The equipment for testing of measuring devices at the low-level radon activity concentration

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Introduction

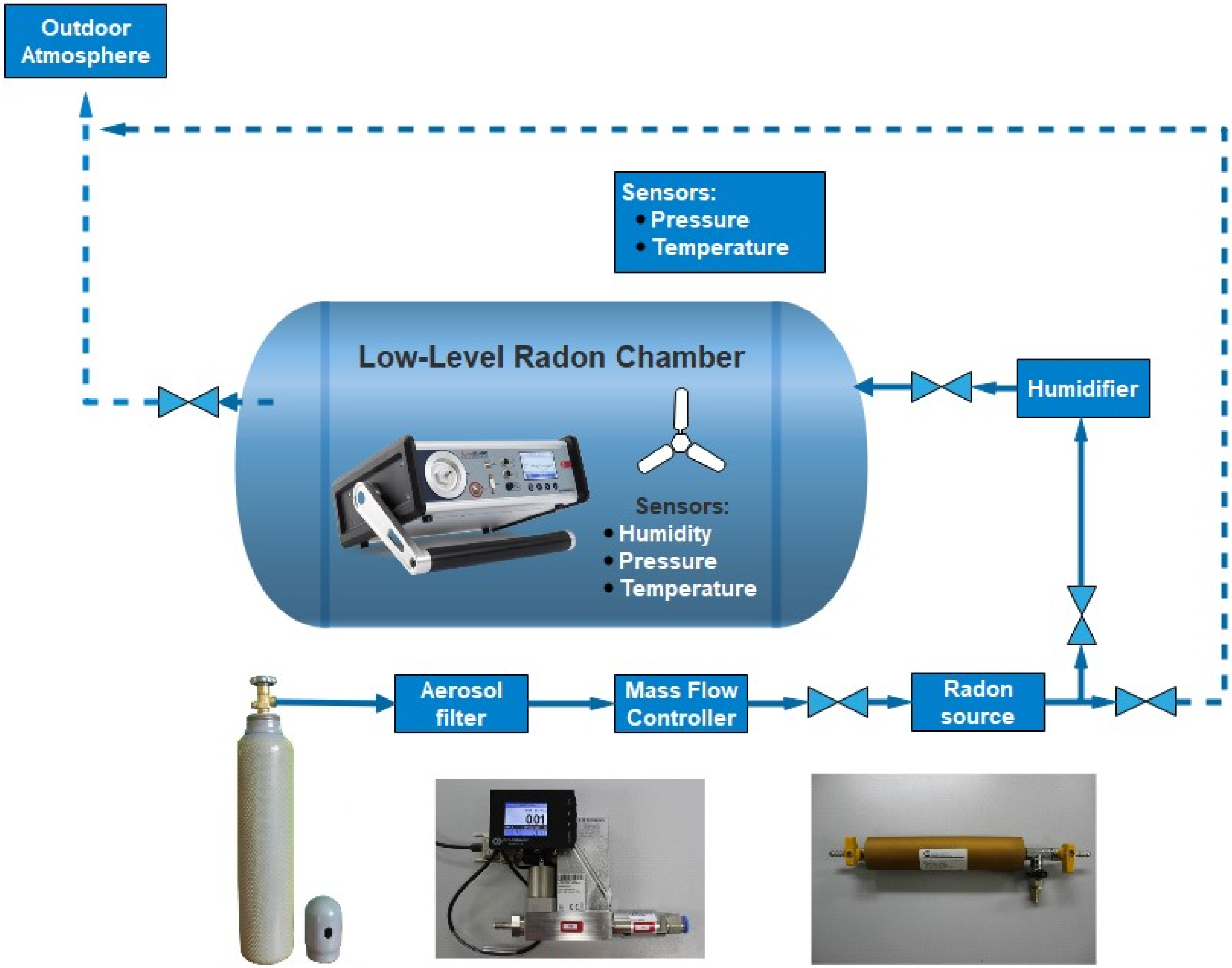
- Radon measurement techniques are simple, efficient and precise
- Levels of relevant activity concentration in European dwellings are laid down (300 $Bq.m^{-3}$)
- Developing and improving of calibration procedures is still actual
- The main goal - maintaining of time stable radon activity concentration on the precise level for several days
- MetroRADON project (European metrology program for innovation and research) + SUJCHBO + CMI

→ New equipment for testing of measuring devices at the low-level radon activity concentration

Equipment construction

Achieving of low-level radon activity concentration:

- ❑ Constant dotting of radon
- ❑ Defined ventilation
- ❑ Radon free air (specific atmospheric condition in the SUJCHBO areal)



Outdoor Atmosphere
Sensors:
Pressure
Temperature
Low-Level Radon Chamber
Humidifier
Sensors:
Humidity
Pressure
Temperature
Aerosol filter
Mass Flow Controller
Radon source

The reference level of radon

- Model of constant radon input and constant ventilation:

$$a(t) = a_o \,.\, e^{-(\lambda+k).t} + \frac{R}{V(k+\lambda)}\left(1 - e^{-(\lambda+k).t}\right)$$

$a(t)$	*radon activity concentration in time t ($Bq \cdot m^{-3}$)*
a_0	*radon activity concentration in time zero ($Bq \cdot m^{-3}$)*
λ	*radon decay constant (h^{-1})*
k	*air exchange intensity (h^{-1})*
t	*time (h)*
R	*radon input rate ($Bq \cdot h^{-1}$)*
V	*volume of radon chamber (m^3)*

- For the steady-state (t = ∞) at a constant air exchange intensity and constant radon input rate:

$$a_{V,Rn} = R_{Rn} / \left(Q_{settled} \,.\, \frac{M.p_{\text{at Q calibration}}}{R.T_{\text{at Q calibration}}} \Big/ \frac{M.p_{\text{at confrontation}}}{R.T_{\text{at confrontation}}} + \lambda.V \right)$$

$a_{V,Rn}$	*radon activity concentration ($Bq \cdot m^{-3}$)*
$Q_{settled}$	*flow rate ($m^3 \cdot h^{-1}$)*
M	*molar mass ($kg \cdot mol^{-1}$)*
$p_{\text{at Q calibration}}$	*air pressure 1013,25 (hPa)*
R	*molar gas constant ($J \cdot mol^{-1} \cdot K^{-1}$)*
$T_{\text{at Q calibration}}$	*temperature 273,16 (K)*
$p_{\text{at Rn confrontation}}$	*air pressure (Pa)*
$T_{\text{at Rn confrontation}}$	*temperature (K)*
λ	*radon decay constant (h^{-1})*
V	*volume of radon chamber (m^3)*
R_{Rn}	*radon emanation power ($Bq \cdot h^{-1}$)*

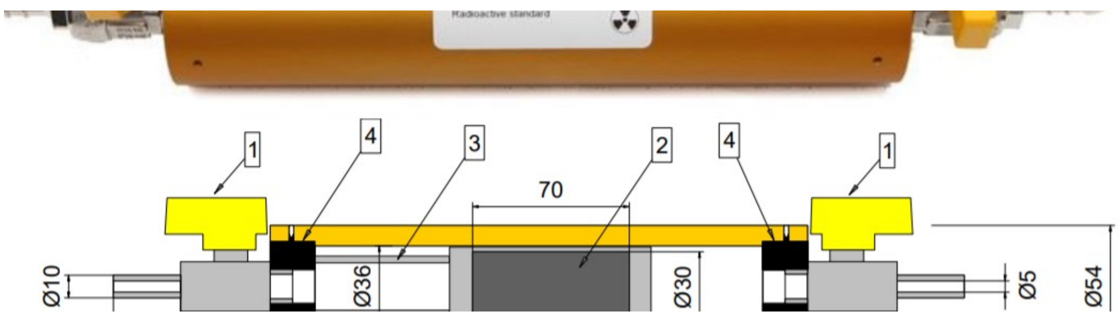
- Expanded uncertainty as the product of the standard measurement uncertainty and the expansion coefficient k = 2 (which corresponds to a coverage probability of about 95 % for normal distribution) following the EA 04/02 was calculated for **2 %**.

Low-level Radon Chamber (LLRCH)

- ❑ 324 litres
- ❑ Special colour
- ❑ 4 sampling points
- ❑ Movable drawer
- ❑ Measuring of climatic conditions
- ❑ Continually regulated ventilator

Low-level radon source

- Stainless steel cylindrical case, ball valves
- Steel tray with Ra-226 placed in the middle of this cylindrical case - radon releases from this thin layer
- Flow-through mode
- The emanation coefficient was determined by measuring the activity of the RnDP (Pb-214/Bi-214) - the activity of Ra-226 is almost equal to 1



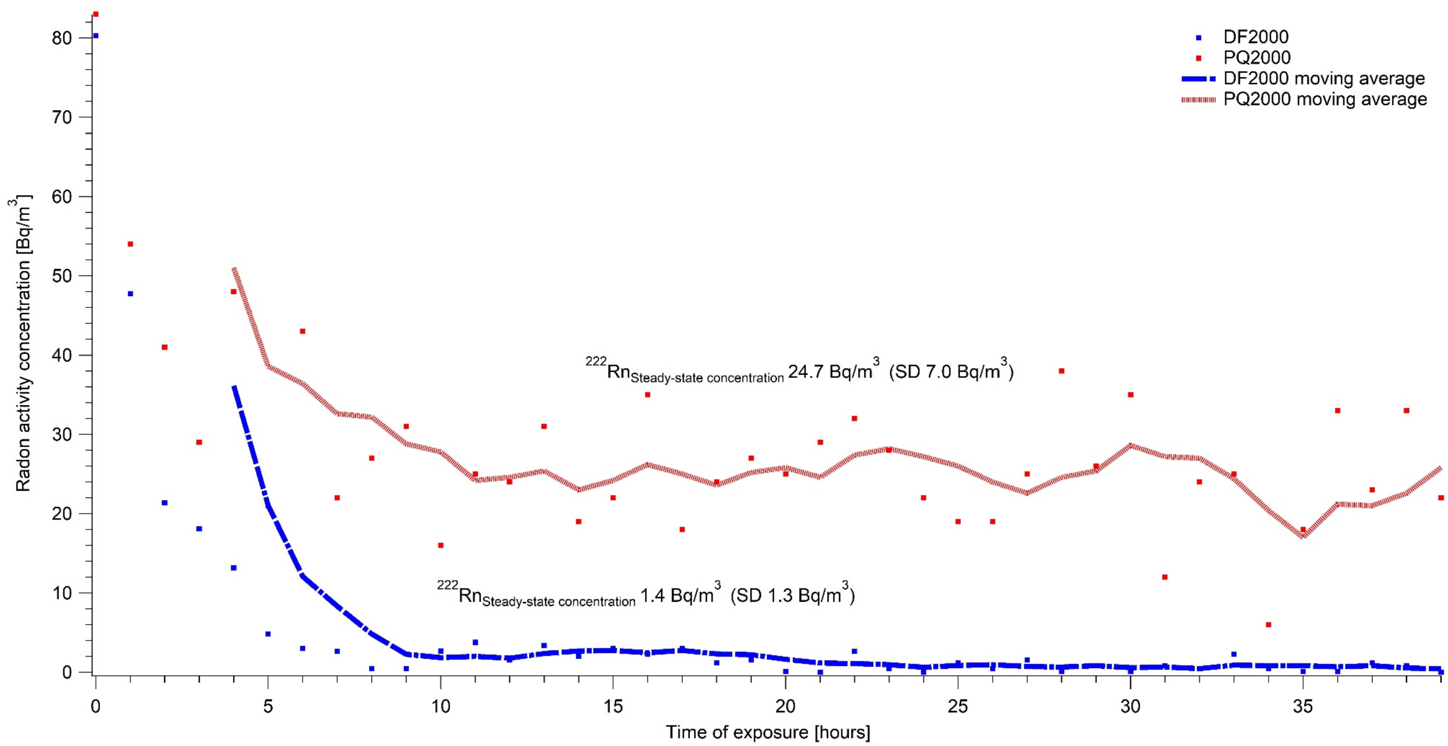
1 – ball valve
2 – emanator
3 – holder
4 – flange

Experiments in LLRCH

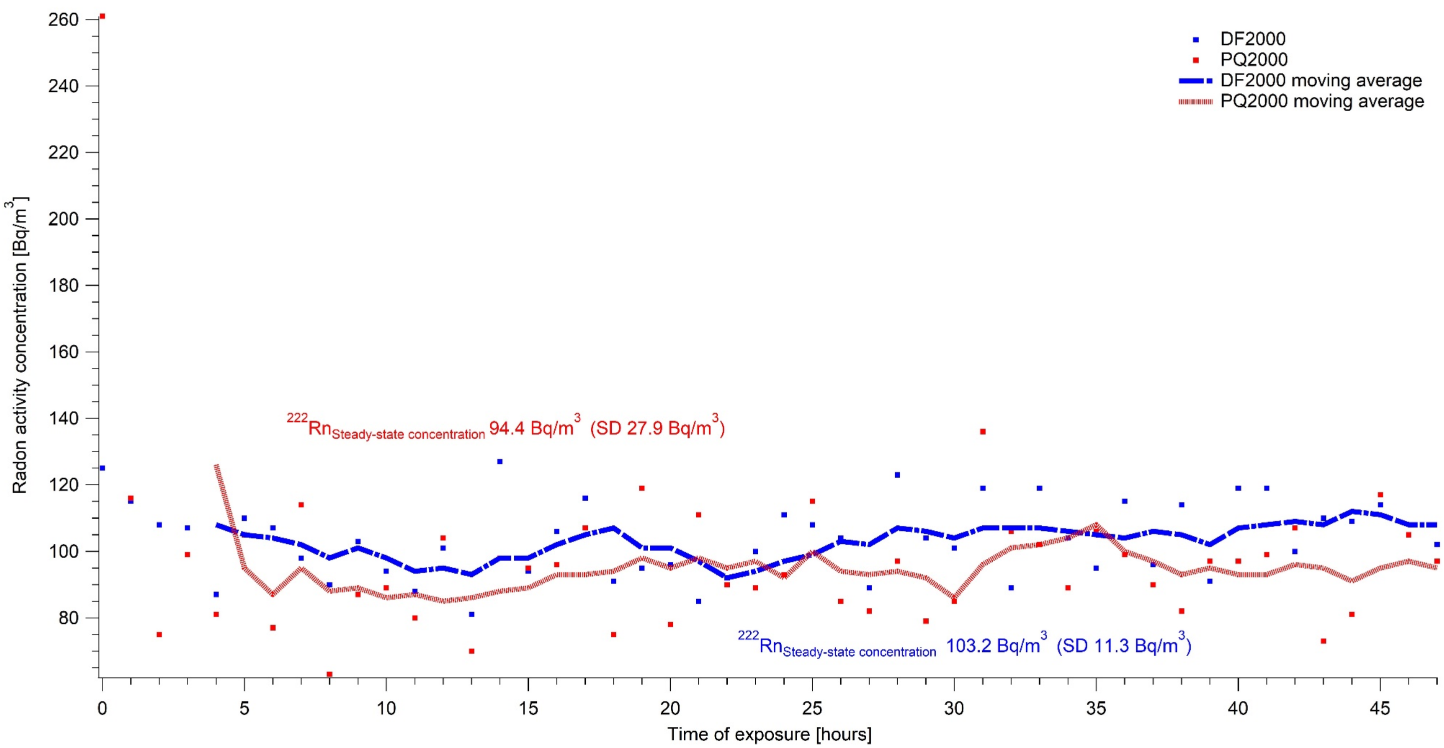
- Calibrated AlphaGuard DF 2000 (background 2.2 ± 1.2 Bq/m^3)
- Calibrated AlphaGuard PQ 2000 (background 29.0 ± 7.0 Bq/m^3)

- Background test
- Experiments under 100, 200 and 300 Bq/m^3

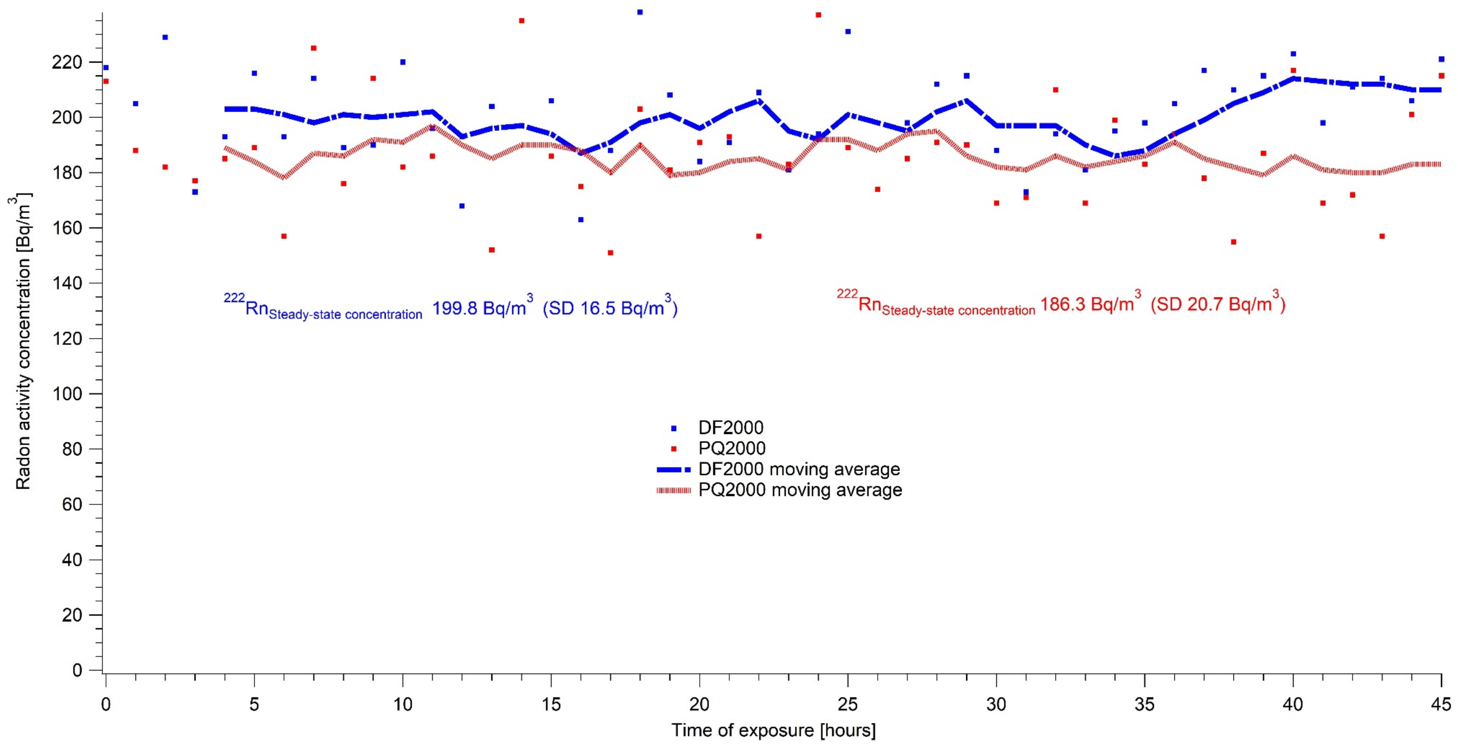
Background test



100 Bq/m^3

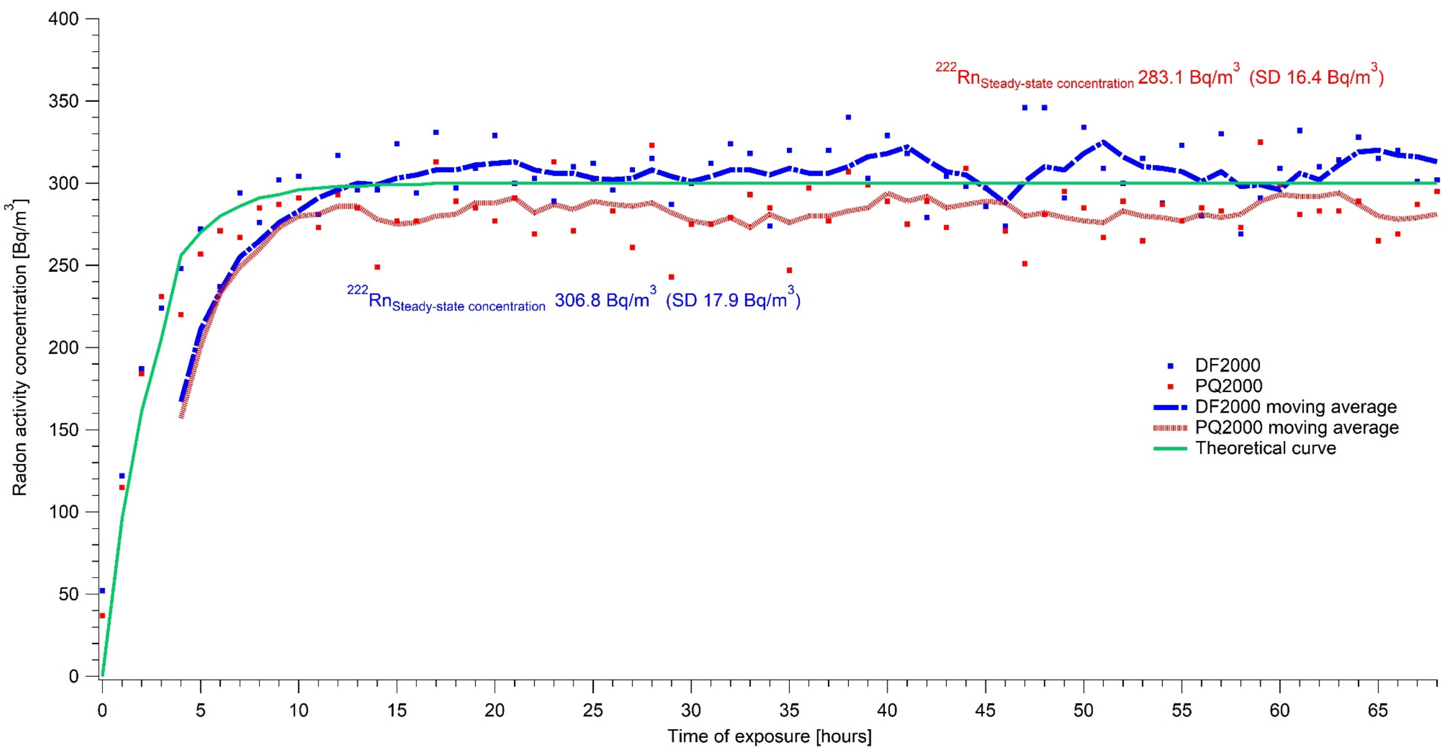

DF2000
PQ2000
DF2000 moving average
PQ2000 moving average
$^{222}Rn_{Steady\text{-}state\ concentration}$ 94.4 Bq/m^3 (SD 27.9 Bq/m^3)
$^{222}Rn_{Steady\text{-}state\ concentration}$ 103.2 Bq/m^3 (SD 11.3 Bq/m^3)
Radon activity concentration [Bq/m^3]
Time of exposure [hours]
260
240
220
200
180
160
140
120
100
80
0
5
10
15
20
25
30
35
40
45

200 Bq/m³



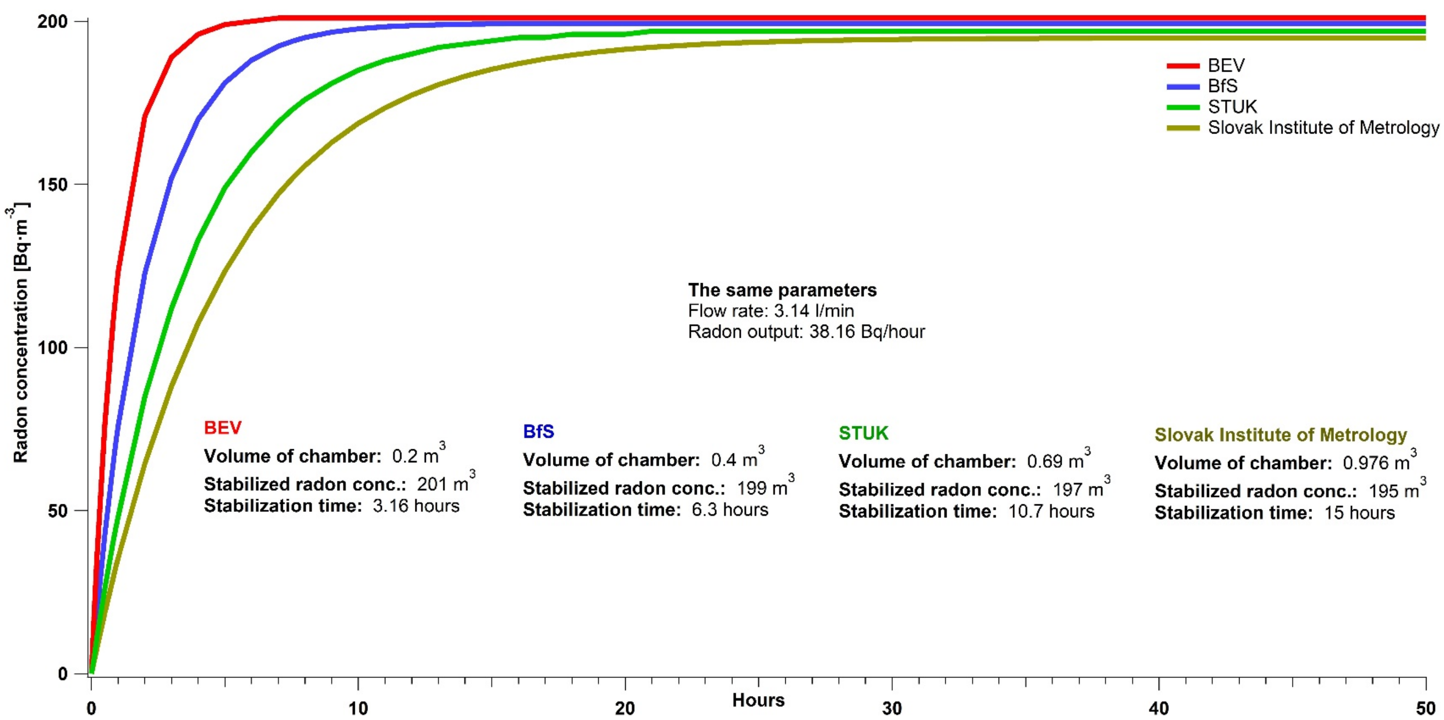
Radon activity concentration [Bq/m³]
Time of exposure [hours]
²²²Rn Steady-state concentration 199.8 Bq/m³ (SD 16.5 Bq/m³)
²²²Rn Steady-state concentration 186.3 Bq/m³ (SD 20.7 Bq/m³)
DF2000
PQ2000
DF2000 moving average
PQ2000 moving average

300 Bq/m^3



$^{222}Rn_{Steady-state\ concentration}$ 283.1 Bq/m^3 (SD 16.4 Bq/m^3)
$^{222}Rn_{Steady-state\ concentration}$ 306.8 Bq/m^3 (SD 17.9 Bq/m^3)
Radon activity concentration [Bq/m^3]
Time of exposure [hours]
DF2000
PQ2000
DF2000 moving average
PQ2000 moving average
Theoretical curve

Model example



Conclusion

- LLRCH was developed for the calibration of measuring devices under a low-level radon activity concentration in the range from 100 Bq/m^3 to 300 Bq/m^3.
- Many tests validated the tightness of the chamber and the possibility of adjusting a stable radon activity concentration on the required level for several days (depends on available amount of radon free air in the pressure vessel).
- Expanded uncertainty is 2 %.
- The climatic parameters are continuously monitored by the sensors placed inside the chambre.
- The level of radon activity concentration is possible to be changed continuously during the experiment.
- The low-level radon source by the CMI is possible to be used for different radon chambers of volume from 200 to 1000 liters.

Thank you for your attention!

JRP EMPIR 16ENV10: MetroRADON

Metrology for radon monitoring