The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Radon metrology for use in climate change observation and radiation protection at the environmental level - traceRadon

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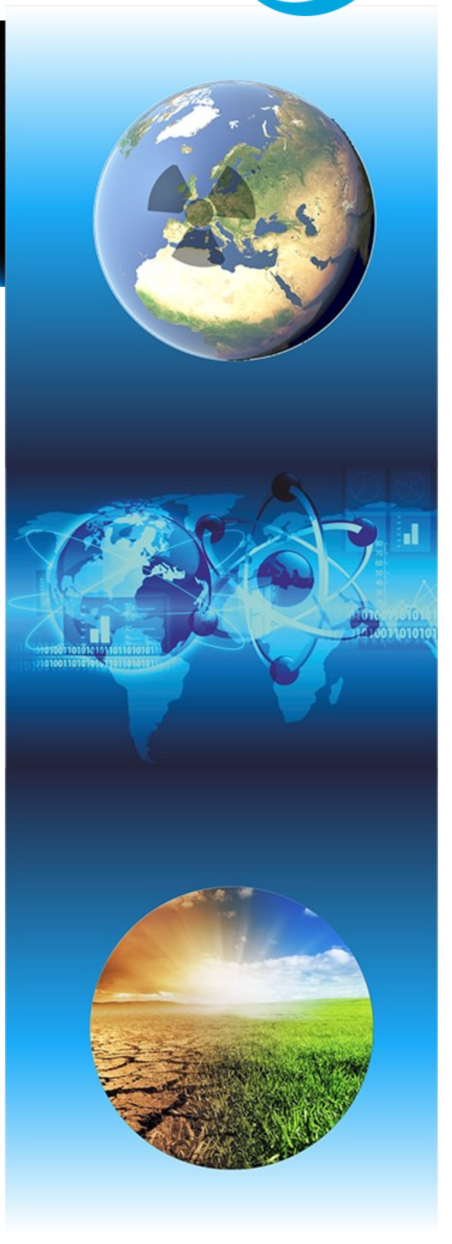
Physikalisch-Technische Bundesanstalt (PTB)

ICRM2023 at IFIN-HH in Bucharest, 2023-03-31



Metrology for climate action

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

ICRM 2023
23rd International Conference on Radionuclide Metrology and its Applications
Bucharest, Romania, 27-31 March 2023

traceRadon

EURAMET

Theme 2: Accuracy requirements for atmospheric composition measurements across economic sectors, and temporal and spatial scales

Pre-recorded presentations

- Primary Standards, Reference Materials, and Uncertainty Analysis for the Measurement of Greenhouse Gases by Mrs./Ms. Christina Cecelski (T2-A1)
- From greenhouse gas fluxes to early warning networks: The importance of radioactive tracers by Dr. Annette Röttger (T2-A2)
- Accurate measurements of greenhouse gases – what we can learn from over 100 audits in 25 years by Dr. Christoph Zellweger (T2-A3)
- Meeting the deman… e gas re… bservat…
- Quantifying rel… ve… -A5
- Developments … re… by
- Calibration of … tu… pe
- Key role of pu… as … S
- Developing Gu… m… s (
- Accelerated te… tio… ar
- Innovative con… s: …)
- Evaluation of s… ne…
- Assessment o… ES… F.
- Quantifying co… 02… co… ang (T2-A14)

From greenhouse fluxes and to early warning networks:

The importance of radioactive tracers

traceRadon partners and collaborators:

PTB, Germany; BFKH, Hungary; CMI, Czech Republic; ENEA, Italy; IFIN-HH, Romania; NPL, United Kingdom; VINS, Serbia; AGES, Austria; CLOR, Poland; INESC TEC, Portugal; JRC, European Commission; LUND, Sweden; SUJCHBO, Czech Republic; UC, Spain; UoB, United Kingdom; UPC, Spain; IDEAS, Hungary; UVSQ, France; Universität Heidelberg, Germany; ANSTO, Australia's Nuclear Science and Technology Organisation, Australia; ERA, European Radon Association, Europe; Met Office, United Kingdom; University of Novi Sad, Serbia; Politecnico di Milano, Italy; University of Codoba, Spain; EURADOS, e.V., Europe; Universität Siegen, Germany; IRSN, France; ARPA Piemonte, Italy; ARPA Valle d'Aosta, Italy;

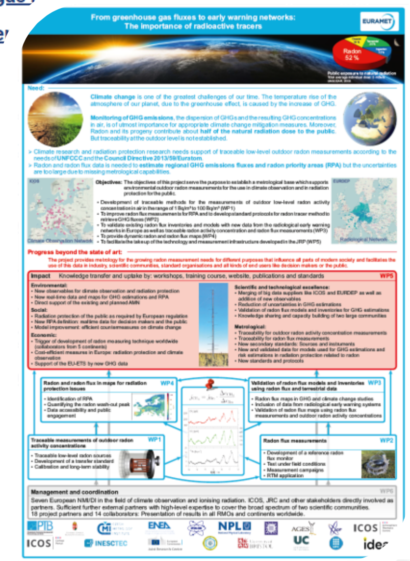
One of the world's greatest challenges lies in combating climate change. Alongside this, the issue of radiological safety seemed less prominent for a long time, but the radioactive tracer "radon" combines both challenges. This brought together different scientific branches with a common need: new metrology for the determination of greenhouse gas fluxes and for the improvement of ambient dose monitoring networks in the environment.

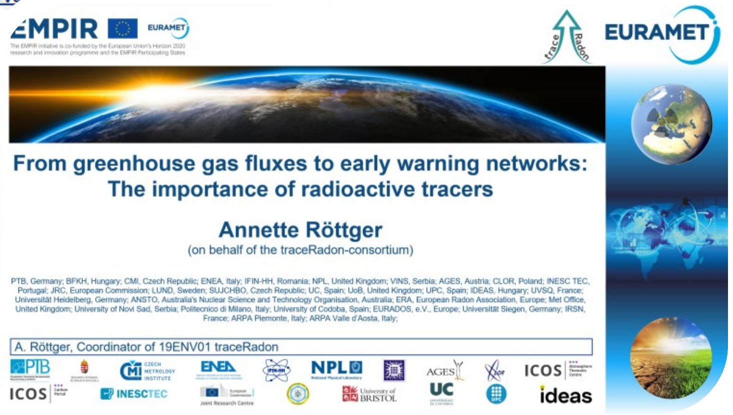
Political decisions need valid data. Implementing expensive measures, whether in climate protection or radiation protection, always means the need to make the success of these measures measurable. Can metrology make its contribution here?

The consortium of the traceRadon[1] project has taken up this challenge by looking for suitable metrics that could enable an assessment. This brought the radioactive noble gas radon into focus, knowing full well that the metrology for its trace measurement in the atmosphere has been lacking up to now. Making measurable what was not measurable before, providing trustworthy data where there was no comparability before and thus paving the way for new approaches like the radon tracer method (RTM) is a promising way for the joint work of WMO and BIPM to solve the most pressing issues of the future.

The traceRadon project shows what is possible when we bring our competencies together. New SI traceability chains for measurement quantities used in climate observation and radiation protection were developed, new customer calibration services for new types of measurement and new types of devices are made available. A first standard protocol for the application of the radon tracer method (RTM) to enable retrieval of greenhouse gas fluxes at atmospheric climate gas monitoring stations and to use radon flux data for the identification of Radon Priority Areas (RPA) is in finalization. Current radon flux models and inventories are validated, while new traceable measurements of radon activity concentration and radon flux are supported by dosimetric and spectrometric data from the radiological early warning networks in Europe for the first time. As a further outcome easy to use dynamic radon and radon flux maps for climate change research and radiation protection in line with Council Directive 2013/59/EURATOM, including their use to identify RPA and radon wash-out peaks are in the formation.

[1] This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating Stat… and from the European Union's Horizon 2020 research and innovation programme.





Bureau International des Poids et Mesures

WORLD METEOROLOGICAL ORGANIZATION

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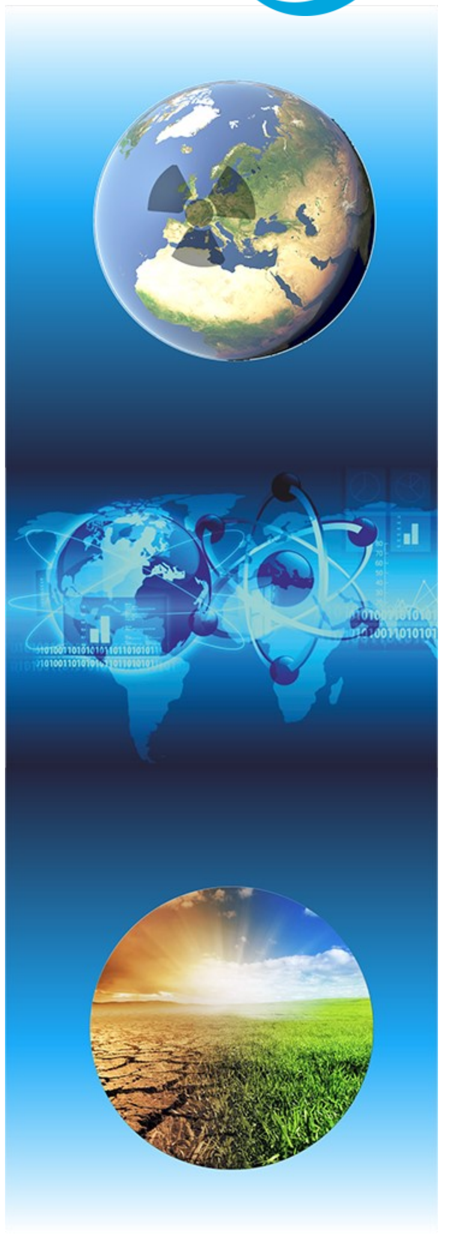
Partners



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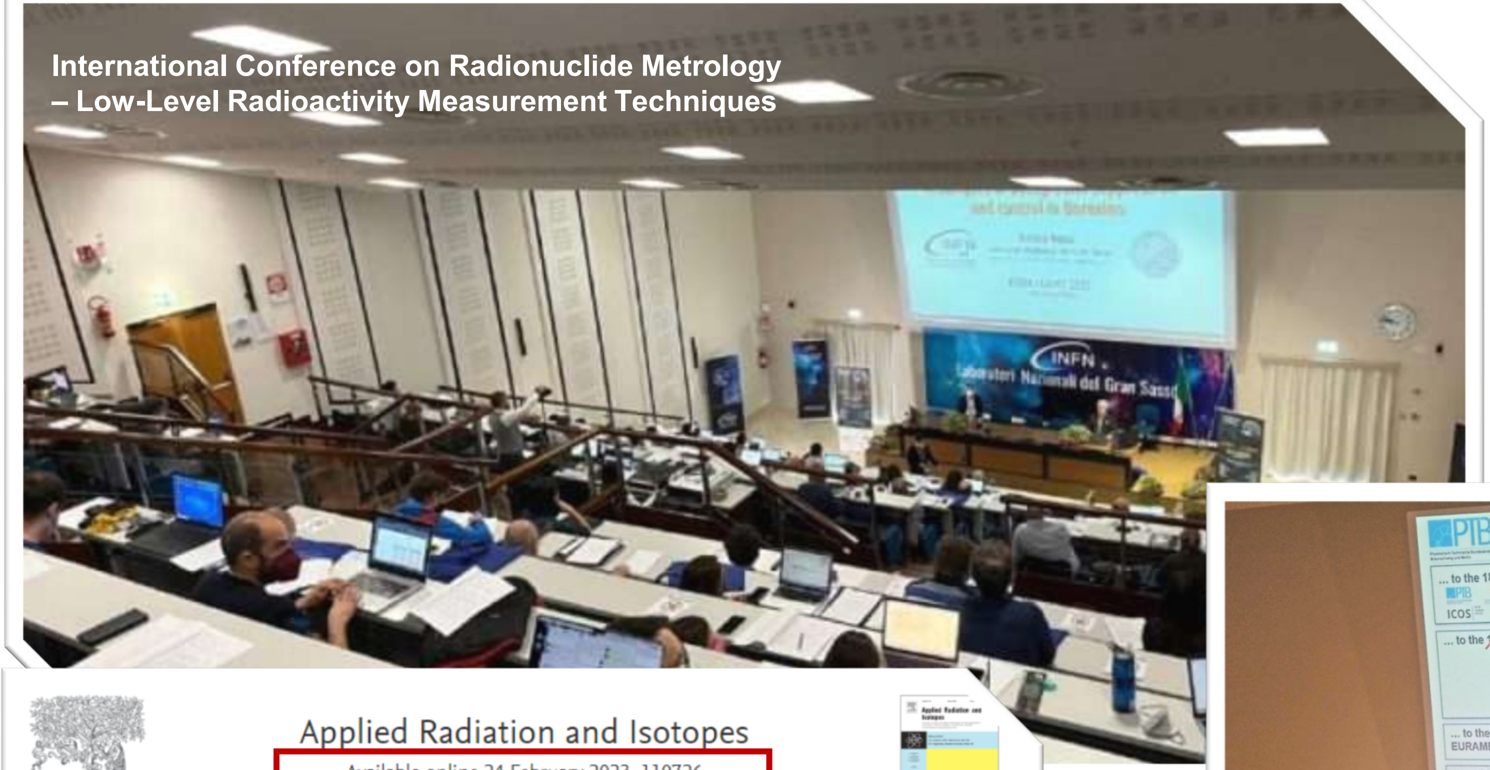
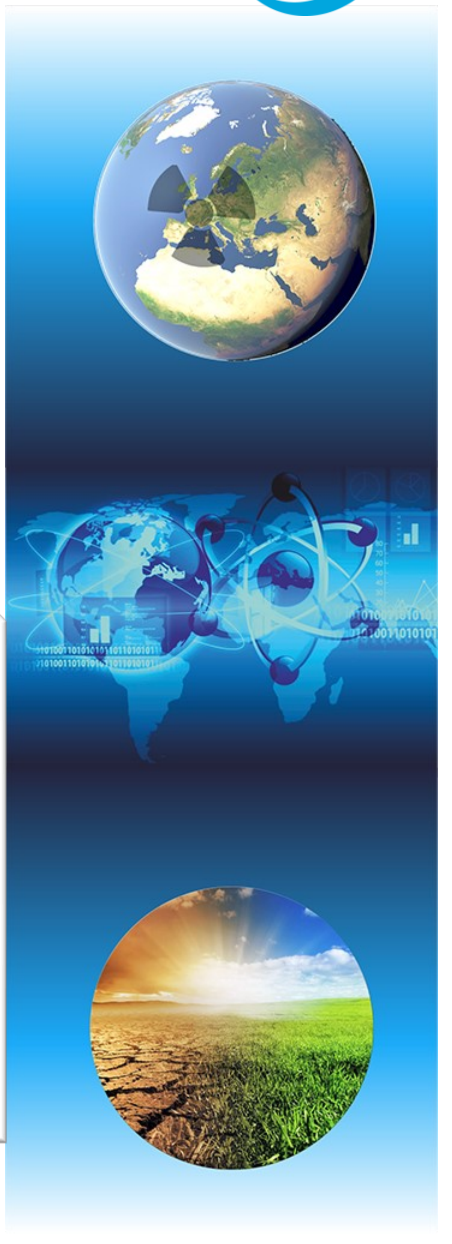


ELSEVIER
Applied Radiation and Isotopes
Available online 24 February 2023, 110726
In Press, Journal Pre-proof ? What's this?

Evolution of traceable radon emanation sources from MBq to few Bq

Stefan Röttger [a], Annette Röttger [a], Florian Mertes [a], Viacheslav Morosch [a], Tanita Ballé [a],
...t Chambers [b]

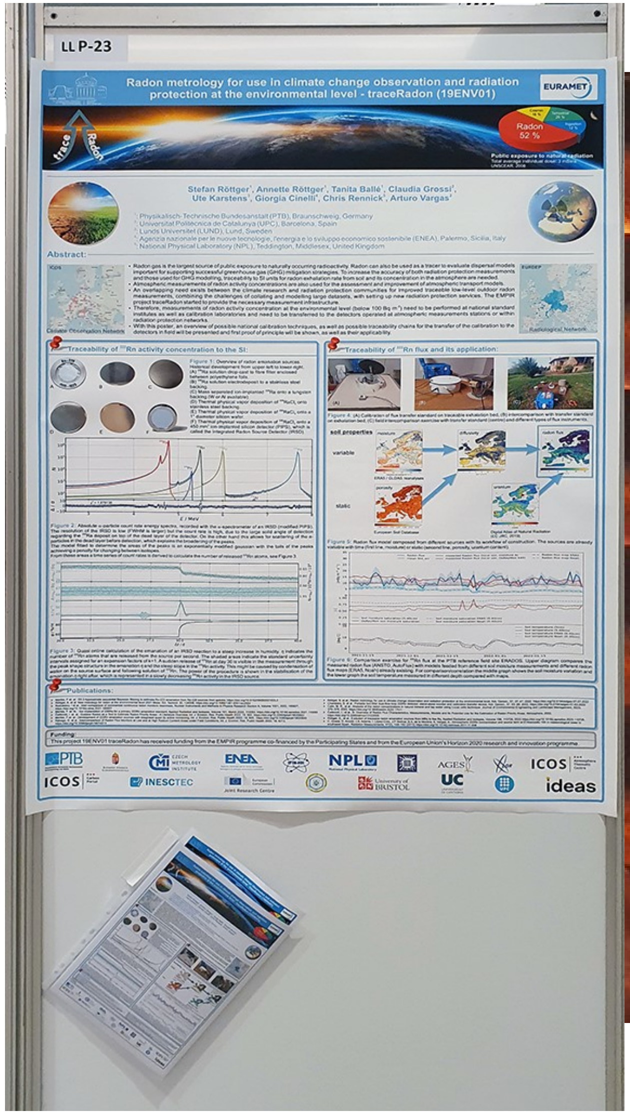
ICRM - LLRMT

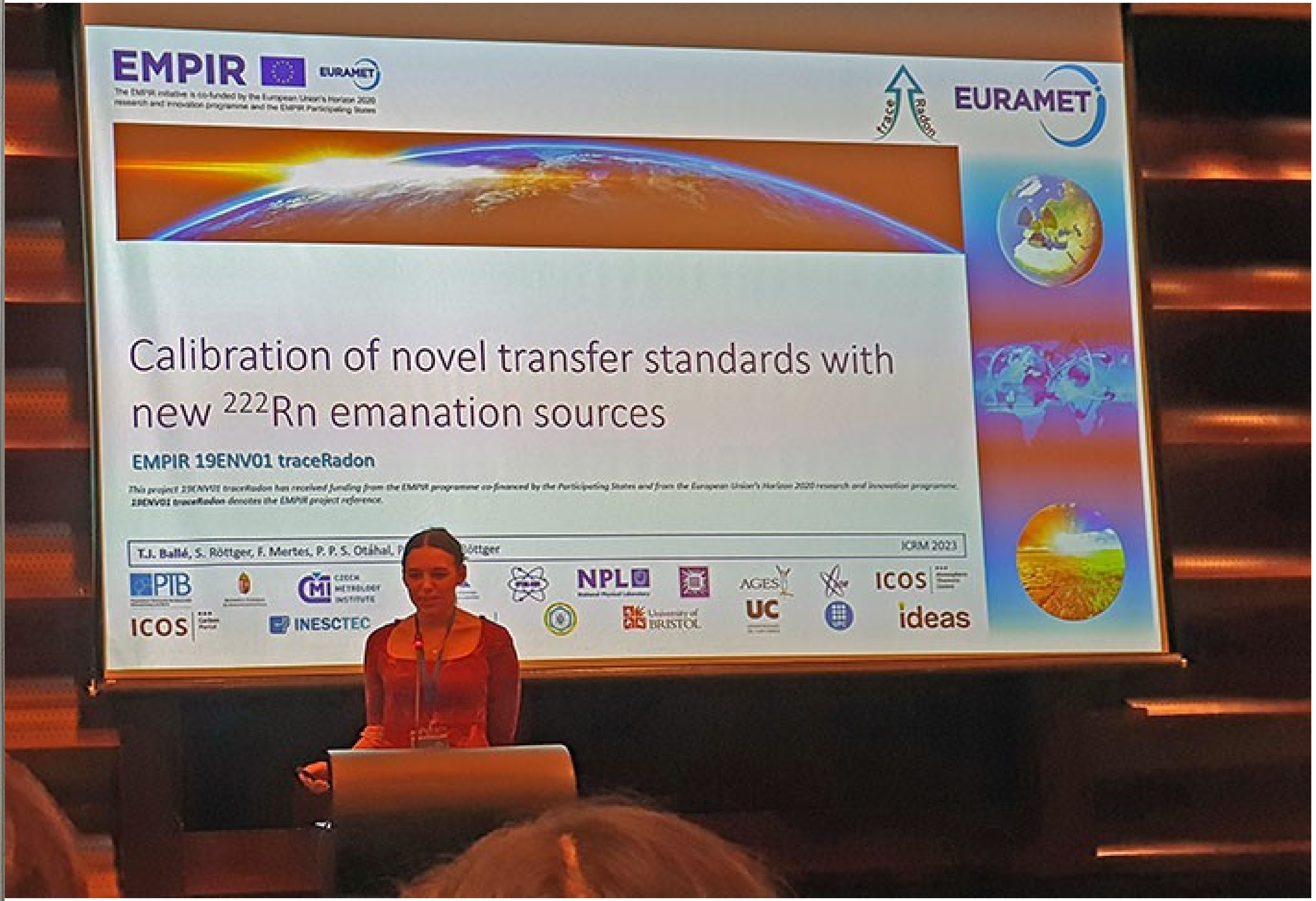


ICOS Scientific Conf. 2022

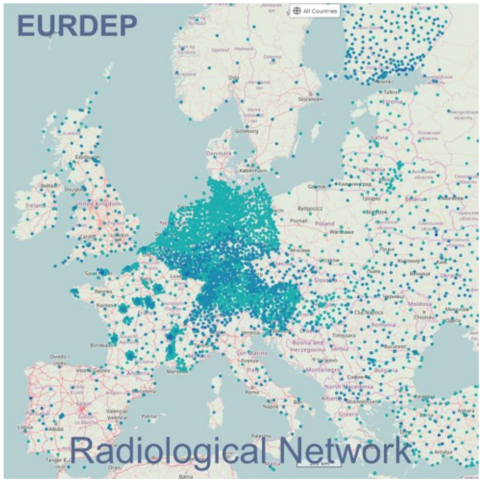
https://www.icos-cp.eu/event/1242

ICRM Conf. 2023





Introduction – Why ?

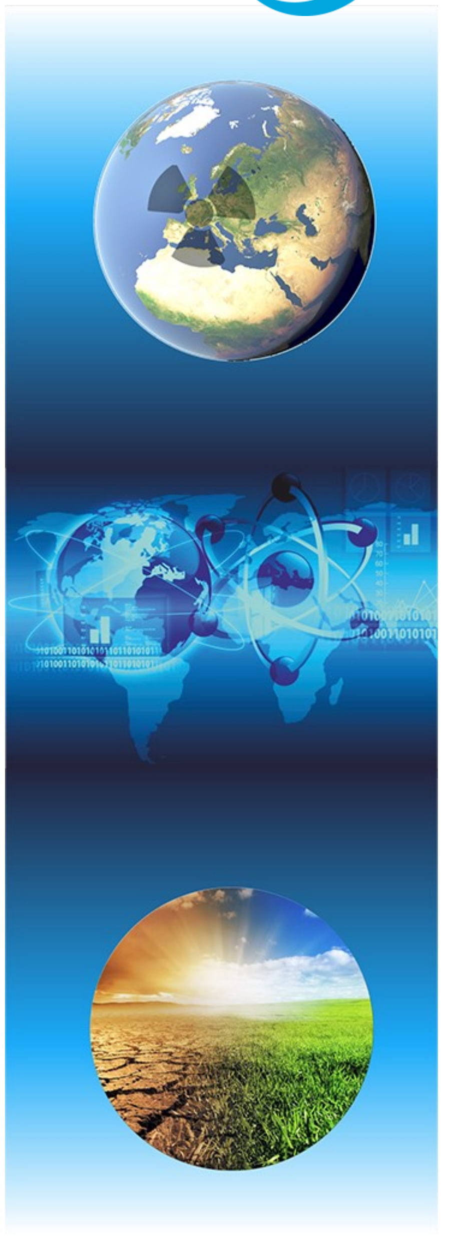


Climate change is one of the greatest challenges of our time.

The temperature rise of the atmosphere of our planet, due to the greenhouse effect, is caused by the increase of GHG emissions.

- ICOS: Monitoring of GHG emissions, the dispersion of GHGs and the resulting GHG concentrations in air, is of utmost importance for appropriate climate change mitigation measures.
- EURDEP: Collection and exchange of radiological monitoring data between participating countries of the radiation in the environment.

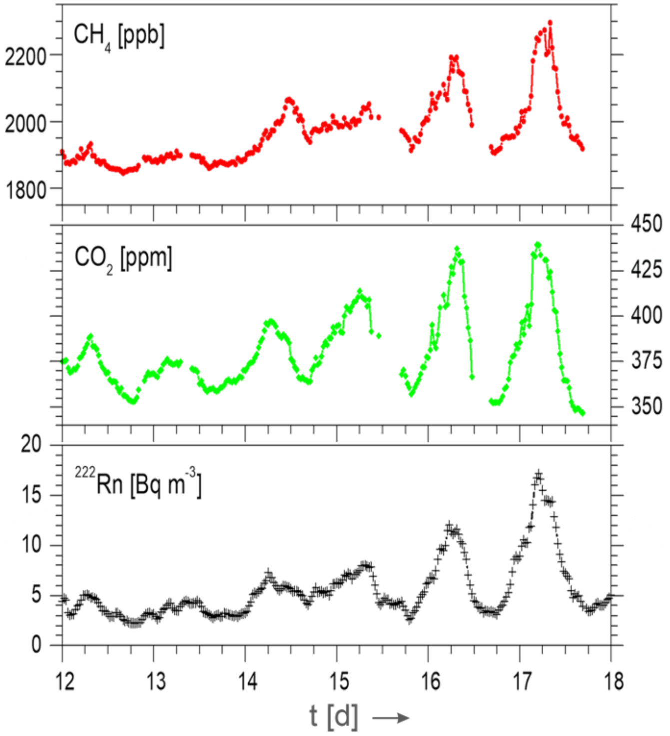
Both networks could profit from radon measurements at the outdoor level. But **traceability to the SI system** is not established yet.



Introduction – For whom?

Why is Radon an issue in **climate observation**?

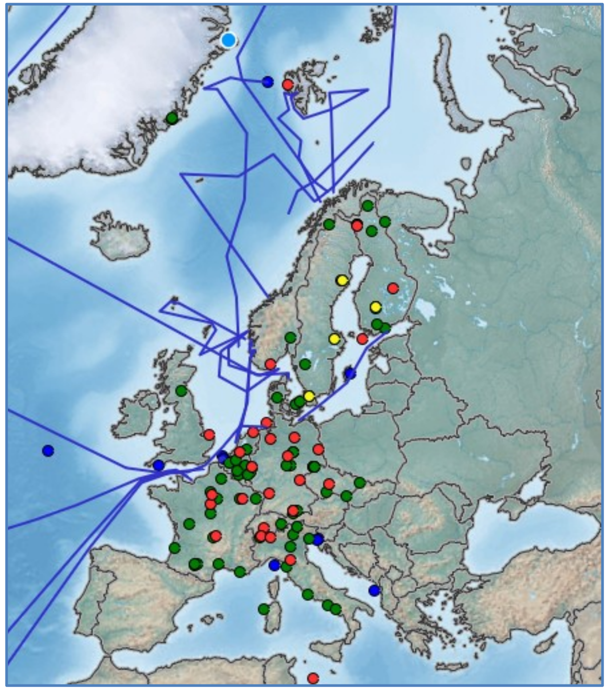
- GHG **flux measurements** are difficult though GHG concentration measure-ments are established.
- With radon activity concentration and radon flux measurements GHG fluxes can be **traced**!

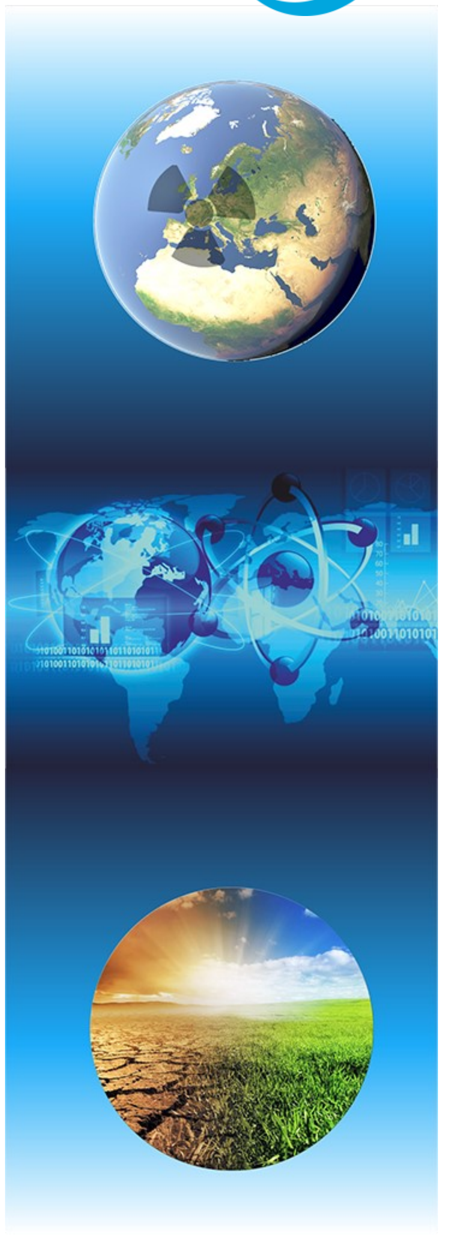


ICOS Atmospheric Station Specifications:

Radon monitor: "At the present stage, Radon-222 measurements are not mandatory in ICOS. However, Radon-222 is recognized as a very valuable measurement, in particular for trace gas flux estimates."

- Determine source terms of GHG





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Introduction – What ?

ICRM 2023 23rd International Conference on Radionuclide Metrology and its Applications | Bucharest Romania 27-31 March 2023

traceRadon

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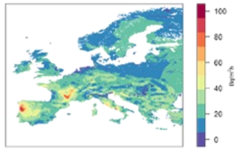
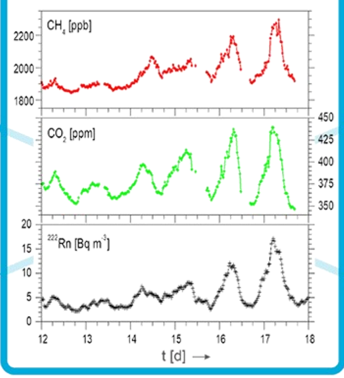
Traceability to the SI system

Radon and radon flux in maps for radiation protection issues — WP4

- Identification of RPA
- Quantifying the radon wash-out peak
- Data accessibility and public engagement



$$j_{CH_4} = j_{Rn} \cdot \frac{\Delta c_{CH_4}}{\Delta c_{Rn}}$$

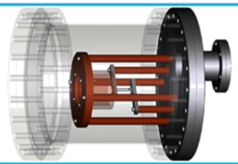


Validation of radon flux models and inventories using radon flux and terrestrial data — WP3

- Radon flux maps in GHG and climate change studies
- Inclusion of data from radiological early warning systems
- Validation of radon flux maps using radon flux measurements and outdoor radon activity concentrations

Traceable measurements of outdoor radon activity concentrations — WP1

- Traceable low-level radon sources
- Development of a transfer standard
- Calibration and long-term stability



Radon flux measurements — WP2

- Development of a reference radon flux monitor
- Test under field conditions
- Measurement campaigns
- RTM application

Management and coordination — WP6

Seven leading European NMI/DI in the field of climate observation and ionising radiation. ICOS, JRC and other stakeholders directly involved as JRP-partners. Sufficient further external partners with high-level expertise to cover the broad spectrum of two scientific communities. High interest by stakeholder community, expressed by 65 letters of support and a large group of 34 potential collaborators.

Radon Tracer Method

1. To develop traceable methods for the measurement of **outdoor low-level radon activity concentration** in the range of **1 Bq m^{-3} to 100 Bq m^{-3}**, with uncertainties of **10 % for k = 1**, to be used in climate monitoring (…) .
2. To develop the capability for traceable **radon flux measurements in the field**, based on the development of a radon exhalation reference system “exhalation bed” and a transfer standard (…) .

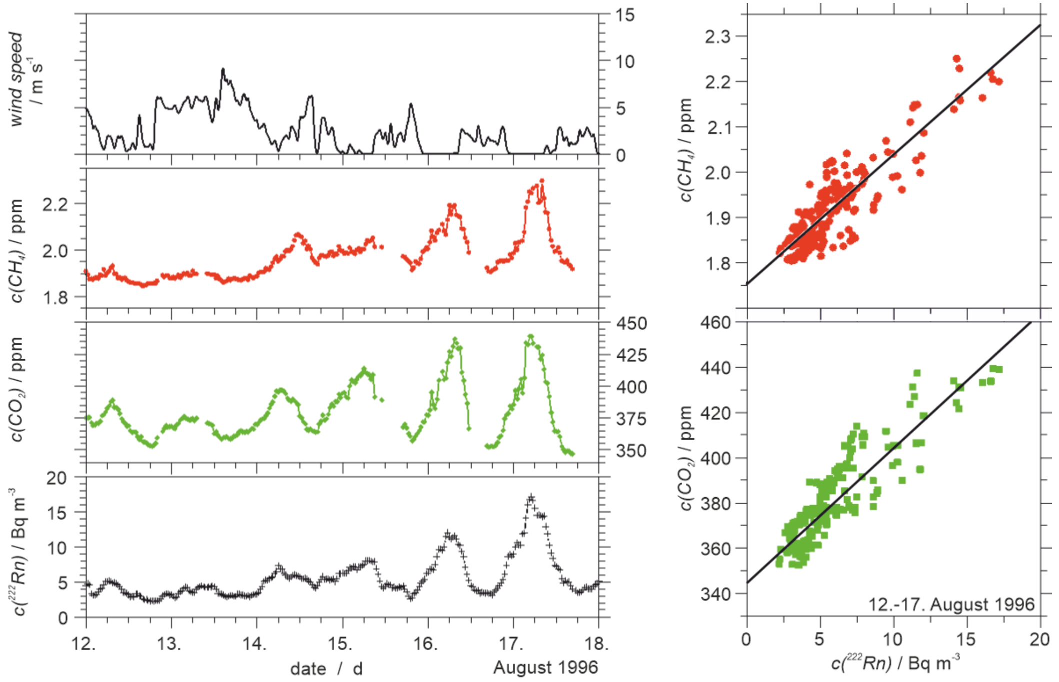
Flux ⟷ Concen-tration

$$j_{\mathrm{CH_4}} = j_{\mathrm{Rn}} \cdot \frac{\Delta c_{\mathrm{CH_4}}}{\Delta c_{\mathrm{Rn}}}$$

3. To **validate current radon flux models and inventories** by the new traceable measurements of radon activity concentration and radon flux (…).

^{222}Radon and climate

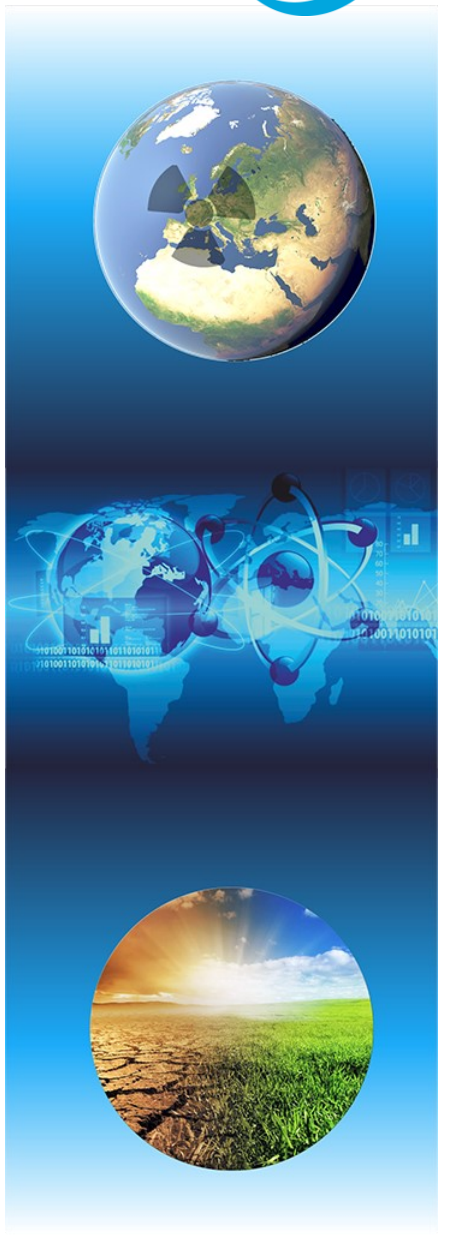
- ^{222}Rn is generated in the ground and takes part in atmospheric transport processes, but has only one well-defined sink (radioactive decay) because it is inert
  - Temporal / spatial distribution is determined by atmospheric transport
  - *Ideal proxy / tracer for modeling atmospheric processes*
  - Validation / improvement of transport models



Röttger et.al. Strahlenschutzpraxis 2021

Radon Tracer Method (RTM):

- The strength of the correlation allows the GHG fluxes to be estimated when the radon flux is known
- Comparability only with traceable calibration!



1: New activity standards

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https://doi.org/10.5194/adgeo-57-37-2022

Advances in Geosciences
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Radon metrology for use in climate change observation and radiation protection at the environmental level

Stefan Röttger[1], Annette Röttger[1], Claudia Grossi[2], Arturo Vargas[2], Ute Karstens[3], Giorgia Cinelli[4], Edward Chung[5,6], Dafina Kikaj[5], Chris Rennick[5], Florian Mertes[1], and Ileana Radulescu[7]

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[4]European Commision, Joint Research Centre, Ispra 21027, Italy
[5]National Physical Laboratory, Teddington, Middlesex, TW11 0LW, United Kingdom
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Correspondence: Stefan Röttger (stefan.roettger@ptb.de)

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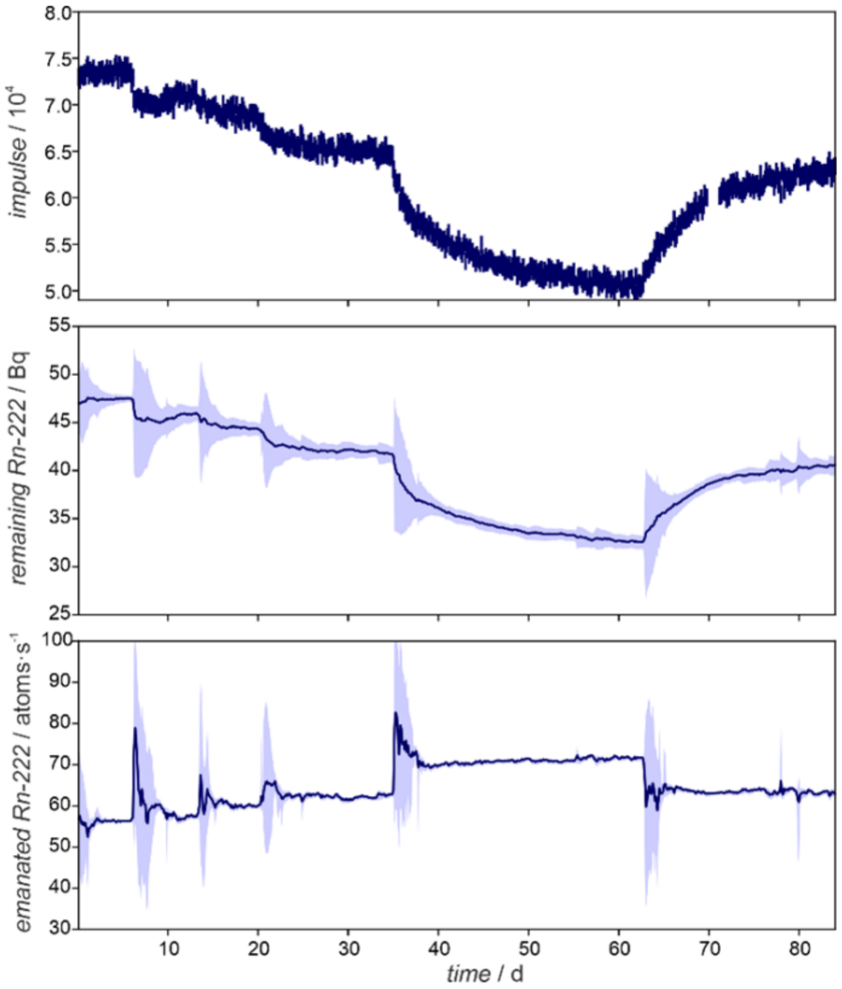
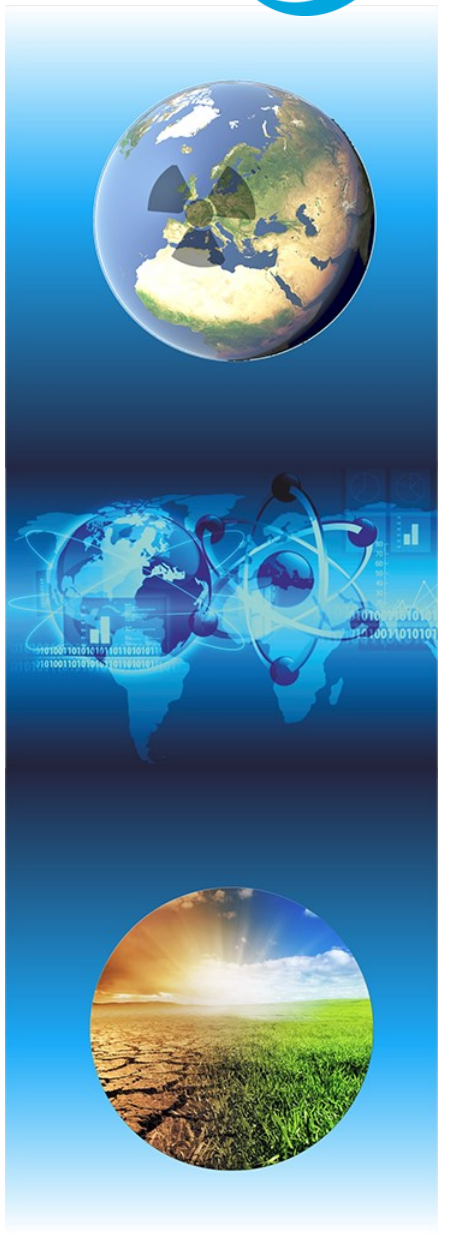


https://adgeo.copernicus.org/articles/57/37/2022/adgeo-57-37-2022.pdf



2: Extending the range

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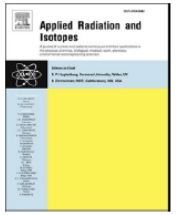
Applied Radiation and Isotopes 196 (2023) 110726

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

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



Evolution of traceable radon emanation sources from MBq to few Bq

Stefan Röttger [a,*], Annette Röttger [a], Florian Mertes [a], Viacheslav Morosch [a], Tanita Ballé [a], Scott Chambers [b]

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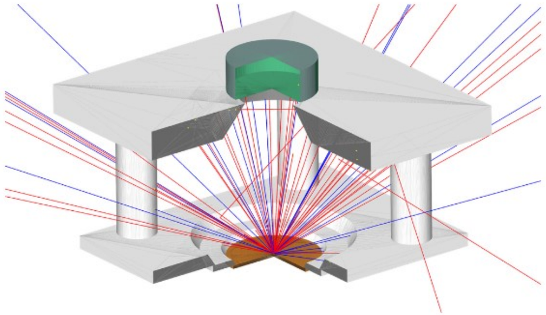

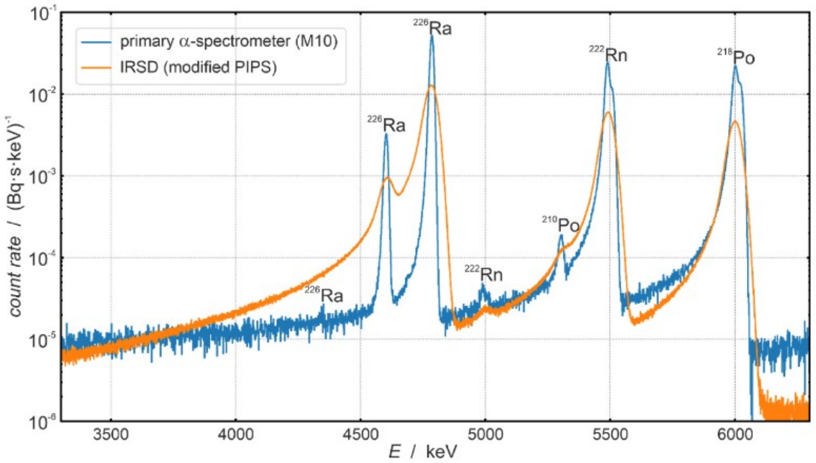

3: New calibrations

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Measurement Science and Technology
Meas. Sci. Technol. 32 (2021) 124008 (13pp) https://doi.org/10.1088/1361-6501/ac298d

New metrology for radon at the environmental level

Annette Röttger[1,*], Stefan Röttger[1], Claudia Grossi[2], Arturo Vargas[2], Roger Curcoll[2], Petr Otáhal[3], Miguel Ángel Hernández-Ceballos[4], Giorgia Cinelli[5], Scott Chambers[6], Susana Alexandra Barbosa[7], Mihail-Razvan Ioan[8], Ileana Radulescu[8], Dafina Kikaj[9], Edward Chung[9,10], Tim Arnold[9,10], Camille Yver-Kwok[11], Marta Fuente[11], Florian Mertes[1] and Viacheslav Morosh[1]

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[8] Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, 077125 Magurele, Romania
[9] National Physical Laboratory, Teddington, Middlesex, United Kingdom
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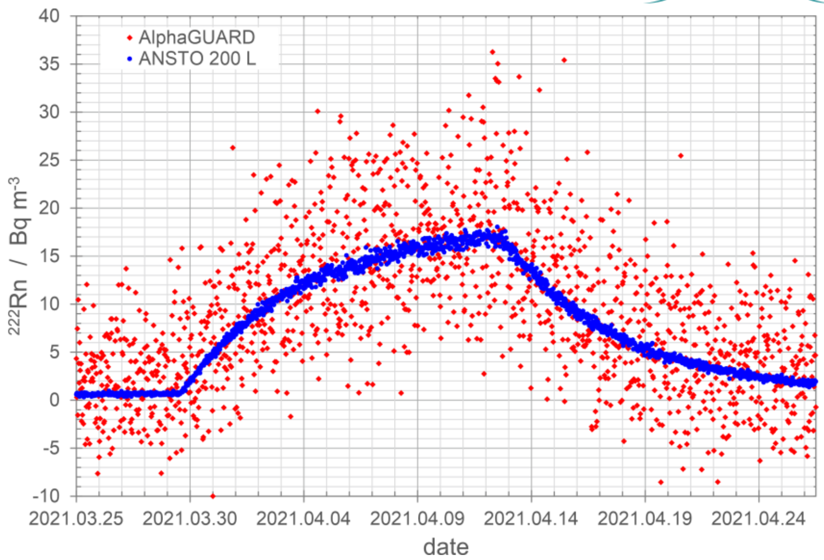

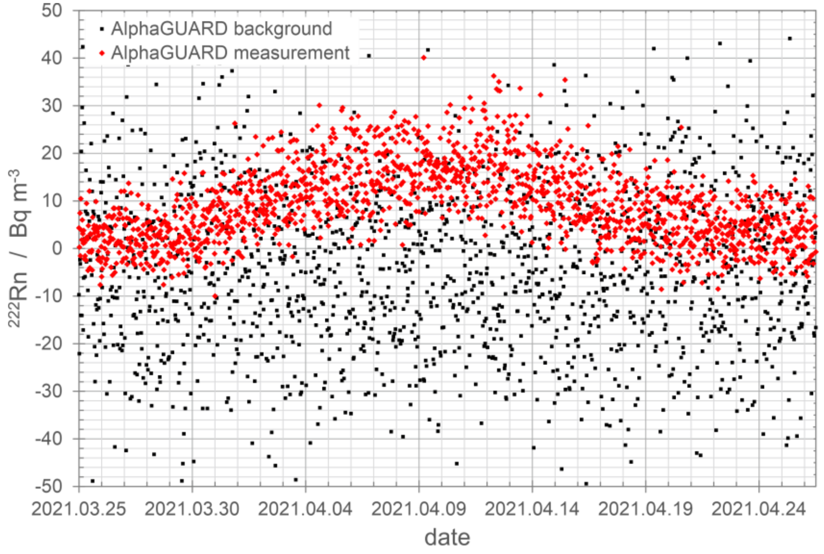

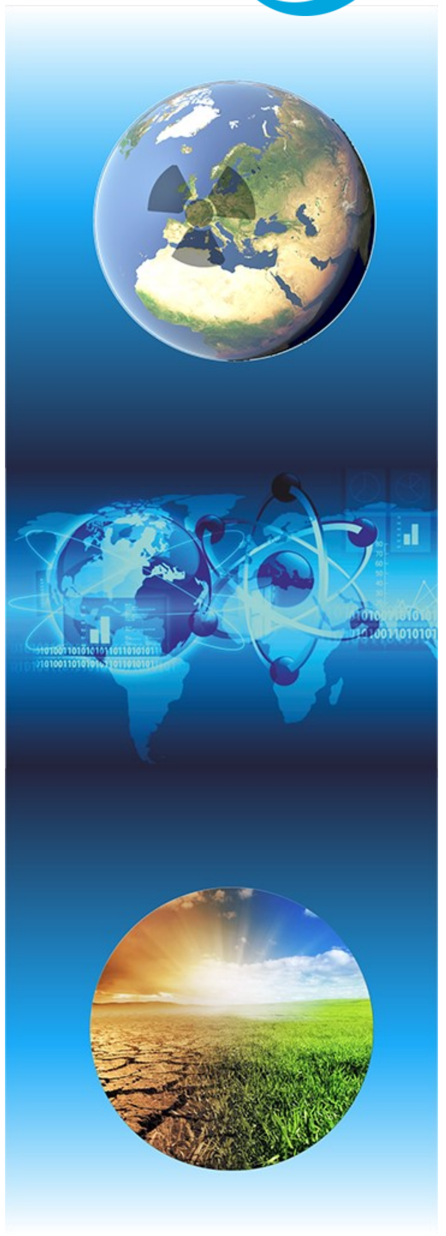

https://iopscience.iop.org/article/10.1088/1361-6501/ac298d

4: New comparisons

Nuclear Inst. and Methods in Physics Research, A 1021 (2022) 165927

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

Inter-comparison of commercial continuous radon monitors responses

I. Radulescu [a,*], M.R. Calin [b], A. Luca [a], A. Röttger [c], C. Grossi [d,e], L. Done [f], M.R. Ioan [a]

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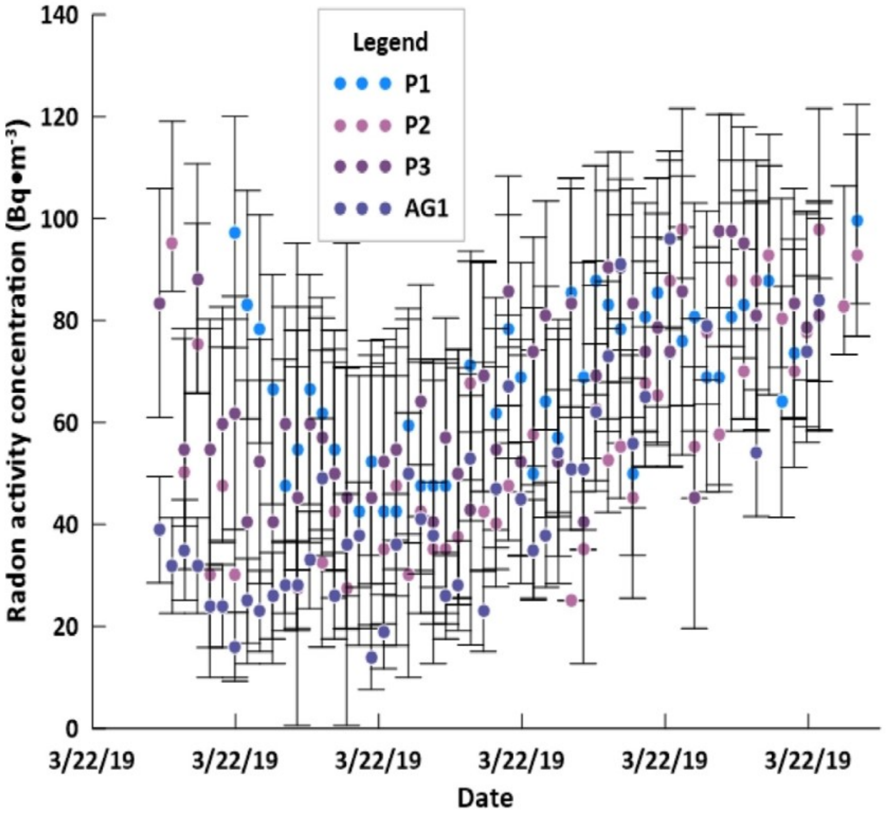
https://doi.org/10.1016/j.nima.2021.165927



5: Advanced technology

Applied Radiation and Isotopes 181 (2022) 110093

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

Check for updates

Ion implantation of ^{226}Ra for a primary ^{222}Rn emanation standard

Florian Mertes[a,*], Nina Kneip[b], Reinhard Heinke[b], Tom Kieck[b], Dominik Studer[b], Felix Weber[b], Stefan Röttger[a], Annette Röttger[a], Klaus Wendt[b], Clemens Walther[c]

https://doi.org/10.1016/j.apradiso.2021.110093

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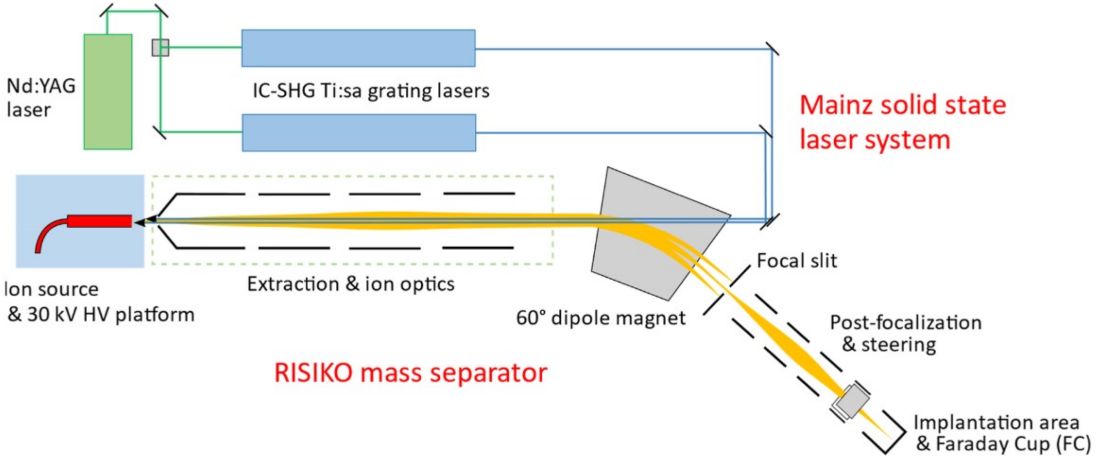

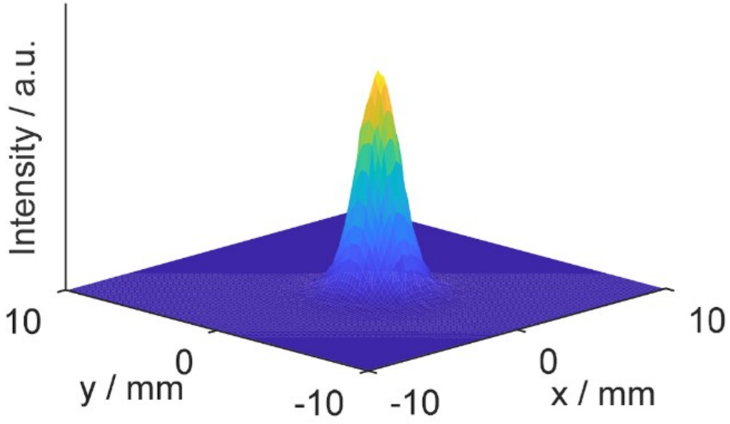

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6: New innovation

International Journal of *Environmental Research and Public Health*

MDPI

Article

Development of ^{222}Rn Emanation Sources with Integrated Quasi 2π Active Monitoring

Florian Mertes *, Stefan Röttger and Annette Röttger

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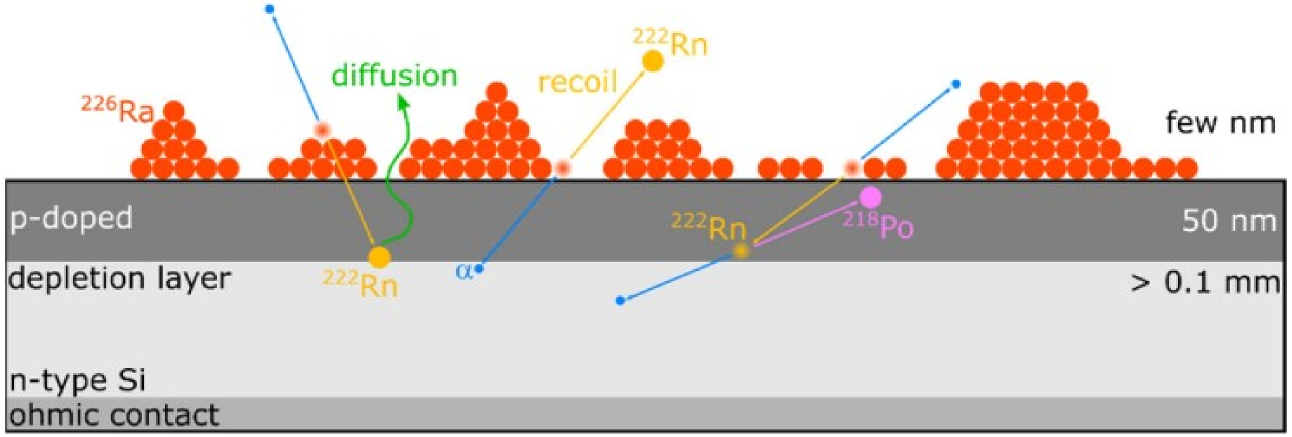

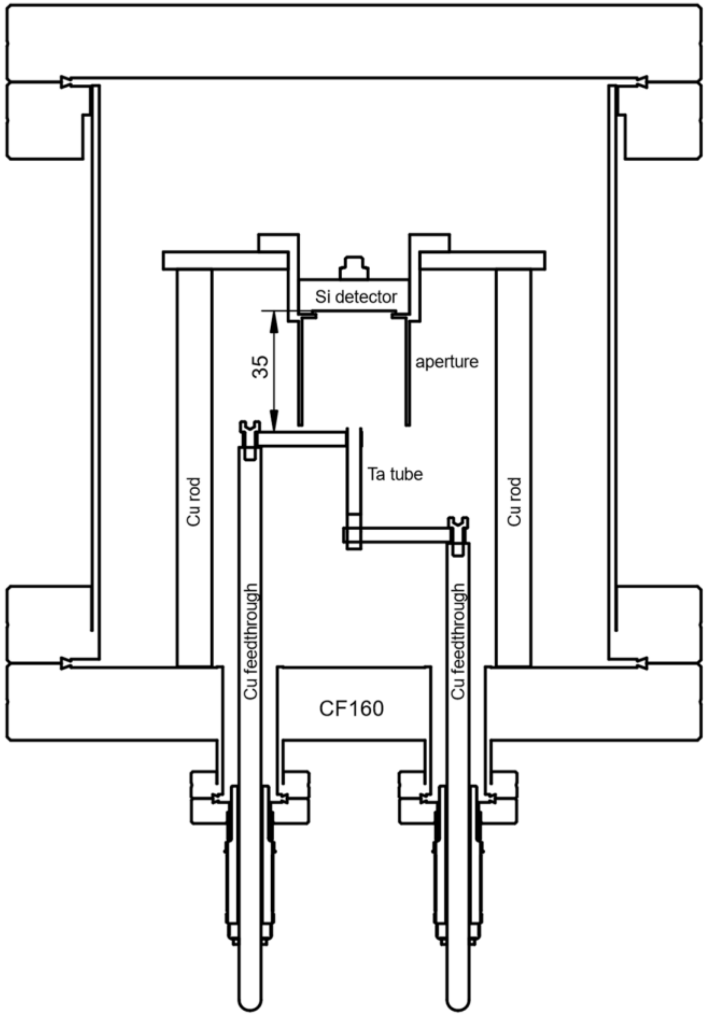

https://doi.org/10.3390/ijerph19020840

7: New field instrument

Adv. Geosci., 57, 63–80, 2022
https://doi.org/10.5194/adgeo-57-63-2022

Advances in Geosciences
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Portable two-filter dual-flow-loop ^{222}Rn detector: stand-alone monitor and calibration transfer device

Scott D. Chambers[1], **Alan D. Griffiths**[1], **Alastair G. Williams**[1], **Ot Sisoutham**[1], **Viacheslav Morosh**[2], **Stefan Röttger**[2], **Florian Mertes**[2], **and Annette Röttger**[2]

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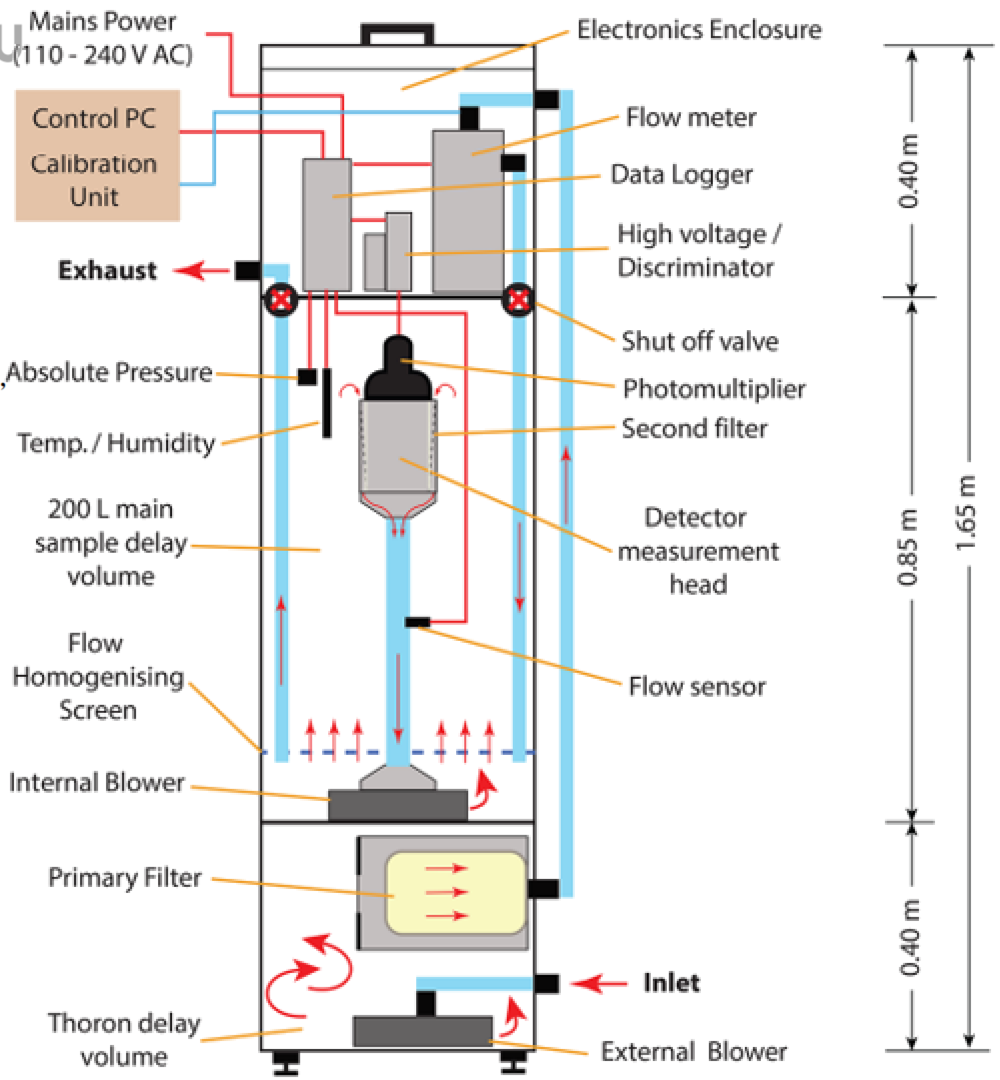
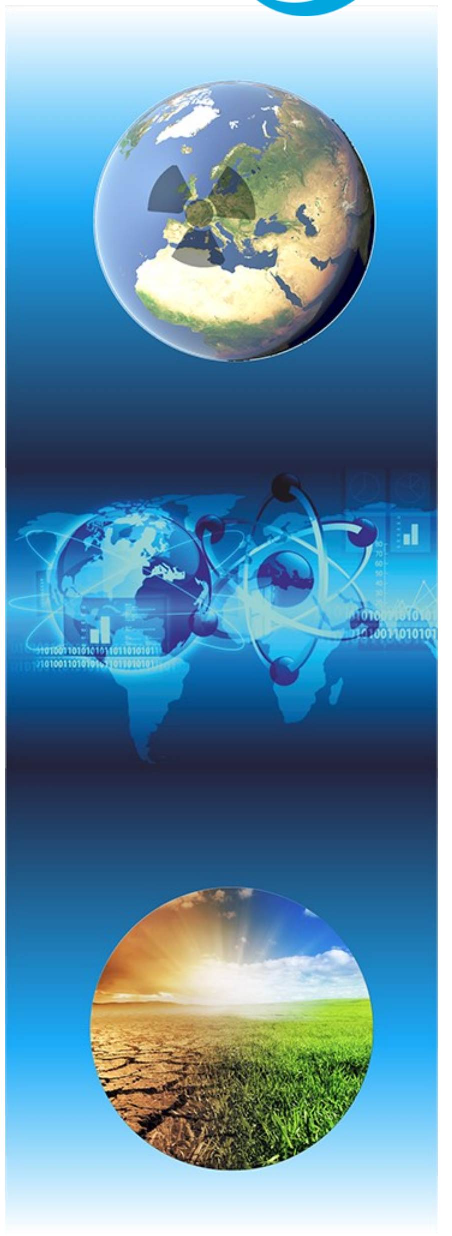
https://doi.org/10.5194/adgeo-57-63-2022





8: New approaches for member states

International Journal of *Environmental Research and Public Health*
MDPI

Review

Outdoor Radon as a Tool to Estimate Radon Priority Areas—A Literature Overview

https://doi.org/10.3390/ijerph19020662

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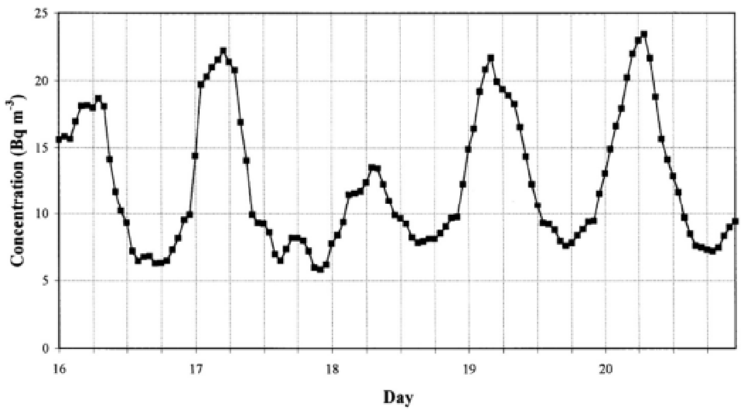
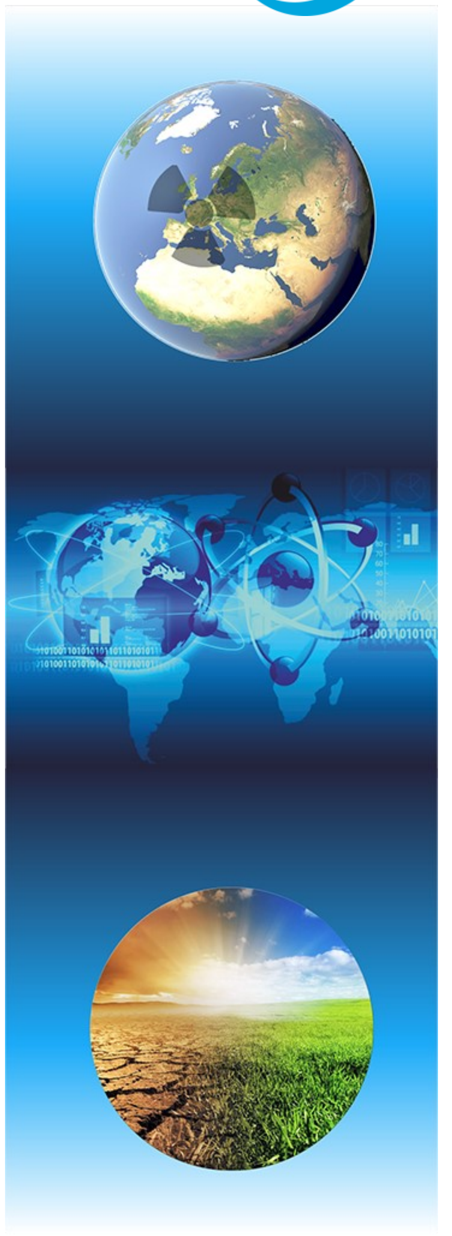


Country	No. of. Locations	Descriptive Statistics Season	Range [Bq m−3]	GM (AM) [Bq m−3]	GSD [Bq m−3]	Map
USA, Missouri [94]	82	Annual	11–110	25	1.5	Yes
USA, Iowa [83]	111	Annual	7–55	29	1.4	Yes
Minesota [83]	64	Annual	4–55	19	1.8	Yes
Turkey [77]	47 30	Winter Summer	19–63.5 7–28	(34.10) (15.34)		
Slovenia [45]	60	Annual	3.7–41.0	11.8		Yes
China [79]	101	Annual	3.6–23.9	(9.3)		
China [89]	165	Annual	3–50	13.2 (14)		No
Serbia [46]	56	Annual	<244	49 (57)	1.8	No
England [95]	69	Annual		6	2	
Norway [82]	82	Winter Summer	4–13 8–210	(5–13) (29–82)		No
Lebanon [81]	24	Summer Autumn Winter	3.2–47.6 1.0–57.0 0.2–66.3	(19.7) (16.1) (13.4)		No.
Ireland [92]	18	Annual	4.2–7.7	(5.6)		No
Japan [78]	696	Annual	1.8–35.3	5.9 (6.1)		No
Germany [85]	173	Annual	3–31	9	1	Yes
Iceland [91]	1	May-july		1.6		No
Malta [73]	3	Summer	0.8–3.6			No
Cyprus [97]	12	August	2–134	9 (11)		No
East Asia [96]	20	3 months	5.3–17.0	(10.7)		No
Syria [102]	36	10 min.	5–66	21 (25)		No
Montenegro [93]	Theor. 1	Annual Annual	6–11 13 ± 4	 (13)		No
Spain [101]	25	Annual	1.2–15.8	(5.2)		No



9: Field intercomparisons

International Journal of *Environmental Research and Public Health*

MDPI

Article

Intercomparison of Radon Flux Monitors at Low and at High Radium Content Areas under Field Conditions

Daniel Rábago [1], Luis Quindós [1,*], Arturo Vargas [2], Carlos Sainz [1], Ileana Radulescu [3], Mihail-Razvan Ioan [3], Francesco Cardellini [4], Marco Capogni [4], Alessandro Rizzo [5], Santiago Celaya [1], Ismael Fuente [1], Marta Fuente [6], Maria Rodriguez [2] and Claudia Grossi [2]

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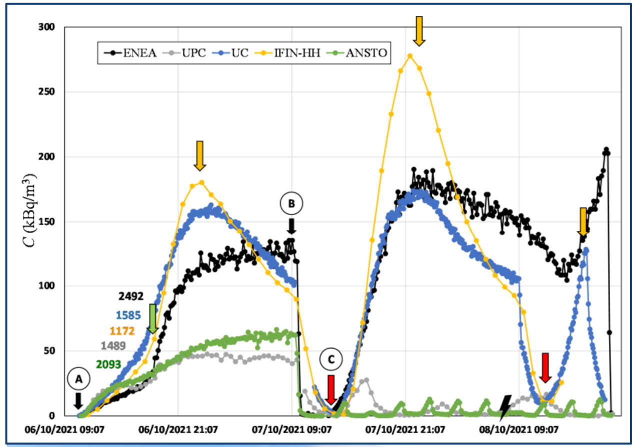

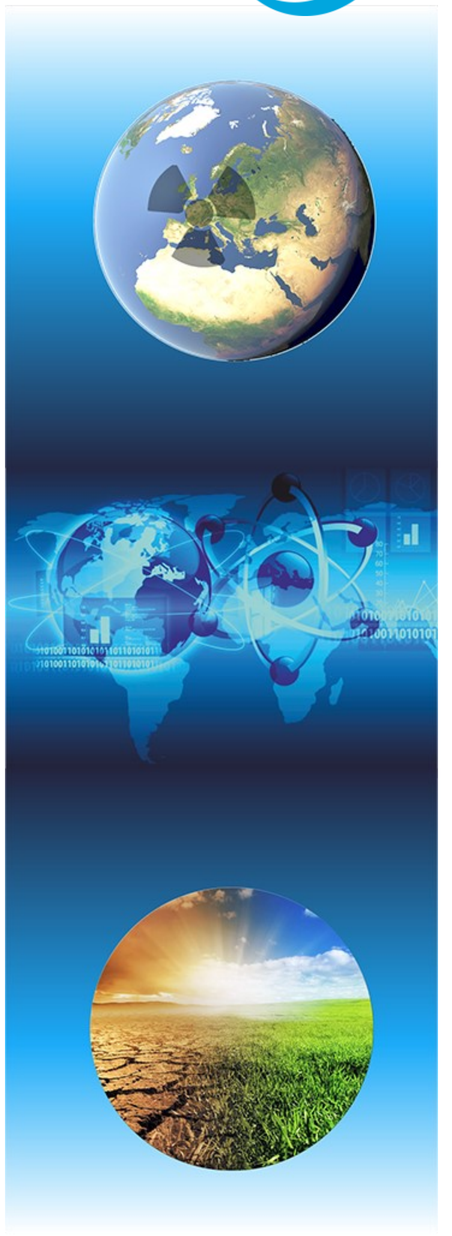

10: New maps

atmosphere

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Review

Overview of Radon Flux Characteristics, Measurements, Models and Its Potential Use for the Estimation of Radon Priority Areas

Igor Čeliković [1], Gordana Pantelić [1], Ivana Vukanac [1], Jelena Krneta Nikolić [1], Miloš Živanović [1], Giorgia Cinelli [2,*], Valeria Gruber [3], Sebastian Baumann [3], Giancarlo Ciotoli [4], Luis Santiago Quindos Poncela [5] and Daniel Rábago [5]

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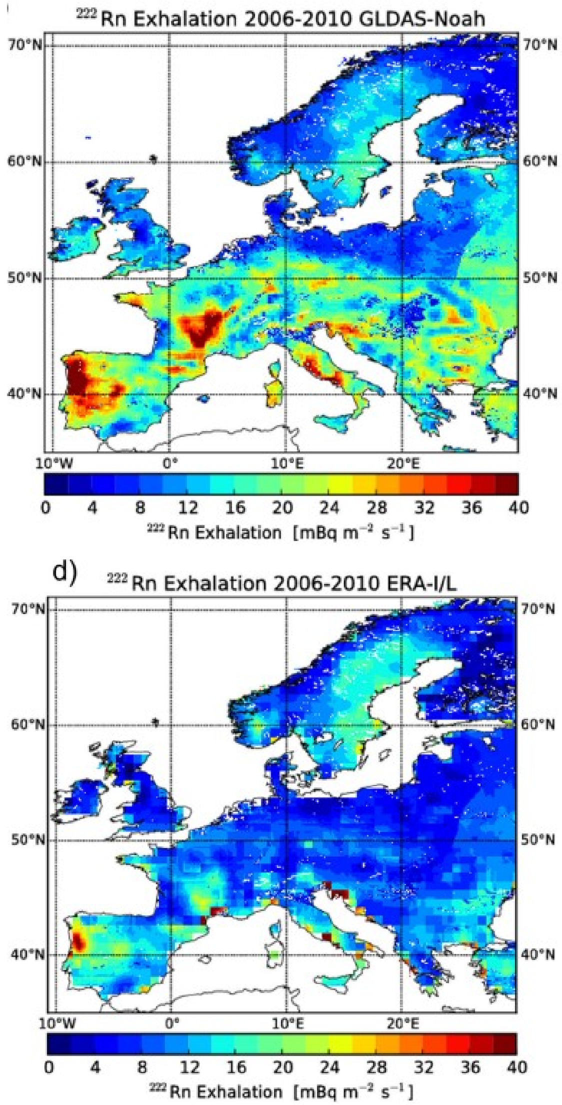

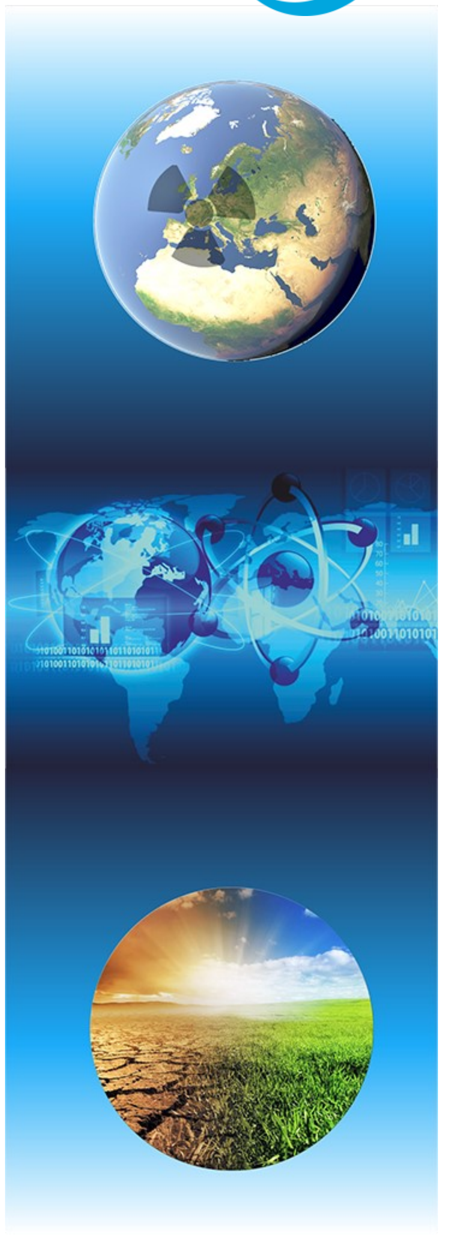

11: Campaigns for authorities

Journal of Environmental Engineering and Landscape Management
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2022 Volume 30 Issue 3: 370–379
https://doi.org/10.3846/jeelm.2022.17411

ANALYSIS OF THE RADON CONCENTRATIONS IN NATURAL MINERAL AND TAP WATER USING LUCAS CELLS TECHNIQUE

M. R. CALIN[1], A. C. ION[2], I. RADULESCU[1*], C. A. SIMION[3], M. M. MINCU[1], I. ION[2]

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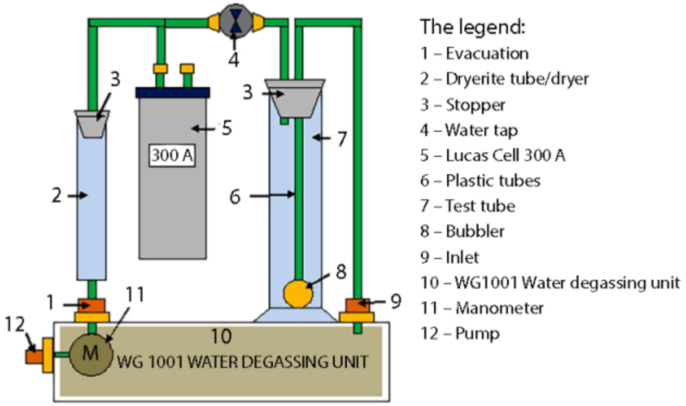

12: Mathematical Procedures

DOI 10.5162/SMSI2021/D3.3

Approximate sequential Bayesian filtering to estimate Rn-222 emanation from Ra-226 sources from spectra

Florian Mertes[1], Stefan Röttger[1], Annette Röttger[1]
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https://doi.org/10.5162/SMSI2021/D3.3

Radioactive system
Assumptions about η

$$F = \begin{bmatrix} -\lambda_{^{222}\mathrm{Rn}} & \lambda_{^{222}\mathrm{Rn}} & -\lambda_{^{222}\mathrm{Rn}} & 0 \\ 0 & -\lambda_{^{226}\mathrm{Ra}} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -\gamma \end{bmatrix}$$

$$p(x_t, y_t) \propto N\left(\begin{bmatrix} \mu_{x_t} \\ K_{l_t}\mu_{x_t} \end{bmatrix}, \begin{bmatrix} \Sigma_{x_t} & \Sigma_{x_t} K_{l_t}^T \\ K_{l_t}\Sigma_{x_t} & K_{l_t}\Sigma_{x_t}K_{l_t}^T + J_{l_t} + R_t \end{bmatrix}\right)$$

$$K_{l_t} = H \int_0^{l_t} e^{F\tau} d\tau$$

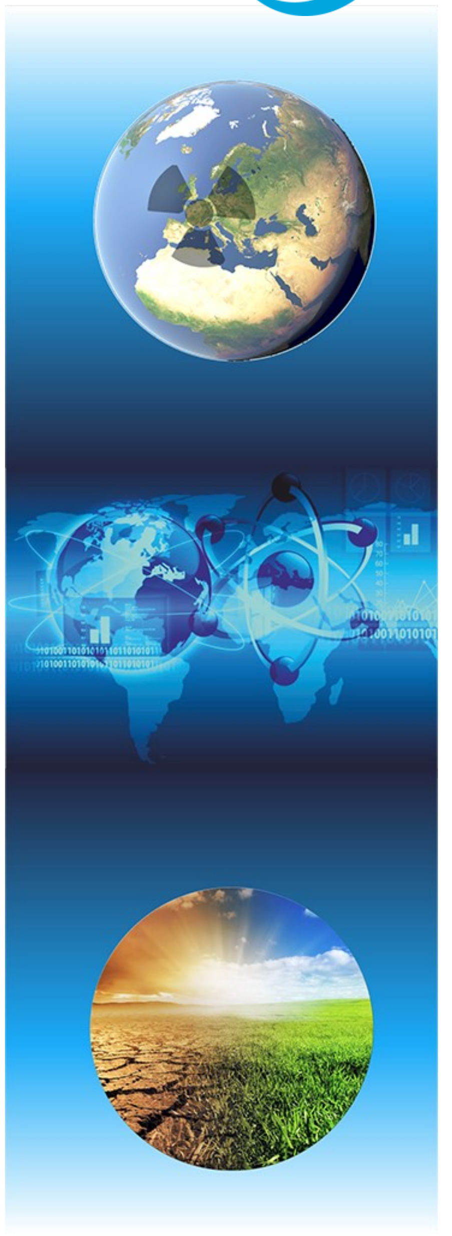
Propagation factor to account for integrating

$$J_{l_t} = H \int_{-l_t}^{0} \int_0^{\tau} \int_0^{\tau} e^{Fa} L Q L^T e^{F^T b}\, da\, db\, d\tau\, H^T$$

Additional variance from integrating the stochastic part of the process (scary, in our case symbolically, Numerical Algorithms are available)

$$R_t$$

Measurement noise Variance. Estimated from observed counting statistics (e.g. $\sigma = \sqrt{N}$)



Special Issue

Physikalisch-Technische Bundesanstalt
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Atmospheric Measurement Techniques

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2023

Outcomes of the traceRadon project: radon metrology for use in climate change observation and radiation protection at the environmental level

01 Mar 2023–01 Feb 2025 | Annette Röttger, Ute Karstens, Claudia Grossi, Helen Worden, Bin Yuan, Huilin Chen, and Hartwig Harder |

Information

An overlapping need exists between the climate research and the radiation protection communities to improve the metrology for atmospheric radon concentration and radon flux measurements. The EMPIR project 19ENV01 traceRadon works toward these goals for the benefit of both large scientific communities by providing the necessary infrastructure for measuring these aforementioned variables. In addition, it will generate data at four selected European sites for validation of radon flux models and inventories and will create the first standard protocol for applying the radon tracer method (RTM). The proposed special issue aims to collect the direct and indirect outcomes of the traceRadon project. It will include papers presenting results of the laboratory and field campaigns carried out within the project. In addition, papers directly related to the project goals will be welcome too.

- Hide

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Aim: on all continents

Last continent reached: Antarctica!

Thanks…

… to the traceRadon-project partners:

… to the traceRadon-project collaborators:

… to the traceRadon-project Stakeholder Committee, Stakeholders, MSU, EURAMET,

… and for your attention!

This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. ***19ENV01 traceRadon*** *denotes the EMPIR project reference.*