WP2: Influence of thoron (^{220}Rn) and its progeny on radon end-user measurements and radon calibrations:

Outcomes of potential interest for industry and stakeholders

Dobromir Pressyanov

SUBG

Should radon monitors/detectors be tested for thoron cross-interference ($CI = \frac{E_{Rn}}{E_{Tn}} \times 100\%$)?

Within MetroRADON: 16 active monitors tested

- $CI \leq 5\%$: 5 (out of 16)
- $5\% < CI \leq 20\%$: 6 (out of 16)
- $CI > 20\%$: 5 (out of 16)

Within MetroRADON: 19 passive detectors tested: 17 commercially available + 2 DVD based

- $CI \leq 5\%$: 8 (out of 19)
- $5\% < CI \leq 20\%$: 9 (out of 19)
- $CI > 20\%$: 2 (out of 19)

The manufacturers of radon monitors/detectors should perform cross-interference testing for their radon instruments and should include this information in the specifications of the instrument.

- The testing of radon monitors for thoron sensitivity should include reference (secondary) thoron monitor that is calibrated with, or traceable to a primary thoron measuring system;

- Thoron homogeneity in the chamber should be checked during exposure or in another experiment under the same exposure conditions (K. Mitev et al. *Appl. Radiat Isot.* 165 (2020) 109259);

- The cross-interference tests should be planned taking into account the possible contribution from thoron progeny (^{216}Po, ^{212}Pb, ^{212}Bi+^{212}Po/^{208}Tl). For instance, after the end of thoron exposure the integrated passive detectors should be left for at least three days at low thoron/radon levels before analysis to leave thoron progeny to decay;

- **A minimum of three days test with a high thoron activity concentration (around 10 kBq.m^{-3} or more) is recommended to determine an accurate final *CI* of the active monitors, instead of the 4 hours at 1000 Bq.m^{-3} required in the IEC 61577-2 standard.**

Basic techniques to reduce the influence of thoron on radon measurements and calibrations:

Passive methods (by diffusion barriers)

- Diffusion through polymer foils (can eliminate thoron influence, eliminates also humidity);
- Diffusion through small gaps/holes;

Active method:

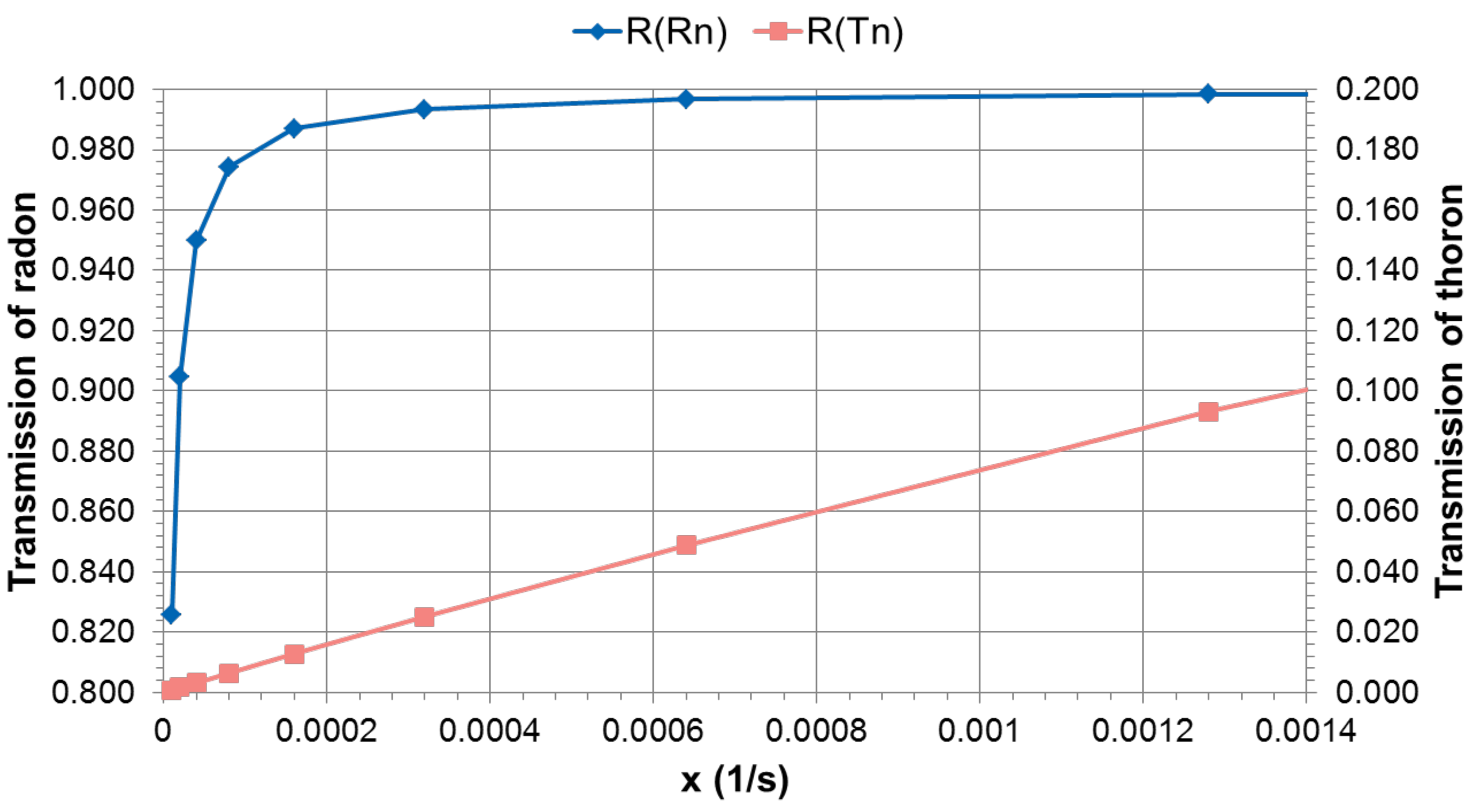
- Delay due to air flow in a pipe;

Other:

- Spectroscopy discrimination between radon and thoron or gross alpha counting in two or more time intervals (active monitors).

Transmission (R) of radon and thoron through diffusion barriers:

$$R = \frac{C_{in}}{C_{out}} = \frac{1}{1+\lambda\tau} = \frac{1}{1+\frac{\lambda}{x}}$$



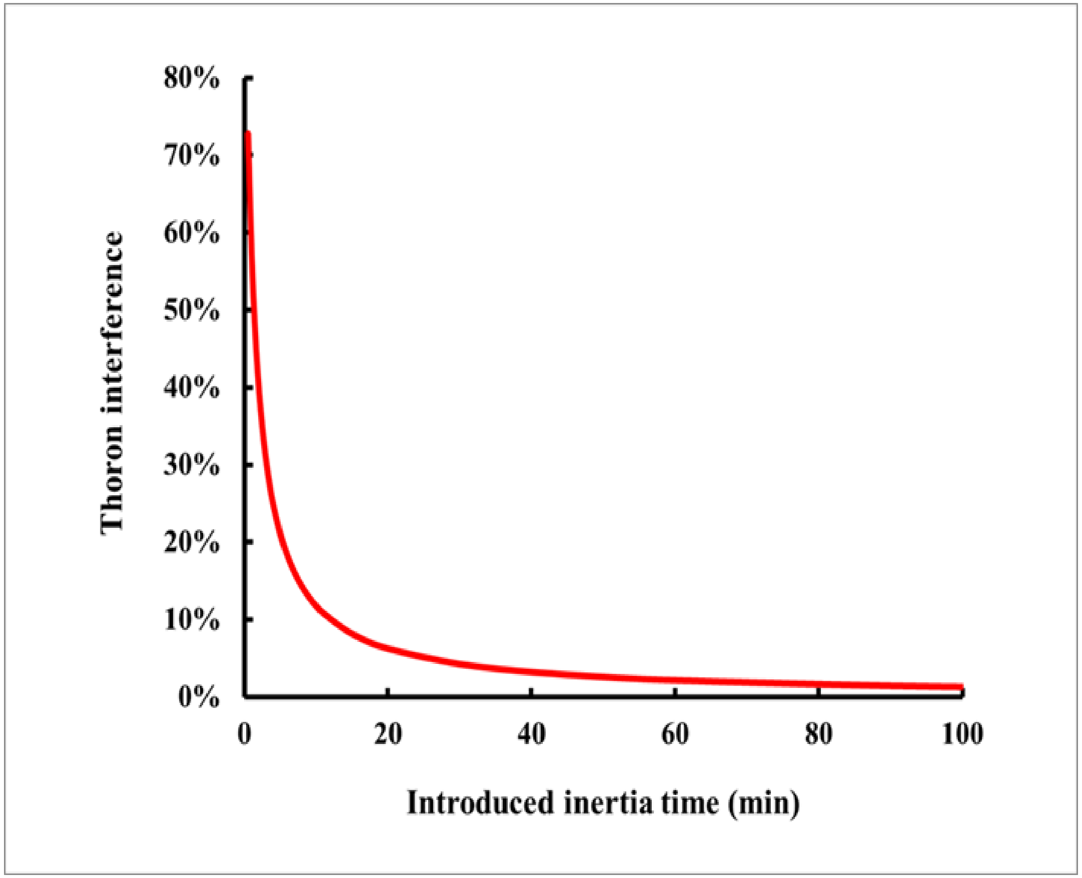
Gaps/holes: $x = \frac{D_{air}A}{Vd}$

Polymer membrane: $x = \frac{PS}{hV}$

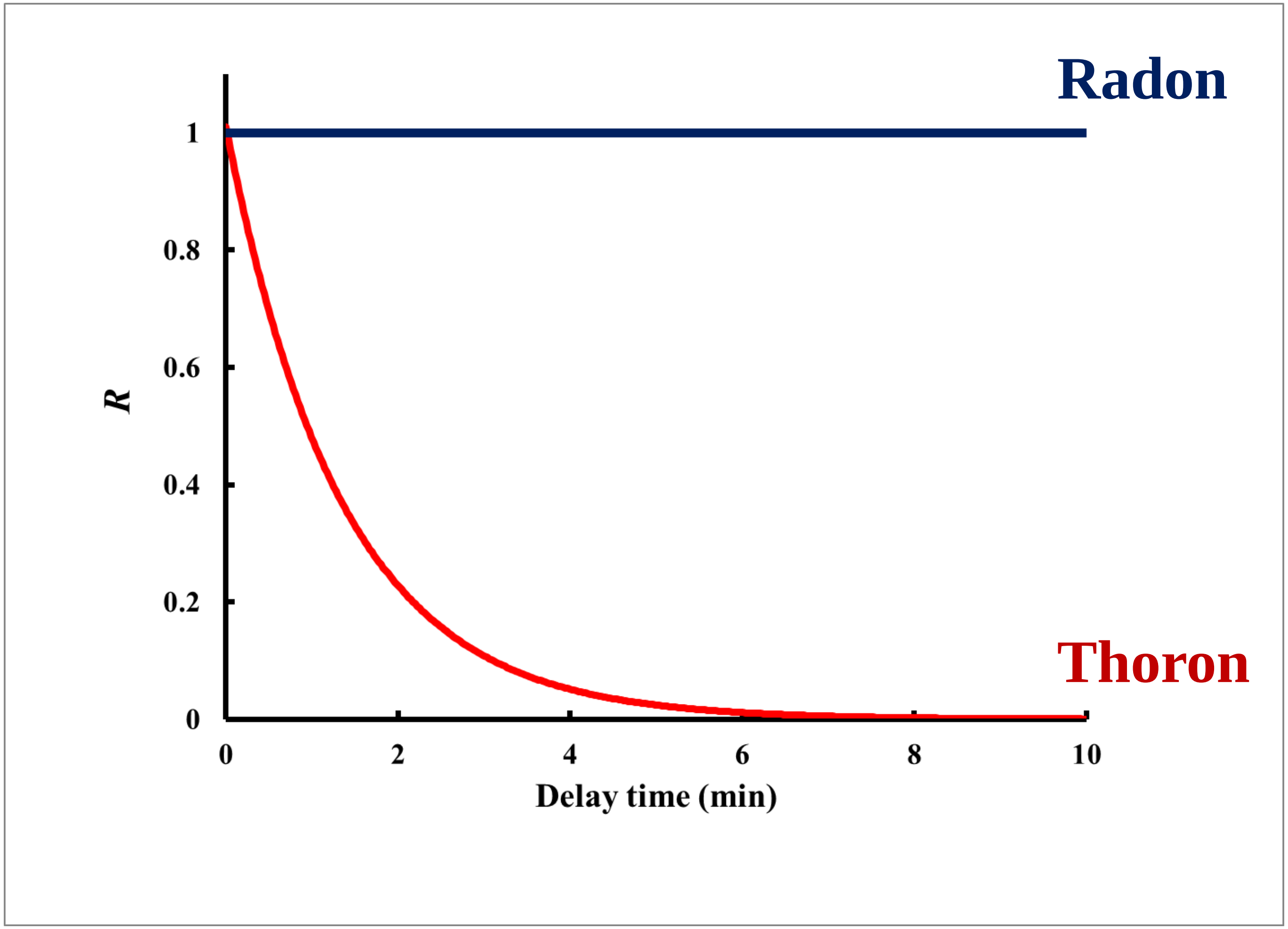
Introducing additional diffusion barrier to active radon monitors

CI = (8.8 ± 1.3) % → **CI=(4.23 ± 0.84) %**

However…inertia in the response is introduced by diffusion barriers against thoron



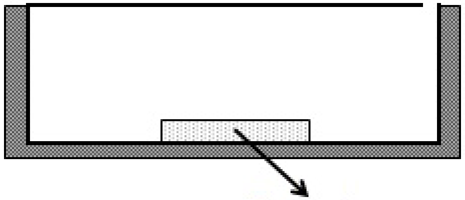
Delay lines: $Delay\ time = \frac{Volume\ of\ the\ line}{Air\ flow{-}rate}$



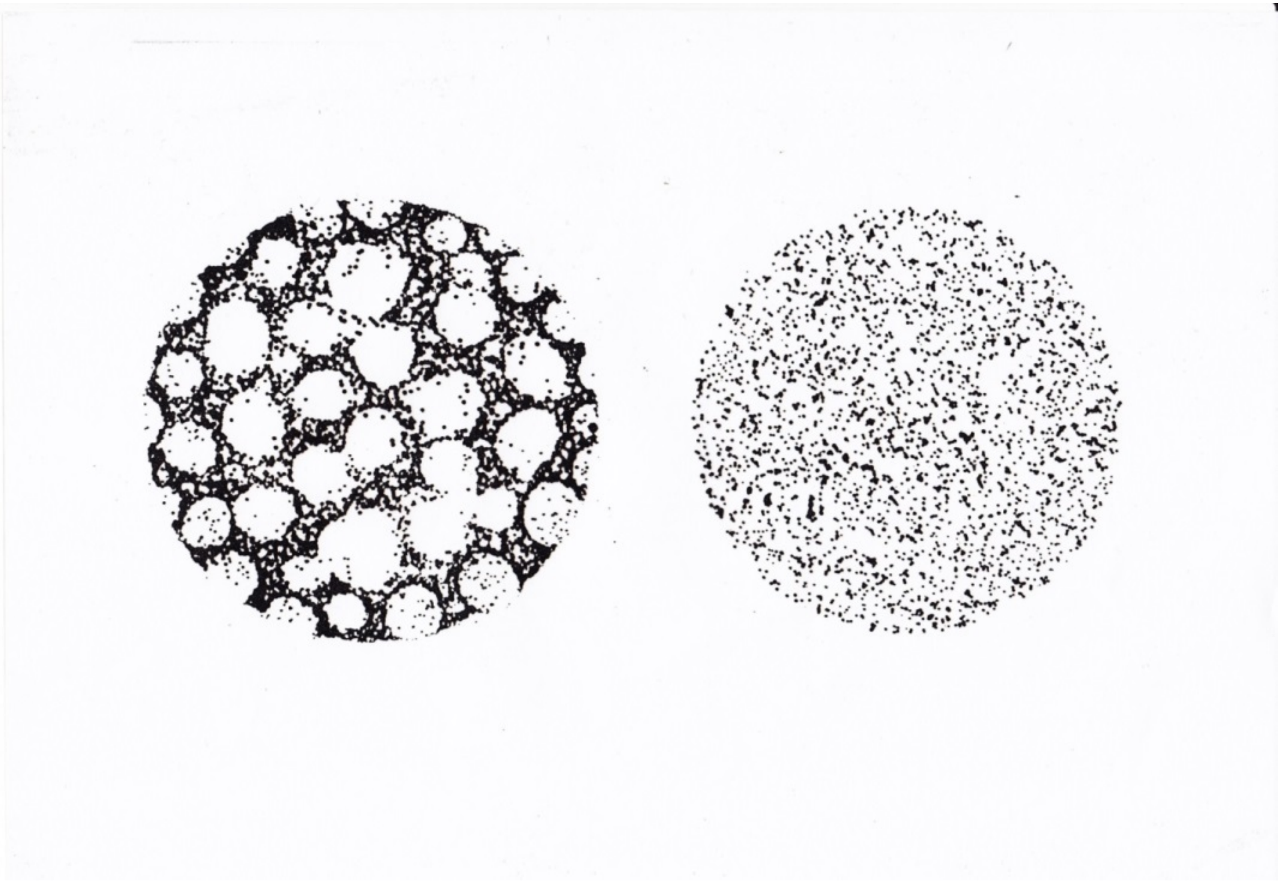
Most passive radon detectors employ diffusion barriers: «polymer foil barrier» or «diffusion through small holes»

Foil-based diffusion chamber (provides anti-thoron and anti-humidity protection)

Gaps/pin-holes based diffusion chambers (thoron influence can be reduced if the holes are sufficiently small)



Problem with humidity for pin-holes diffusion-chambers, water can also block diffusion if the holes are small (small holes provide more efficient thoron reduction)



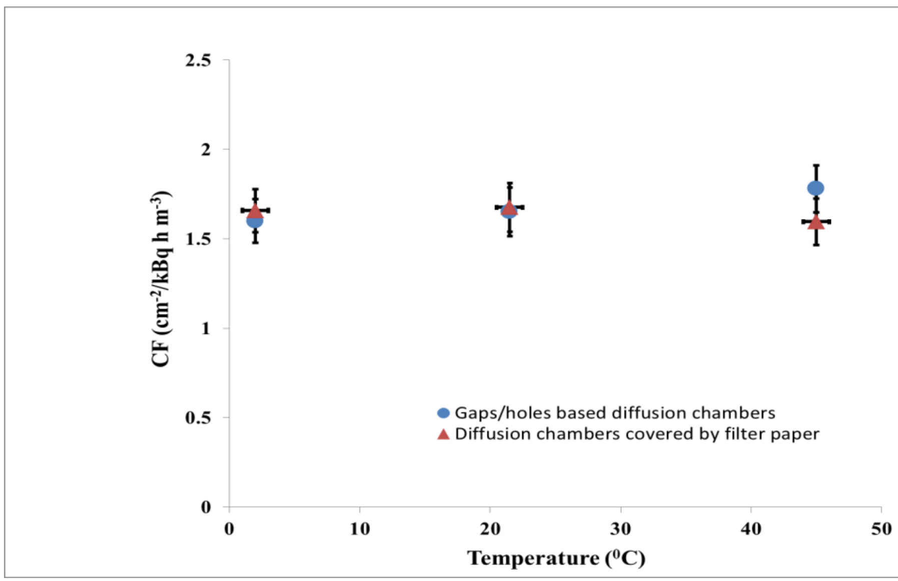
Diffusion through polymer foils in diffusion chambers: thoron interference and humidity influence are reduced, but a temperature bias is introduced

THE PROBLEM WITH TEMPERATURE DEPENDENCE OF RADON DIFFUSION CHAMBERS WITH ANTI-THORON BARRIER

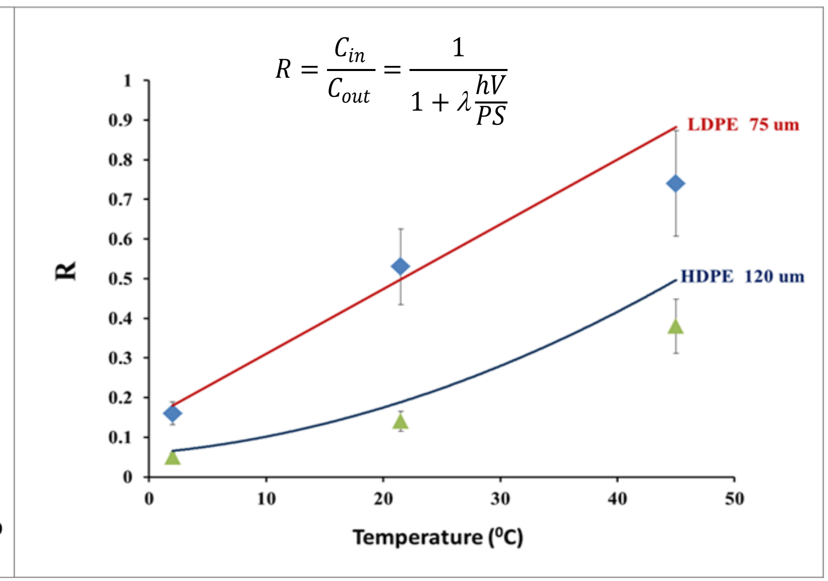
DOBROMIR PRESSYANOV[1], DIMITAR DIMITROV[2]

[1] Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia, Bulgaria
[2] Mining and Geology University "St. Ivan Rilski", Sofia, Bulgaria
E-mail: pressyan@phys.uni-sofia.bg

Received July 18, 2019

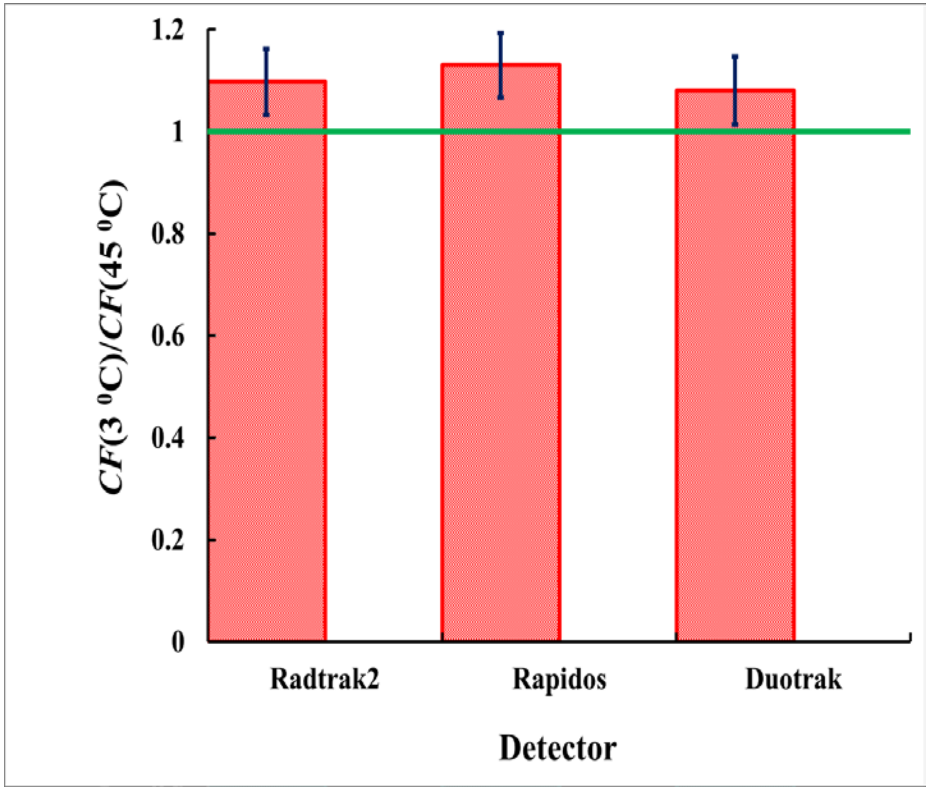


Anti-thoron barrier: gaps/pin holes
(LR-115/II detectors)



Anti-thoron barrier: polymer foil
(LR-115/II detectors)

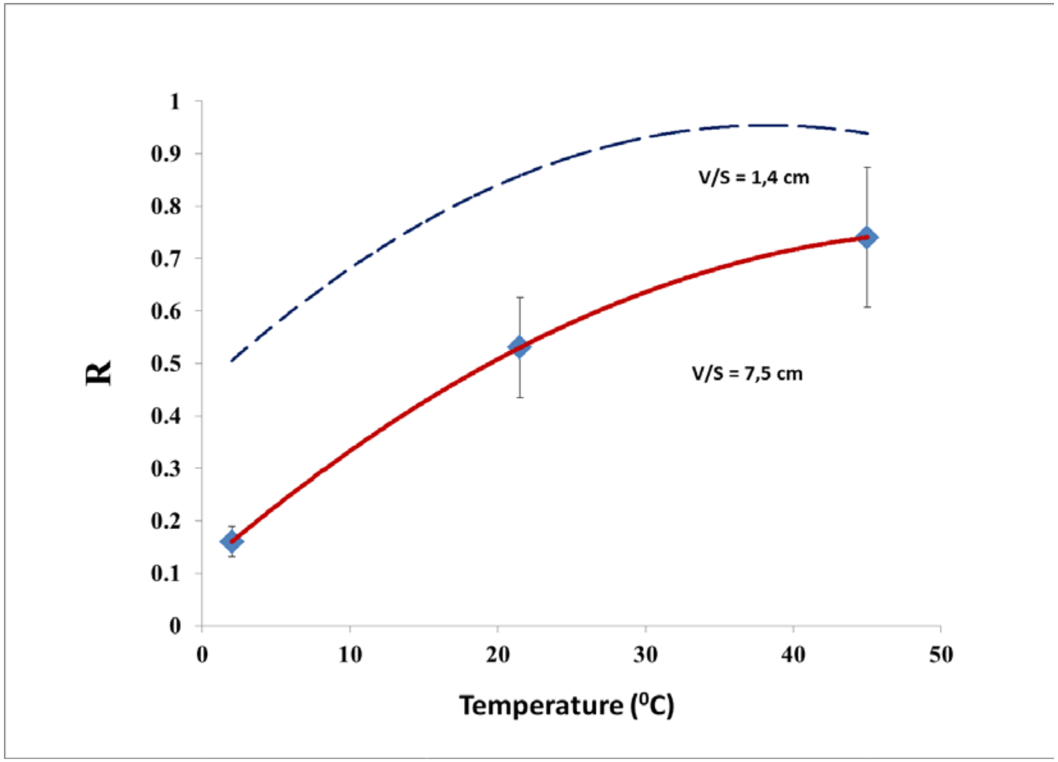
However…many detectors also show temperature dependence: The ratio of calibration factors at 3 ^{0}C to 45 ^{0}C of some RADONOVA diffusion chambers with CR-39 detectors.



Within 3 – 45 ^{0}C the calibration factor drops by 8 – 13%

Surprisingly…the temperature dependences introduced by polymer anti-thoron barriers and that of many radon detectors were found to be reciprocal. This led to a novel concept for diffusion barriers designed as a "compensation module".

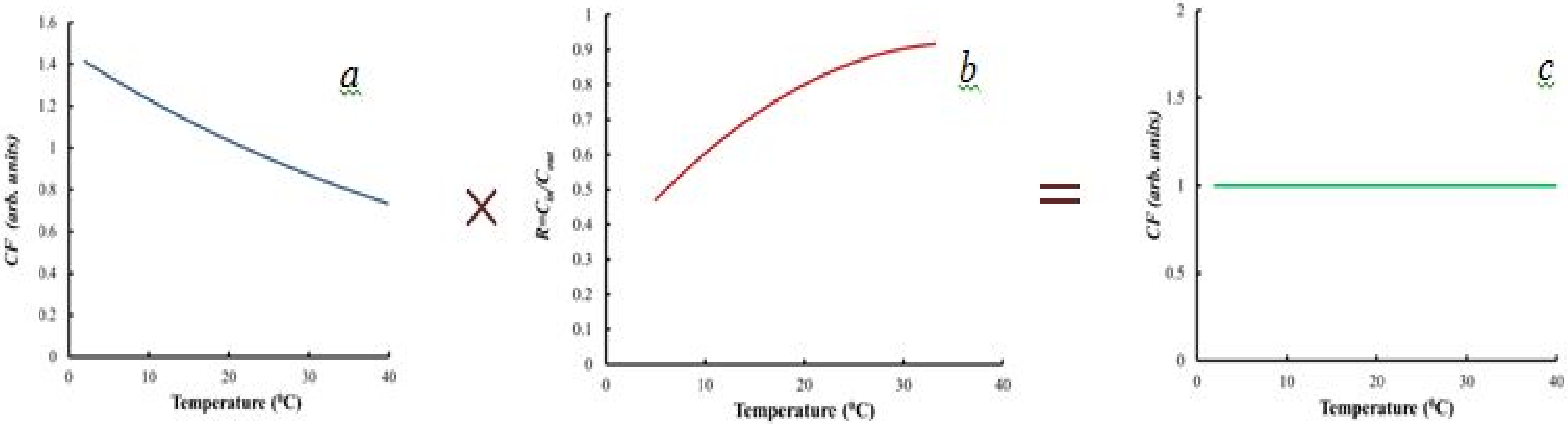
Experimental results with a membrane of 75 μm thick low density polyethylene foil and *V/S* = 7.5 cm



The temperature dependence might be altered by varying $\frac{hV}{S}$ and the polymer material. When $h \ll L_D$:

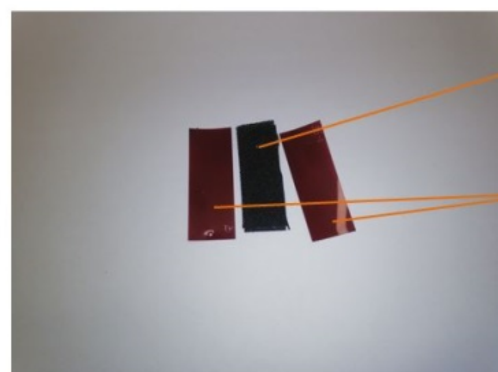
$$R = \frac{C_{in}}{C_{out}} = \frac{1}{1+\frac{\lambda hV}{SP}},$$

The concept of the "compensation module" (D. Pressyanov, *Patent Appl. Bulg. Nr. 112897, WIPO Appl. Reg. Nr. PCT/BG2020/000003*)

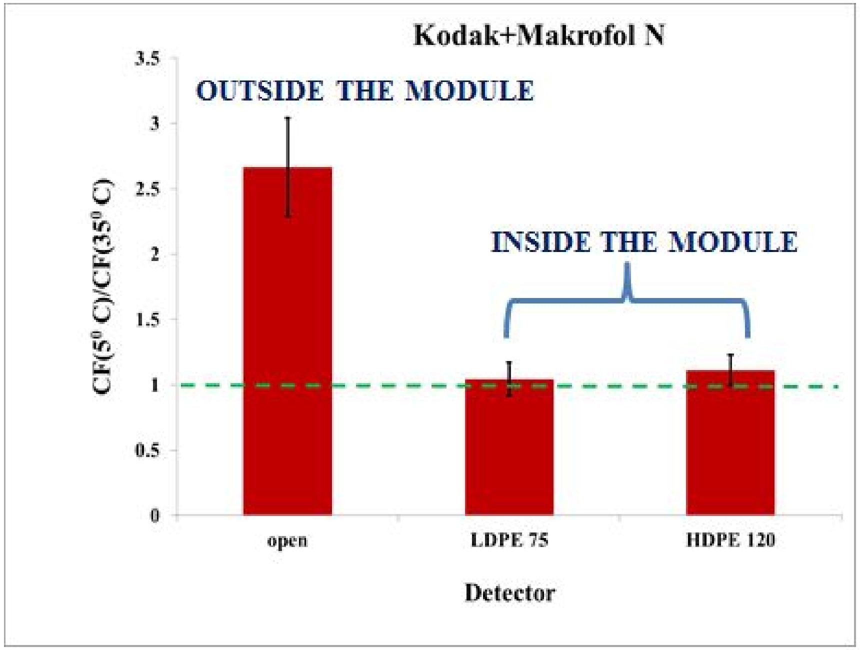


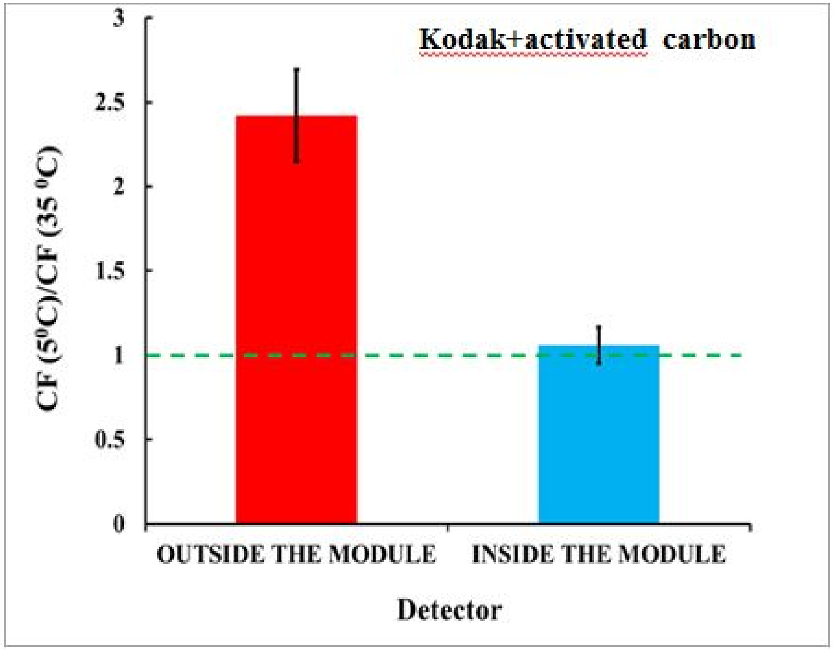
Usable with detectors which response decreases with the increase of the temperature. This can be used to reduce/eliminate the <u>temperature dependence + thoron influence + humidity influence</u>.

Pilot experiments with different compensation modules



Experimental results





This can reduce the temperature bias + thoron interference + humidity influence

Reducing thoron interference: Active monitors

- For active monitors for which fast reaction to rapidly changing concentrations is required a spectrometric discrimination between radon and thoron is probably the best option;

- If spectral discrimination is not used but the active monitors are expected to have a fast reaction, a proper approach is to incorporate a delay line either within the instrument design or as supplementary module;

- For active monitors for which fast reaction to rapidly changing concentrations is not required, and which work in a diffusion mode, additional diffusion barrier can be used.

Reducing thoron interference: Passive detectors

- For passive detectors diffusion barriers might be considered in the design and tested in the prototypes. If instruments are scheduled to work at high humidity the use of diffusion barriers based on polyethylene foils of low density polyethylene is recommended;

- For monitors/detectors in which the usage of polyethylene packing is planned to reduce the thoron interference, a temperature bias may be introduced. Methods for handling and taking account of this bias are proposed in the Deliverable 2 of MetroRADON;

- For detectors with a response that decreases with the increase of the temperature, by the new compensation module proposed (patent pending**) reduction/elimination of the influence of thoron + temperature + humidity can be achieved simultaneously.**

Thank you!