdot \lambda \cdot z}$$

ε: Emanation factor
C_{Ra}: Radium concentration (Bq/kg)
ρ : Bulk density (kg/m^3)
L: Diffusion length (m)
z: Thickness (m)
λ(Rn): Radon decay constant (h^{-1})

$L \approx 1.6$ m (estimated from porosity and humidity) [Rogers & Nielson. 1991]

Characterization: Theoretical

Characterization: Theoretical Aproach

$$E = \varepsilon \cdot C_{\mathrm{Ra}} \cdot \rho \cdot \lambda \cdot z$$

ε	C_{Ra} (Bq/kg)	ρ (kg/m^3)	λ (h^{-1})	z (m)
0.45	214	893 ± 1	0.0075575(4)	0.15

$$E = 98 \pm 10 \ \mathrm{Bq\ m^{-2} h^{-1}})$$

Characterization: Experimental

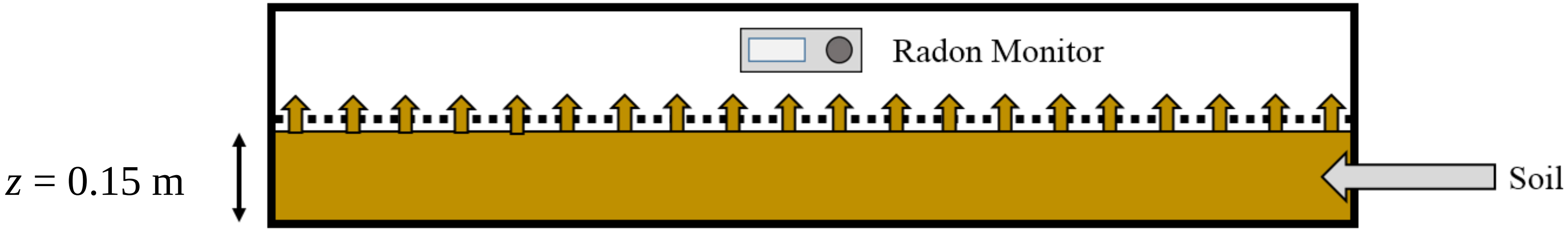
Characterization: Experimental Aproach

- Whole exhalation bed as accumulation chamber by forcing all the Rn exhaled stay inside the volume [Gutierrez-Alvarez et al. 2020]

- Radon accumulation inside the chamber:

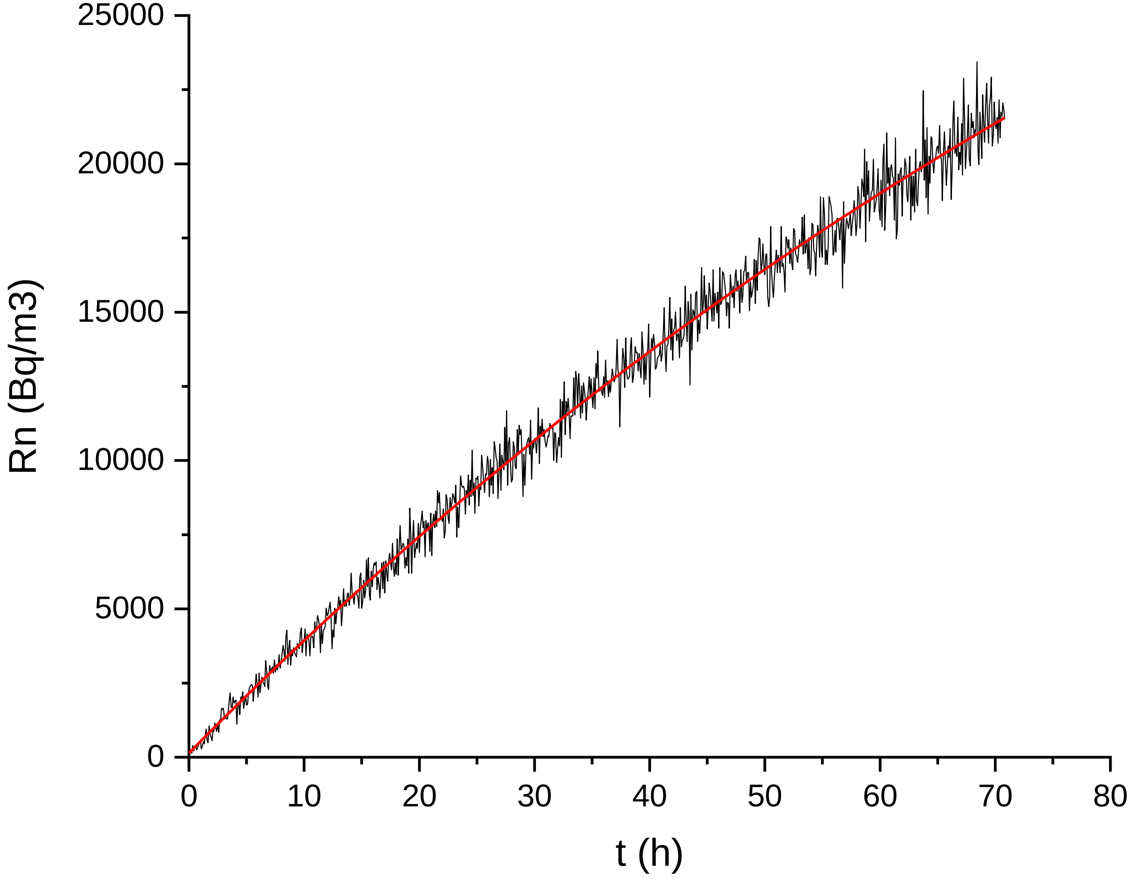
$$C_{Rn}(t) = C_0 e^{-\lambda' t} + \frac{ES}{V\lambda'}\left(1 - e^{-\lambda' t}\right)$$

$\lambda' = \lambda(\mathrm{Rn}) + \lambda(\mathrm{backdiffusion}) + \lambda(\mathrm{leakages})$



Characterization: Experimental

Characterization: Experimental Aproach



$$C_{Rn}(t) = C_0 e^{-\lambda' t} + \frac{ES}{V\lambda'}\left(1 - e^{-\lambda' t}\right)$$

λ'= λ(Rn)+ λ(backdiffusion)+ λ(leakages)

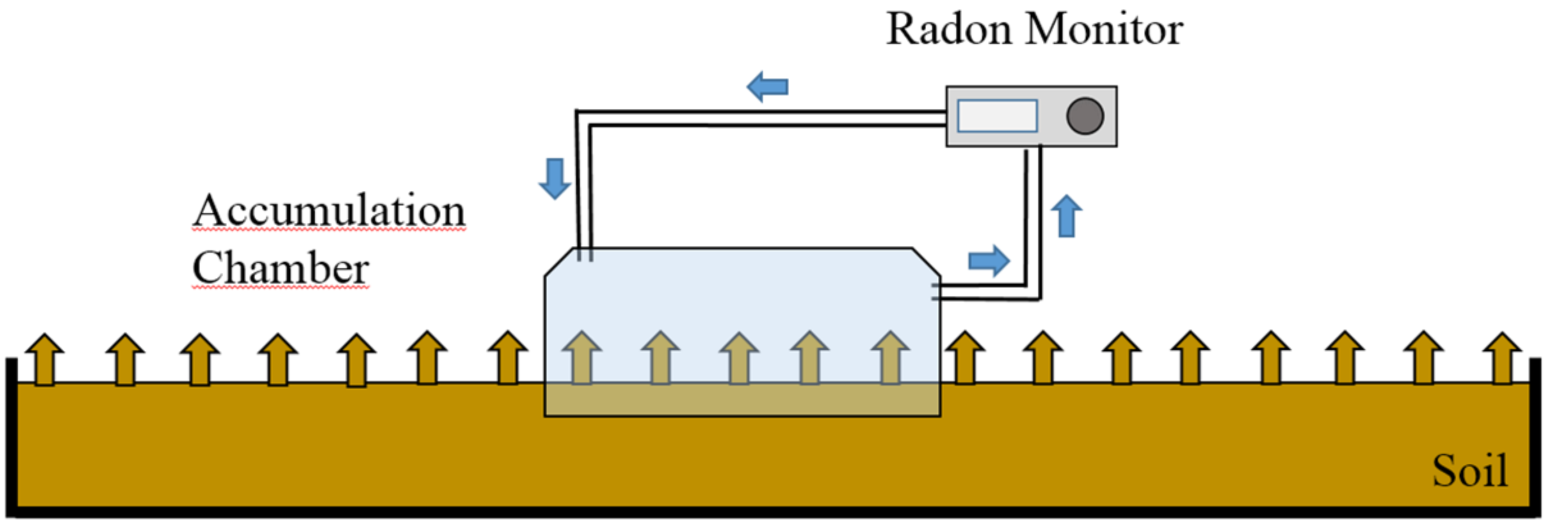
$$E \ = 91 \pm 5 \ \mathrm{Bq\ m^{-2}h^{-1}})$$

Calibration

- Real conditions: Accumulation chamber
- Calibrate the Continuous radon flux monitor according to the experimental and theoretical results

$$E = \frac{V}{S}\frac{\Delta C_{Rn}}{t}$$

[ISO 11665-7. 2012]



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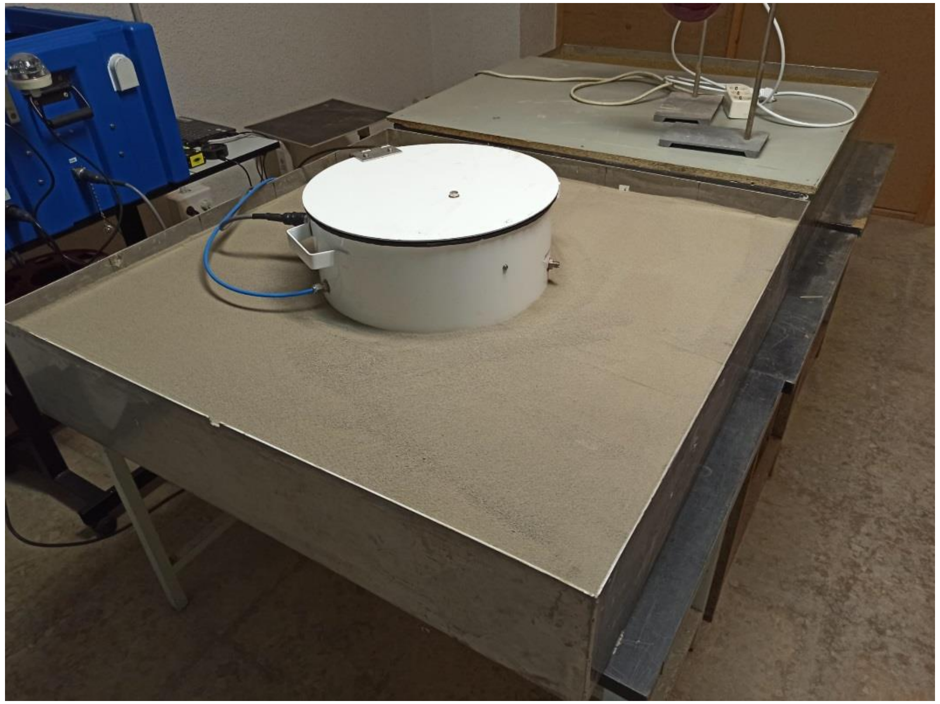
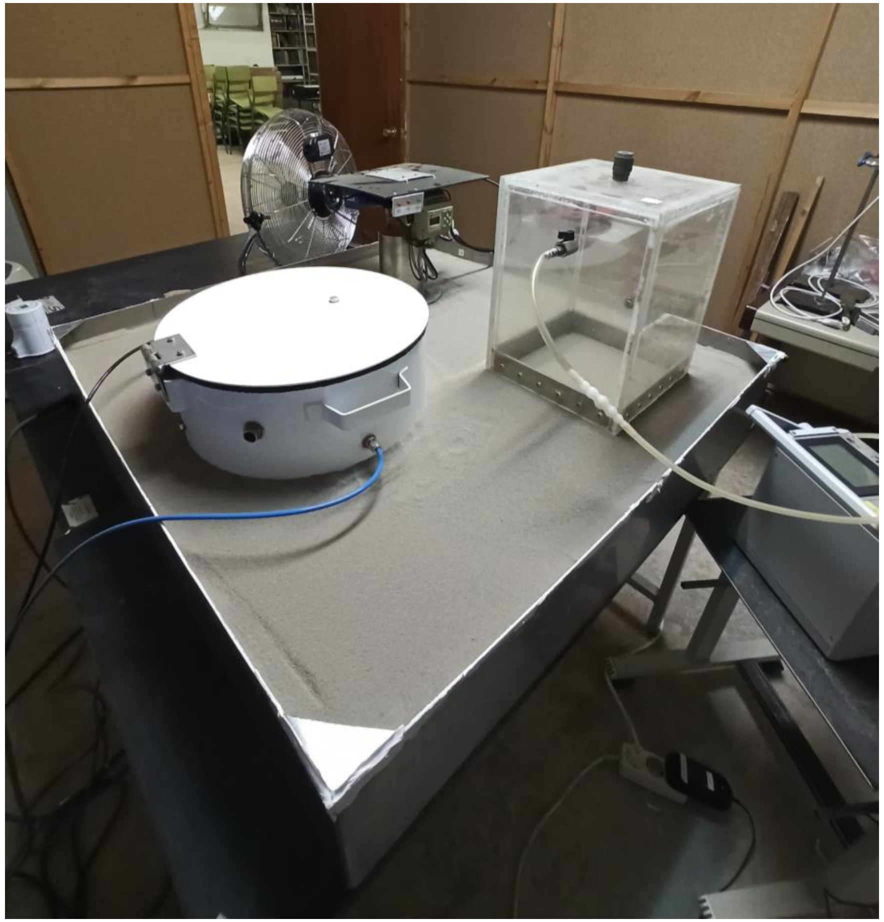


Australian Government | ANSTO

- Automatic system (1 hour accumulation, 2 hours open)
- AlphaGUARD + Pump + raspberry + sensors

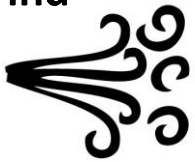
Calibration

- Some devices simultaneously
- Different accumulation times
- Shape
- Rn Monitors

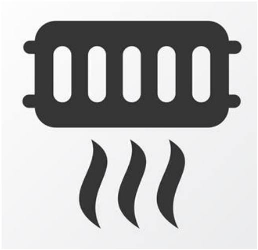


Calibration: Environmental parameters

Wind

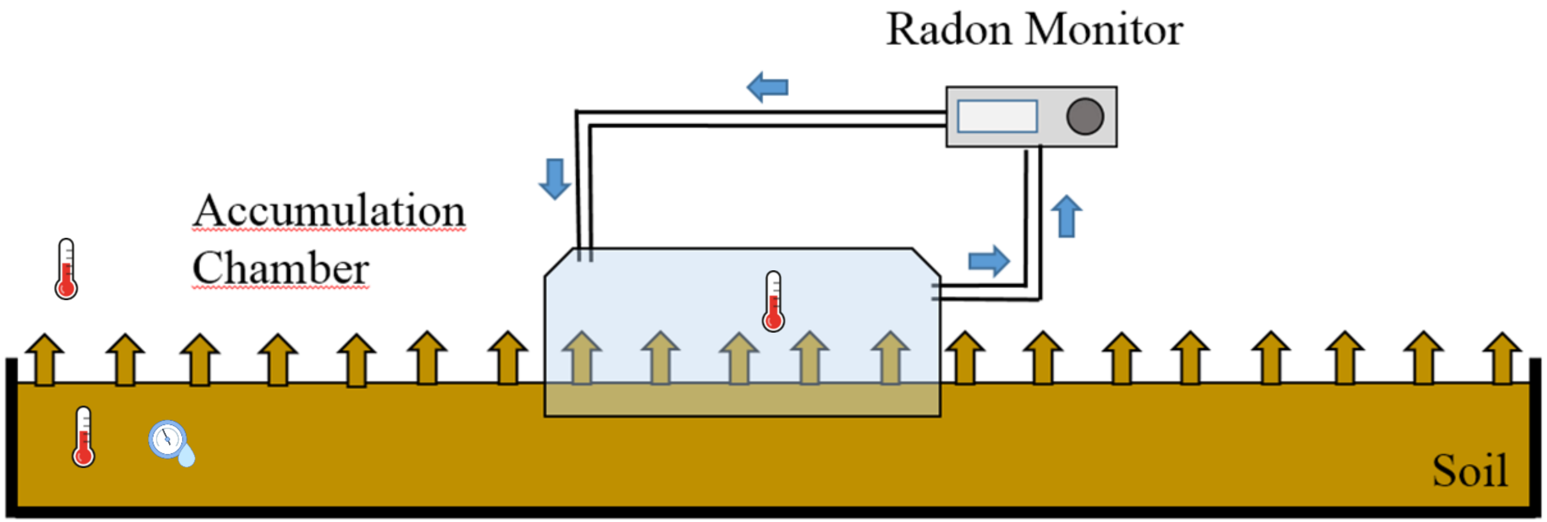


Heating



Rain

- Soil moisture
- Temperature sensors
  - Inside-outside the accumulator
  - Inside the soil
- Pressure sensor difference between soil, outside air and inside the accumulator



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