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.

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 4 official collaborating institutions and an Industry Interest Group of 24 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 first results of the work done in the first year of the project 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 2nd 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!

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

The aim of WP1 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)[1] 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 (EU-BSS) for indoor radon concentrations at workplaces (article 54) and dwellings (article 74).

After a survey of the technical properties of the different calibration chambers in the partner institutes, the development of emanation sources with constant, stable emanations and activity measurements of the emanated radon traceable to primary standards started. This includes the development of new methods for source productions as well as the development of online-measurement systems for the continuous monitoring of the radon emanation from these sources. Alongside the electrodeposited sources (shown in Fig. 1), PTB has recently produced several ^{226}Ra sources by ion-implantation after non-resonant laser ionization of gaseous ^{226}Ra. The implantation was carried out at 30 kV acceleration potential into tungsten and aluminum targets. Simulations have shown that the average implantation depths are 10 nm and 20 nm for the respective materials. Lateral ion-beam profile and thus activity profile is estimated to be a 2D-Gaussian-Distribution with a FWHM of 1.5 mm. Radium activity is known from an integration of measured ion-current, but will be verified

[1] Consultative Committee for Ionizing Radiation, Section II: Measurement of radionuclides; International Bureau of Weights and Measures (BIPM)

with defined solid angle alpha spectrometry. The thusly produced sources feature ^{226}Ra activities ranging from 500 Bq to 1 200 Bq. Shortly, the emanation of ^{222}Rn from these sources will be investigated.

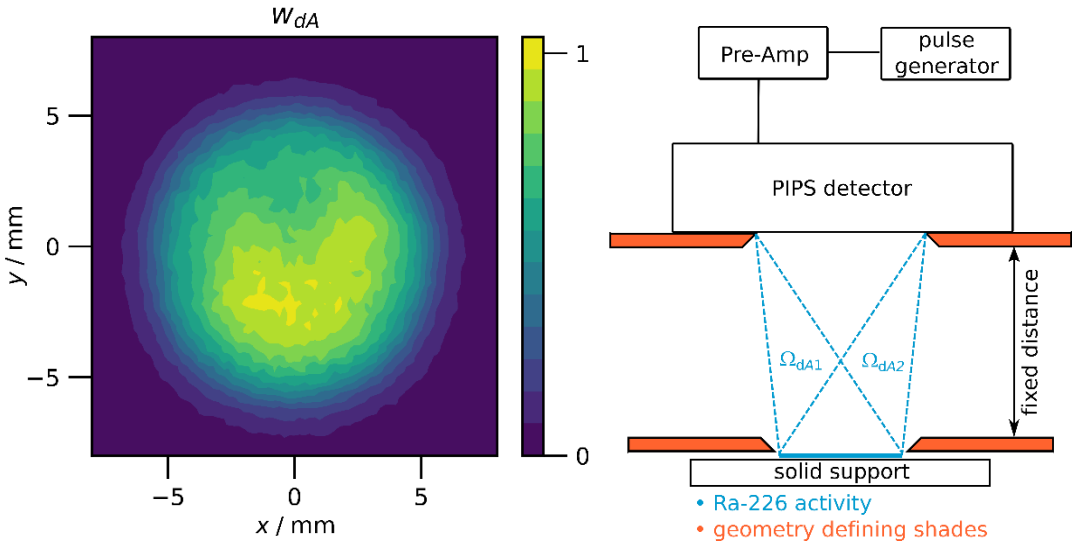

Figure 1. Absolute activity determination of Ra-226 electrodeposited sources by defined solid angle alpha spectrometry.

The results of the recent developments with electrodeposited sources have been presented at the IRPA European Congress 2018. The poster is also available in the Documents Section of the MetroRADON website.

Parallel to the source developments, the work started at the calibration chambers to ensure that the new emanation sources can be included into radon tight gas circuits at the partners' calibration chambers. For the realization of stable activity concentrations in the calibration chambers two prerequisites must be fulfilled. The emanated radon activity of the sources must be measured traceably to primary activity standards, and the volume of the chambers and the whole gas circuits must be measured traceably to volume standards of national metrology institutes. These kinds of measurements are under way or have already been finished. In addition, the instrumentation at the calibration chambers for the monitoring of temperature, air pressure and humidity will be completed, shortly.

SÚJCHBO continued to build the technical infrastructure of the Low-Level Radon Chamber (LLRCh) and verifyed the gas tightness of the LLRCh. The technical peripheries, mainly focused to measure the physical conditions of the inner LLRCh atmosphere, were added. The measuring features of the AlphaGUARD PQ2000 PRO with AlphaGUARD DF 2000 were compared. The influence of the measuring device background was identified as a crucial point of the low-level radon concentration measurements. The background of these measuring devices will be studied further in a radon-free atmosphere. The usability of grab sampling methods from low volume radon chambers for radon concentration measurements was verified. The individual technical devices needed for the realization of the radon-tight gas circuit were specified and radon tightness was ensured. The possibilities of the radon source placing inside or outside the LLRCh (important due to influence of gamma dose rate for electrets) measuring system response were considered.

At IFIN-HH's radon chamber equipment for the monitoring and control of environmental parameters of the radon chamber (like a portable air conditioning system, humidifier and dehumidifier) has been implemented for the development of instrument calibration procedures for radon concentration in the range (100 - 300) Bq/m^3. The new technical installations as well as dedicated computer software for automated functioning of the radon chamber are currently being tested.

A paper on the design of the radon chamber was presented at the IRPA European Congress 2018, NORM session, in The Hague, Netherlands, 4-8 June 2018: A. Luca, L. Serbina, C. Varlam, M. Sahagia, D. Schitea, I. Faurescu, O. Sima, M.-R. Ioan, A. Antohe, C. Teodorescu, V. Batrineanu, C. Ivan and L. Teodorescu – Designing and construction of a new radon calibration facility in Romania. It will be published in the IRPA proceedings and is currently submitted for a peer reviewed publication in the Journal on Radiological Protection. A PDF version of the conference presentation is available in the Documents Section of the MetroRADON website.

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.

After establishing stable thoron atmospheres at the thoron calibration chamber at IRSN (BACCARA) and establishing a calibration protocol, a joint ^{220}Rn calibration exercise of the most commonly used radon measurement devices has been conducted in May 2018. The participating laboratories (IRSN, SUBG, STUK and BEV-PTP) sent their thoron secondary reference instruments to IRSN (Fig.1), where they were calibrated using the primary thoron system. The calibration covers three thoron activity concentrations around 5 kBq/m^3, 50 kBq/m^3 and 400 kBq/m^3. The experimental arrangement in the BACCARA chamber just before the start of the calibration is shown in Fig. 2.

In parallel to the calibration experiments, a study of the homogeneity of the thoron atmosphere in the chamber is carried out. The proposed methods for the quantification of thoron homogeneity include: numerical calculations (IRSN), measurement methods based on capture of thoron progeny in polycarbonates or aerogel and subsequent liquid scintillation counting (SUBG, LNHB) and methods based on track-etch counting of solid state nuclear track detectors (SUBG).

Construction of a new thoron exposure system at STUK is finished and inter-comparison of in-house thoron instruments has been carried out. Inter-comparison of recently purchased flowmeters delivered with a valid calibration certificate traceable to the primary standard showed that the calibration of these instruments varies up to 10 %. The test method for measuring cross-interference given by standard IEC 61577-2 was found inadequate during the first tests. Work on addressing these findings has started. A literature review of potential techniques and materials to reduce the influence of thoron on radon measurements and calibrations was conducted. About 70 articles have been found of which about 40 have been included in the review report that is available in the Documents Section of the MetroRADON website.

Figure 2. Preparation of the secondary reference instruments for the calibration.

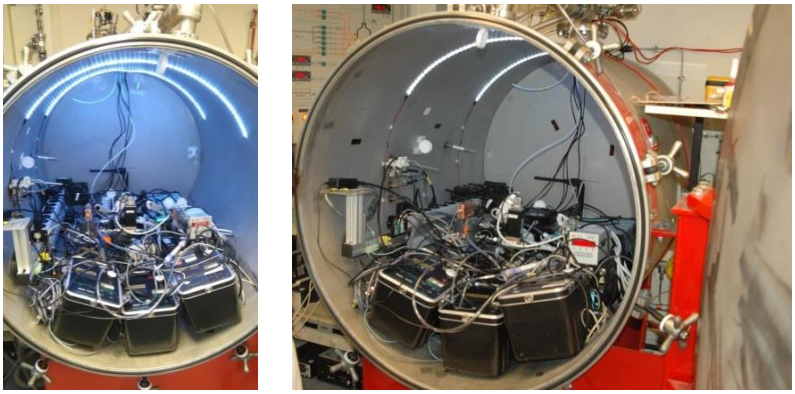

Figure 3. Arrangement of the detectors in the BACCARA chamber at IRSN just before the start of the calibration.

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

The aims of WP3 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.

Overview and analysis of indoor radon surveys in Europe

To produce a literature review of existing indoor radon surveys in Europe, VINS (in cooperation with AGES and the JRC) collected papers from journal databases, conference papers from international and national proceedings and found additional papers by analysing references listed in the papers already identified.

In September 2017 VINS started a review of the papers collected on existing indoor radon surveys in Europe. Literature was analysed regarding different steps of the “survey chain”, e.g. from survey design (corresponding to a given survey policy) through sampling and measurements to evaluation and interpretation. From each paper the following information was collected: country name, title of paper and authors, area covered by the survey, survey goal, sampling strategy, sampling procedure, measurement technique, evaluation of single measurement, survey period, time of year during which the survey was conducted, single measurement duration, number and type of locations, evaluation of

survey, interpretation of results, whether quality assurance was included, thoron measurements and comments/links for the paper. A review will be available by end of 2018 on the MetroRADON website.

In order to collect missing information from the literature, and to obtain information about how the countries intend to transpose the EU-BSS into national law, a questionnaire on indoor radon surveys has been designed by JRC and AGES. The questionnaire is structured in six sections: introduction; information about respondent; characteristics of indoor radon survey; measurements methods; data management, statistical treatment, aggregation and mapping; policy on indoor radon. In December 2017 the questionnaire was distributed to various institutions with the purpose to include data from national and regional surveys collected by universities, research institutions and competent authorities. Between December 2017 and May 2018, universities, research institutions and competent authorities from 24 European countries have duly completed and returned 55 questionnaire forms on national and regional indoor radon surveys.

In parallel, SUBG completed reviewing if using CDs/DVDs for retrospective radon measurements for indoor radon surveys (CD/DVD method) is applicable. A literature review of more than 50 relevant publications was made and a document with the full texts and a short summary of ten of them (considered as the most relevant to MetroRADON tasks) was prepared and delivered to the WP3 leader.

The main directions were: Retrospective dosimetry of radon and thoron indoors (incl. for the purposes of radon mapping); Identification of radon priority areas and buildings with annual average ^{222}Rn levels above the reference level; Retrospective evaluation of the effect of building retrofit on radon levels; Measurements in working places (incl. underground mines). The conclusion is that the comprehensive research output to date proves that the CD/DVDs from the stock stored indoors can be used as ^{222}Rn detectors in radon surveys. They can provide short-term estimates of the annual average ^{222}Rn concentration (averaged over the years of exposure) with relative uncertainty better than 24 %. Eventually, the uncertainty can be much lower, when individual calibration and corrections are applied. Retrospective evaluation of the effect of building retrofit on ^{222}Rn levels is possible by comparing two CD/DVDs of different age.

Overview and analysis of geogenic radon surveys in Europe

To produce a literature review of existing geogenic radon surveys in Europe, BFKH (in cooperation with VINS, AGES and BfS) collected journal papers by using journal databases, conference papers from international and national proceedings and found additional papers by analyzing references listed in the papers already identified. The results of this research have been summarized in a dedicated report (Geogenic Radon Potential – Summary of literature) and in a condensed version (Geogenic Radon Potential – Short overview) that are available in the Documents Section of the MetroRADON website. They main focus of the report is on: geogenic radon potential concepts; relationships between various parameters used to estimate geogenic radon potential; spatial distribution of radon in Europe, and distribution of radon measurement methods and measurement devices in Europe.

In order to collect missing information from the literature, and to obtain information about how the countries intend to transpose the EU-BSS into national law, a questionnaire on geogenic radon surveys has been designed. The questionnaire is structured in six sections: introduction; information about respondent; radon measurement in soil gas surveys; radon exhalation rate surveys; radon in water; external gamma dose rate; U concentration in soil/rock; airborne; other. Between December 2017 and

May 2018, universities, research institutions and competent authorities on national and regional surveys from 19 European countries have duly completed and returned 28 questionnaires.

In addition, UC and IRSN evaluated the existing ISO standards EN ISO 11665-7 and ISO 11665-11 on the methodology of radon exhalation measurements and of radon concentration in soil gas measurements, in order to assess whether and how appropriate the methodologies in these standards are for use in the MetroRADON project. After reviewing the two ISO standards 11665-7 (Measurement of radioactivity in the environment—Air: radon-222—Part 7. Accumulation method for estimating surface exhalation rate) and 11665-11 (Measurement of radioactivity in the environment—Air: radon-222—Part 11) UC and IRSN agree that they are well related to the MetroRADON project. The work of Task 3.3 (Intercomparison excercises at field conditions) might provide some data relevant to evaluating the methods and giving some elements for further revision of the standards.

One comment on the EN ISO 11665-7 could be sent to the ISO group: to give another example for the measurement of a radon exhalation rate above 5 $mBq.m^{-2}.s^{-1}$ (Annex B, B.5 Example) in order to be within the scope of the standard since the result of the current example is lower than the limit value given in the scope of the standard.

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

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). In the framework of this activity the first set of 10 CDs and 10 DVDs has been exposed for 6 months in UC's Saelices el Chico laboratory and the processing and analysis of the exposed disks is currently ongoing in SUBG. SUBG is also developing and evaluating a detector system for continuous, unperturbed monitoring of radon in soil gas concentrations. A dedicated detector for that purpose has been developed and currently its performance in in-situ measurements is being tested.

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. Therefore, an exercise is currently being carried out in cooperation with institutions from all over Europe working on radon mapping in their respective countries. All participants will apply their mapping method and definition of delineation of radon areas in their countries to two test data sets from a region in Austria and Spain. Afterwards the variability of methods and outcomes will be discussed together with how the different strategies influence the results. The exercise is ongoing, first results will be available in autumn 2018.

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 WP5 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 WP5 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.

As a first step the relevant European radon calibration facilities were identified. To ensure traceability, the quantity “radon activity concentration” must be related to primary quantities through an unbroken chain of calibrations. For this purpose, a questionnaire has been sent to all project partners to fill in and distribute to accredited radon calibration laboratories or to the most relevant radon calibration laboratories in their country or other European countries.

The results of the questionnaire were evaluated, and 14 European radon calibration facilities have been identified, evaluated and selected for validation and traceability exercises in the radon activity concentration ranges from 100 Bq/m^3 to 300 Bq/m^3 and from 300 Bq/m^3 to 10 000 Bq/m^3. The following information was evaluated based on the results from the questionnaires: legal forms of laboratories; accreditation status; radon activity concentration measuring instruments which represent the highest metrological level; methods of calibration; calibration ranges; uncertainties of calibration capabilities; size of radon chamber; climatic conditions; additional parameters which can be monitored or controlled; number of calibrations.

In May 2018 the intercomparison for the validation of European radon calibration facilities in the range from 300 Bq/m^3 to 10 000 Bq/m^3 (radon intercomparison) has started. Hereto, the German Federal Office for Radiation Protection (BfS) provides an electronic radon instrument AlphaGUARD as transfer comparison device since it is commonly used. The device will be sent consecutively to each of the participating laboratories. Between calibrations at each participant’s laboratory, BfS will check the proper operation of the device and its compliance with metrological requirements.

For the purpose of comparison, the transfer comparison device shall be placed in the corresponding radon atmosphere to perform exposures in agreement with the routine procedures of the participant. In order to cover a wide range of typical exposures, the device should be exposed to three radon atmospheres at levels of 400 Bq/m³, 1 000 Bq/m³ and 6 000 Bq/m³. As a result of the intercomparison, the precision and performance of European radon calibration facilities as well as differences in traceability will be identified. It thus contributes to further harmonization of radon metrology in Europe. Due to the large number of laboratories that request participation and the short time scheduled, the intercomparison will be carried out in two stages. In the first stage mainly the national metrology institutes are involved. The second stage will expand the intercomparison to the other laboratories. It is intended to accomplish the first stage by June 2019.

BfS together with input from all partners has developed the protocol for the comparison exercise to validate the traceability, performance and precision of European radon calibration facilities in the range of 300 Bq/m³ to 10 000 Bq/m³ and selected three calibration points.

The results and findings from the intercomparison exercise will be a part of the guideline and recommendations on calibration and measurement procedures for the determination of radon concentration in air that will be published in 2020.

MetroRADON at conferences and first publications

First MetroRADON results were already presented at several conferences, e.g. 5th European IRPA Congress (IRPA 2018), 2nd International Workshop on the European Atlas of Natural Radiation (IWEANR 2017), 12th Conference on Geostatistics for Environmental Applications (geoENV 2018).

Two literature review reports were conducted: "Review of potential techniques and materials to reduce the influence of thoron on radon measurements and calibrations" and "The Geogenic Radon potential in Europe".

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

MetroRADON – upcoming events

MetroRADON presentations are confirmed already for several conferences in the next months, e.g. 14th International Workshop on the Geological Aspects of Radon Risk Mapping, Prague, (GARRM), Nuclear Science Symposium and Medical Imaging Conference, Sydney (IEEE NSS-MIC), Annual Conference of the International Association for Mathematical Geosciences, Olomouc (IAMG 2018), 9th International Conference on High Level Environmental Radiation Areas, Hirosaki (ICHLERA 2018).
Several more presentations are planned for future conferences, such as the 22nd International Conference on Radionuclide Metrology and its Applications (ICRM'19), Salamanca.

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

Figure 4. The MetroRADON consortium at Kick-off meeting in Vienna, June 2017 and 1st progress meeting in Braunschweig, February 2018

Further contact and information:
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