The CD/DVD method within MetroRADON and beyond

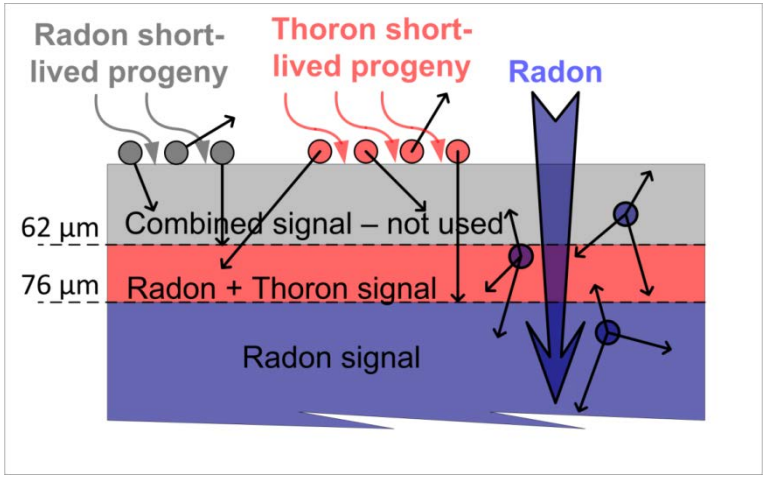
Dobromir Pressyanov

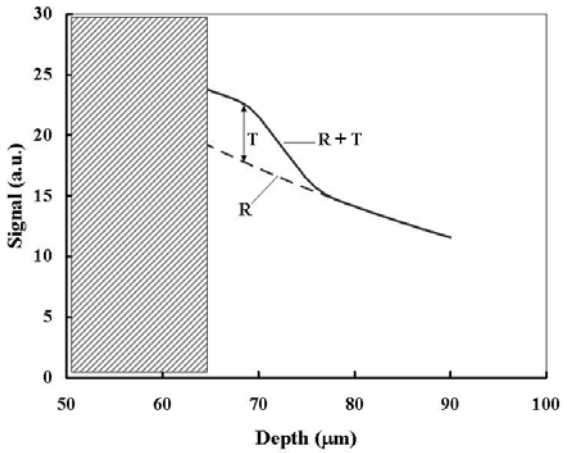
SUBG

The concept of the CD/DVD method

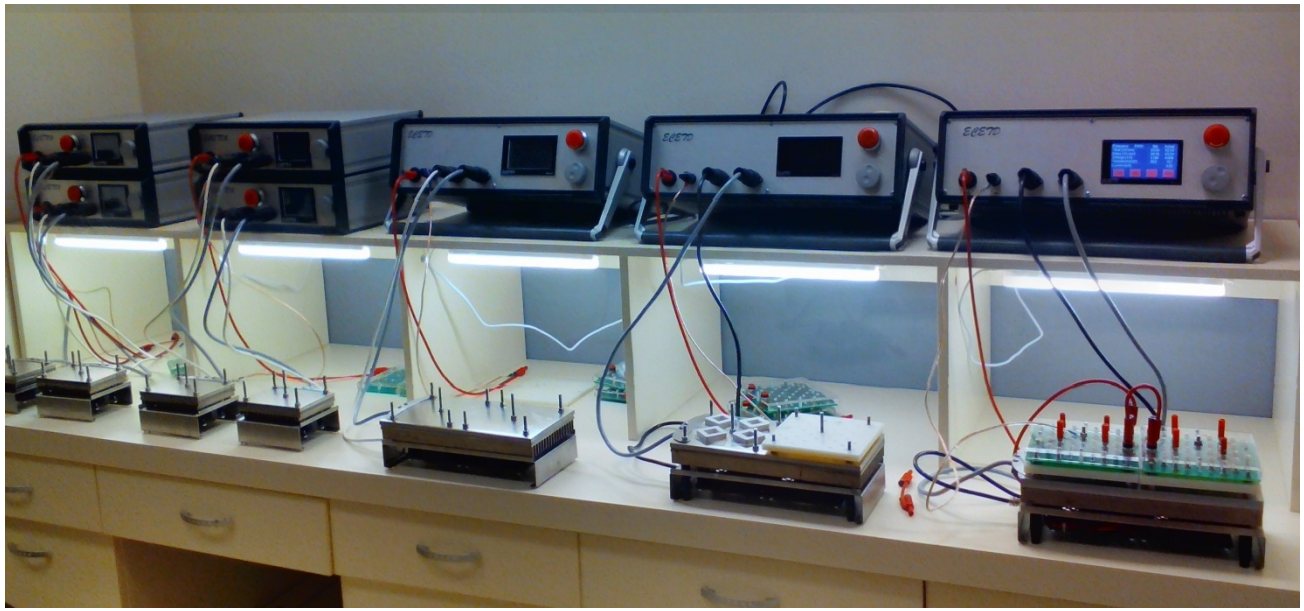
- **Possible to use “detectors” that are already available in (almost) any dwelling.**
- **Absorbs radon, which further diffuses in depth;**
- **Alpha particles create tracks on it (ECE is the best suited etching procedure for the method);**

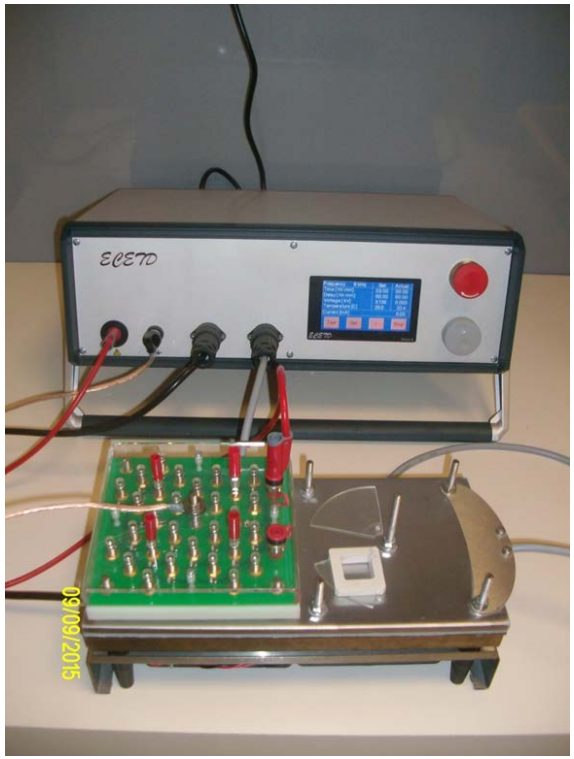
First the method was considered as a tool for radon epidemiology, but later… it was found useful for many other applications.





Theequipment for processing CDs/DVDs (FP7-EURATOM Project DoReMi). Capacity to etch up to 50 CD/DVD specimens in parallel.



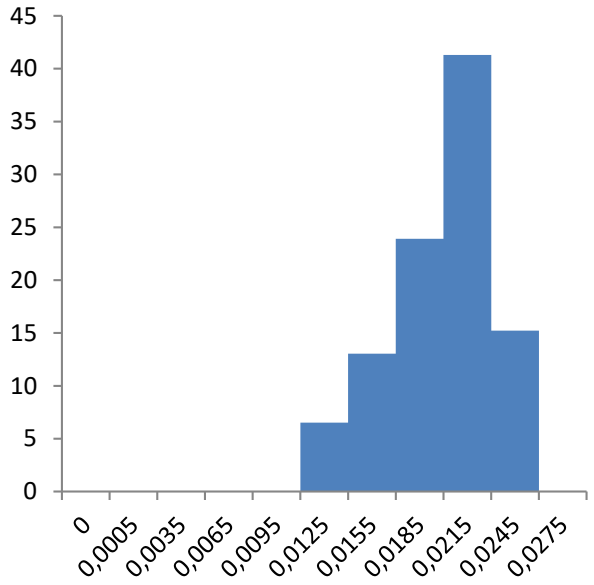


CD/DVD method: data processing

$$C = \frac{n - n_b}{CF.t} = \frac{n_0}{CF.t}$$

$$\frac{u(C)}{C} = \sqrt{\frac{u^2(n_0)}{n_0^2} + \frac{u^2(CF)}{CF^2} + \frac{u^2(t)}{t^2}}$$

- **Track-counting statistics (Poisson);**
- **Disk dating (t; $\Delta = t_{max} - t_{min}$; $u(t) = 0.289\Delta$);**
- **Calibration (CF): standard and individual (*a posteriori*).**



CF (cm^{-2}/kBq h m^{-3})

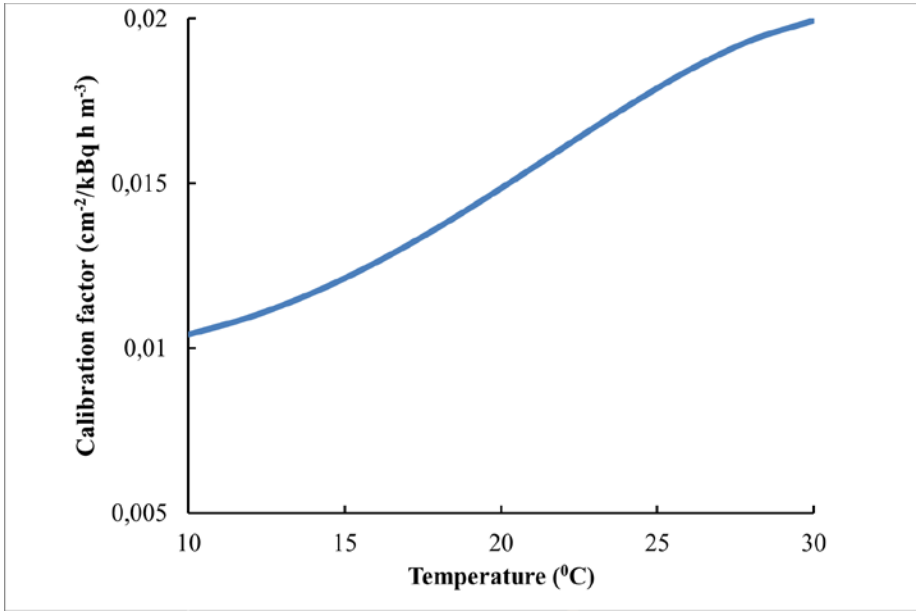
Calibration laboratory in SUBG. Calibration at different temperatures within $-15^0 \div +60^0$ C. Pure and mixed $^{222}Rn/^{220}Rn$ atmosphere at static and dynamic exposure conditions (*Journal of Environmental Radioactivity* 166 (2017) 181-187).

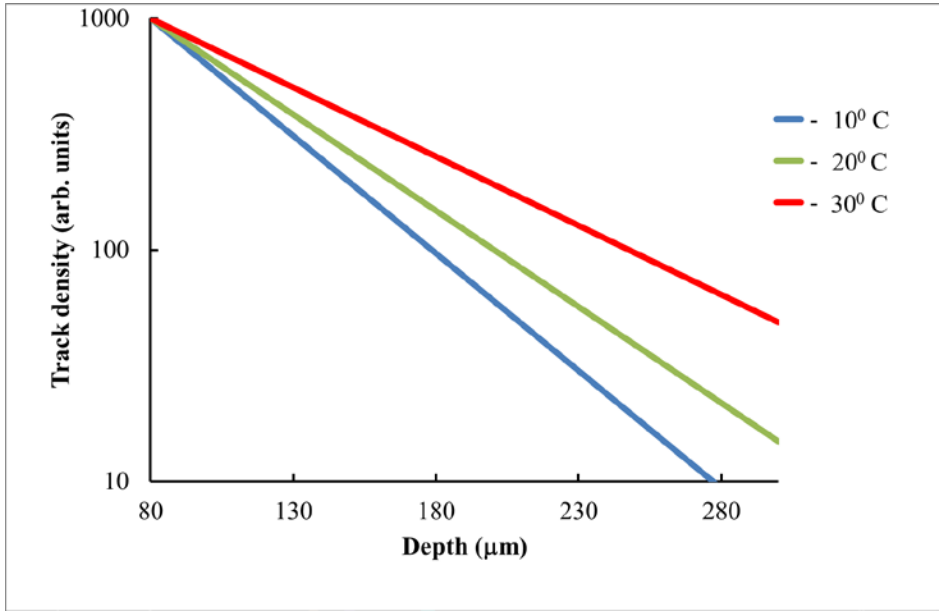
In particular the influence of following factors was studied:

- **Pressure (within 0.5 – 1.5 atmosphere);**
- **Humidity (0-100%);**
- **Temperature (2 – 40^0 C);**
- **Dust deposition;**
- **Ciggarette smoke;**
- **Mode of storage of CDs/DVDs (bare, in jewel case, in envelope etc.);**
- **Effect of ^{210}Po growth in the detector volume alter long exposure times;**
- **Detector fading (for up to 20 years);**
- **Effect of laser light used to read/write CDs/DVDs.**

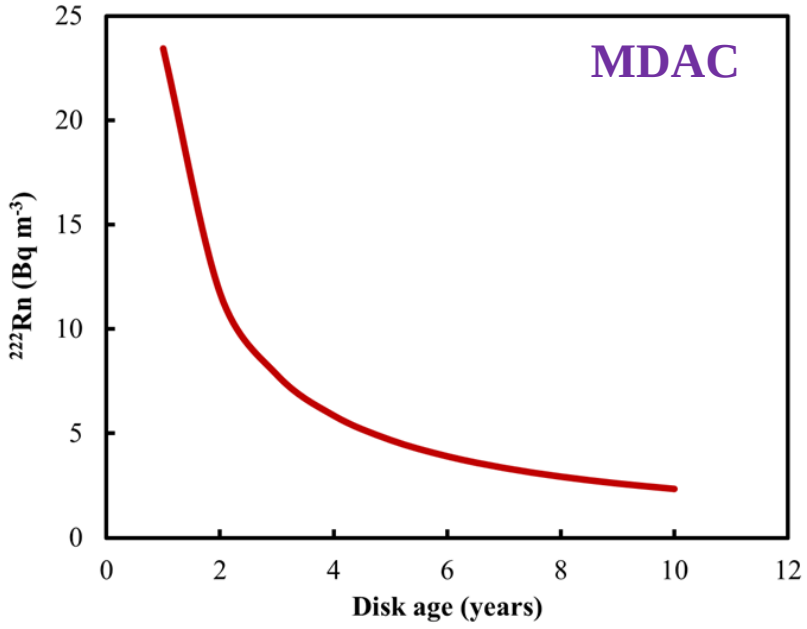
New (addressed within MetroRADON): Test under extremely variable ^{222}Rn concentrations and temperature.

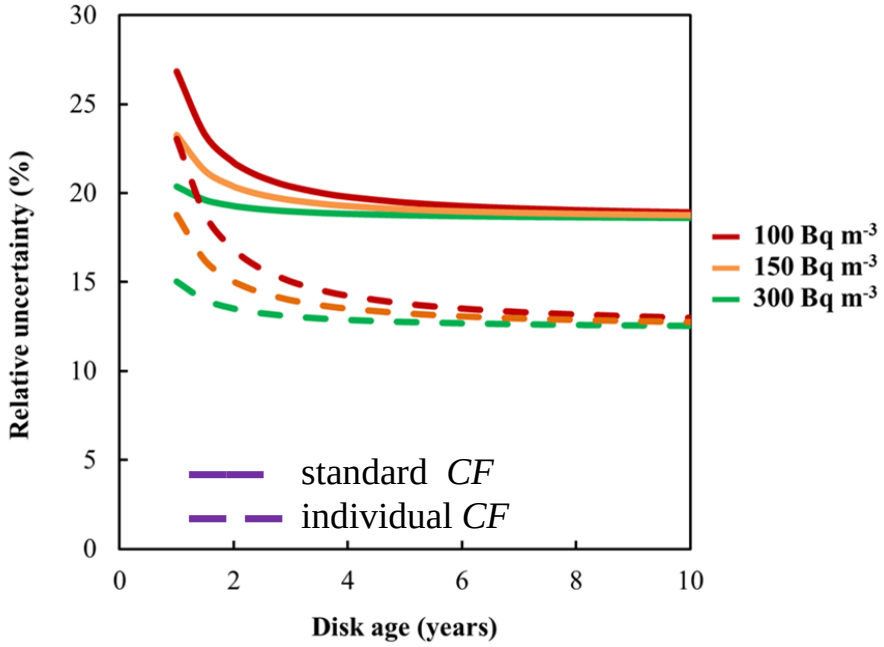
Calibration factor for ^{222}Rn can be adjusted for the temperature during exposure. If the temperature is not known a posteriori correction can be applied. It is important to calibrate under realistic environmental conditions!





CD/DVD method and MetroRADON priorities: sensitivity and uncertainty…





Dating in interval with a width 0.25 of the disk age

Quality assurance of the CD/DVD method for ^{222}Rn: STAR traceability.

DEUTSCHER KALIBRIERDIENST **DKD**

Kalibrierlaboratorium / *Calibration laboratory*

Akkreditiert durch die / *accredited by the*
Akkreditierungsstelle des Deutschen Kalibrierdienstes

Bundesamt für Strahlenschutz
Standort Berlin
Köpenicker Allee 120 – 130
10318 Berlin

DKD-K-23001

Nr. 523
DKD-K-23001
2010-08

Kalibrierschein
Calibration certificate

Kalibrierzeichen
Calibration mark

Gegenstand *Object*	***Radon measurement devices using solid state nuclear track detectors***
Hersteller *Manufacturer*	**University of Sofia Laboratory of Dosimetry and Radiation Protection**
Typ *Type*	**CD / DVD**
Fabrikat/Serien-Nr. *Serial number*	**50 disks see table on page 3**
Auftraggeber *Customer*	**Dr. Dobromir S. Pressyanow Laboratory of Dosimetry and Radiation Protection, Faculty of Physics University of Sofia "St. Kliment Ohridski" 5 James Bourchier Blvd. Sofia BG-1164, Bulgaria**
Auftragsnummer *Order No.*	**209**
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	**3**
Datum der Kalibrierung *Date of calibration*	**19.08.2010**

Dieser Kalibrierschein dokumentiert die Rückführung auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Der DKD ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.
This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the International System of Units (SI).
The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung sowohl der Akkreditierungsstelle des DKD als auch des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift und Stempel haben keine Gültigkeit.
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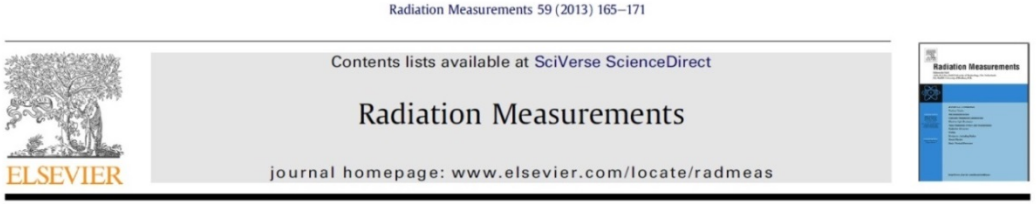
Stempel *Seal*	Datum *Date*	Stellv. Leiter des Kalibrierlaboratoriums *Deputy Head of the calibration laboratory*	Bearbeiter *Person in charge*
Deutscher Kalibrierdienst DKD-K-23001	13.12.2010	H. Buchröder	E. Foerster / C. Wegner



Radiation Measurements 59 (2013) 165–171

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Radiation Measurements

journal homepage: www.elsevier.com/locate/radmeas

Traceability of CDs/DVDs used as retrospective ^{222}Rn detectors to reference STAR laboratory

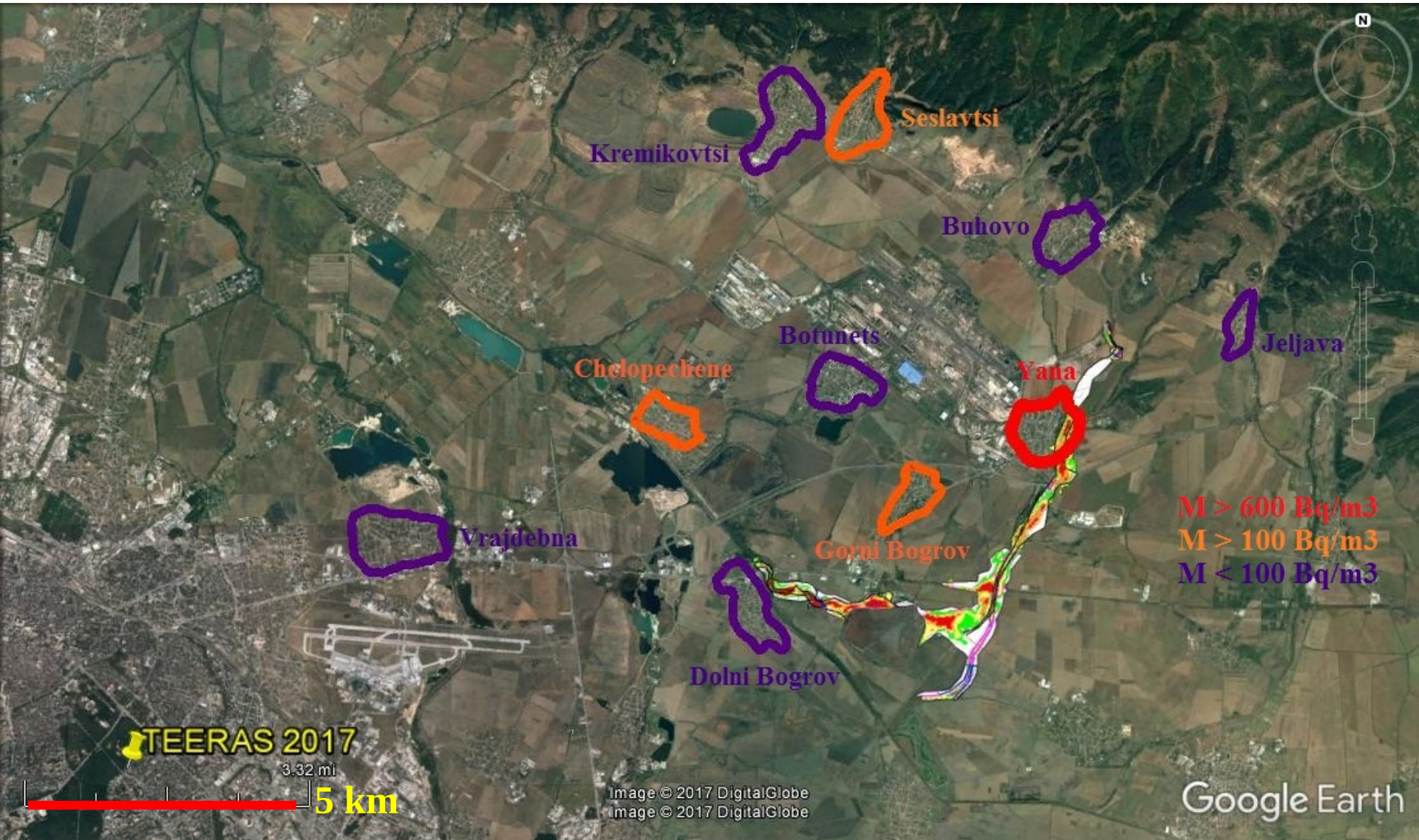
D. Pressyanov [a,*], E. Foerster [b], S. Georgiev [a], I. Dimitrova [a], K. Mitev [a]

[a] *Sofia University St. Kliment Ohridski, Faculty of Physics, 5 James Bourchier Blvd., Sofia, Bulgaria*
[b] *Radon Calibration Service Laboratory, Federal Office for Radiation Protection (BfS), Berlin, Germany*

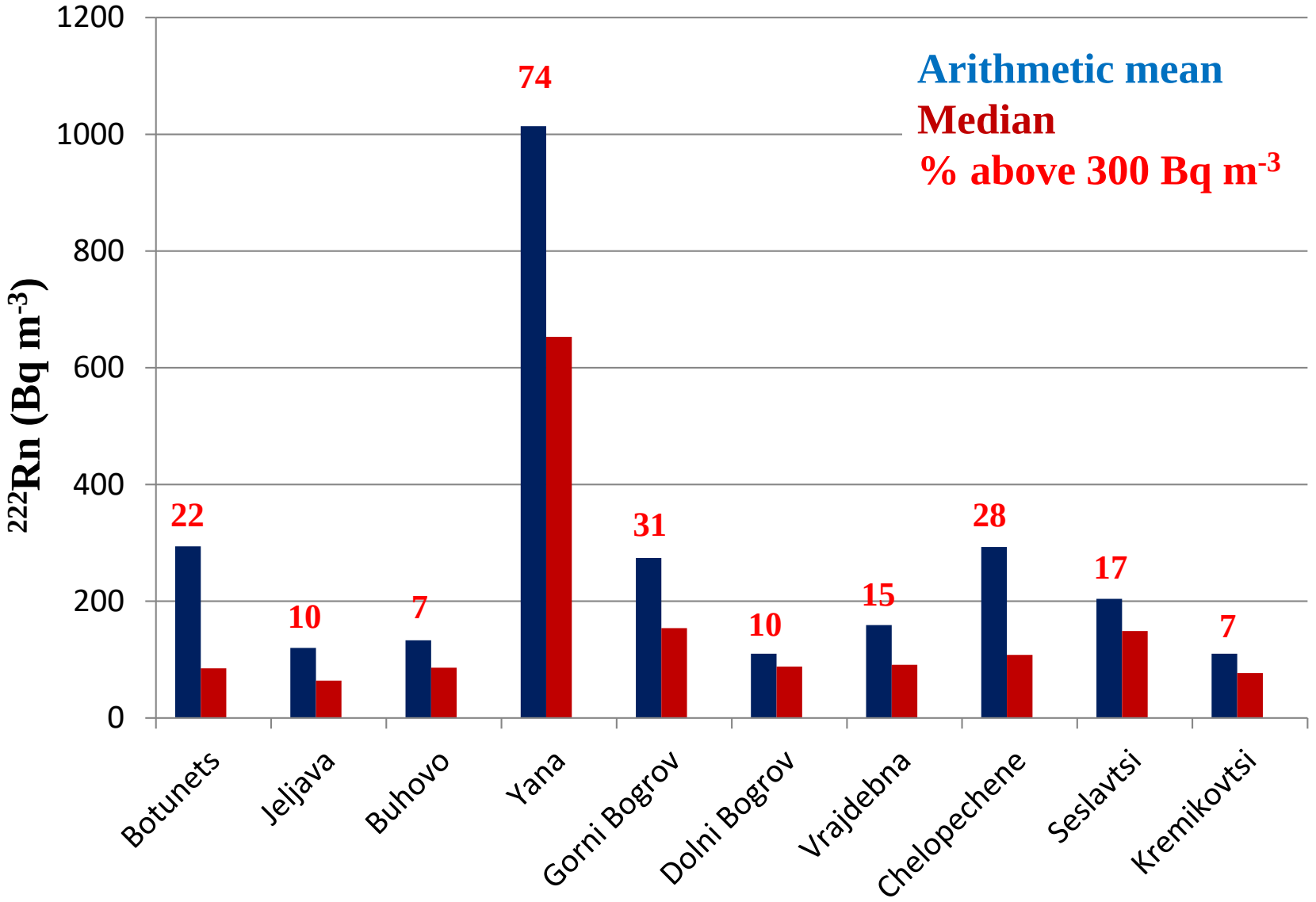
Basic applications:

- **Before MetroRADON;**
- **Within MetroRADON;**
- **And beyond…**

CDs/DVDs used to identify radon prone areas: 462 CDs/DVDs from 336 private houses analyzed (*Journal of Environmental Radioactivity* 196 (2019) 274–280)

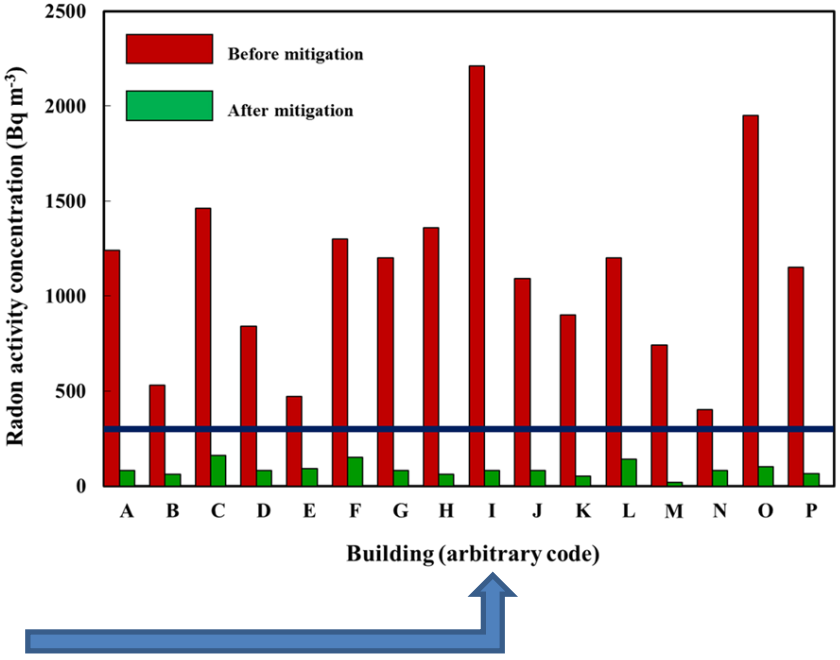


Average and medians

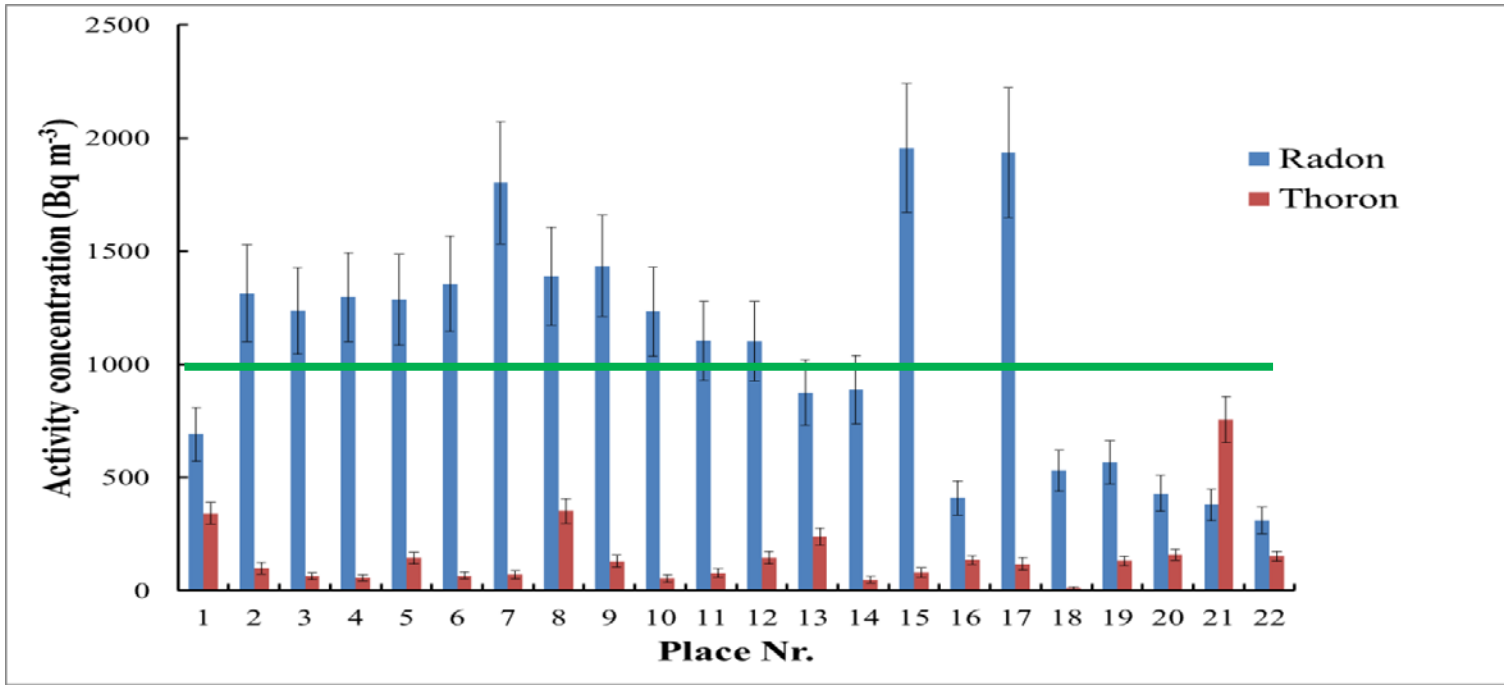


European Council Directive 2013/59/EURATOM: the reference levels are based on the annual average radon concentrations. By CDs/DVDs the annual average concentrations can be determined fast (e.g. even within one day from the decision to test).

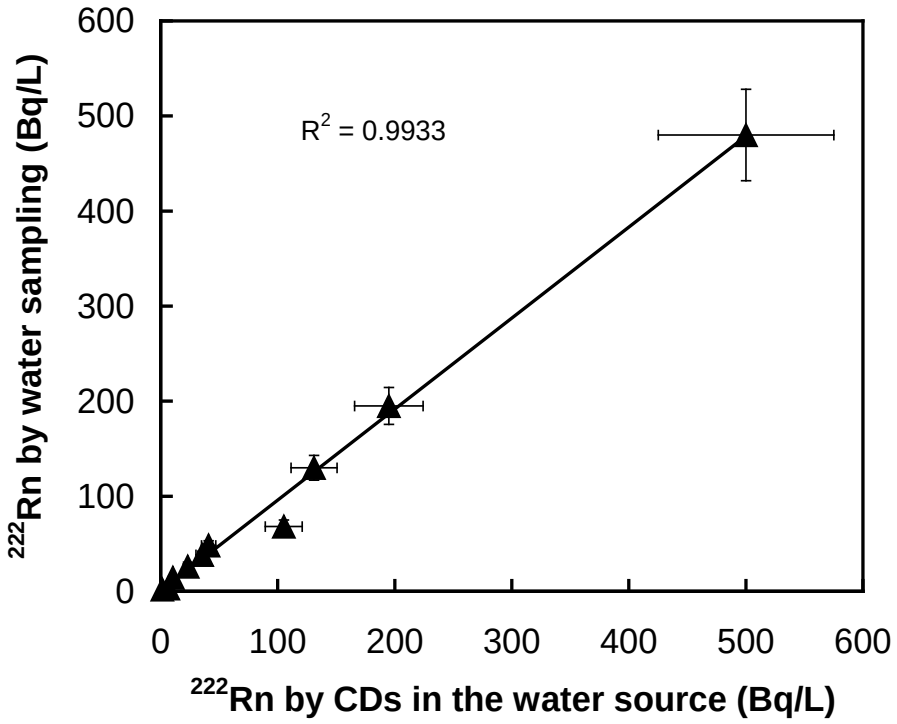
- "Traditional" prospective measurements: 3-12 months. Too long time just to tell whether there is a problem;
- CD/DVD method: one working day (8 hours). Radon problem (> 100 Bq m^{-3}!) can be identified by any home stored CD/DVD that is more than one year old;
- The probability for false alarm with CDs/DVDs is 5% with one year old disk and even less with older. No probability to skip the problem, provided that the disk is correctly dated.
- RESULT: Timely communication and option for prompt mitigation.



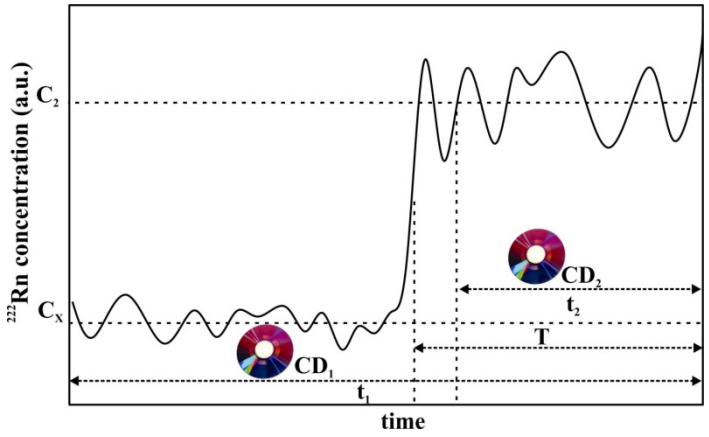
CD/DVD method in mines and caves: Cost-efficient option for passive radon monitoring in the heavy underground environment

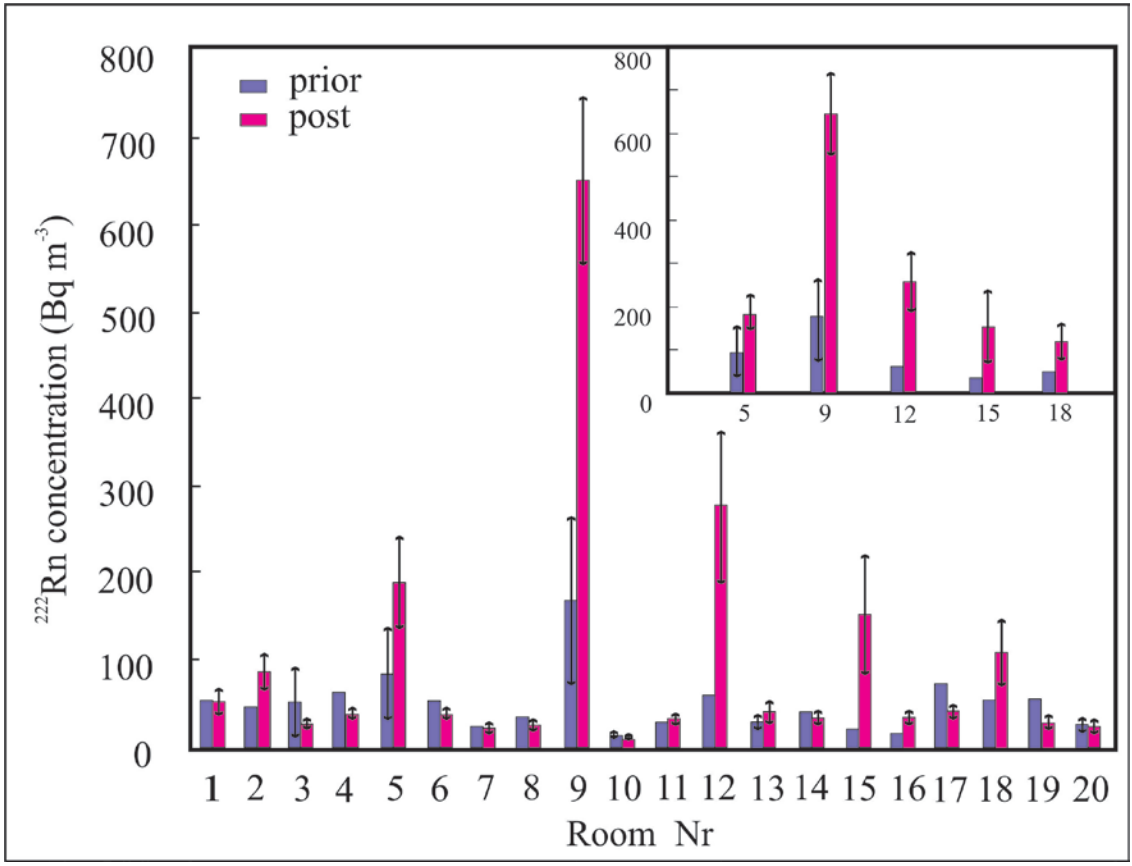


Radon in water: possibility for measurement directly in the source



CDs/DVDs and energy-efficiency retrofit: two disks of different age can be used to see retrospectively the effect of building reconstruction on radon levels (*Journal of Environmental Radioactivity* 143 (2015) 76 - 79).





The CD/DVD method within MetroRADON: Testing under extremely variable ^{222}Rn concentrations.

International Journal of
Environmental Research and Public Health

MDPI

Article

Testing and Calibration of CDs as Radon Detectors at Highly Variable Radon Concentrations and Temperatures

Dobromir Pressyanov [1,*], Luis Santiago Quindos Poncela [2], Strahil Georgiev [1], Ivelina Dimitrova [1], Krasimir Mitev [1], Carlos Sainz [2], Ismael Fuente [2] and Daniel Rabago [2]

1 Faculty of Physics, "St. Kliment Ohridski", Sofia University, 1164 Sofia, Bulgaria
2 Radon Group, University of Cantabria, 39005 Santander, Cantabria, Spain
* Correspondence: pressyan@phys.uni-sofia.bg

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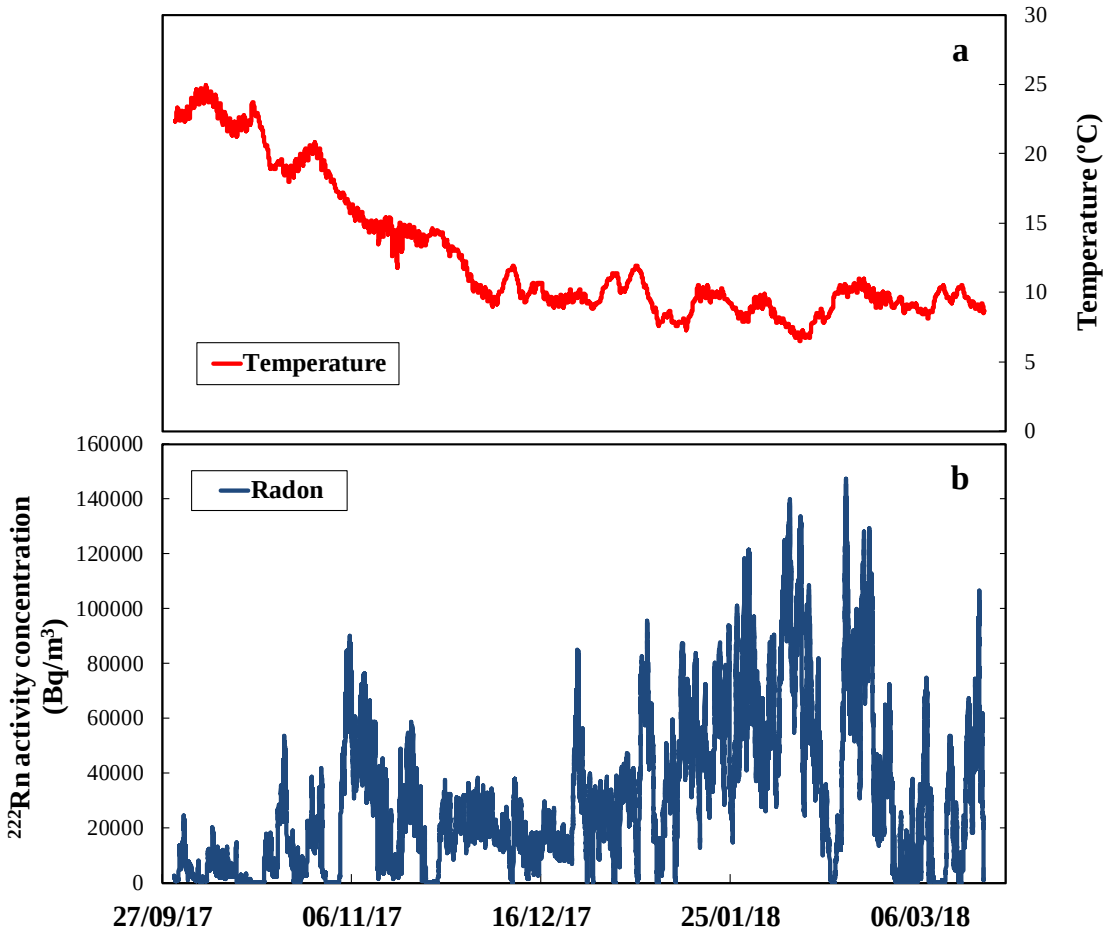
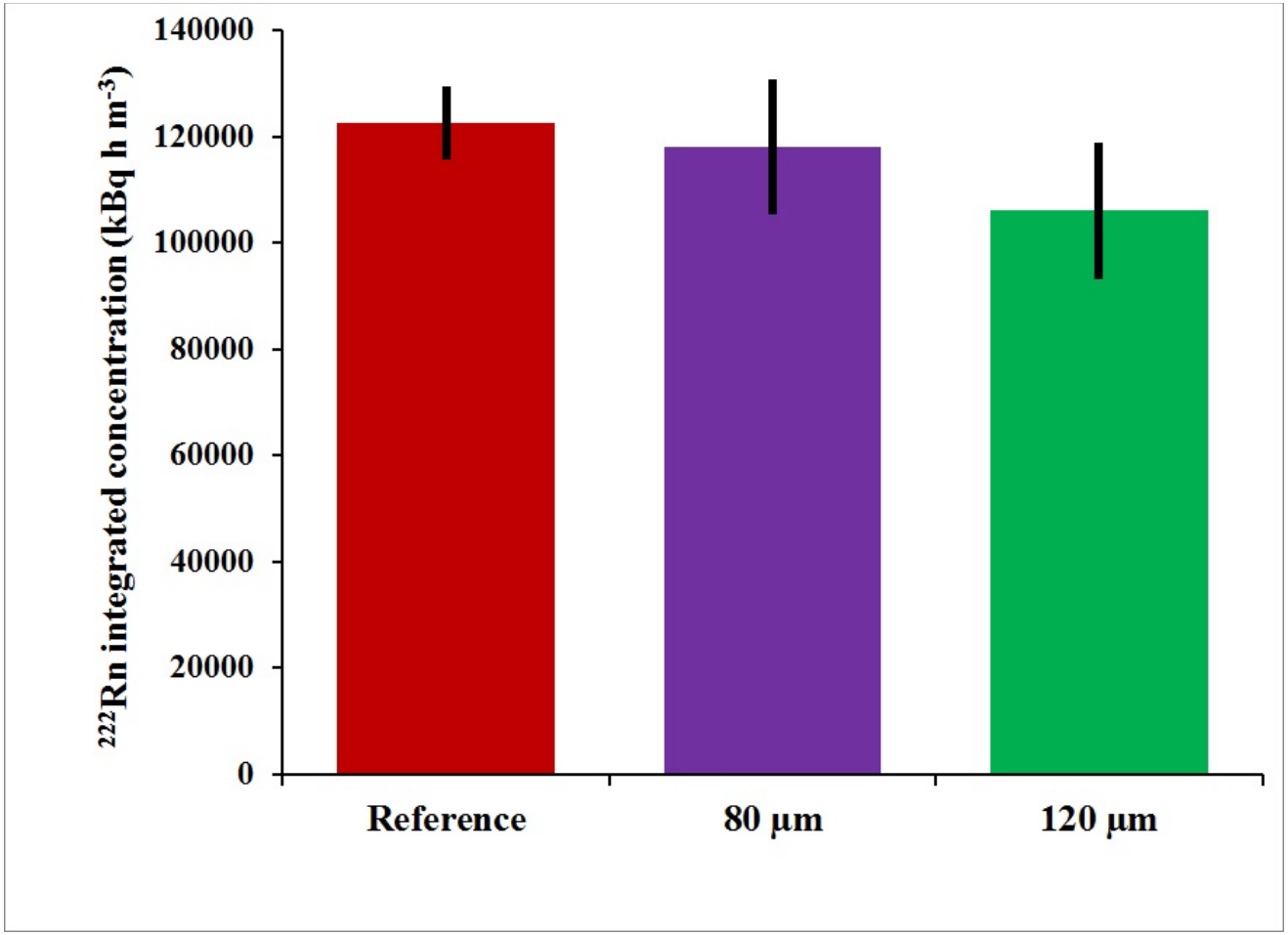
check for updates

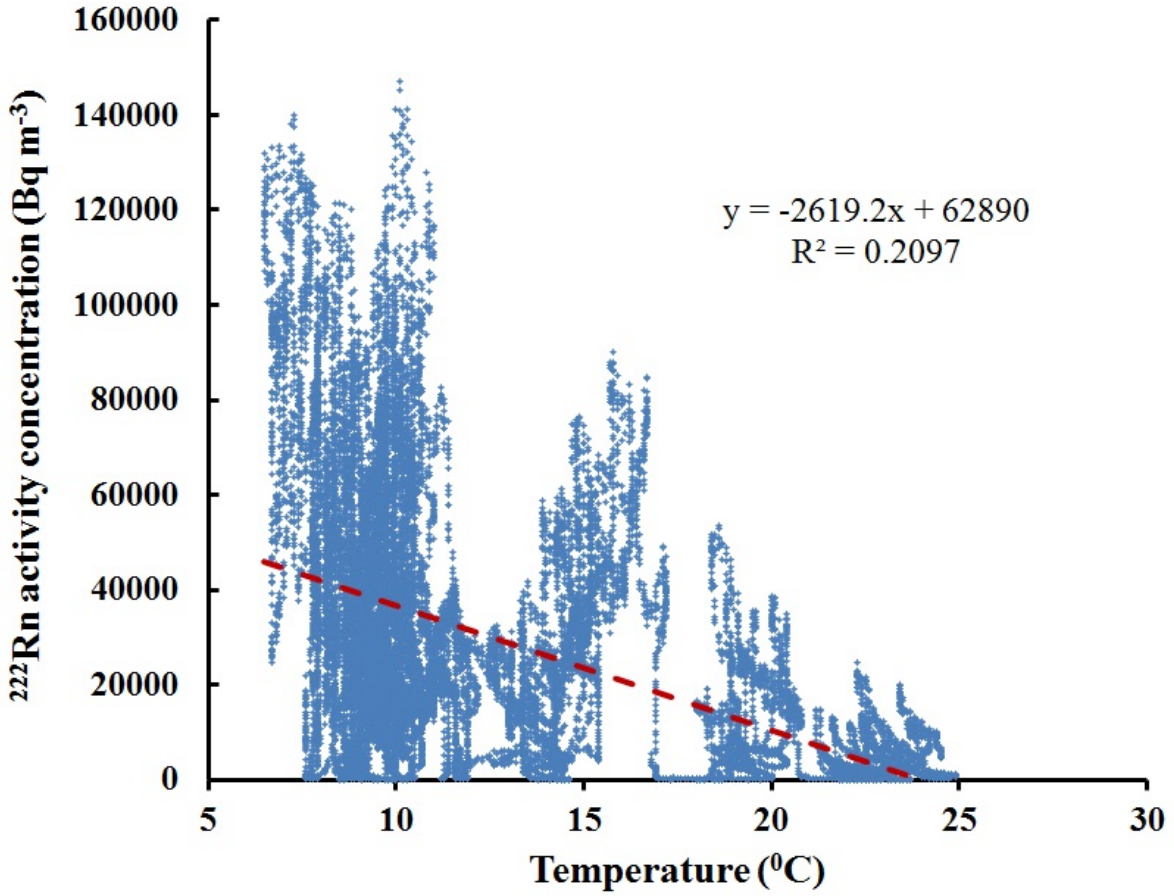
Temperature and concentration profile during the exposure



Correspondence with reference measurements



Weak correlation between ^{222}Rn concentrations and the temperature



Correction for the correlation leads to almost perfect agreement with the reference ^{222}Rn exposure

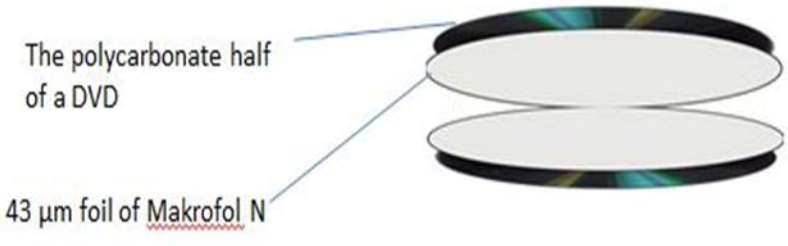
Scenario	^{222}Rn exposure (kBq h m^{-3})		
	At 80 μm	At 120 μm	Reference
With CF at 12.6 ºC	118000 ± 12000	106000 ± 12000	122500 ± 6100
With CF adjusted for real exposure	122000 ± 12000	110500 ± 12000	

Within MetroRADON and beyond: highly sensitive detection options. DVDs have a very low background on their internal polycarbonate surface

Surface with very low background: 1.1 ± 0.3 cm^{-2}

The background can be further reduced by thermal annealing and special modes of track-counting that discriminate defects different from alpha tracks

Within MetroRADON (and beyond): a novel method for passive ^{222}Rn measurements with sufficient sensitivity for use even in low background nuclear laboratories



The novel method employs DVDs-based detector modules of:

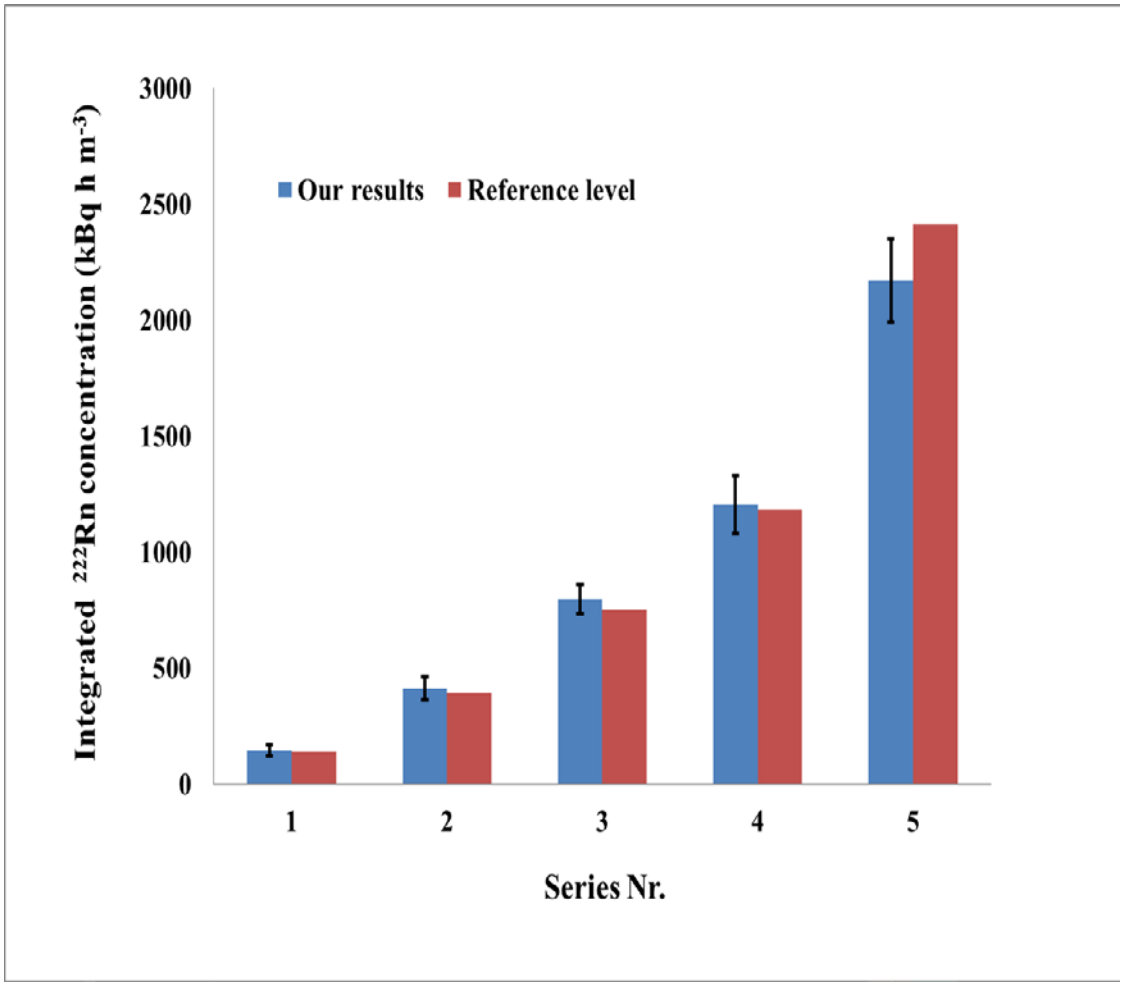
- low background ($\boldsymbol{n_B}$),
- large total detection area ($\boldsymbol{S}$)
- increased sensitivity ($\boldsymbol{CF}$)

$$MDAC = \frac{2.71+4.65\sqrt{n_B}}{CF.t.\sqrt{S}}$$

$$C_A = \frac{n - n_b}{CFT_{\exp}}$$

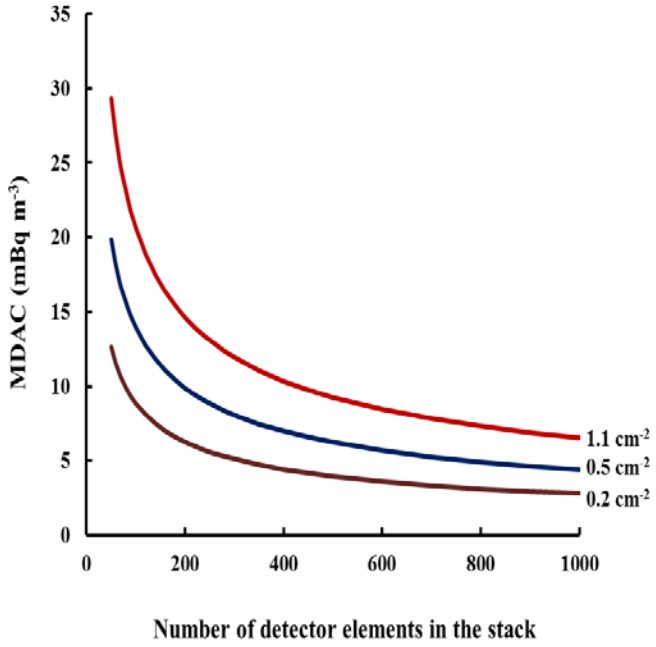
Detector element of total area of 200 cm^2

QA of the method: performance at the Public Health England (PHE-UK) 2017/2018 radon inter-comparison

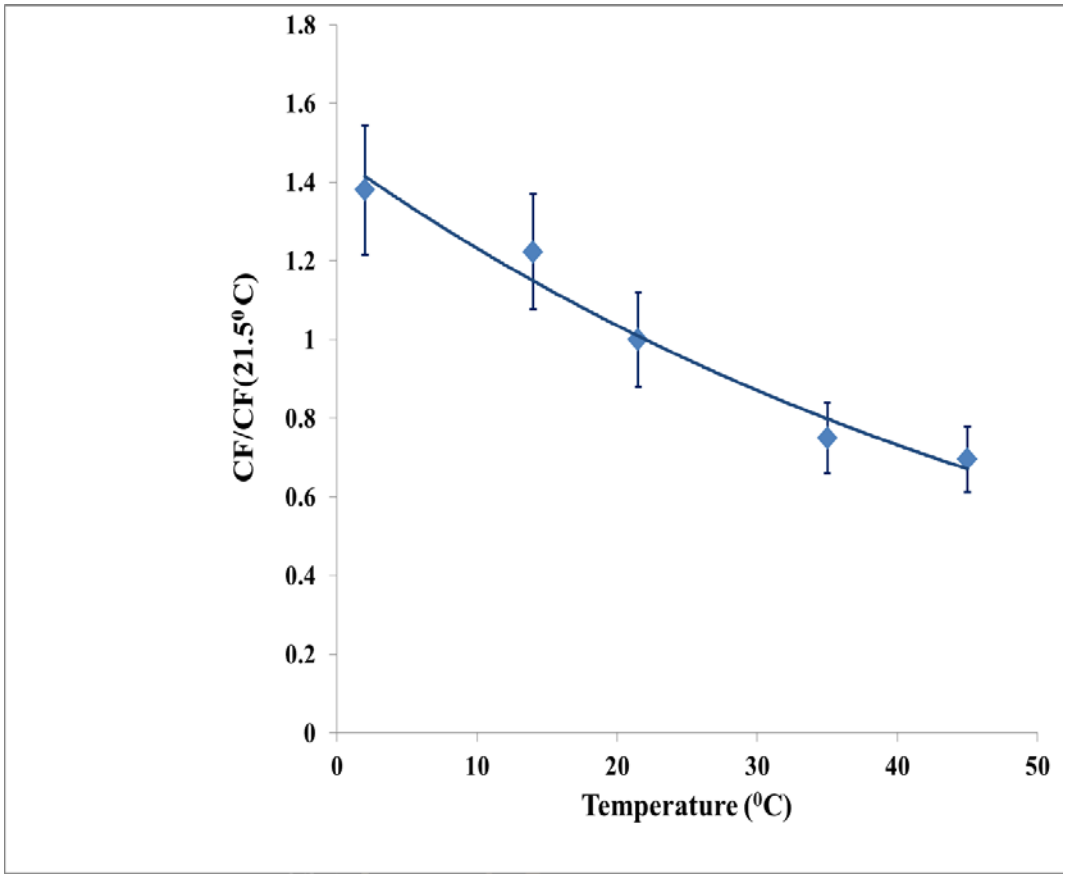


Possibility for unique sensitivity with stack of detector elements: MDAC for one year exposure (blank detectors should be stored in radon-free air)

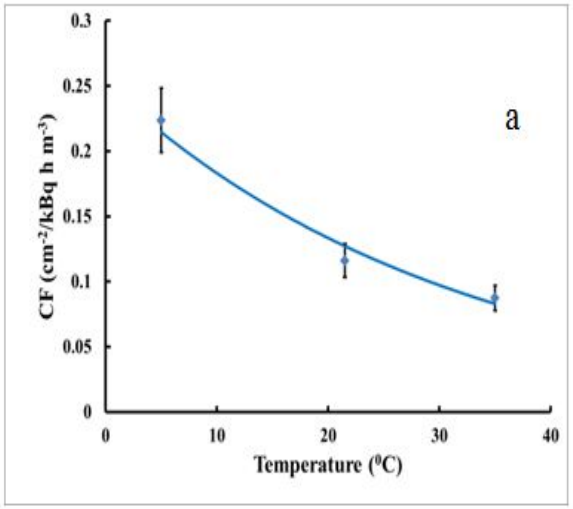
$$MDAC = \frac{2.71+4.65\sqrt{n_B}}{CF.t.\sqrt{S}}$$



The problem: substantial temperature dependence of the response…



Beyond state-of-the art: A module can be designed with *R(T)* that compensates that of *CF(T)* so that *CF*×*R* ≈ const.:



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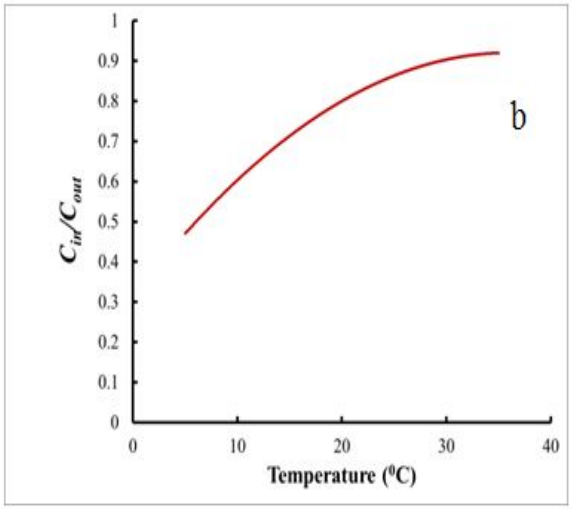

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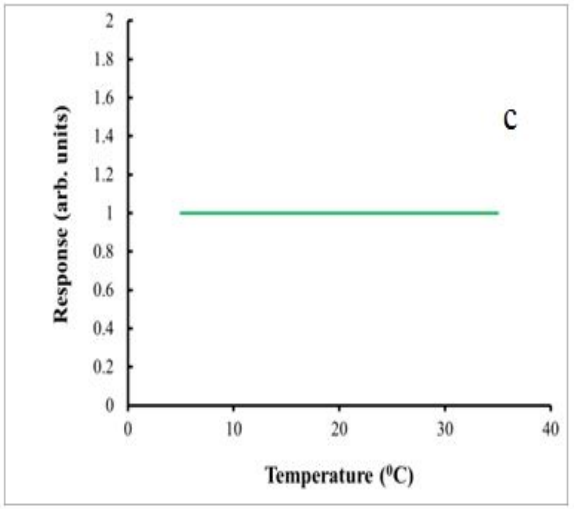
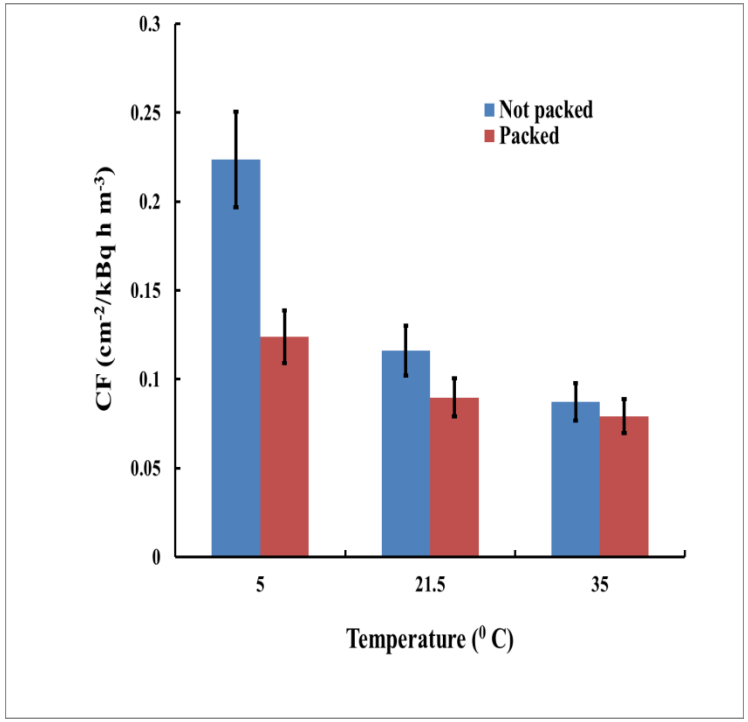


Patent application submitted (Bulg. Pat. Appl. Reg. Nr. 112897, WIPO Appl. Reg. Nr. PCT/BG2020/000003, priority: 19.03.2019. MetroRADON project was acknowledged.

Proof-of-the-concept: the “module” is a hermetic package of foil of 75 μm low density polyethylene with controlled *V/S* ratio (≈ 4 cm)

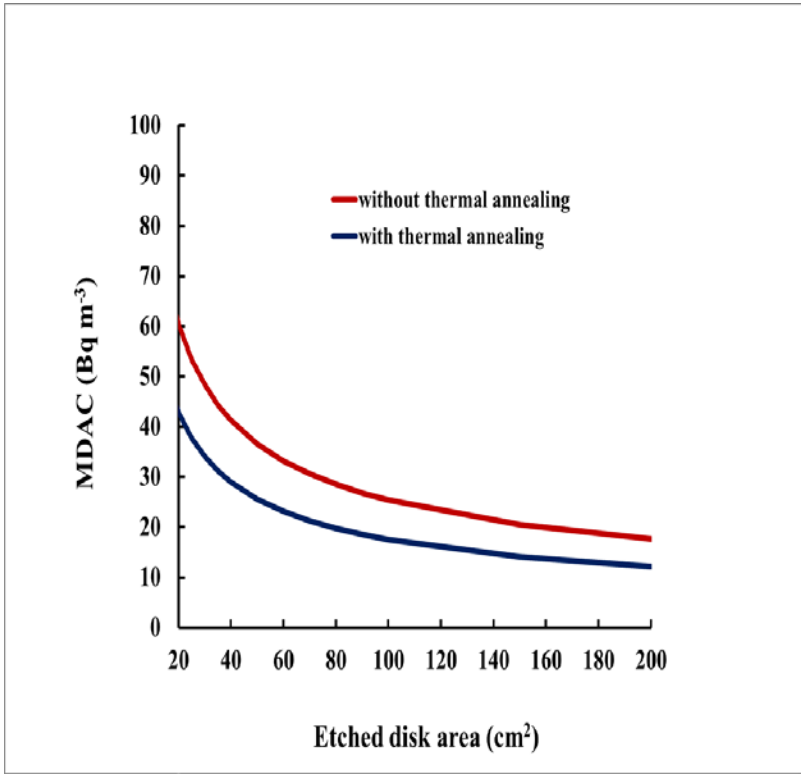
Results…



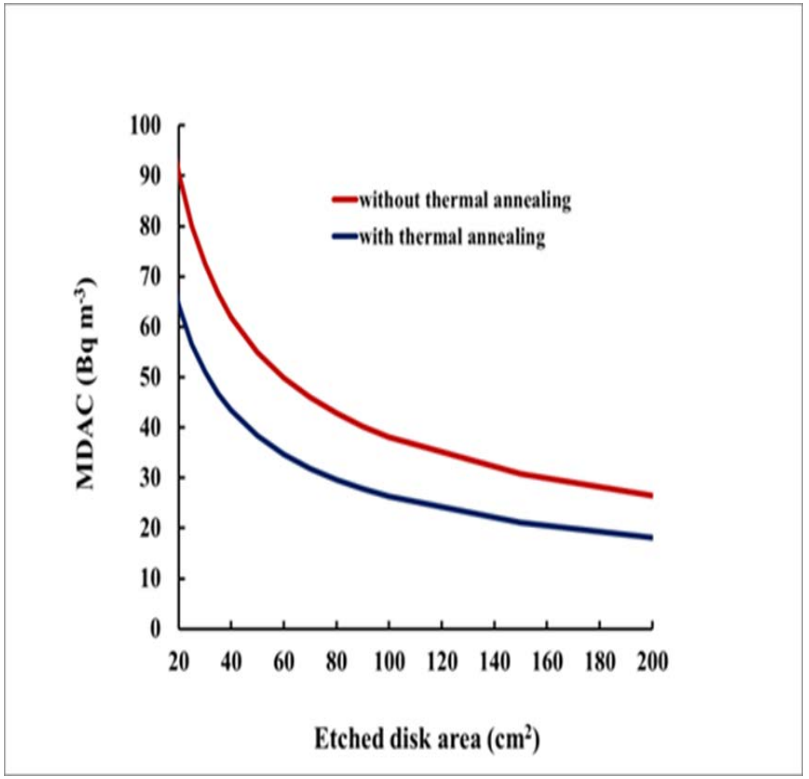
NB: The module (package) is also an effective barrier against humidity and thoron interference!

Minimum detectable activity concentration after one week exposure (disk element surface area = 200 cm^2)

Not packed detectors



Detectors packed in the compensating module



Thank you!