Radon, methods and instrumentation for its measurement

Joint ICTP-IAEA Workshop on Advanced Solutions for Field Measurements

Trieste, 8. – 19. 8. 2022

Content

- History
- What is radon and why it is so important to measure
- Mobility of radon in environment
- Radon measurement techniques
  - Radon progeny air sampling
  - Radon in soil field measurements
  - Radon in water field measurements

History

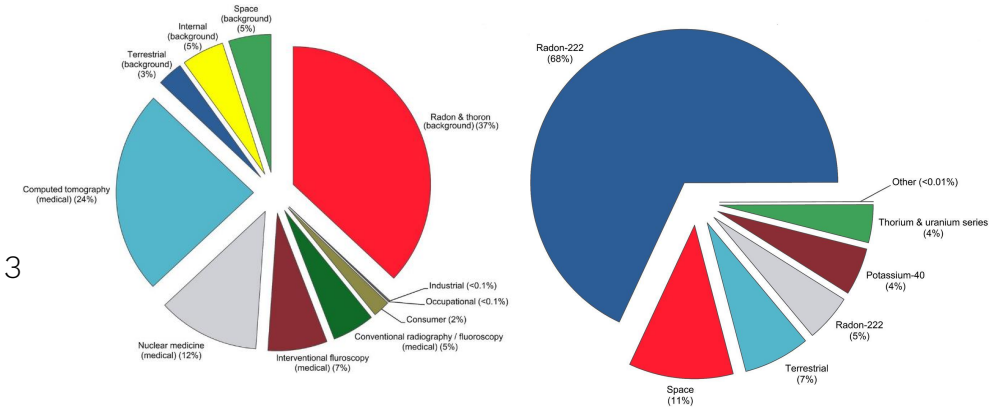
- Discovered in 1900 by F. E. Dorn
- „RADium emanatiON“ → RADON

The story of Stanley Watras

In 1984, a worker by the name of Stanley Watras triggered a radiation detector while helping build a nuclear power plant in Pennsylvania. This baffled the installers of the safety equipment because there was no radioactive material in the plant yet. They had just installed the equipment and assumed it was merely malfunctioning. The equipment turned out to be working correctly. They tested his house and found such high levels of radon that his person had become radioactive (~ 100 000 Bq/m^3) → Risk equivalent to smoking of 135 packs of cigarettes per day

What is radon and why it is so important to measure?

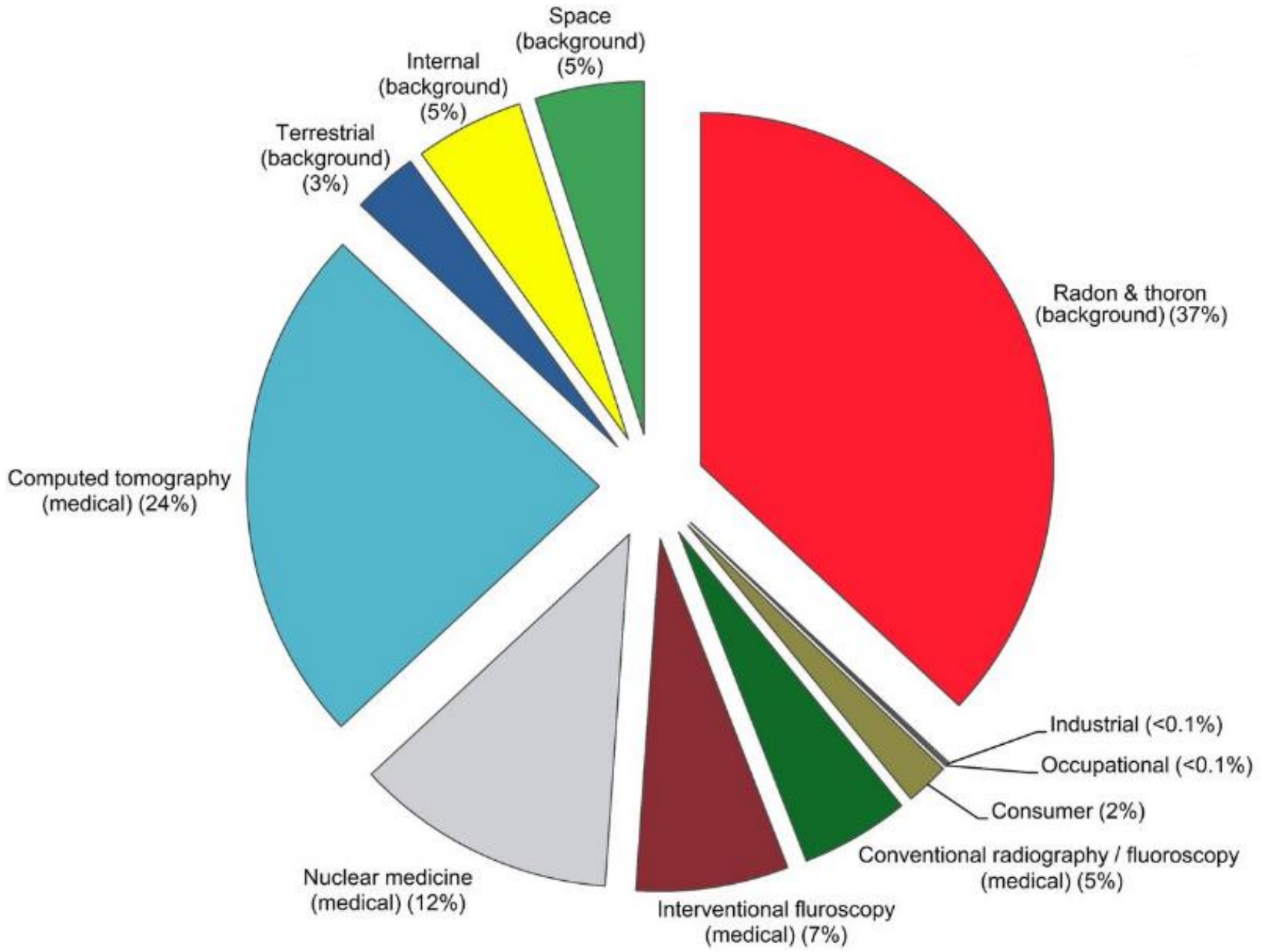
- A radioactive gas, does not have a single stable isotope
- Rn-222 (→ U-238), Rn-220 (→ Th-232, thoron), Rn-219 (→ U-235, actinone)
- Alpha emitters with a short half-life
- Soluble in water (51%) and in non-polar organic solvents (toluene)
- Can be caught on activated carbon (-71 °C)
- Can be found in
  - Subsoil (→ in buildings, in building materials)
  - Groundwater
  - Atmosphere in various concentrations (< 10 Bq/m^3

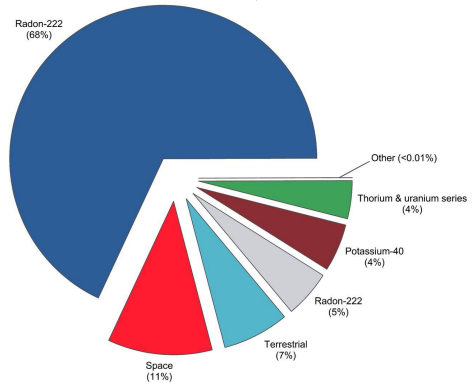


asure?

actinone

e)

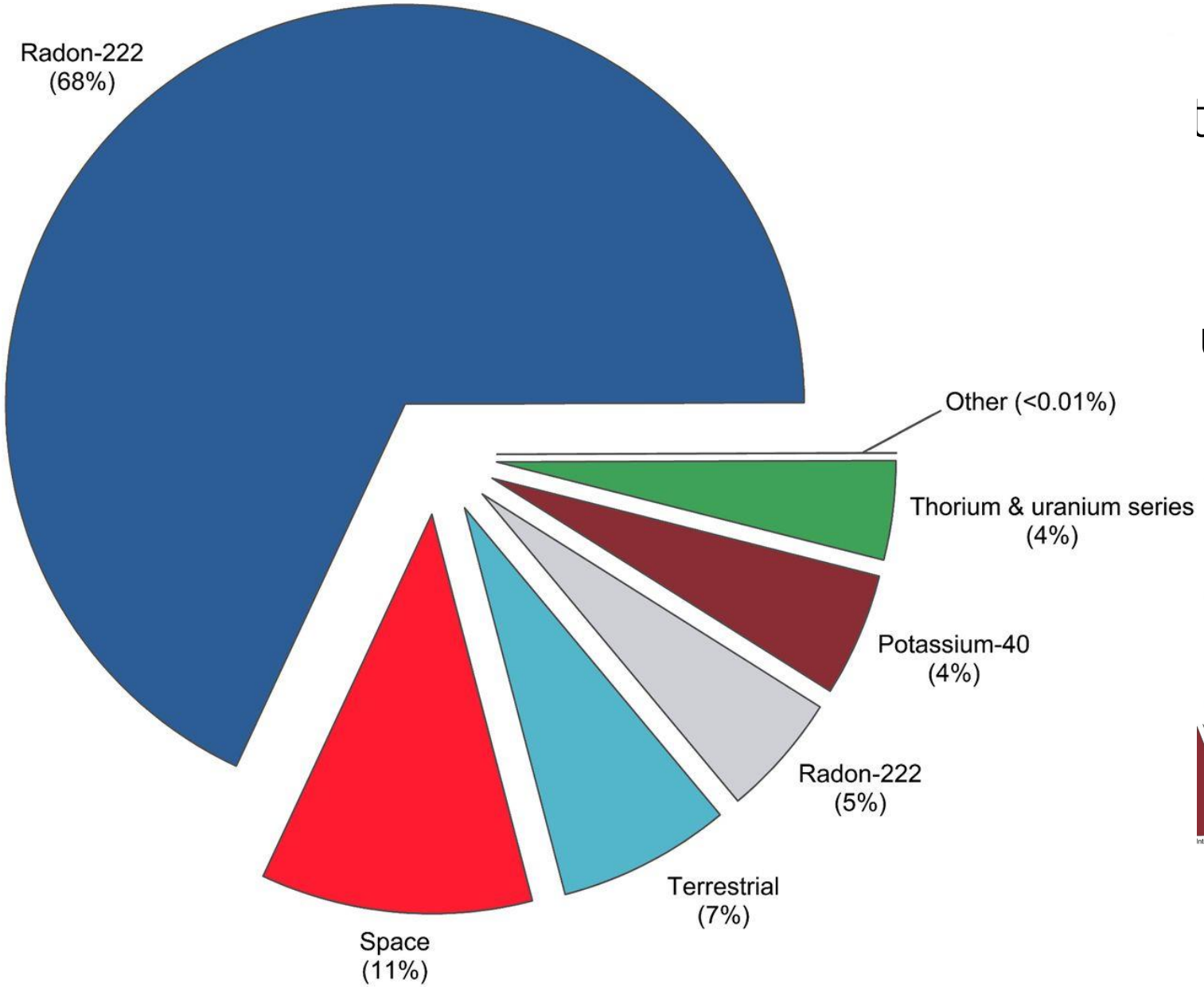


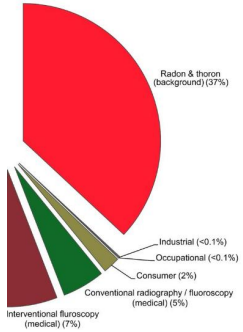


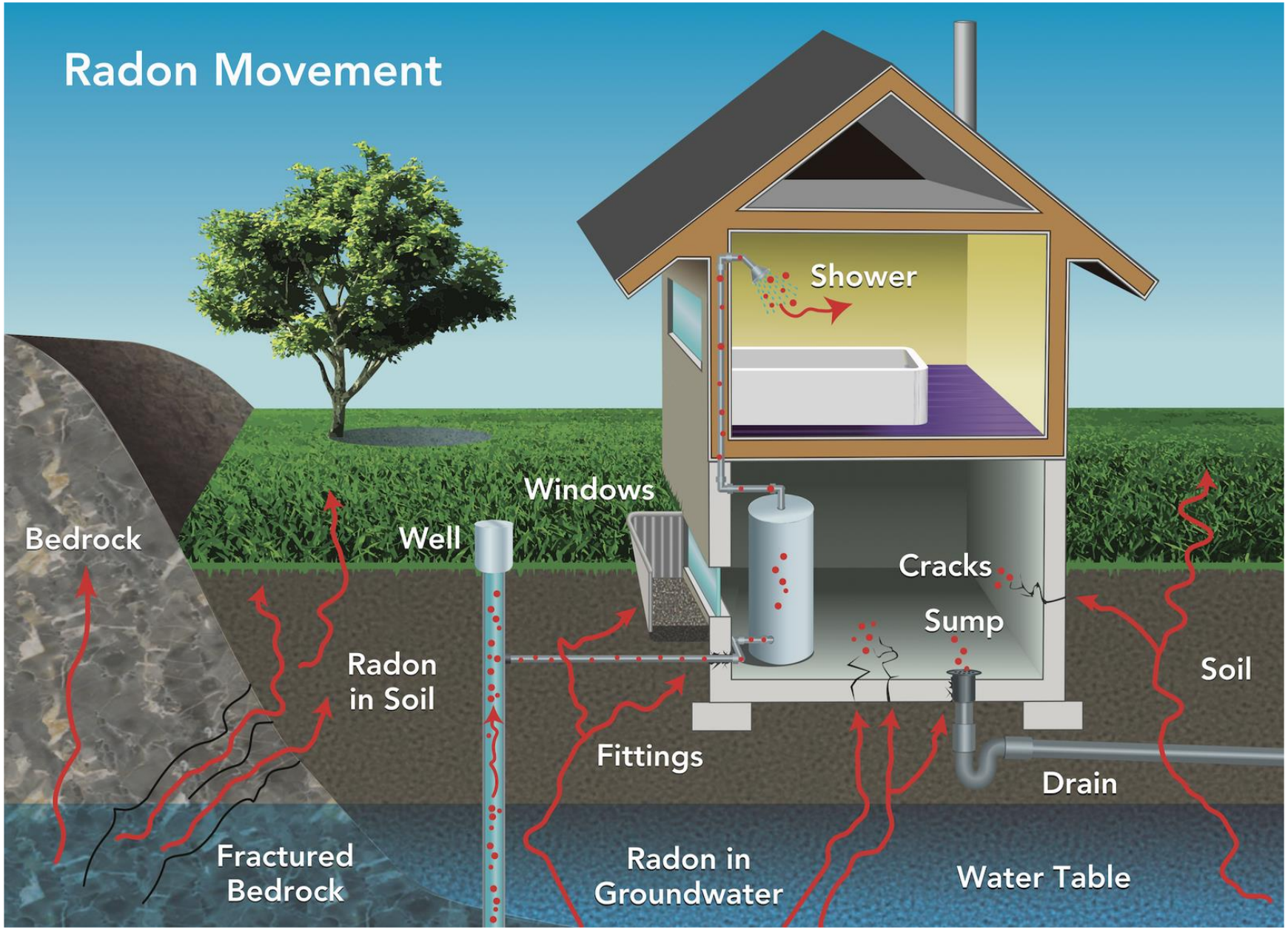
to measure?

U-235), actinone

(toluene)





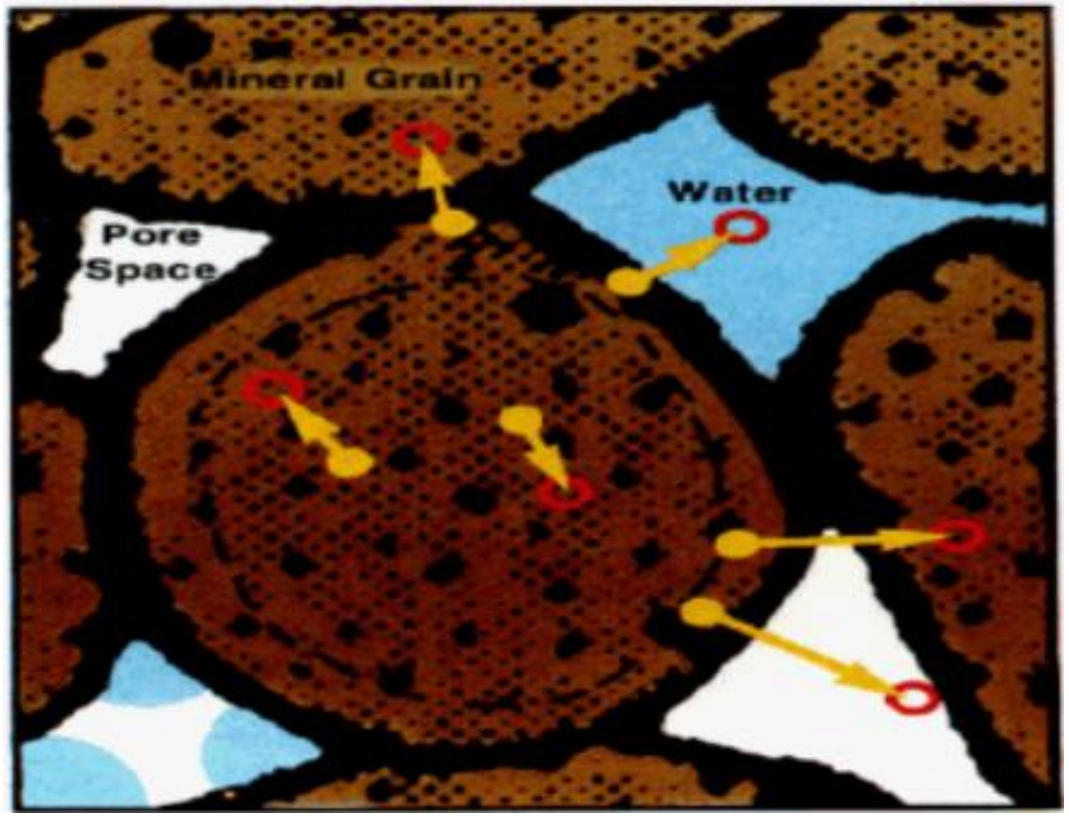

Radon Movement
Shower
Windows
Bedrock
Well
Cracks
Sump
Radon
in Soil
Soil
Fittings
Drain
Fractured
Bedrock
Radon in
Groundwater
Water Table

Mobility of radon

The concentration and mobility of radon in soil are dependent on several factors

- Soil's radium content and distribution
- Soil porosity & permeability to gas movement
- Moisture content

These characteristics are, in turn, determined by the soil's parent-material composition, climate, and the soil's age or maturity.

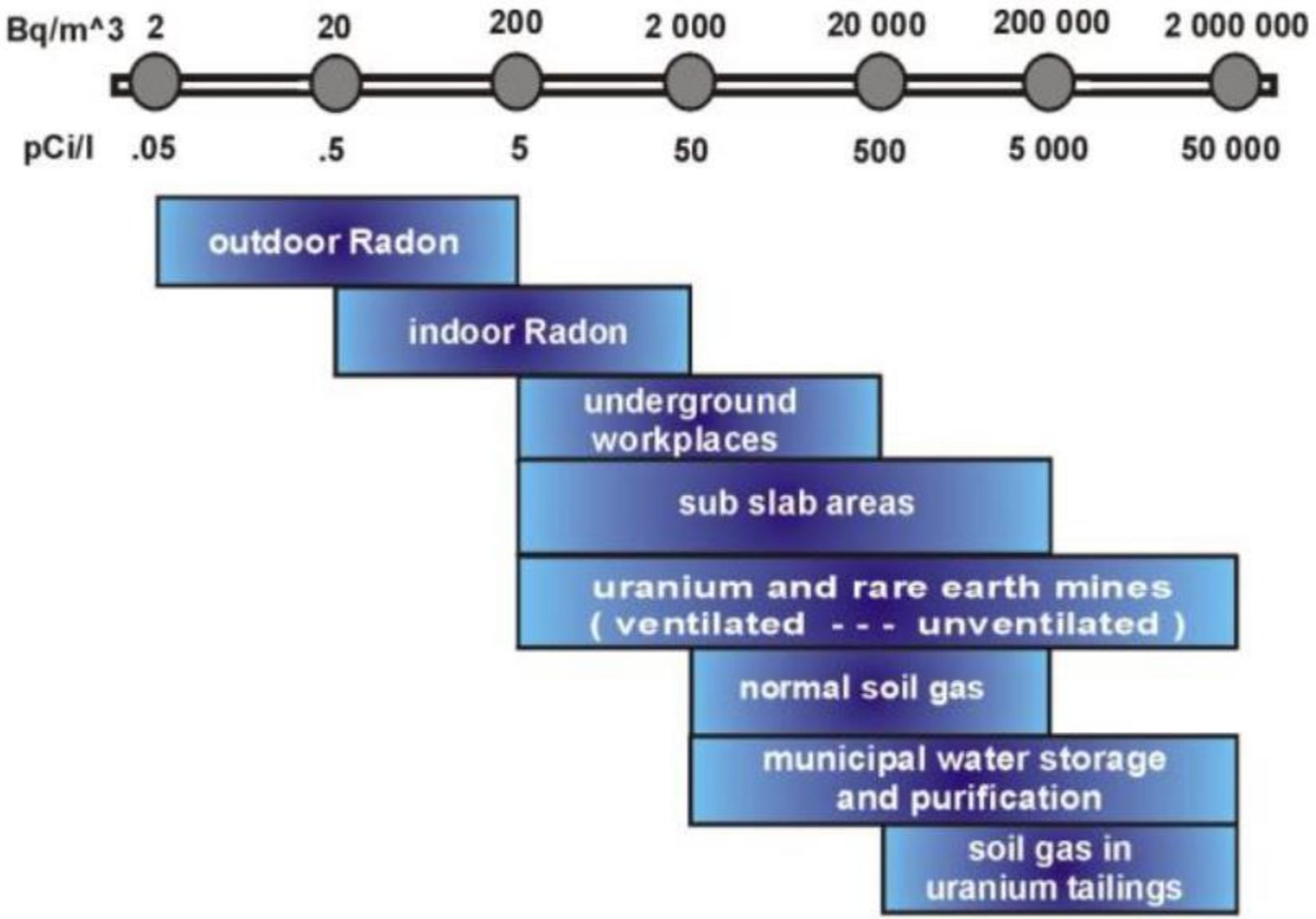


Mobility of radon

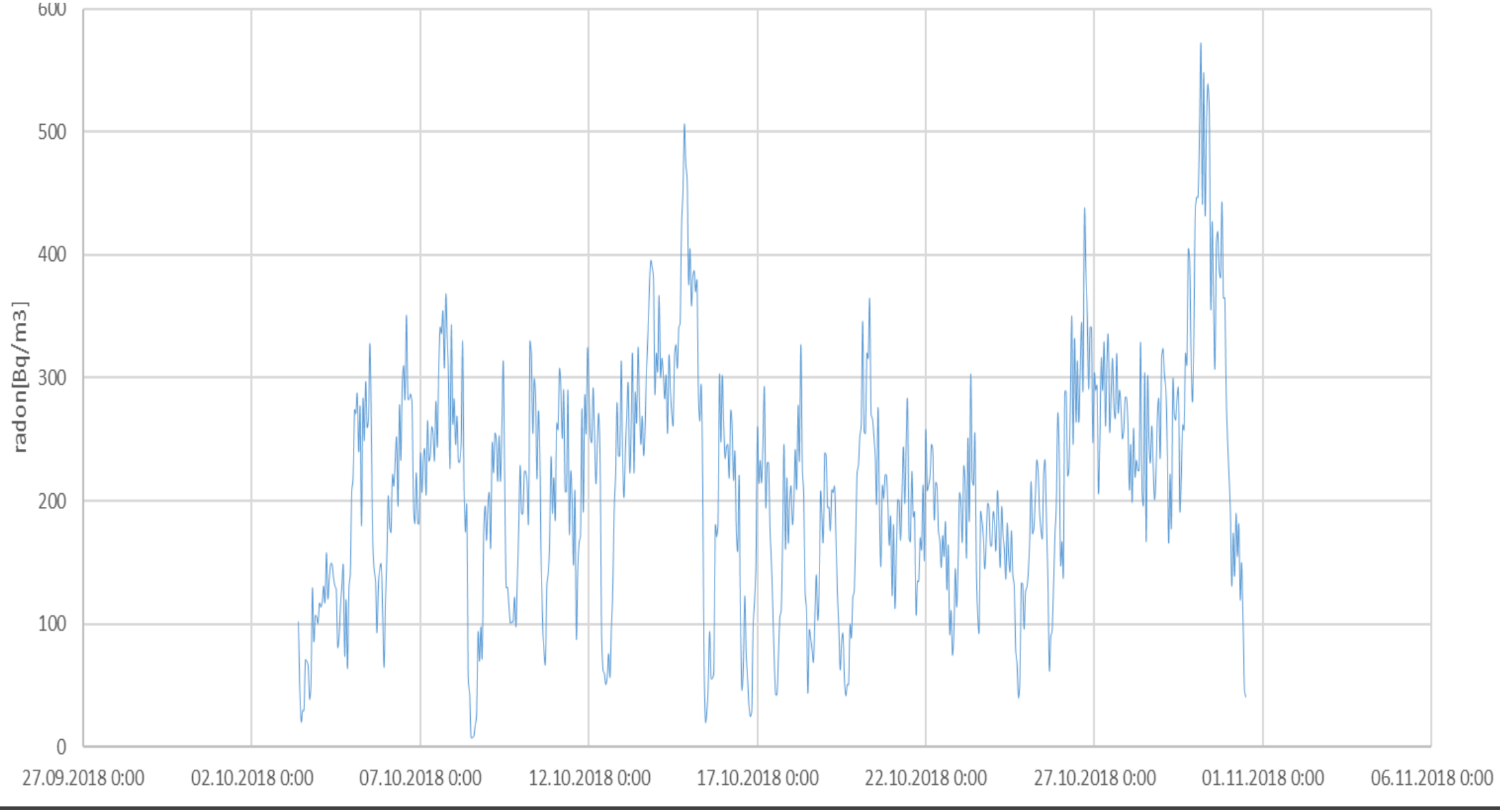
Radon transport in soils occurs by two processes:

- **Diffusion** (Radon atoms move from areas of higher concentration to areas of lower concentration in response to a concentration gradient)
- **Conduction (Flow)** (Soil air moves through soil pores in response to differences in pressure within the soil or between the soil and the atmosphere, carrying the radon atoms).

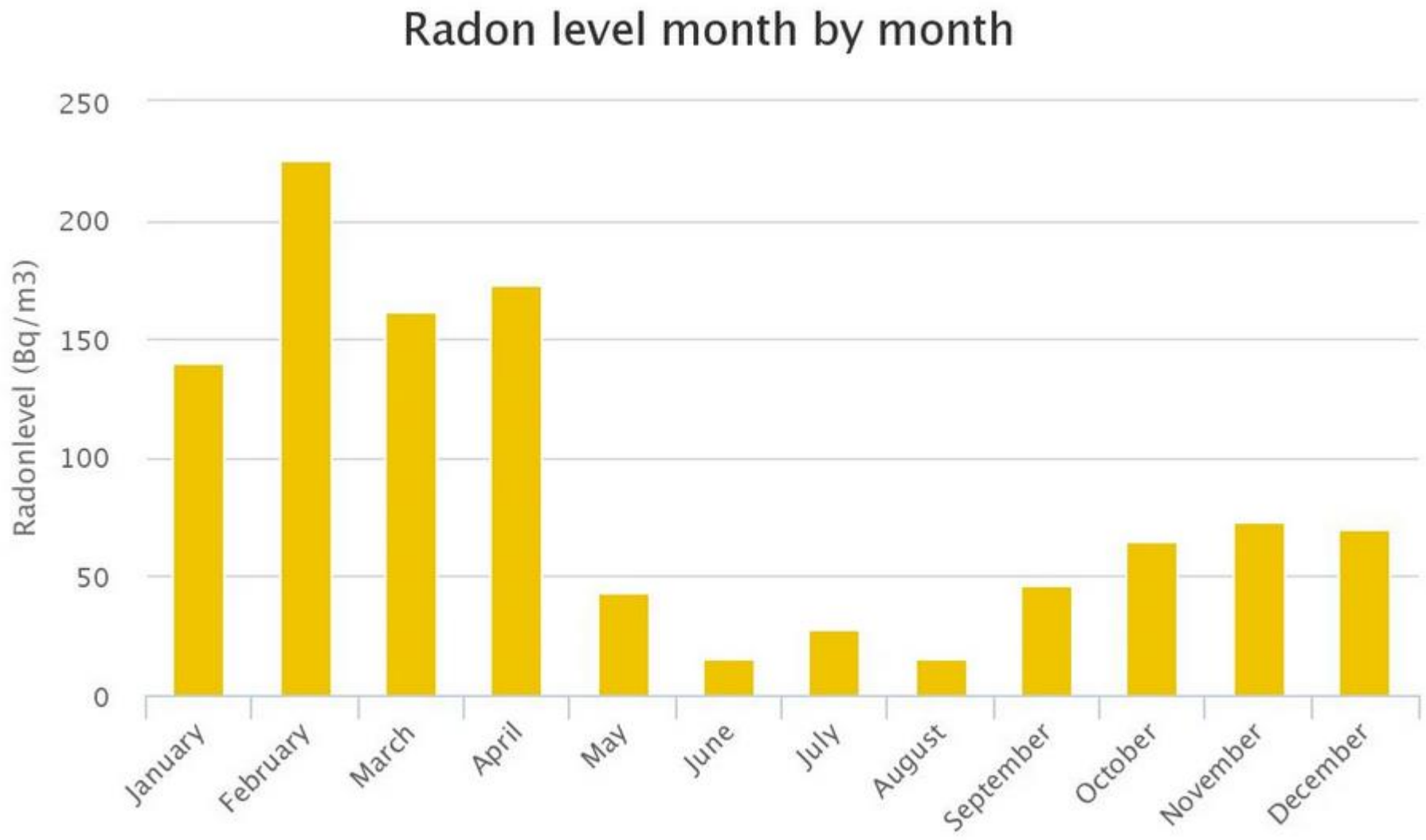
Diffusion is the dominant radon transport process in soils of low permeability, whereas flow tends to dominate in highly permeable soils. In low-permeability soils, much of the radon may decay before it is able to enter a building because its transport rate is reduced. Conversely, highly permeable soils, even those that are relatively low in radium, such as those derived from some types of glacial deposits, have been associated with high indoor radon levels.


Bq/m^3 2 20 200 2 000 20 000 200 000 2 000 000
pCi/l .05 .5 5 50 500 5 000 50 000
outdoor Radon
indoor Radon
underground workplaces
sub slab areas
uranium and rare earth mines (ventilated - - - unventilated)
normal soil gas
municipal water storage and purification
soil gas in uranium tailings

Short-term indoor radon measurement in a school building



Long-term indoor radon measurement



Source: www.airthings.com

Radon measurement

Types of measurement

- Determination of the radon index
- Long-term measurement of buildings
- Short-term and continuous measurement of underground spaces (storage, mines), water
- Radon diagnostics (finding sources and supply routes of radon)
- Radon as an earthquake precursor

Measurement methods

- Ionization & Electret chambers
- Lucas chambers
- Silicon detectors
- Passive track detectors
- Liquid scintillation counting

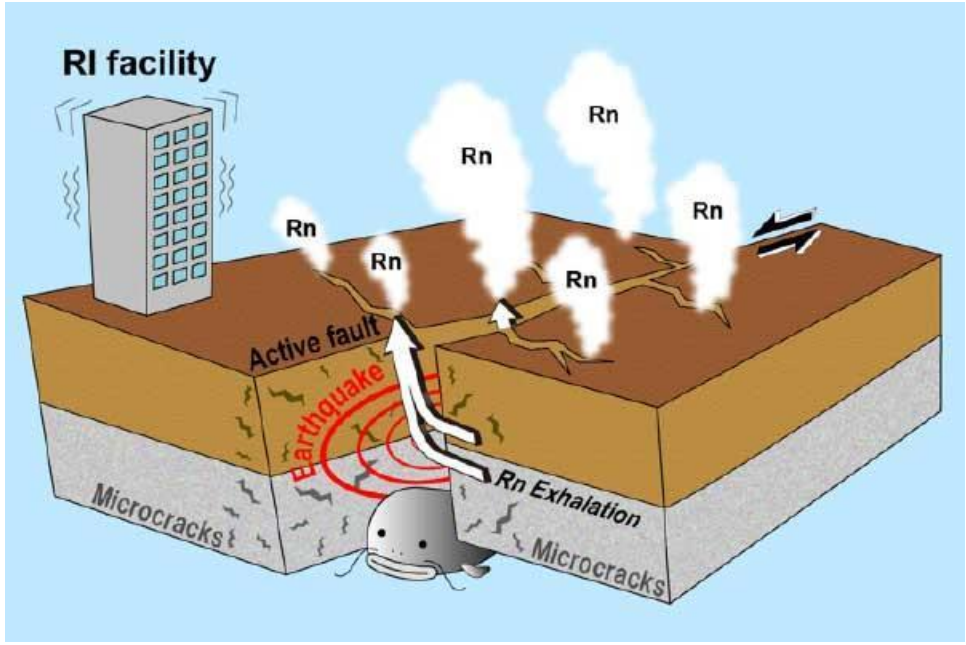
Sampling methods

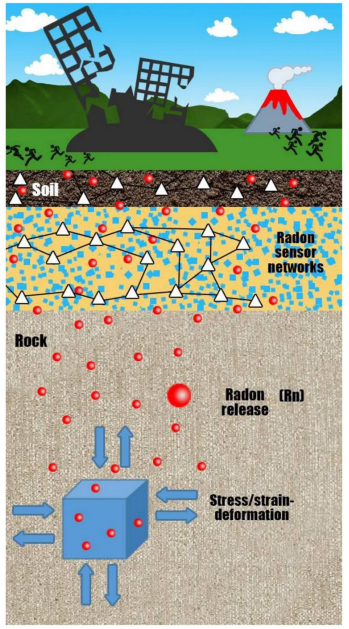
- Extraction
- Emanation
- Diffusion
- Air pumping
- Adsorption

Radon as a precursor of Earth cracks

In the last decade, several studies have concluded that elevated concentrations of radon gas in soil or groundwater could be the sign of an imminent earthquake. It is believed that the radon is released from cavities and cracks as the Earth's crust is strained prior to the sudden slip of an earthquake.

The same for volcano activities





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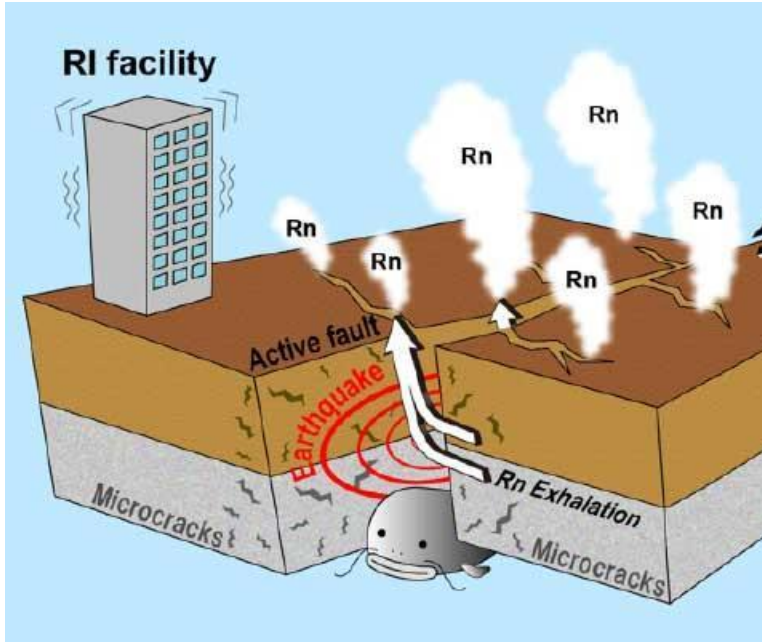

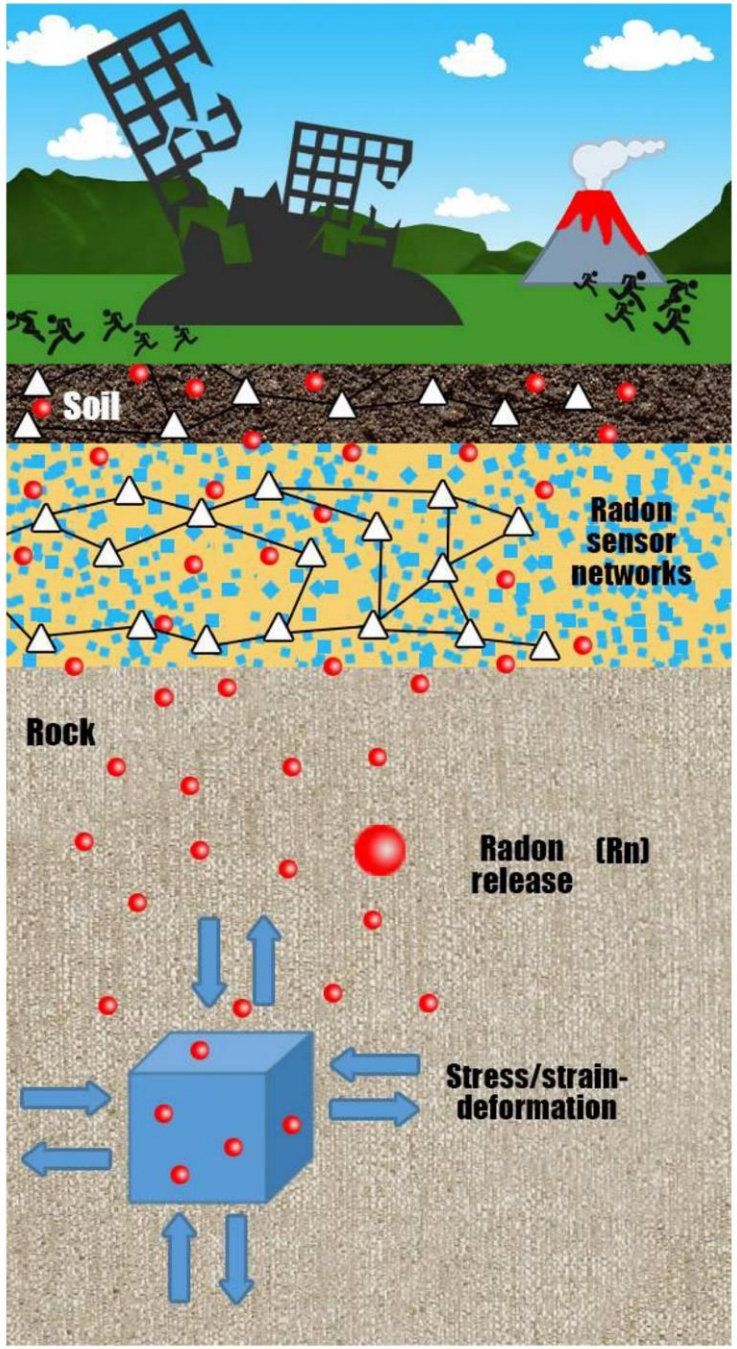


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Detektor Radonu
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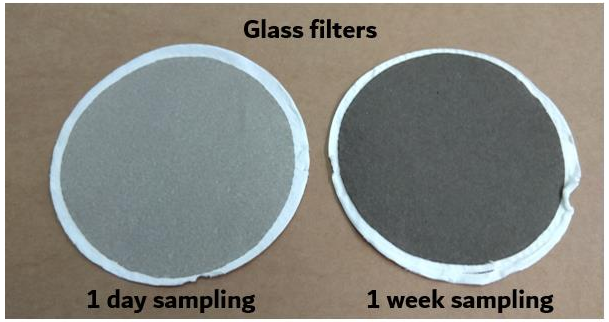
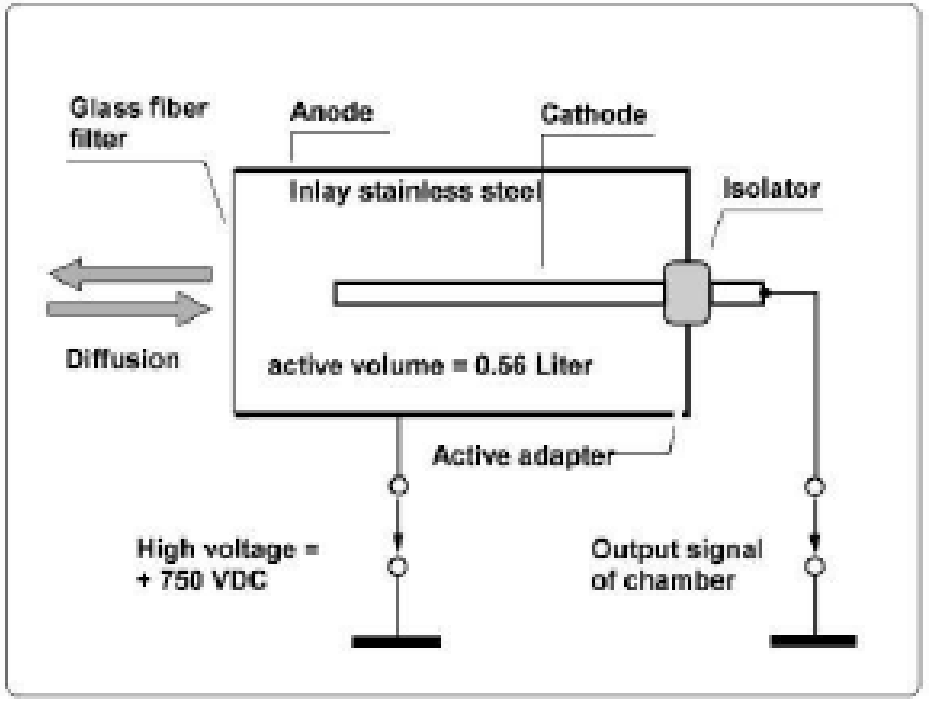
Radon monitor
RADIM 3
RS232
Go
K 113 06
SMM Prague
J.P.-060


ALPHAGUARD

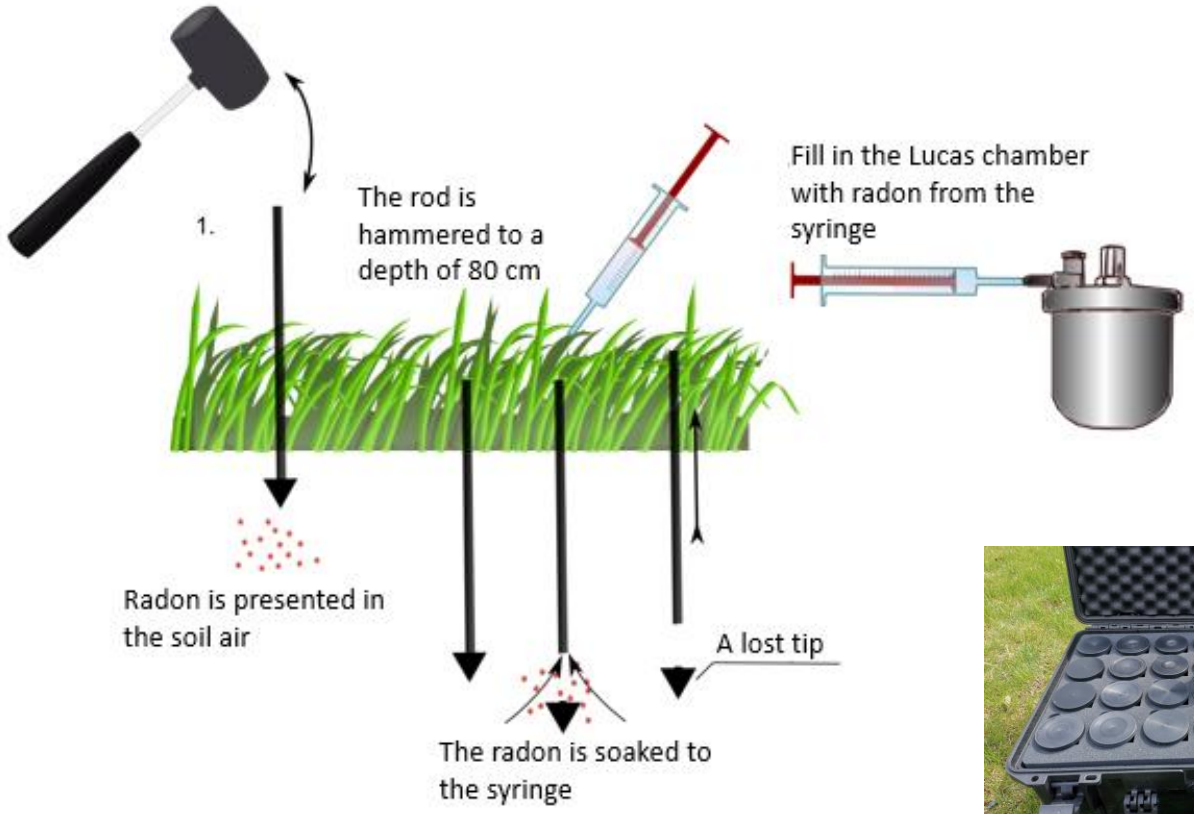
Radon progeny air sampling



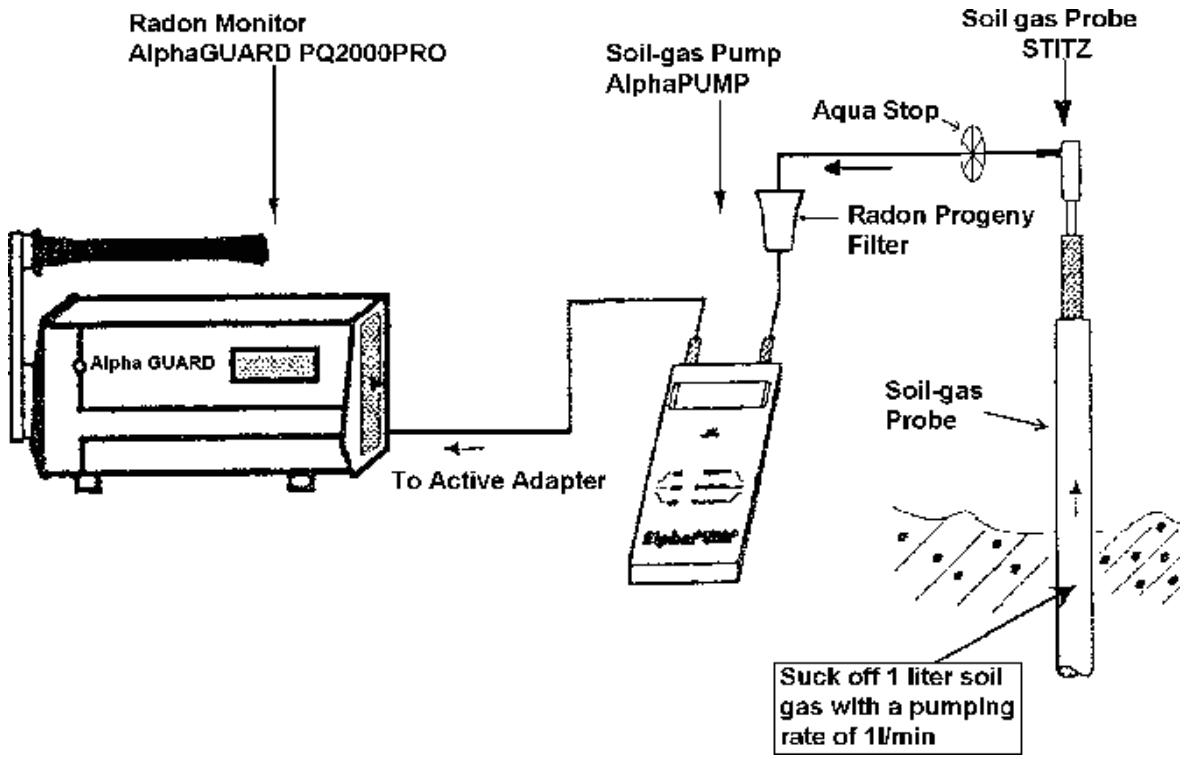
Field radon-in-soil measurement by using Alphaguard



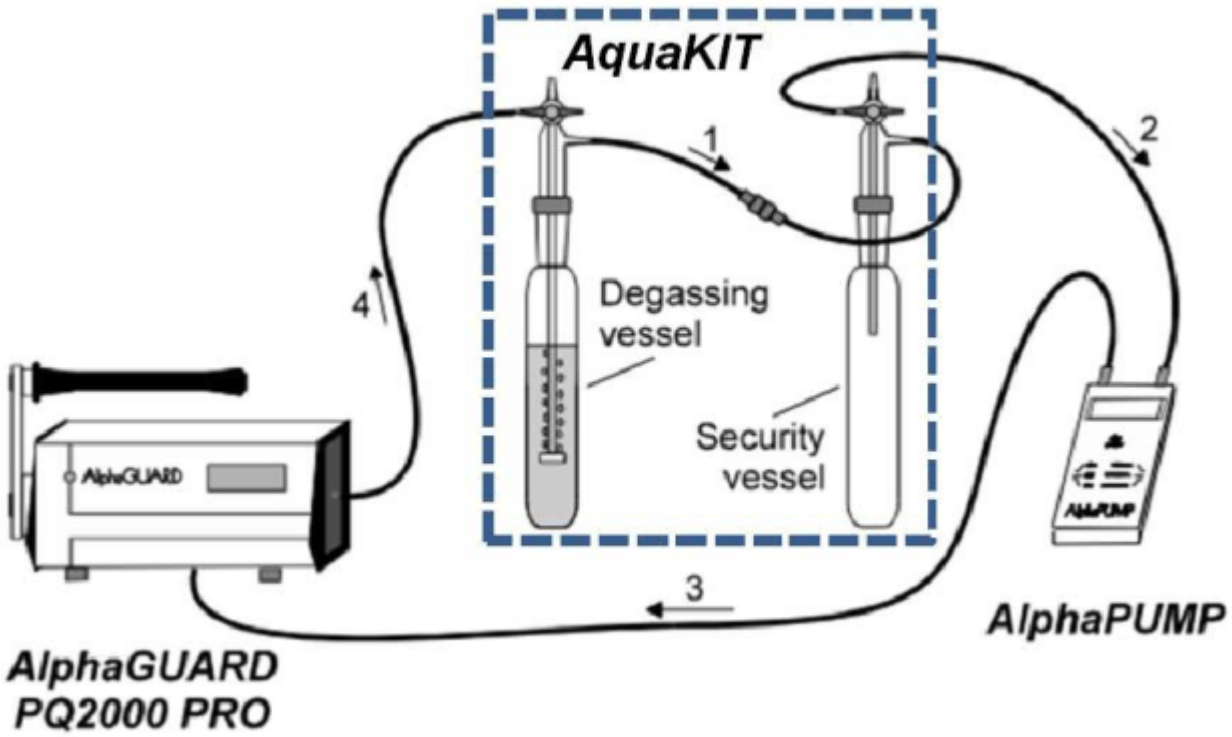
Field radon-in-soil measurement by using Lucas chambers



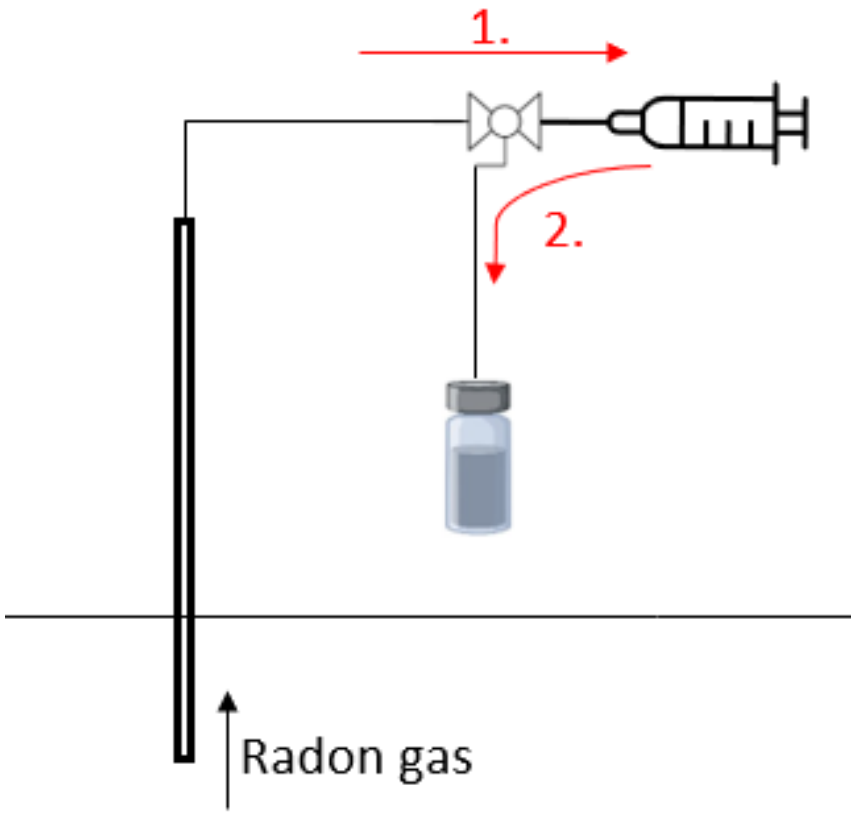
Field radon-in-soil measurement by using AlphaGuard



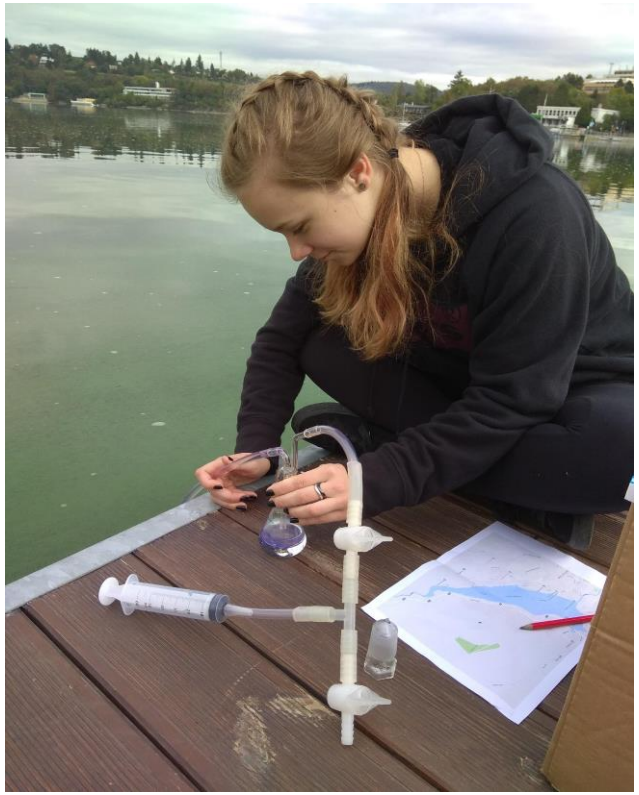
Field radon-in-water measurement by using AlphaGuard



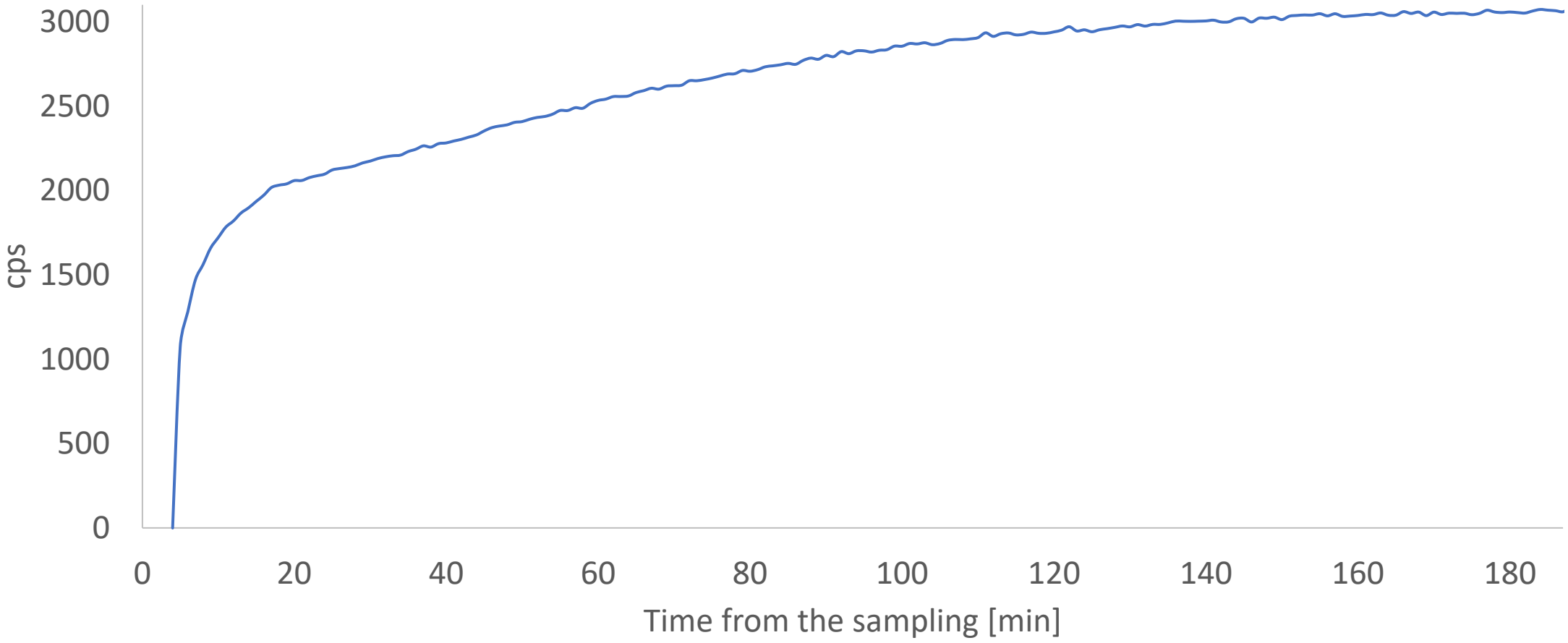
Sampling of soil radon for measurement by using liquid scintillation



Sampling of water for radon measurement by using liquid scintillation



Change in the radon and its progeny activity



Conclusion

- Measurement of radon with regards to the radiation protection
- The radon is measured through it decay products (Po-218, Pb-214, Bi-214)

- Radon is presented everywhere (a part of the natural decay chains)
- Any radioactive isotopes in the soil that are incorporated into the food chain can end up in the human body
- The radionuclides can enter the food chain mainly by transport from soil and water

Thank you for your attention!

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