Radon diffusion studies using RadonEye Plus2 electronic monitor

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Introduction

Society is paying increasing attention to radon in the living environment. Outdoors, in the open air, the concentration of radon is low. However indoors where we spend significantly more time, radon concentrations can be significantly higher.

To prevent radon from infiltrating into buildings from the ground, various material barriers such as membranes or special concrete can be installed between the soil and the building interior

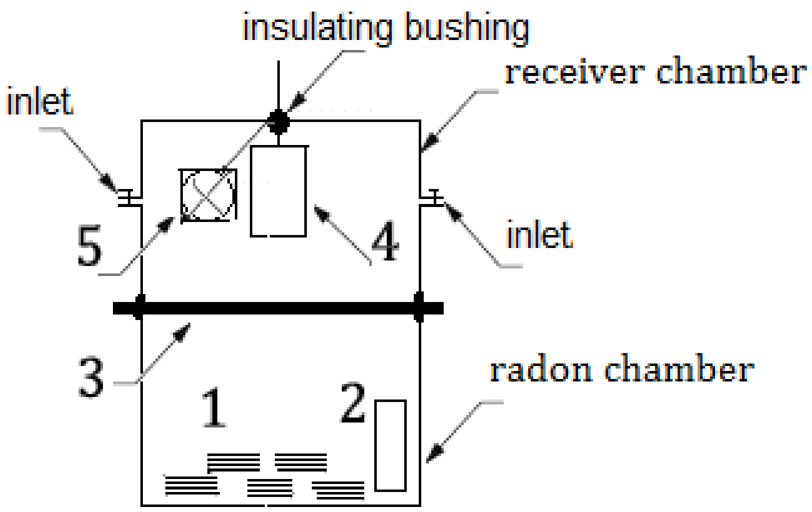
Introduction

As radon barrier membranes are often available without certificates, there was a need to find a way to characterise the radon barrier properties of these membranes.

It is also often necessary to determine the diffusion coefficient for different concrete mixtures.

Material and method I

A simple two-chamber measuring device is used to determine the diffusion rate and diffusion coefficient of radon in different concrete samples and barrier films.



1 – radium rich material (NORM residues) as the source of radon;
2 - measuring device for measuring radon concentration in a radon chamber, AlphaE;
3 – sample;
4 - measuring device for measuring radon concentration in a reciever chamber, RadonEye+2;
5 – fan for homogenizing radon concentration in the receiving chamber

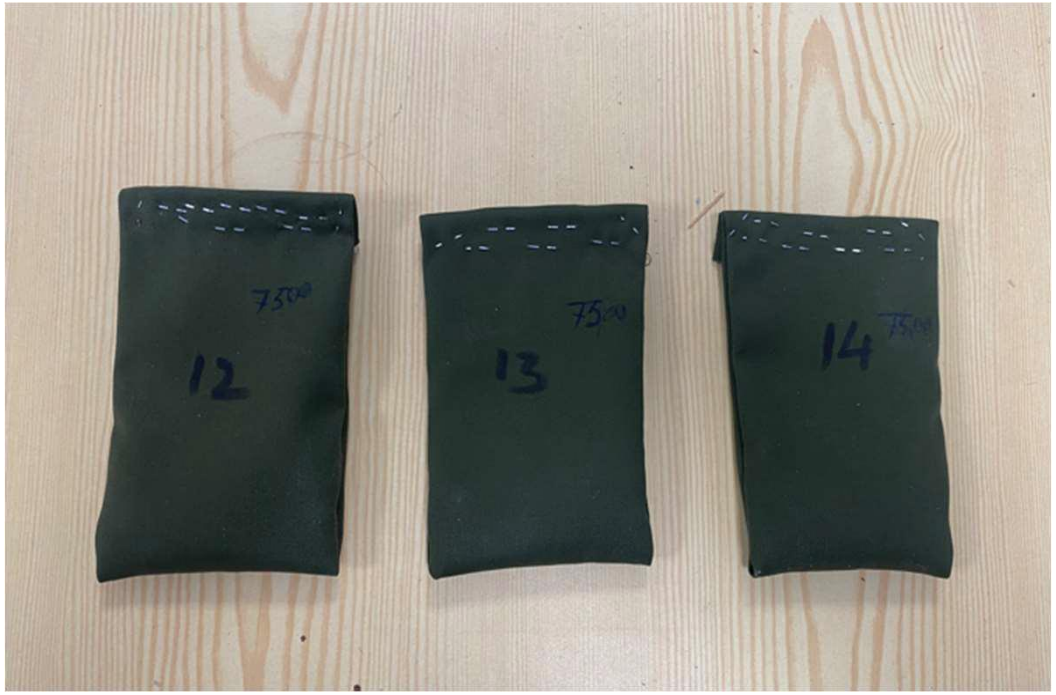
The volume of the radon and measuring chamber is 12 liters.

Material and method II

Radon source –

radium-rich zeolite from a water purification plant filter;

emanation coefficient determined by gamma spectrometry: 57%



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Material and method III

The radon concentration in the radon chamber increases until secular equilibrium is reached.

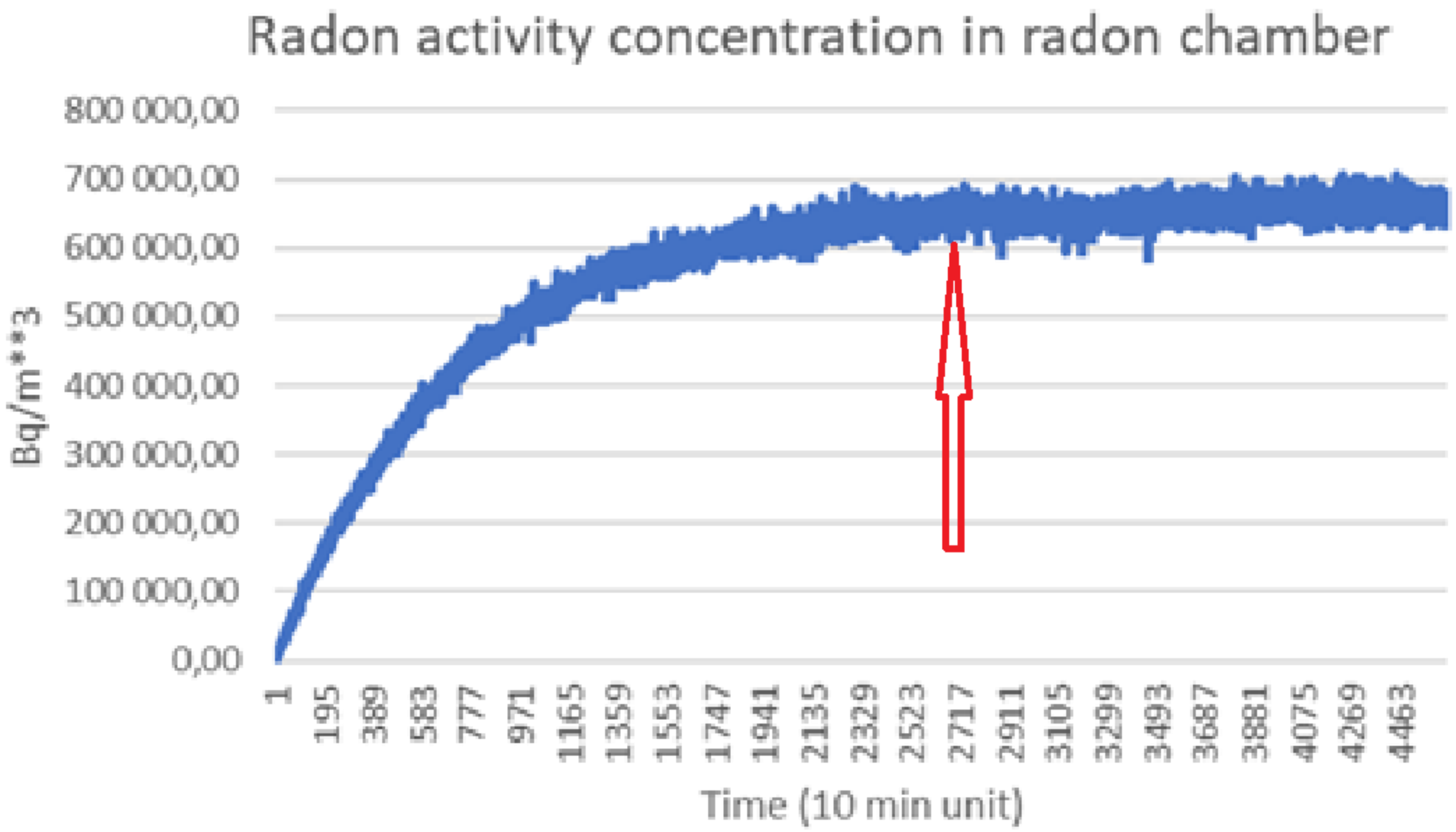
A stable radon flow through the sample is established.

The radon concentration in the radon chamber was measured with an AlphaE radon monitor.

- Detector: Diffusion chamber with silicon diode
- Measuring range: From 20 Bq/m3 to 10 MBq/m3
- Instrument calibrator error: 10%
- Measuring cycle: Adjustable from 1 min to 12 hours
- Autonomy: up to 6 months (rechargeable via USB)

Material and method IV

Typical radon activity concentration curve in a radon chamber after closing the chamber



Material and method V

After closing the measuring set up, the radon concentration in the measuring (receiver) chamber begins to increase due to radon infiltrating from the radon chamber.

21 days after a 95% equilibrium level has been reached in the radon chamber, the measuring chamber is flushed with radon-free air and the valves are closed.

The radon level in the measuring chamber begins to rise steadily under previously established stable radon diffusion flow conditions.

The radon concentration in the radon chamber was measured with an RadonEye+2 radon monitor.

— Detector : pulsed ion chamber

— Range : 7 - 9,435 Bq/m^3

— Accuracy : < ±10%

— Data communication : Wi-Fi (internet), Bluetooth

Material and method VI

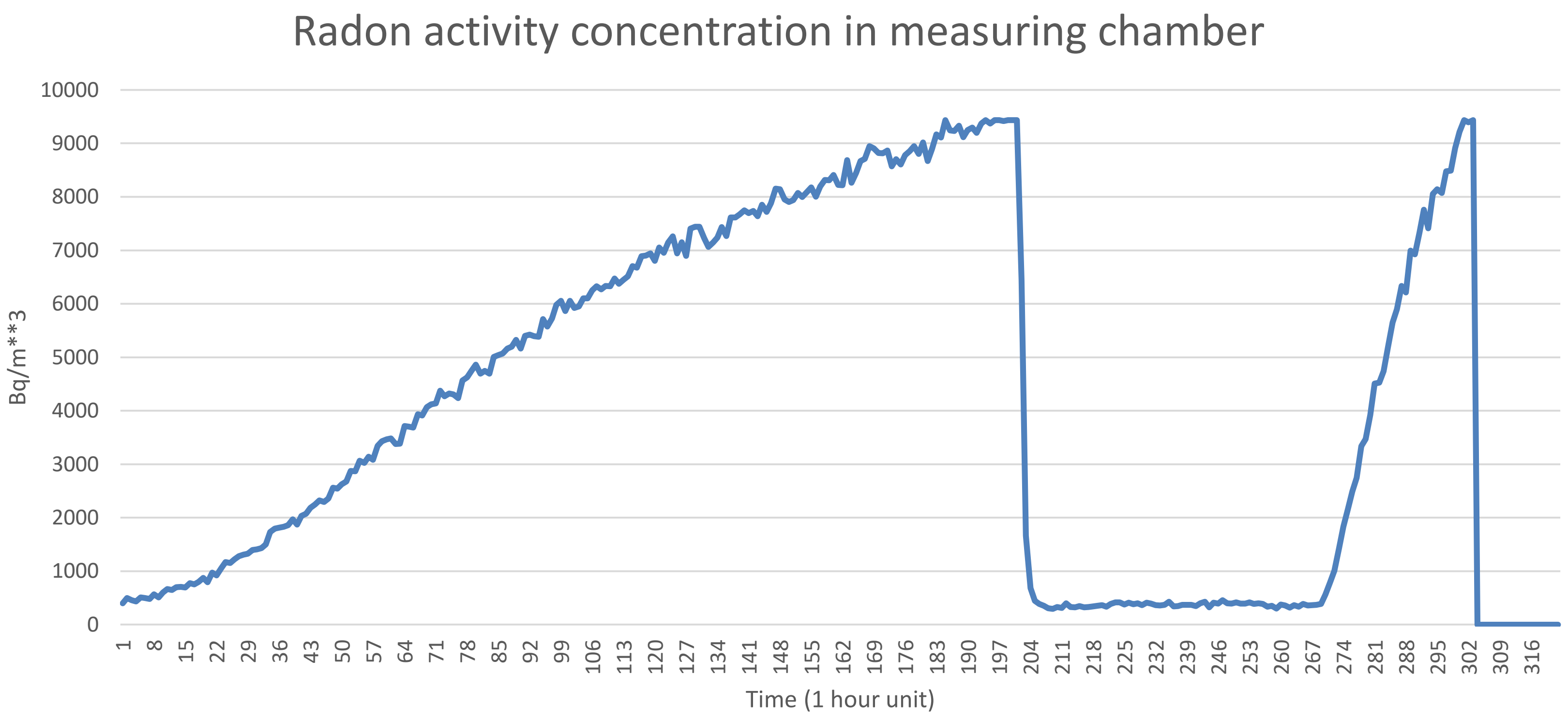
Instrumentation

Radon Eye Plus2

AlphaE

Material and method VII

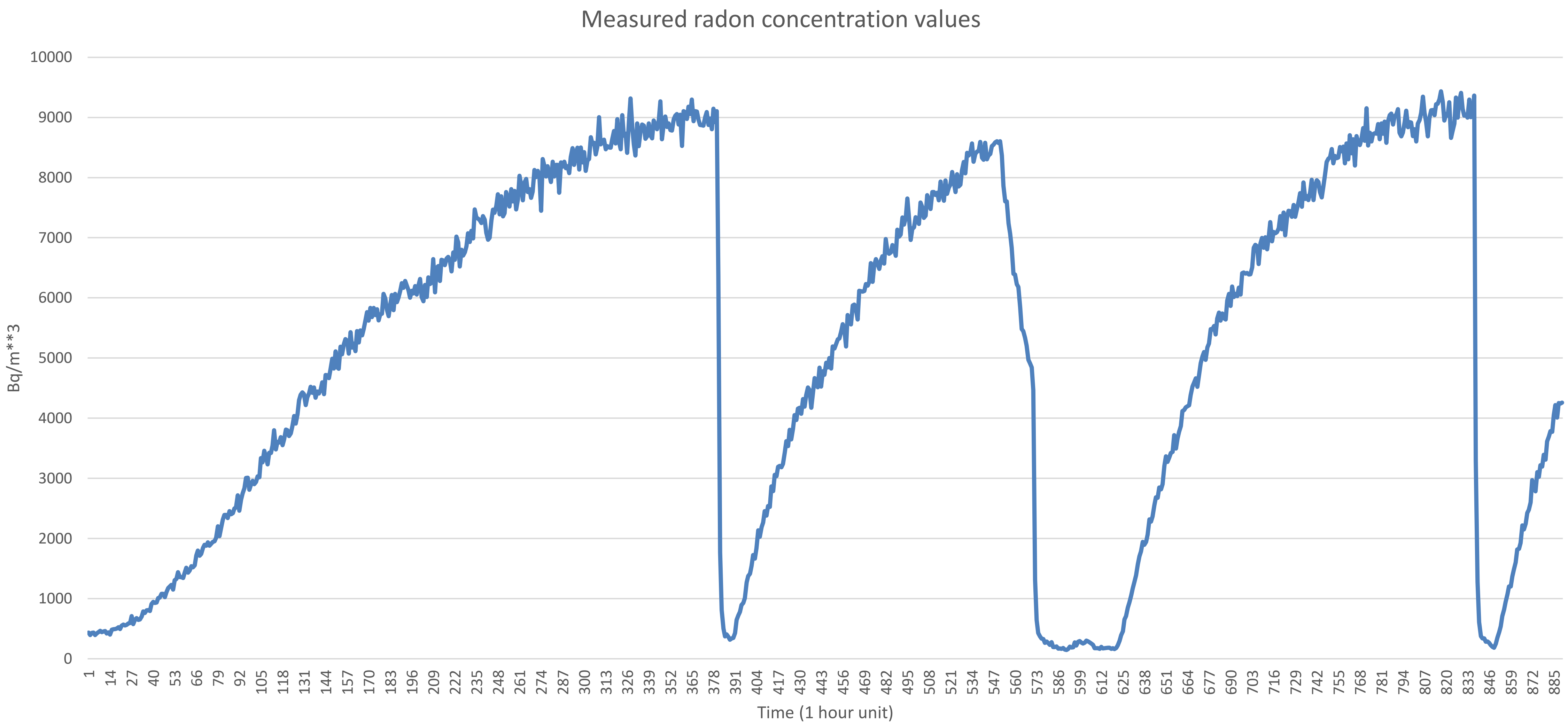
Radon activity concentration in the measuring chamber (receiving chamber), measured with RadonEye+2



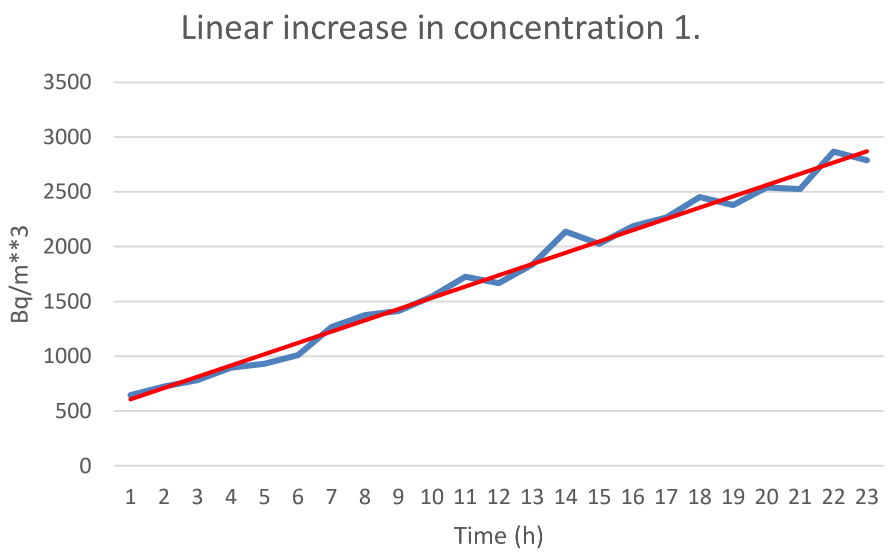
Material and method VIII

The increase in radon concentration, i.e. the rate of radon diffusion through the sample under investigation, is quasilinear for at least 24 hours after the measurement chamber has been ventilated. During the same experiment, the chamber was ventilated and the increasing radon concentration was measured several times, with the rate of increase in radon concentration being the same in all cases within the limits of uncertainty.

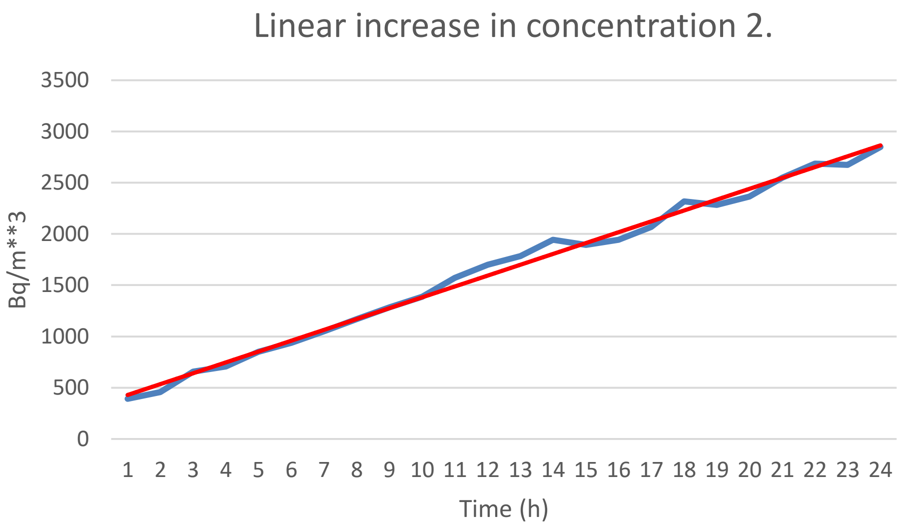
Material and method IX



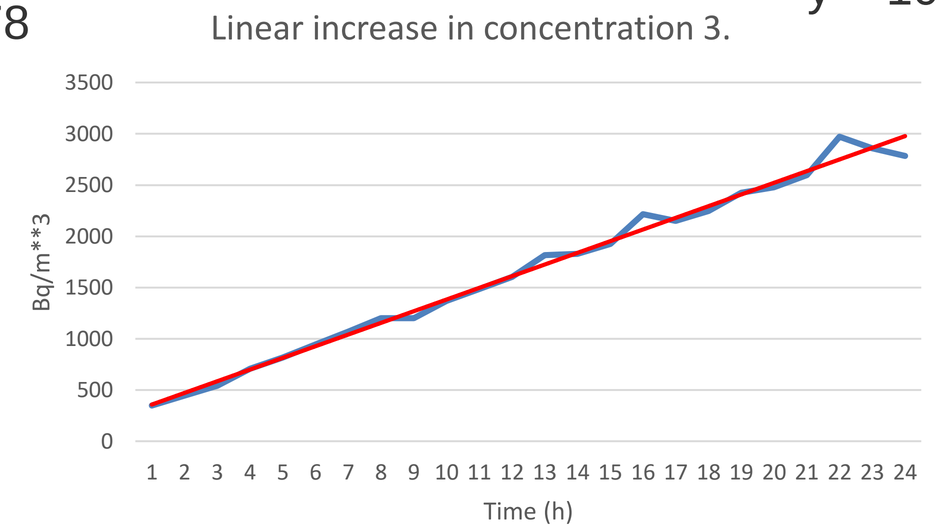
Material and method X



y = 102,78x + 504,78



y = 105,9x + 322,83



y = 113,79x + 245,66

Material and method XI

Using the formula expressing Fick's first law:

$$D_v = \frac{D_t * S * \Delta C}{l},$$

where:

D_v – rate of diffusion;
D_t – diffusion coefficient;
S - area of the tested material;
ΔC - concentration gradient;
l - thickness of the sample;

we can derive the following formula for calculating radon diffusion coefficients:

$$D_t = \frac{D_v * l}{S * \Delta C}$$

Discussion

The resulting formula reflects the increase in radon concentration in the measuring chamber without taking into account radon decay:

$$C_{\text{lin}}(t) = C_0 + \frac{S}{V}t$$

where:

V – volume of the room (m^3)

C(t) – radon concentration at time *t* (Bq/m^3)

C_0 – initial concentration (Bq/m^3)

S – radon inflow into the room (Bq/h)

Considering the decay of radon, we obtain a formula expressing the concentration value:

$$C_{\text{decay}}(t) = \frac{S}{\lambda V} + \left(C_0 - \frac{S}{\lambda V}\right) e^{-\lambda t}.$$

λ – decay constant (h^{-1}), $\lambda = \frac{\ln 2}{T_{1/2}}$

Discussion

The relative difference between the two models is expressed by the following formula:

$$\Delta_{rel}(t) = \frac{\left(C_0 + \frac{S}{V}t\right) - \left(\frac{S}{\lambda V} + \left(C_0 - \frac{S}{\lambda V}\right)e^{-\lambda t}\right)}{\left(C_0 + \frac{S}{V}t\right)}$$

or in percentages:

$$\Delta_{\%}(t) = \frac{C_{\text{lin}}(t) - C_{\text{decay}}(t)}{C_{\text{lin}}(t)} \times 100\%.$$

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Discussion

(h)	C_lin (Bq/m³)	C_decay (Bq/m³)	Difference (Bq/m³)	Relative difference (%)
0	322,89	322,89	0,00	0,00
1	428,79	425,96	2,83	0,66
2	534,69	528,25	6,44	1,21
3	640,59	629,77	10,82	1,69
4	746,49	730,53	15,96	2,14
5	852,39	830,53	21,86	2,56
6	958,29	929,78	28,51	2,97
7	1064,19	1028,29	35,90	3,37
8	1170,09	1126,07	44,03	3,76
9	1275,99	1223,11	52,88	4,15
10	1381,89	1319,44	62,45	4,52
11	1487,79	1415,05	72,74	4,89
12	1593,69	1509,95	83,74	5,26
13	1699,59	1604,16	95,44	5,61
14	1805,49	1697,67	107,82	5,97
15	1911,39	1790,49	120,90	6,33
16	2017,29	1882,64	134,65	6,68
17	2123,19	1974,11	149,08	7,02
18	2229,09	2064,92	164,17	7,37
19	2334,99	2155,07	179,92	7,71
20	2440,89	2244,56	196,33	8,05
21	2546,79	2333,41	213,38	8,38
22	2652,69	2421,62	231,07	8,71
23	2758,59	2509,20	249,39	9,04

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RESULTS

Sample	Diffusion coefficient, m^2/sec		Uncertainity
RadonSperre	$4{,}25\times10^{-12}$	±	$7{,}39\times10^{-13}$
BlueSeal	$5{,}51\times10^{-12}$	±	$1{,}16\times10^{-12}$
ERGO Foil	$9{,}43\times10^{-12}$	±	$1{,}98\times10^{-12}$
PrimX 0,4-2	$9{,}97\times10^{-10}$	±	$4{,}72\times10^{-10}$
PrimX 0,55-1	$1{,}62\times10^{-8}$	±	$9{,}25\times10^{-9}$

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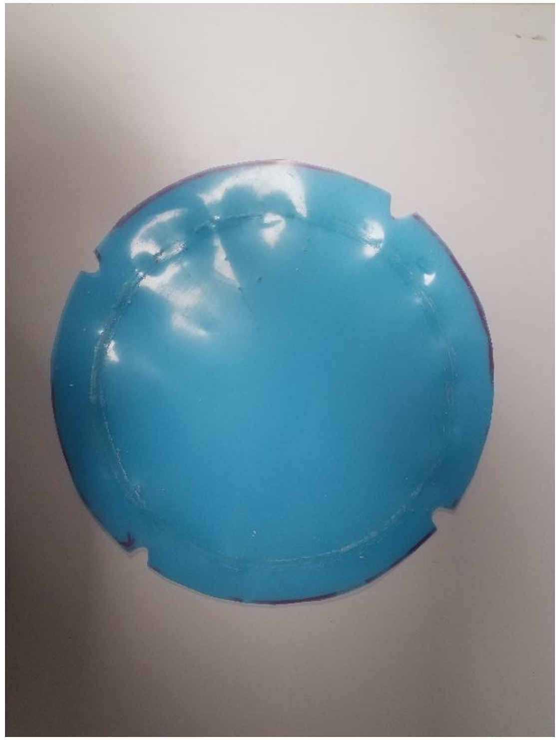
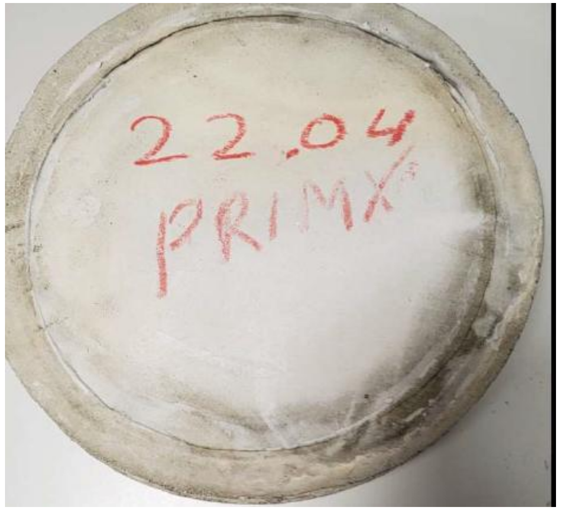
Picture of the test device

Examples of samples

RadonSperre



BlueSeal



Concrete sample

Thank you for your attention!