



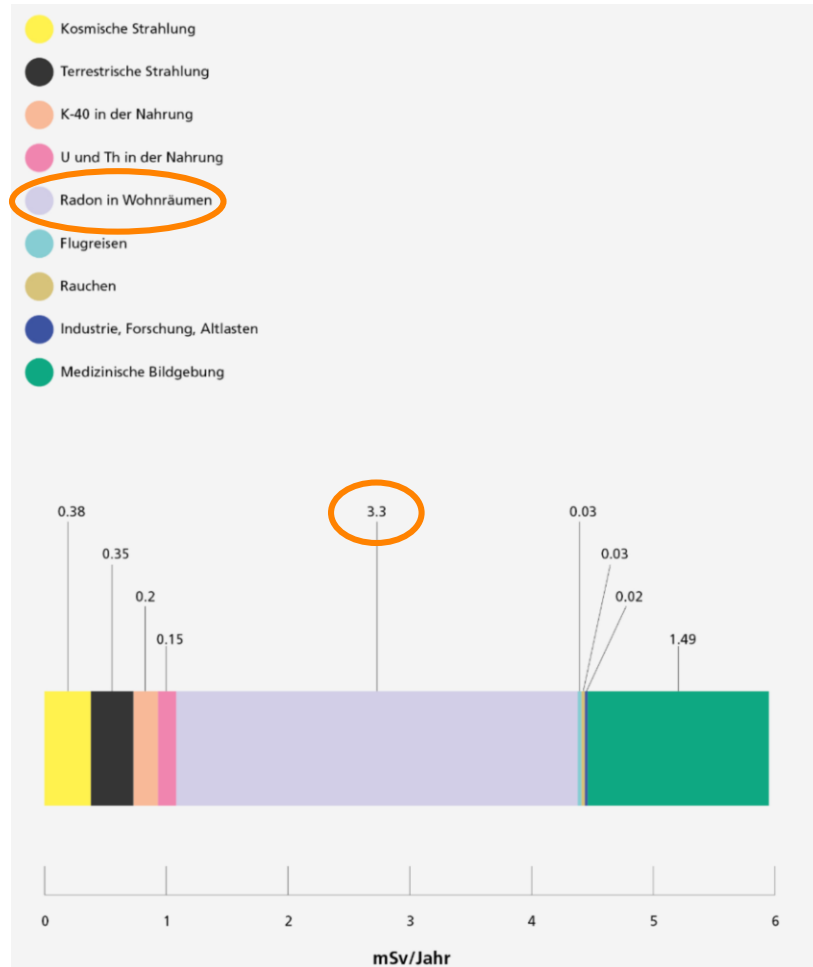
Radon Dosimetry

KSR Seminar, Bern, 25.03.2022

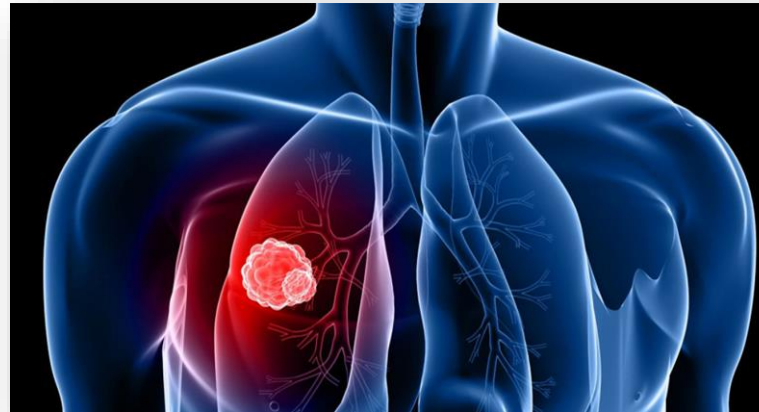
Roland Krischek

suva

Introduction



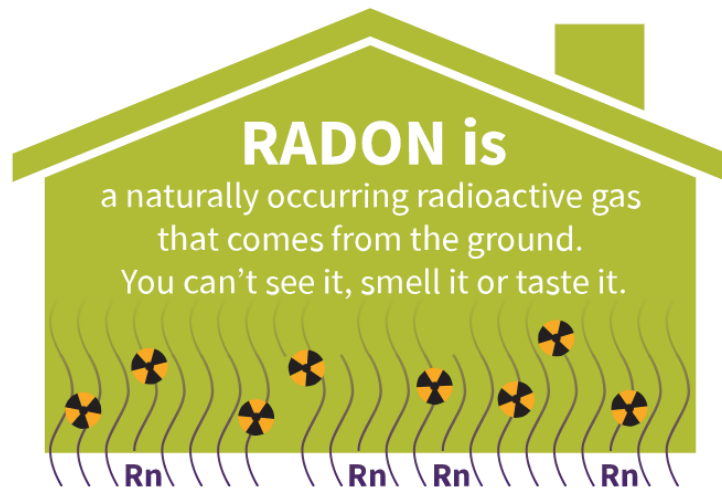
- Radon makes **the largest contribution of radiation** exposure to the Swiss population.
- Radon is the **second most common cause of lung cancer** (approx. 200-300 per year in Switzerland)



Source: <https://www.bag.admin.ch/bag/de/home/gesund-leben/umwelt-und-gesundheit/strahlung-radioaktivitaet-schall/strahlung-gesundheit/strahlenexposition-der-schweizer-bevoelkerung.html>

Introduction

Radongas Concentration
[Bq/m³]



workers or habitants
with monitoring device



=



Dose [mSv]



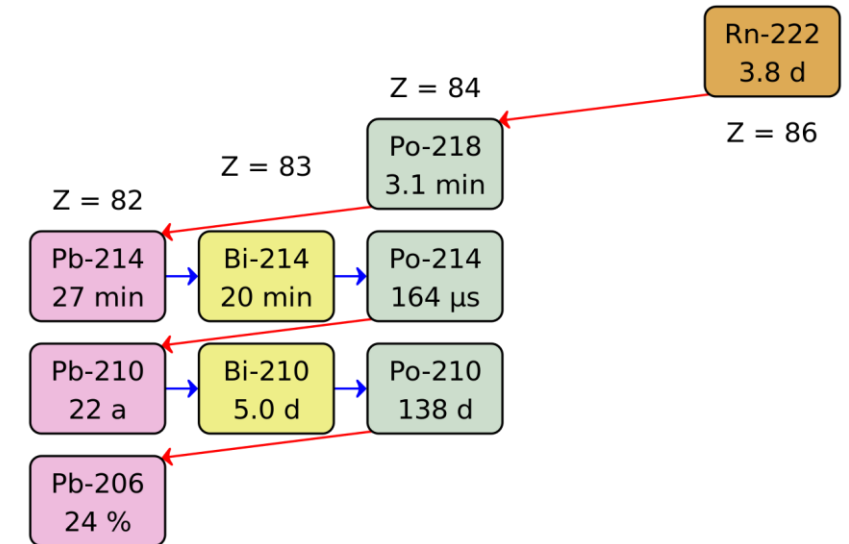
- **Factors involved:** monitoring device, exposition time, breathing rate, particle size, radon progeny, equilibrium factor, epidemiology, science, ...

Radon dosimetry: factors involved

Radon Progeny

- Almost all of the lung dose caused by radon comes from the short-lived **radon progeny**:

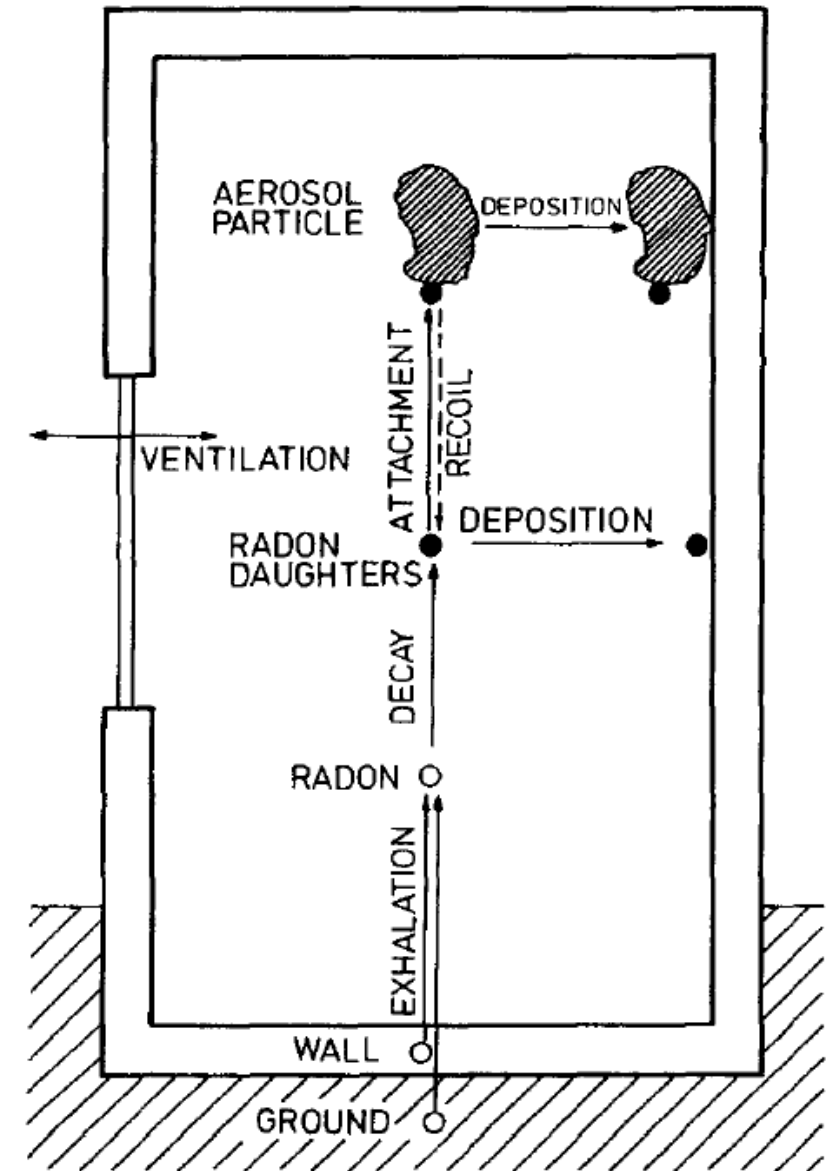
	Effective dose [Sv/Bq]	Portion
Radon gas	4.4×10^{-10}	< 2%
Radon progeny		> 98%
^{218}Po	3.8×10^{-9}	
^{214}Pb	1.8×10^{-8}	
^{214}Bi	1.5×10^{-8}	



Attachement and Deposition

Basic indoor processes:

- **radioactive decay**: formation of radon progenies
- **accumulation**: on aerosol particles
- **deposition**: to walls and floor
- **transport**: by ventilation

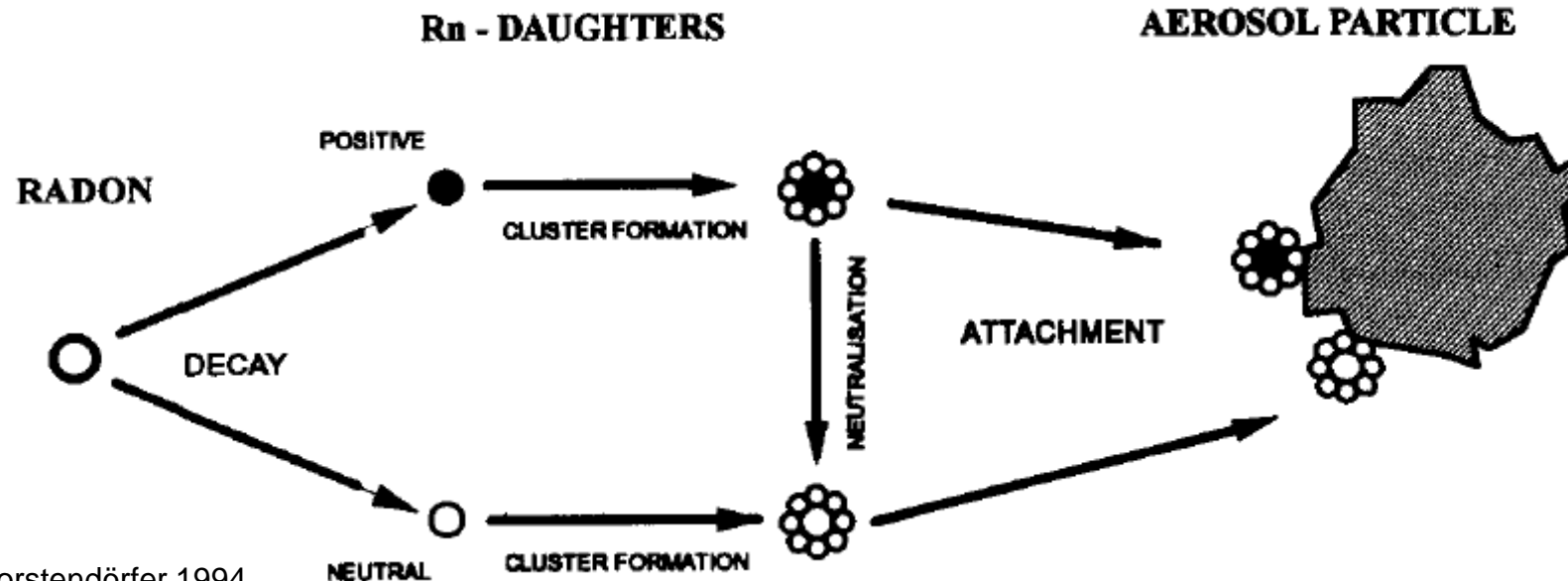


Source: Porstendörfer 1994

Equilibrium Factor

Deposition: **Equilibrium Factor**

- **Equilibrium factor = 1**: all radon progeny are in the air (no plate out)
- **Equilibrium factor = 0**: no radon progenies are in the air
- In indoor workplaces **F= 0.4** is usually assumed (ICRP 137)

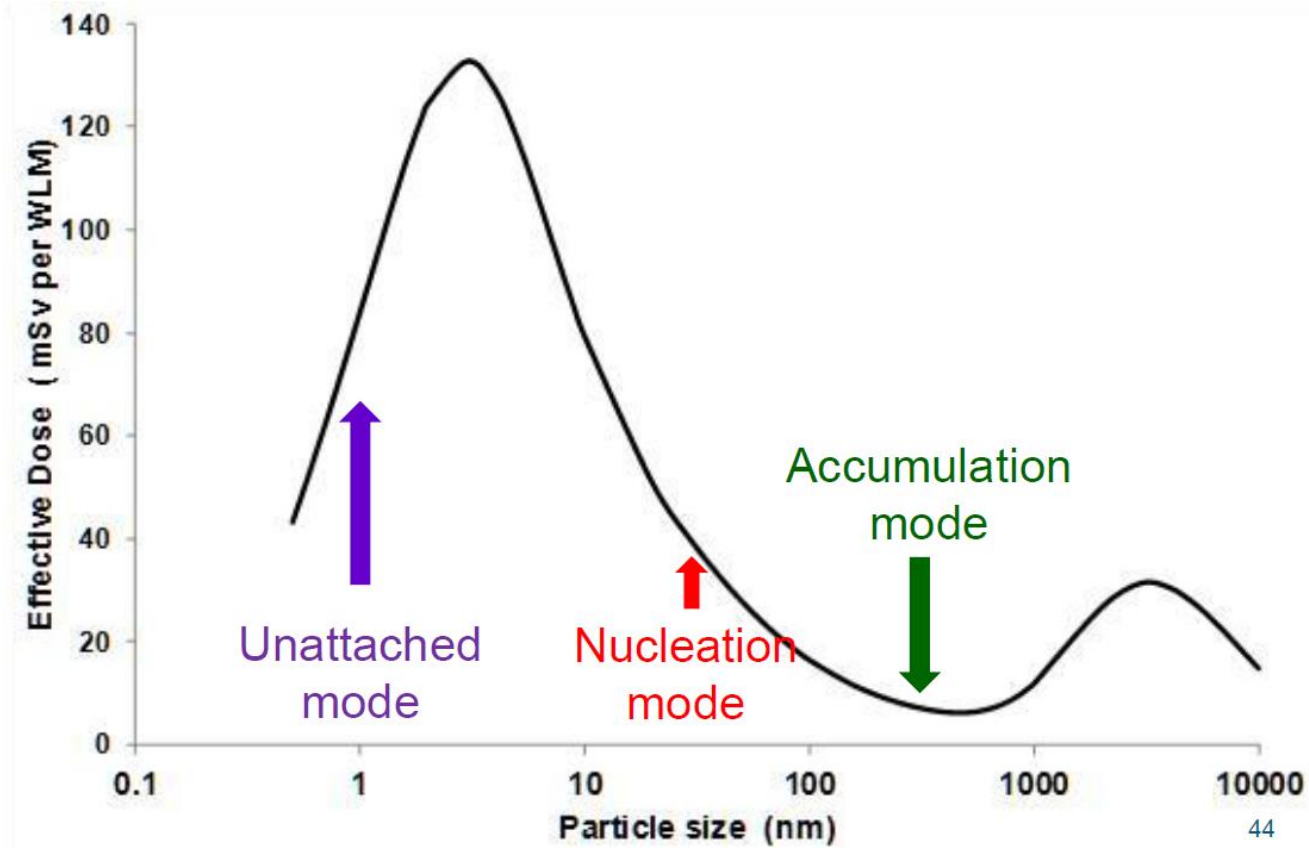


Source: Porstendörfer 1994



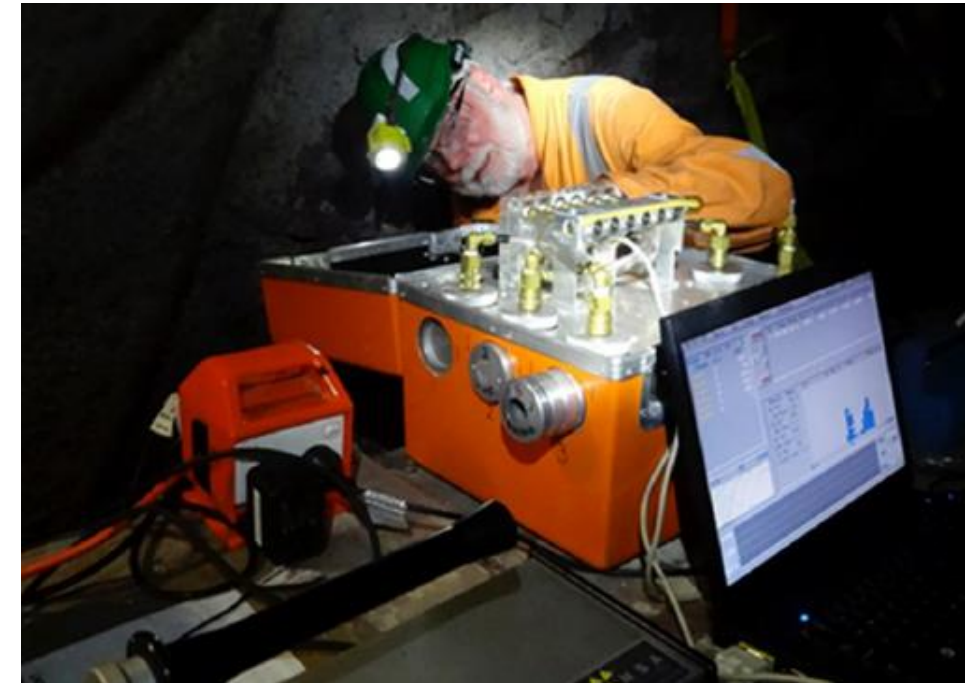
AlphaPM: Measuring Device for Equilibrium Factor

Particle Size



1 WLM = $6.37 \times 10^5 \text{ Bqhm}^{-3}$ (F=1)

Source: ICRP 137, 2017

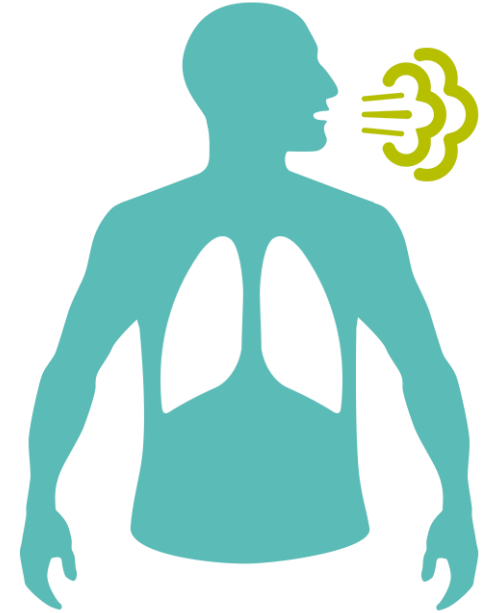


Measuring Device for particle size

Source: Solomon, July 2011

Breathing rate and dose calculation

Breathing rate reference worker, indoor workplaces with 2/3 sitting, 1/3 light exercise (breathing rate = $0.86 \text{ m}^3\text{h}^{-1}$)	$22 \text{ mSv/MBqhm}^{-3}$ 14 mSv/WLM
Normal breathing rate reference worker, indoor workplaces with light exercise (breathing rate = $1.2 \text{ m}^3\text{h}^{-1}$)	$31.4 \text{ mSv/MBqhm}^{-3}$ 20 mSv/WLM



Sources: ICRP 137, 2018; Harrison and Marsh, 2012

Radon exposed workplaces in Switzerland

Radon Exposed Workplaces, Possible Examples



Military



Underground facilities



Tunnel construction



Tunnel operation



Cheese or wine cellars



Caves



Water facilities

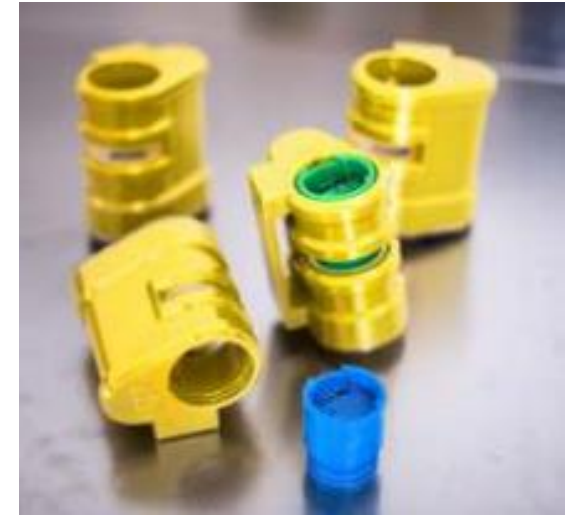


Technical galleries

Personal Radon Dose Meters

Personal Alpha Dosimeter (PAD)

- The individual sampler is an air pumping system to draw air through the dosimeter head. A battery operated pump is enclosed in a box to be worn on the belt of an individual being monitored.
- PAD is capable of measuring the actual exposure of individual workers to alpha radiation from **radon** and thoron **progeny** and long lived radioactive dust.



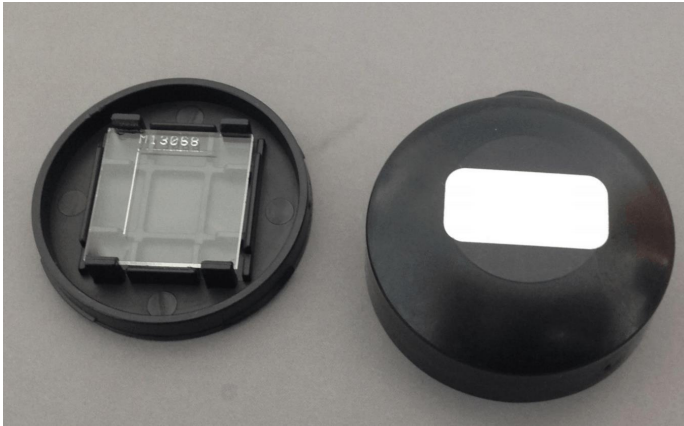
Features

Sampling Flow Rate	4 l/h \pm 20%
Operating Time	> 12 hrs
Charging Time	12 hrs
Dimensions	94 x 79 x 63 mm
Weight	300 g
Operating Temperature	-10°C to 45°C



Source: <https://radiationsafety.ca/personal-alpha-dosimetry/>

Nuclear Track Radon Detectors



- Radon diffuses into chamber. Alpha decay of radon is detected by nuclear track detector.
- Only the radon concentration is measured. No progenies.
- State of the art (long term) measurements for radon in buildings. They are also used as personal dosimeters.

Radon Dosimetry in Switzerland

Swiss Dosimetry Ordinance, annexe 12

- Dose is calculated using the following parameters:

$$E = F \times c_B \times IRCY$$

E: effective dose in **mSv** per year

F: equilibrium factor (set as 0.4 or as measured)

c_B: **1.87 x 10⁻⁵ mSv/Bqhm⁻³** dose conversion factor (based on ICRP 115, ICRP 103)

IRCY: **Integrated radon gas concentration** over one **year** during the effective **residence time** of a person at a radon-exposed workplace (in Bqh/m³)

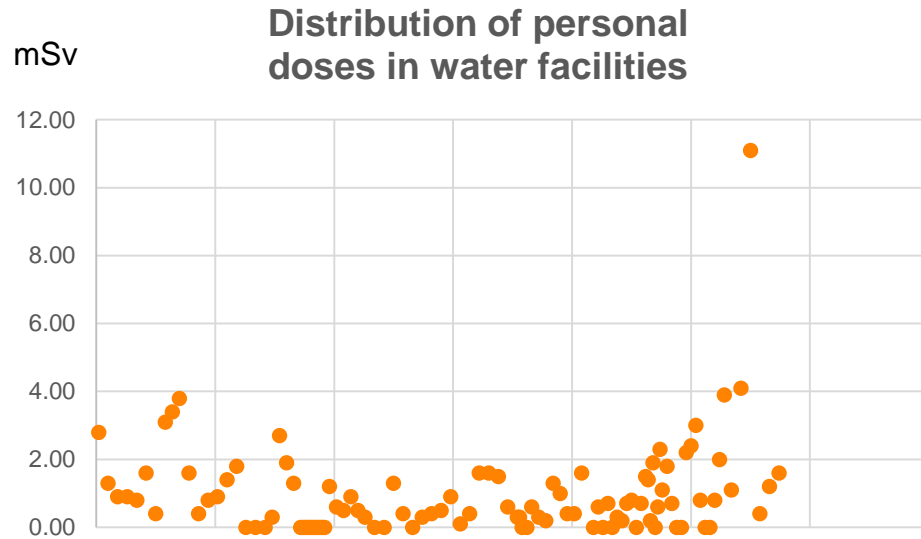
For simplicity: Particle size and breathing rate are not considered



Source: <https://www.fedlex.admin.ch/eli/cc/2017/504/de>

Personal Radon Measurements

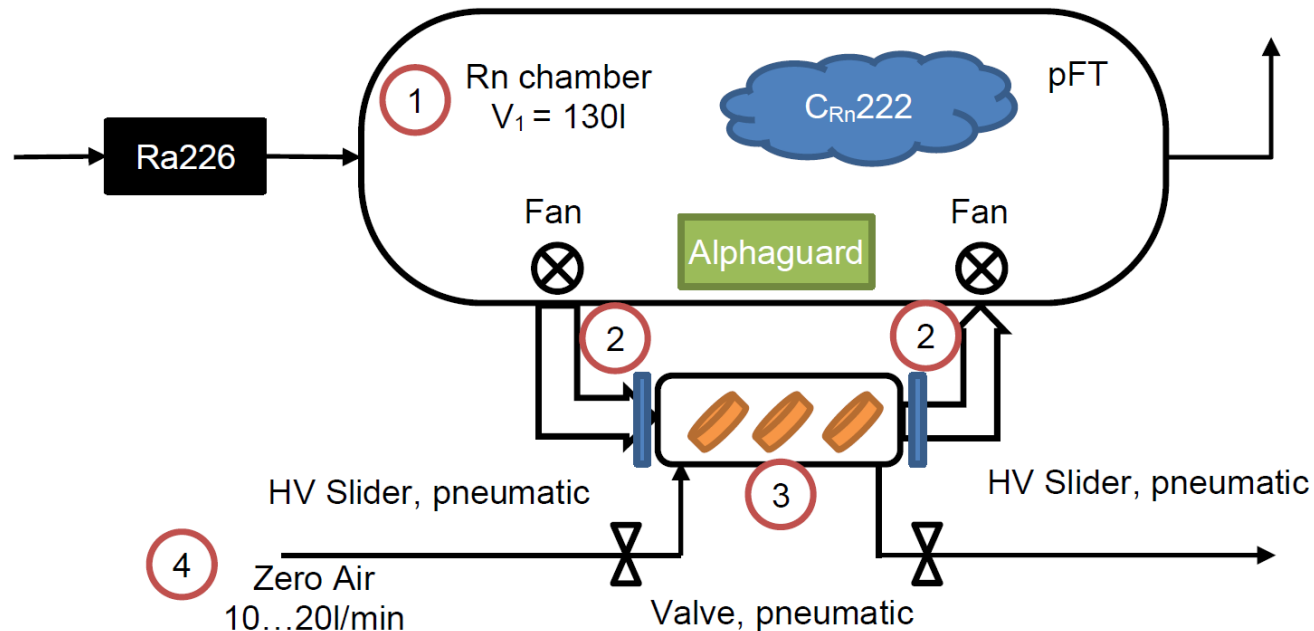
- Suva already performed personal measurement in water facilities:



People are exposed to high radon concentrations but with short exposure time (15-30 min. per facility). Question: Is the response time of the detectors sufficient?

Short term measurements in the radon chamber @ Metas

Lucie Maret in the group of Peter Peier performed several measurements:



1: ^{130}I reference chamber with known radon concentration

2: Slide valve and ventilator

3: Test chamber, volume $\sim 10\text{ l}$

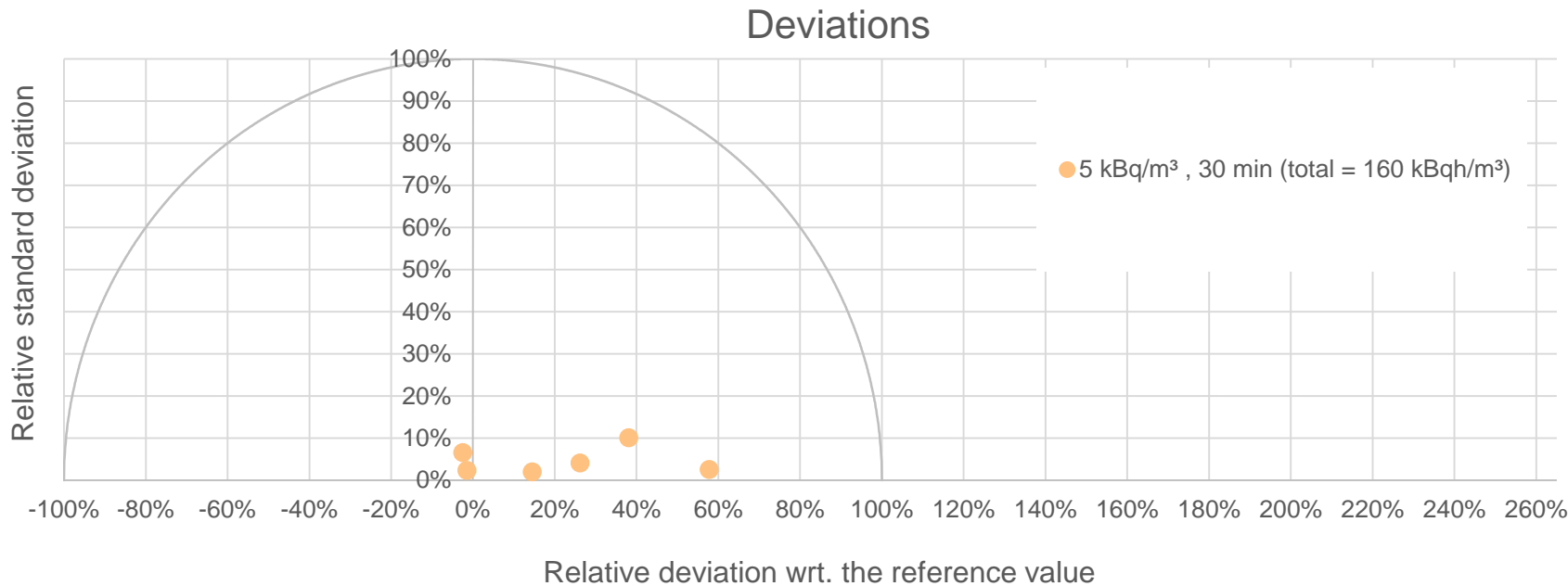
4: Zero air supply for flushing the chamber with low radon air (10...50 l/min)

Short term measurements in the radon chamber @ Metas

Short term exposure (64 pulses) of radon dosimeter:

- series with 30 min and series with 15 min exposure

PRELIMINARY DATA



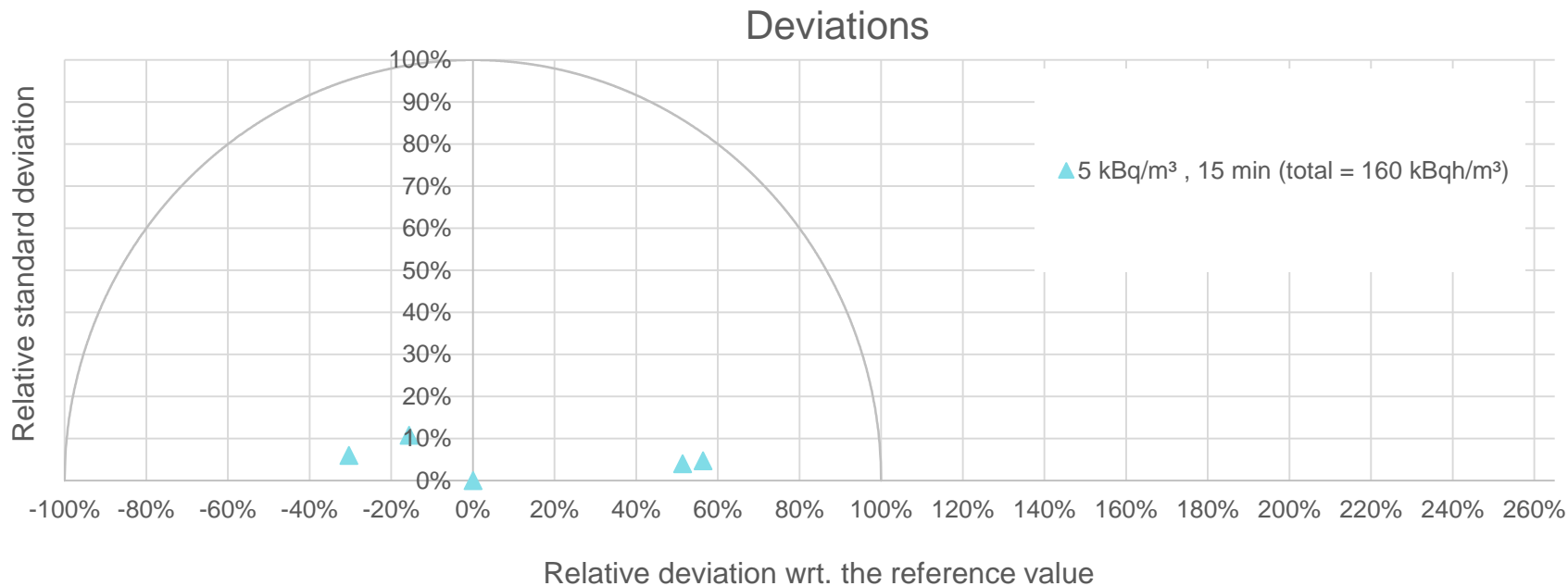
- Each point represents the measurement accuracy of 5 dosimeters from 1 manufacturer.
- The reference value of 160 kBqh/m³ was measured with an AlphaGuard

Short term measurements in the radon chamber @ Metas

Short term exposure (128 pulses) of radon dosimeter:

- series with **30 min** and series with **15 min** exposure

PRELIMINARY DATA



- Each point represents the measurement accuracy of 5 dosimeters from 1 manufacturer.
- The reference value of 160 kBqh/m³ was measured with an AlphaGuard

Outlook

Outlook

- **Interpretation of short term measurements and choice of corresponding dosimeter**
- Search for **other radon exposed workplaces** in Switzerland
- **FOPH Radon Action Plan 2020-2030** (together with Suva)
 - Official **radon dosimetry service** in Switzerland to register doses
 - Evaluation of **other factors involved** in the dose determination (for ex. breathing rate)
 - Evaluation of **protective measures**
 - Integration of measurements at radon exposed working places in the **radon database** of the FOPH

Thank you for your attention.

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Radiation protection

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