Executive Summary

The 3-year Research Project MetroRADON (Metrology for Radon Monitoring) started in June 2017 and is funded within the European Metrology Programme for Innovation and Research (EMPIR). The purpose of the project is to develop reliable techniques and methodologies to enable SI traceable radon activity concentration measurements. More information about the tasks of the project can be found in the 1st newsletter and on the MetroRADON website. First results were discussed already in the 1st status report and 2nd newsletter.

Due to the relevance and topicality of the subject, the consortium of 17 partners from national metrology institutes and research institutes was expanded with currently 7 official collaborating institutions and an Industry Interest Group of 26 companies was initiated. In addition, co-operations with existing networks and research programmes were established. The high interest in collaboration and in the topics of MetroRADON confirms the importance of the project for a variety of European stakeholders in the field of radon.

First results were presented on several conferences all over Europe and first reports are available.

This status report describes the status and work done in the first half of the project, focused on the newest results, structured by work packages. In addition some of the dissemination activities at conferences and first reports are listed and linked. Some highlights are summarized also in the 3rd Newsletter. All the mentioned material is available on the MetroRADON website and directly linked in this status report.

If you are interested in collaborating with MetroRADON or want to join the Industry Interest Group, please contact us!

Contact

Hannah Wiedner, JRP coordinator
Bundesamt für Eich- und Vermessungswesen
Physikalisch-Technischer Prüfdienst
Arltgasse 35, 1160 Wien
AUSTRIA
contact@metroradon.eu

Announcement: Comparison of existing radon gas primary standards according to CCRI(II) rules

The last comparison of radon activity concentration under the auspices of CCRI[1] was undertaken in Europe in the early 2000s and the data is more than 10 years old. Within the framework of MetroRADON two new comparisons of National Metrology Institutes (NMI)/Designated Institutes (DI) capabilities for ^{222}Rn and ^{220}Rn in the range of a few kBq will be undertaken to assure the quality of these calibration facilities.

If you are interested in participating, please contact us until end of February 2019!

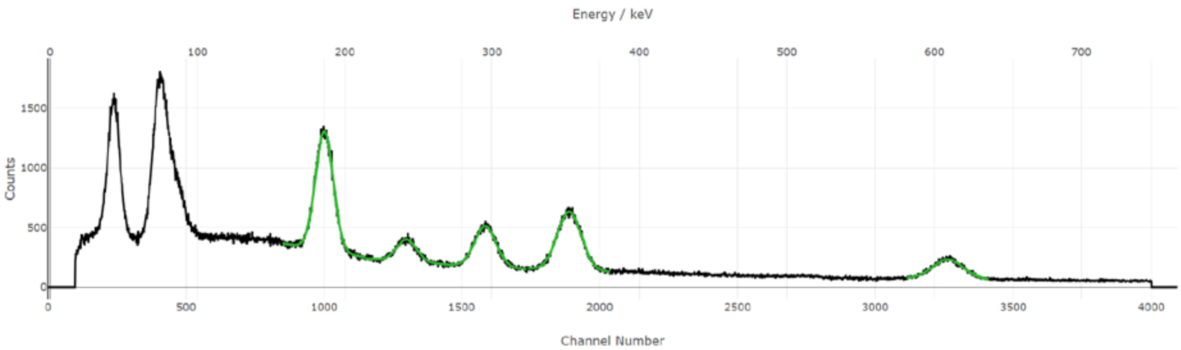
[1] Consultative Committee for Ionising Radiation, Section II: Measurement of radionuclides, BIPM, Sèvres, France

Development of novel procedures for the traceable calibration of radon measurement instruments at low activity concentrations (WP 1)

The aim of work package 1 (WP 1) is (i) to develop radon gas activity standards for the realization of reference fields for radon activity concentration in air, (ii) to undertake two CCRI(II) comparisons of existing radon gas primary standards at different European NMIs/DIs for ^{222}Rn and ^{220}Rn in the range of a few kBq and (iii) to develop novel procedures in order to calibrate radon measurement instruments traceable to primary standards in a range of activity concentrations (100 Bq/m^3 to 300 Bq/m^3) with relative uncertainties ≤ 5 % (k = 1). This activity range is relevant for regulations defined by the European Council Directive 2013/59/EURATOM for indoor radon concentrations at workplaces (article 54) and dwellings (article 74).

A main part of WP 1 is the development of emanation sources with constant, stable emanations and activity measurements of the emanated radon traceable to primary standards .

At PTB the production of new emanation sources based on electrodeposition and ion implantation of ^{226}Ra is ongoing. Recently, an online-measurement setup for the emanation coefficients has been implemented. It is based on a solid-state scintillator and a digital MCA coupled with a Raspberry Pi. The Raspberry Pi functions as a storage and data evaluation device, which automatically derives the emanation coefficients and assigned uncertainties from the measured gamma-spectra. The obtained data is stored in a database and is accessible through a web front end (Fig.1), which is hosted on the Raspberry Pi. Measurements of the emanation coefficients of new sources are now carried out in controlled environments with the new device. Thereby, the produced sources show improved stability towards relative humidity compared to the PTB's old emanation source design.



Real Time 7200 Live Time 7192.01513671875

Parameter	Ra-226 186 keV	Pb-214 249 keV	Pb-214 295 keV	Pb-214 351 keV	Bi-214 609 keV
Count Rate / s^-1	11.13 +/- 0.06	2.29 +/- 0.05	4.64 +/- 0.06	7.47 +/- 0.07	3.27 +/- 0.08
Area	80076	16505	33381	53717	23544
Center chan.	1001	1299	1586	1890	3262

Figure 1: Screenshot of the web front end showing an evaluated gamma spectrum

JRC has prepared emanation sources by drop deposition and chemisorption. They try to follow a green approach and prepare multi-purpose radon sources for air/water, reduce waste and the use of reagents and reusable electrolyte. The filter papers with the drop deposited ^{226}Ra source were sealed in a radon permeable material. Chemisorption was done on solid surfaces or in porous materials. The emanation power of the drop deposition radon sources is in the order of 0.7, the emanation power of chemisorption around 0.2. The soruces preparation will be further optimised and tests in larger volume chambers will be carried out in the next steps within the project.

CEA has prepared emanation sources of ^{222}Rn and ^{220}Rn with a relative standard uncertainty of 2 %. ^{226}Ra and ^{228}Th liquid sources were respectively used to prepare these sources by precipitation techniques. The powder of the precipitation is safely placed between two filters and composes the emanation source. The influence of the humidity, temperature, and air pressure on the emanation rate was studied on ^{220}Rn source. The measurements for the ^{222}Rn source are in progress.

CEA has also developed a method for direct and traceable measurement of the activity concentration of ^{222}Rn and ^{220}Rn in an air flow. The device is composed by a loop inside which the gas circulates. The temperature, humidity and air pressure are controlled, and the measurement of the gas concentration is realized with a chamber equipped with a PIPS detector. This chamber is part of the loop.

CMI with the help of SUJCHBO have developed and tested long-term stable radon low activity emanation flow-through source based on mass flow controller. The source is generator of ^{222}Rn (radon output is 0,0106(1) Bq/s) with a defined activity in the gas phase (5,058(51) kBq). Radon is released from the solid phase with high emanation power (0,998(10)). The radon source (emanator) is in the form of polymer foil on a stainless-steel plate. The source is enclosed in an aluminium alloy cylindrical case equipped with two ball valves at each end and placed in the middle of the case. The source is at BfS where further experiments will be performed.

Another main aim of WP 1 is to conduct comparisons of existing radon gas primary standards at European NMIs/Dis in the few kBq range according to CCRI(II) rules. Currently the comparison protocol and schedule are being developed and parties interested in participating are asked to contact the MetroRADON consortium.

At IFIN-HH a new radon gas source in a glass vial was recently prepared and standardized by using a calibrated HPGe gamma-ray spectrometry system (relative method, based on the secular equilibrium between radon and its gamma-ray emitter daughters, i.e. ^{214}Pb and ^{214}Bi). This allowed the successful testing of the radon standard system from IFIN-HH, in view of the participation in the comparison of the activity of ^{222}Rn gas standards..

A third big aim of WP 1 is the development of traceable procedures for the calibarion of radon measurement instruments at low activity concentrations. Parallel to the source developments, work is underway at the calibration chambers to ensure that the new emanation sources can be included into radon tight gas circuits at the different calibration chambers for testing of suitable calibration procedures.

SÚJCHBO has upgraded their low-level radon chamber (LLRCh) by placing an an adjustable fan in the inner volume of their LLRCh and verifying its functionality. The measurements were realized by a calibrated device for measuring of the spatial distribution of the air flow speed and direction. Approriate parameters of the low-level radon source were modelled. In cooperation with CMI the technical concept of the new low-level radon source was worked out and the flow rate meter was selected. The functionality of the whole system was tested after the connection of the low-level radon source with the LLRCh. Based on the first experiments with the low-level radon source an issue was identified with the very low relative humidity in the inner volume of the LLRCh caused by using of propellant gas. This problem was solved by adding the humidifier to the radon line. Funcitonality testing of the whole low-level radon source system in the range from 100 Bq/m^3 to 300 Bq/m^3 was carried out and uncertainty determination of the whole system of the radon low-level atmosphere has started.

BfS has set up a facility for the realization and dissemination of the measurement quantity radon activity concentration. The basic component of the facility is a radon-tight chamber with a certified volume traced back to a standard volume at PTB. The facility is equipped with instruments for monitoring temperature and air pressure. This basic setup is extended by an additional volume as well as by devices for online-monitoring of the actual radon activity concentration and for extraction of a defined quantity of radon-loaded air.

The facility uses emanation sources releasing a constant radon activity. Thus, a constant radon activity concentration establishes inside the calibration chamber over time. A first emanation source was provided by CMI. With applying an air flow through the source, the released radon is conveyed into the calibration volume. The same air flow is diverted from the chamber. Thus, the chamber operates in an open mode, where the high of the activity concentration inside depends on the radium activity, the emanation rate of the produced radon as well as the volume flow of air. Since radium activity and radon emanation rate are intrinsic characteristics of the source, the resulting level of the radon activity concentration can be controlled by the volume flow. Figure 2 shows the radon activity concentration established inside the calibration chamber using the source from CMI and a volume flow of about 2.1 L/min. The measurements were taken by flow-through scintillation cells.

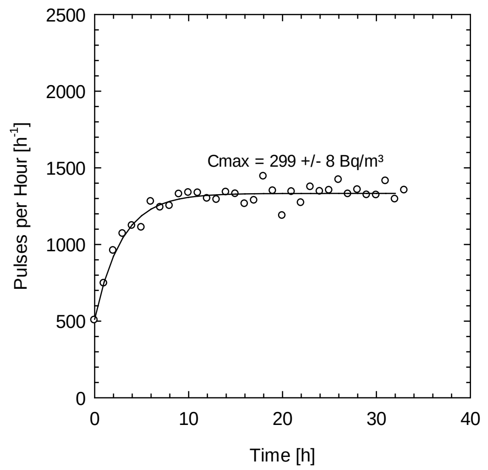


Figure 2: Buildup of a constant radon activity concentration inside the calibration chamber at BfS

Calibration procedures in radon chambers – especially at low-level radon concentration in air (100 Bq/m^3 to 300 Bq/m^3) - involve several specific metrological aspects that are under study at IFIN-HH: the activity uncertainty of the used radon source, study of the radon volume distribution (homogeneity) in the radon chamber, radon activity decay in a long time period, validation of the new software (automated functioning of the radon chamber), the volume calibration of the radon chamber and the calibration of the temperature and pressure sensors.

By the date of this status report, a Radon Scout monitor (SARAD) and α-track detectors (CR-39 type) have been used for tests in this radon chamber. For the future acquisition of an AlphaGUARD radon monitor for use as a reference instrument and routine measurements is planned.

Influence of thoron and its progeny on radon end-user measurements and radon calibrations (WP 2)

The aim of WP 2 is to investigate and reduce the influence of thoron (^{220}Rn) and its progeny on radon (^{222}Rn) end-user measurements and radon calibrations. For this purpose a ^{220}Rn calibration exercise has been carried out in BACCARA after testing the homogeneity distribution of ^{220}Rn in the exposure chamber. 7 monitors of WP 2 partners that will serve as reference instruments in their future experiments within WP 2 were calibrated in the reference system developed and constructed in CEA/IRSN (Figure 3).

SUBG assessed experimentally the homogeneity in its 50 L (empty) calibration chamber by LSC of aerogels method and by SSNTDS (Kodak Pathe LR-115/II was used). The results indicated that the thoron distribution in the chamber is homogeneous within the experimental uncertainty (about 10 %). IRSN assessed experimentally the homogeneity of the thoron atmosphere in an empty BACCARA (IRSN radon chamber) using the same instrument (RAD 7) placed successively in different locations. The relative differences of the thoron activity concentration measurement was found below 10 %. Because the instruments placed in the test chamber might influence the distribution of thoron in the test bench atmosphere SUBG and IRSN assessed the homogeneity in BACCARA under real exposure conditions (with eight instruments inside). Both methods developed in SUBG were used (LSC of aerogels and SSNTDs). Under such conditions, higher inhomogeneity was observed: up to 66 % (LSC) and 61 % (SSNTD).

The partners' monitors were 4 instruments of AlphaGUARD 2000 RnTn PRO and 3 instruments of RAD 7. To avoid the influence of the thoron inhomogeneity on the calibration of the instruments, a measurement set-up was organized, so the inlet nozzles of all instruments to be within close distance (few cm) from each other (Figure 4). Within such circumstances the influence due to the thoron inhomogeneity was estimated to be less than 7 %.

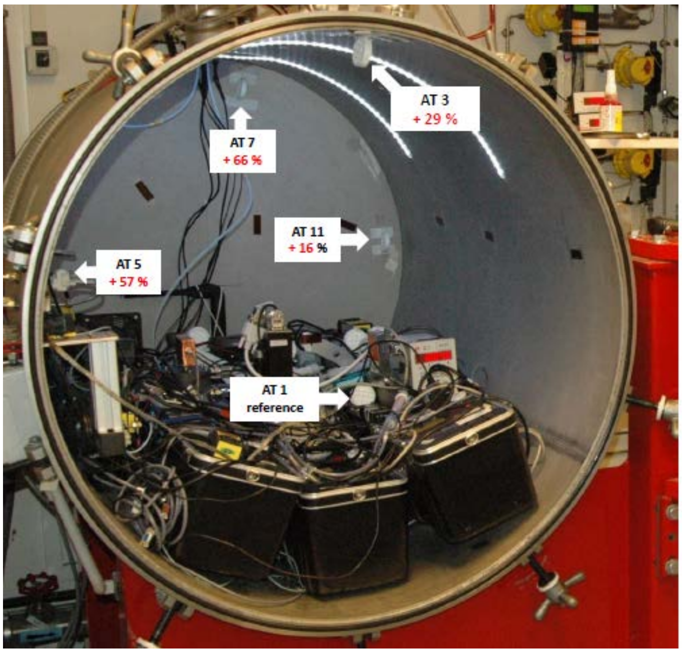


Figure 3: Snapshot of the experimental set-up for the ^{220}Rn calibration exercise at BACARRA. The boxes with the numbers show the measured ^{220}Rn concentrations by the LSC method relative to that at the reference (i.e. the sampling point)

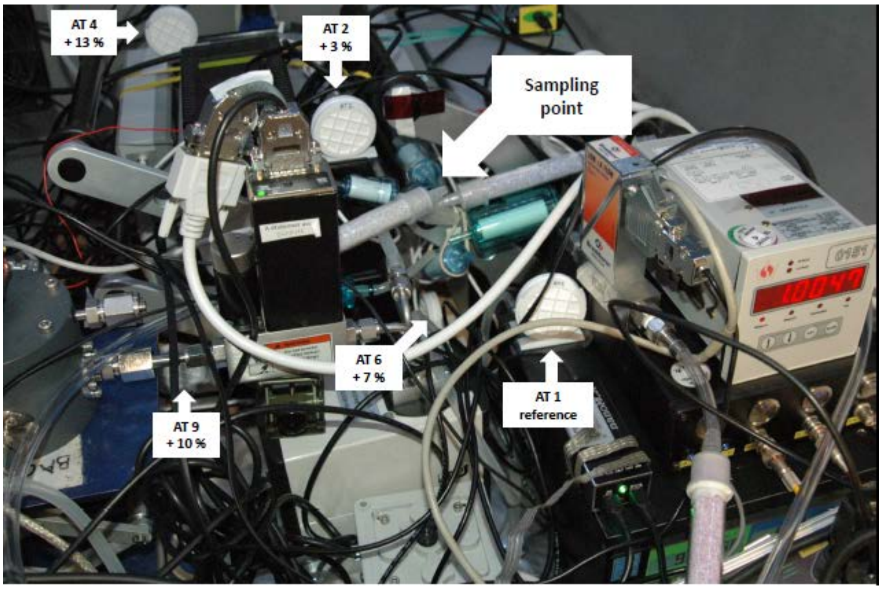


Figure 4: Snapshot of the sampling point with the inlets of all the instruments. The boxes with the numbers show the LSC estimated ^{220}Rn concentrations relative to that at the reference

From the results of the calibration procedure, first conclusions for the experiments planned for the investigation of the influence of thoron on radon measurements were drawn.

To gain a better understanding of the thoron inhomogeneity under real exposure conditions IRSN carried out a numerical simulation of the flow velocity and the thoron concentration with a direct inlet of the thoron inside the chamber at laminar regime. In order to improve the homogeneity and quality of the limit condition of this inlet an air nozzle was designed and built for the inlet of thoron inside the chamber. Flow simulations have been carried out with the instruments inside BACCARA but without taking the ventilator into account. Experiments were carried out to characterize the velocity distribution behind and in front of the ventilator. The next step (planned for the future) is to take into account the ventilator in the simulation for both the empty chamber and the chamber filled with instruments.

A study on the influence of thoron on two types of active radon monitors, five types of SSNTDs, and two types of passive detectors was carried out. Experiments with commercial passive radon detectors are planned for the future.

STUK and SUBG performed a review of potential techniques and materials to reduce the influence of thoron on radon measurements and calibrations and summarized the findings in a dedicated report available in the Documents Section of the MetroRADON website.

Based on the findings of this review, activity experiments of diffusion properties of ten different polymer materials were organized using ^{222}Rn as a surrogate of ^{220}Rn. A method for determination of solubility, diffusion coefficient and permeability based on follow-up of the desorption of ^{222}Rn from the polymer materials (foils, plates) was used. This allows accurate timing during the desorption process and accurate determination of the parameters at different temperatures. Two methods of measuring the activity of ^{222}Rn absorbed in the polymer materials areused. (1) The ^{222}Rn activity in the foils is measured by LSC in Cherenkov mode withthe thin foils placed directly in LSC vials filled with distilled water and (2) by gamma-spectrometry using an HPGe detector.

For four types of polymer foils the coefficient of diffusion and the solubility are determined for temperatures 5 °C and 20 °C. Experiments (at room temperature) are ongoing with ten other polymer materials.

A characterization of proper thoron barriers among the studied materials commenced. As within the review a problem with possible large influence of temperature on the barrier properties of polymer materials was identified, an additional experimental study of this dependence (not planned initially) was started and the results will be taken into account in the selection of the best suited thoron diffusion barriers.

Comparison and harmonization of radon measurement methodologies in Europe (WP 3)

The aims of WP 3 are (i) to collect and analyse meta-information on radon surveys performed and existing radon databases in European countries, (ii) to evaluate if the data and methodologies are comparable and (iii) how they could be harmonized in case of methodical inconsistency.

Intercomparison exercise under field condition

An intercomparison exercise has been carried out between 5th – 8th November 2018 in the framework of MetroRADON WP 3. The exercise has been organized by the University of Cantabria (Spain) in the laboratory of Natural Radioactivity (LNR) (Fig.5). The laboratory is located at the facilities of the former uranium mine managed by the National Company ENUSA (Ciudad Rodrigo, Salamanca, Spain).

The number of participants was limited to 20 by the organizers, due to logistic reasons. The maximum number of participants was reached, which shows the great interest from the radon community for such kinds of activities. The participants came from 14 countries (Figure 5).

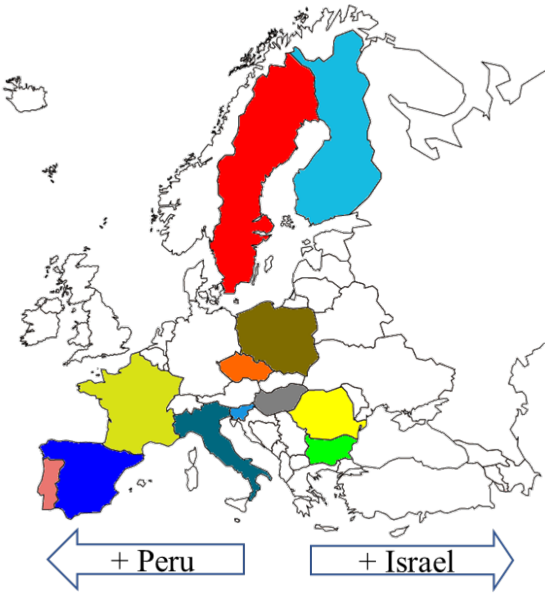


Figure 5: Left: Countries from which the participants came from; Right: Laboratory of Natural Radioactivity (LNR), Ciudad Rodrigo, Spain

The activities have been focused on radon exposure in air for passive and active monitors with two level of exposures, radon in soil and radon exhalation from soil. Figure 6 shows some impressions of the activities of the intercomparison exercise in the area of the former uranium mine.

At the moment the results are being analysed and a report will be prepared, which will be available at the the MetroRADON website soon.

Figure 6: Left: Exposure of the passive and active monitors in the laboratory; Right top: radon exhalation measurements; Right bottom: radon in soil gas measurements; Area surrounding the laboratory of Natural Radioactivity (LNR), Ciudad Rodrigo, Spain

Report on literature review of indoor radon surveys in Europe

The aim of this report is to provide a literature review of existing indoor radon surveys in Europe. Different steps of the "survey chain", e.g. from survey design through sampling, measurements to evaluation and interpretation, that yield an output have been explored. Journal papers and papers in international and national conference proceedings were reviewed, resulting in data collected from 45 countries. The information contained in the report should serve as an input to propose approaches to reduce inconsistencies and improve harmonization of indoor radon data.

The report is published as a Technical Report by the Joint Research Centre of the European Commission and available online. Below you find the publication details.

PANTELIĆ G, ČELIKOVIĆ I, ŽIVANOVIĆ M, VUKANAC I, NIKOLIĆ JK, CINELLI G, GRUBER V, Literature review of Indoor radon surveys in Europe, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-97643-8 (online), doi:10.2760/977726 (online), JRC114370

Radon priority areas and the development of the concept of a geogenic radon hazard index (WP 4)

Definition and delineation of Radon Priority Areas

An important topic of MetroRADON is the definition and delineation of Radon Priority Areas (RPAs), which are geographical regions in which after criteria to be stated, indoor radon levels can be expected so high that preventive, mitigating or remedial action should be applied with priority, as requested by European law. As a result of estimation from data, delineation of an area is inevitably affected by uncertainty. Understanding it and being able to quantify it is an important element of quality assurance in labelling an area Radon Priority Area or not. Aspects of classification uncertainty have been addressed in several conference presentations (GeoENV Belfast, IAMG Olomouc and GARRM Prague) and in a journal article in 2018 (publication details below). Presentations are available in the Documents Section of the MetroRADON website. The work is ongoing until the end of the project and will be summarised in a report.

Bossew, P., Radon Priority Areas – Definition, Estimation and Uncertainty, Nuclear Technology and Radiation Protection 33, 3 (2018) p. 286-292. https://doi.org/10.2298/NTRP180515011B

New developments in estimation of Radon Priority Areas

SUBG and UC are evaluating the precision and applicability of the CD/DVD method for retrospective radon measurements for use for identification of radon priority areas (RPAs). The exposure of CDs/DVDs at Saelices el Chico laboratory is under way. The results from the first exposure demonstrated very good correspondence between CDs (SUBG) and UC radon monitors results. SUBG also participated in the radon in air, radon in soil and radon exhalation from soil inter-comparison, organized by LaRUC laboratory from 5 to 10 Nov. 2018.

A novel version of the CD/DVD-method with expanded sensitivity was developed by SUBG (Figure 7). This version makes it possible to measure low ^{222}Rn concentrations (100 Bq/m^3 to 300 Bq/m^3 and even lower) within short exposure times (few days). This version can be useful for short-term integrated measurements of radon exhalation from soil, radon diagnostics and other purposes. Detectors of such design performed very well in the 2017 Public Health England (UK) international laboratory inter-comparison of passive radon detectors. According to the reported reference levels, within the 5 exposure groups the observed differences from the reference ^{222}Rn concentration was 1.8 %- 10 %. An oral presentation at IEEE Nuclear Science Symposium and Medical Imaging Conference 2018 (IEE NSS/MIC 2018) was focused on the possibility to measure low to very low radon levels using this approach.

SUBG has performed pilot successive continuous radon in soil-gas field measurements with a continuous ^{222}Rn in soil-gas monitor recently developed. The monitor is based on radon absorption in scintillating polymers and its first field tests demonstrate that the concept is very useful and promising. The first results were presented at the 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference, Sydney (IEE NSS/MIC 2018). The presentations are available in the Documents Section of the MetroRADON website.

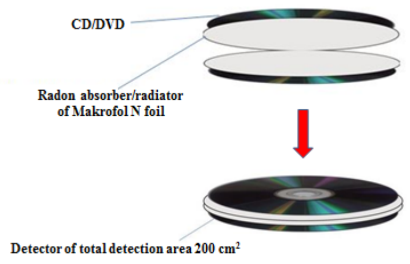


Figure 7: The CD/DVD based detector of enhanced sensitivity and large total detection area

Harmonisation of radon priority areas across borders

In the framework of the MetroRADON task "Harmonisation of radon priority areas across borders", mapping methods which are used in various countries are evaluated and tested for their comparability and usability for other countries by AGES, BfS and UC. Two real-world indoor data sets together with geological and other geogenic supporting information from a region in Austria and Spain was supplied by AGES and UC. The exercise was carried out in cooperation with five institutions from all over Europe working on radon mapping in their respective countries. All participants analysed the data and applied their mapping method and definition of delineation of radon areas in their countries to the two test data sets. The task turned out challenging but results are consistent. An example is shown in Figure 8. First results were presented at the GARRM workshop in Prague in September 2018. The presentation is available in the Documents Section of the MetroRADON website. Results will be summarised in the report of WP 4 and a publication in a peer reviewed paper is planned.

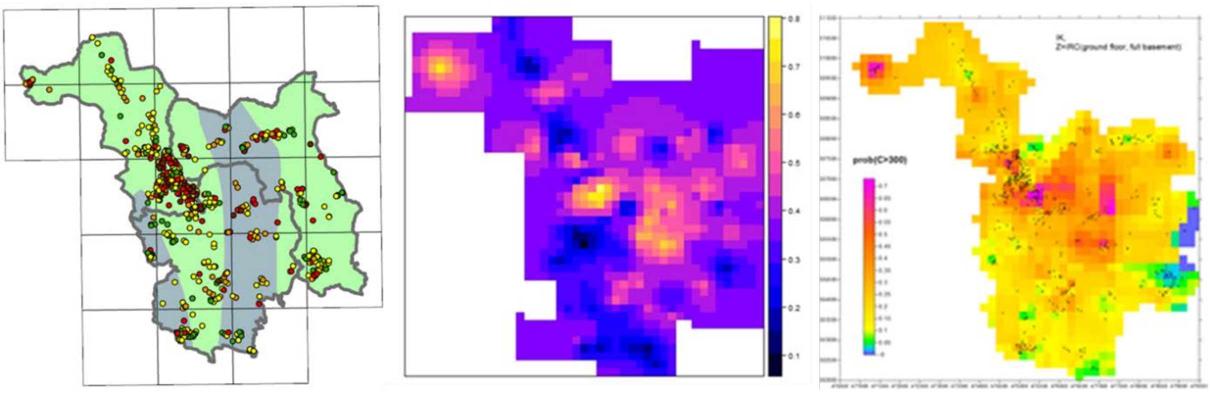


Figure 8: Mapping exercise: Left – raw indoor radon data and geology; centre and right – two maps of the probability that indoor radon concentration exceeds 300 Bq/m^3

Validation of traceability of European radon calibration facilities (WP 5)

Many existing laboratories still look for uniform traceability to a validated radon standard. The aim of WP 5 is to validate the traceability of existing European radon calibration facilities over the ranges from 100 Bq/m^3 to 300 Bq/m^3 and 300 Bq/m^3 to 10 000 Bq/m^3. In WP 5 international comparisons will be performed that will fulfill the need to provide confidence in the capability of European radon calibration facilities in the field of radon activity concentration measurements in air.

Identification, evaluation and selection of European radon calibration facilities for validation of traceability

A questionnaire was sent to selected European calibration facilities for radon concentration measurement in air**.** The main objective of the questionnaire was to be able to serve European radon calibration facilities in a better way by identifying needs and work on solutions to their problems. Each MetroRADON partner institute were in charge of collecting data from European radon calibration facilities in its country and neighbouring countries. The data were then transferred to the BFKH, Hungary, who compiled the data.

Among the participants there are four research institutes, four universities and national public health centre. Nine of the participants are national metrology institutes or designed institutes. A part of these organisations is accredited for radon measurements, other part declares themselves for this activity. The result shows the survey was comprehensive.

AlphaGUARD is the most common used instrument for radon measurement, used as the highest level standard for metrology, as well as a working standard. A broad measurement range can be achieved with a combination of measurement devices. A very low measuring limit (1-2 Bq/m^3) can be achieved by some of the participants. The number per calibration per year shows significant differences among the institutes. This number should depend on various conditions. Radon chambers are an important part of calibration process and are used in very different sizes (0.2 m^3 to 20 m^3). The questionnaire helps to choose the appropriate institute for calibration and institutes to be involved in international comparisons.

Validation of traceability, performance and precision of European radon calibration facilities in the range from 300 Bq/m^3 to 10 000 Bq/m^3

In order to validate the traceability of European radon calibration facilities, a measurement intercomparison is being conducted. 16 European radon calibration facilities expressed their interest in participating the intercomparison. The German Federal Office for Radiation Protection (BfS) provides an electronic radon instrument AlphaGUARD as transfer comparison device for the intercomparison. The transfer comparison device is sent consecutively to each of the participating facilities. The facility exposes the device in radon atmospheres with activity concentrations of about 400 Bq/m^3, 1 000 Bq/m^3 and 6 000 Bq/m^3. The average value of the radon activity concentration indicated by the transfer comparison device is set in relation to the reference value ascertained by the facility for the respective radon atmosphere. These values are used to assess the closeness of agreement between the calibration results. The intercomparison has started in March 2018. Due to the high number of participants interested in the intercomparison this activity will be ongoing until August 2019.

MetroRADON at conferences and publications

MetroRADON results were already presented at several conferences, e.g. GeoENV Belfast, IAMG Olomouc and GARRM Prague.

Some reports were published: "Review of potential techniques and materials to reduce the influence of thoron on radon measurements and calibrations", "Literature review of Indoor radon surveys in Europe"

The first paper was published within MetroRADON framework:

Bossew, P., Radon Priority Areas – Definition, Estimation and Uncertainty, Nuclear Technology and Radiation Protection 33, 3 (2018) p. 286-292

Presentations, posters and reports can be found in the Documents Section on the MetroRADON website.

MetroRADON – upcoming events

Relevant upcoming conferences in the scope of MetroRADON in 2019 are: EURADOS winter school, Lodz Radon in the Environment 2019, Krakow; European Geophysical Union (EGU2019), Vienna; International Conference on Radiation in Various Fields (RAD2019), Herceg-Novi; 5th International Conference on Environmental Radioactivity (ENVIRA2019), Prague; 9th International Conference against Radon at Home and at Work, Prague; 22nd International Conference on Radionuclide Metrology and Its Applications (ICRM2019), Salamanca.

More details can be found in the Upcoming Activities Section on the MetroRADON website.

Figure 9: The MetroRADON consortium at project meeting in Warsaw, November 2018

Further contact and information:

www.metroradon.eu
contact@metroradon.eu