NUKLEONIKA 2020;65(2):127–132
doi: 10.2478/nuka-2020-0020

ORIGINAL PAPER

Radon intercomparison tests – Katowice, 2016

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Abstract. At the beginning of the year 2016, the representatives of the Polish Radon Centre decided to organize proficiency tests (PTs) for measurements of radon gas and radon decay products in the air, involving radon monitors and laboratory passive techniques. The Silesian Centre for Environmental Radioactivity of the Central Mining Institute (GIG), Katowice, became responsible for the organization of the PT exercises. The main reason to choose that location was the radon chamber in GIG with a volume of 17 m^3, the biggest one in Poland. Accordingly, 13 participants from Poland plus one participant from Germany expressed their interest. The participants were invited to inform the organizers about what types of monitors and methods they would like to check during the tests. On this basis, the GIG team prepared the proposal for the schedule of exercises, such as the required level(s) of radon concentrations, the number and periods of tests, proposed potential alpha energy concentration (PAEC) levels and also the overall period of PT. The PT activity was performed between 6th and 17th June 2016. After assessment of the results, the agreement between radon monitors and other measurement methods was confirmed. In the case of PAEC monitors and methods of measurements, the results of PT exercises were consistent and confirmed the accuracy of the calibration procedures used by the participants. The results of the PAEC PTs will be published elsewhere; in this paper, only the results of radon intercomparison are described.

Keywords: Active and passive monitors • Polish Radon Centre • Proficiency test • Radon

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Received: 2 December 2019
Accepted: 17 January 2020

Introduction

Intercomparison experiments are crucial for ensuring the validity and reliability of results. Thus, all laboratories with accredited methods or those who apply for accreditation participate in such measurements. Moreover, the new European Union Basic Safety Standards (EU-BSS, [1]) require the preparation of the National Radon Action Plan, which should be a comparison of radon testing methods to ensure compliance with requirements of the regulations. Usually, it means that the detection limit of any method should be lower than 10% of the recommended threshold value. In the case of radon, the recommended value for workplaces and dwellings is, according to EU-BSS, 300 Bq/m^3. Taking into considerations this limit, the detection limit of any method for radon estimation should be 30 Bq/m^3 or lower.

In Poland, a new Atomic Law has been published [2], containing the same requirements as EU-BSS [1], related to the National Radon Action Plan. The Polish Radon Centre (PRC) is a society consisting of Polish institutions that conduct investigations of radon levels in the air, water and soil over the past two decades. In the past, PRC has organized comparative measurements of radon concentrations in air and water. The results and conclusions of the previous experiments have already been published [3, 4]. The problem of conformity of the results obtained from radon measurements conducted in different countries by different investigators has been emphasized since many years all over the world (World Health Organization; [5]). To achieve such compatibility, special comparison exercises (proficiency tests, PTs) are organized, sometimes within particular countries or for participants from different countries [6, 7]. Furthermore, specialized laboratories offer such a service to the institutions responsible for radon monitoring in dwellings [8–13].

To prepare PRC member institutions to undertake extended radon measurements, it has been decided to launch the preparations for the PTs, taking into account the predicted changes in European and Polish legal systems. In June 2016, another round of interlaboratory comparative measurements of the concentration of radon and its short-lived decay products in the air was organized (the list of participants – see Table 1). The organization of the tests and the evaluation of the validity and reliability of the results obtained by the participants were taken up by the Silesian Centre for Environmental Radioactivity of the Central Mining Institute (GIG) in Katowice.

Fig. 1. The view of the radon chamber.

The Silesian Centre for Environmental Radioactivity GIG has a radon chamber made by the Feutron Company (Germany).

The GIG radon chamber consists of two main parts (Fig. 1):

I. Main chamber with dimensions 2.75 m × 2.75 m and height 2.25 m. The volume of the main chamber is 17.0 m^3.
II. The airlock with dimensions 1.25 m × 1.00 m and height 2.25 m. The volume of the airlock is 2.8 m^3.

Methods

For radon monitors and passive methods, three different exposures were prepared, with significantly different radon concentrations. Three Pylon flow-through ^{226}Ra sources were applied for this purpose.

The exposures in the radon chamber were carried out from the 6th to the 16th of June 2016. Different

Table 1. List of participants

No.	Participant name	Participation in radon PT	Participation in radon PAEC PT
1	University of Wrocław	Yes	Yes
2	University of Silesia in Katowice, Institute of Physics	Yes	
3	University of Łodz	Yes	
4	Institute of Nuclear Physics PAN, Kraków (IFJ PAN)	Yes	Yes
5	Nofer Institute of Occupational Medicine (IMP)	Yes	Yes
6	Institute of Nuclear Chemistry and Technology	Yes	Yes
7	Medical University of Bialystok	Yes	
8	Central Laboratory for Radiological Protection CLOR	Yes	
9	Building Research Institute	Yes	
10	Central Mining Institute, Silesian Centre for Environmental Radioactivity	Yes	Yes
11	AGH University of Science and Technology	Yes	
12	Lodz University of Technology	Yes	Yes
13	Bundesamt für Strahlenschutz Berlin	Yes	
14	Wrocław University of Science and Technology	Yes	Yes

Note: PAEC – potential alpha energy concentration.

Fig. 2. The view of the interior of the radon chamber during the PTs.

exposure durations and radon concentrations were applied. During each exposure, all radon detectors, both passive and active, were placed in the chamber (Fig. 2). The active devices were set for continuous operation – to measure and monitor all concentration changes caused by source exchange, ventilation of the chamber, and so on.

The following active and passive devices belonging to several different measurement groups were placed in the radon chamber:

- three RAD7 active radon monitors,
- three AlphaGuard monitors,
- one RadStar monitor,
- one EQF 3220 monitor,
- one Pylon AB-5 monitor,
- one SRDN-3 monitor.

The RAD7 and AlphaGuard active monitors were set for continuous measurement for all the 10 days of exposures. The passive detectors listed below were removed from the chamber by the respective scientific groups after each exposure period. For charcoal canisters, the exposure times were shorter due to the demand of 48 hours standard exposure time for PicoRad canisters. The durations and reference concentrations of radon for all individual exposures are shown below; the specific exposure times for PicoRads are also given:

- PT 1 exposure lasted for 48 hours (from 6/06/2016, 12:00 hours to 8/06/2016, 12:00 hours). The reference concentration of radon was 14.84 kBq/m^3; to obtain this concentration, a radon source owned by GIG was used. The exposure value was 712.3 kBq·h/m^3.
- PT 2 exposure lasted for 114 hours (from 8/06/2016, 16:00 hours to 13/06/2016, 10:00 hours) for track detectors. The PicoRad canisters were exposed from 10/06/2016, 15:00 hours to 13/06/2016, 10:00 hours. The exposure was longer than 48 hours, routinely used for such detectors. During this exposure, the radon sourced from the Institute of Occupational Medicine in Łódź was used. The radon reference concentration was 0.337 kBq/m^3, and the exposure value was 45.2 kBq·h/m^3.
- PT 3 exposure lasted 68 hours (from 13/06/2016, 14:00 hours to 16/06/2016, 10:00 hours) for track detectors. The PicoRad detectors' exposure lasted from 14:00 hours on 13/06/2016 to 14:00 hours on 15/06/2016 (except for three detectors from the University of Silesia, which were left in the chamber until 10:00 hours on 17/06/2016). During this exposure, a source of radon obtained from the Institute of Nuclear Physics PAN in Kraków was used. The radon reference concentration was 0.936 kBq/m^3, and the exposure value was 67.39 kBq·h/m^3.

Results

Three flow-through Pylon sources were used to prepare the reference radon atmospheres. During these exposures, the PTs of the passive detectors were also conducted. Similarly, a comparison of grab sampling, with the use of Lucas cells, was performed.

The exact concentrations for the three exposures were 14.84 ± 0.44 kBq/m^3, 0.337 ± 0.010 kBq/m^3 and 0.936 ± 0.028 kBq/m^3, respectively. The uncertainties of the reference concentrations were calculated on the basis of sources' certificates, and extended uncertainties of ±3% were applied.

The results of the comparative measurements are summarized in Tables 2, 3 and 4.

Table 2 presents the radon concentration results obtained by participants using active detectors/methods for all three exposures. Table 3 shows the radon concentration results obtained by the participants using passive detectors. This table also shows the results of the measurement using PicoRad detectors. Table 4 summarizes the radon concentration measurements obtained using the Lucas cells.

The participants' codes are known to each institution involved in the measurements; in the situation where a participant has performed measurements using several instruments, a number assigned to that instrument was added to the participant's code.

The criterion for assessing the results of each participant was based on the analysis of the Z_{score} value [14–16], calculated according to the following formula:

$$Z_{score} = \frac{(x_i - x_{ref})}{\sigma} \quad (1)$$

where: x_i – participant's result; x_{ref} – reference value (reference concentration value for each exposure); and σ – the value of the standard deviation of obtained results, after the rejection of outliers.

The absolute value of the Z_{score} parameter determines whether the result of a particular participant is acceptable.

If $|Z_{score}| \leq 2$, this result is satisfactory;

If $2 < |Z_{score}| < 3$, this result is doubtful but acceptable;

If $|Z_{score}| \geq 3$, this result is unsatisfactory.

The assessment of the measurement results obtained by the participants is presented in Tables 5, 6 and 7. Table 5 shows the results for the active methods, Table 6 presents the evaluation of results obtained using track detectors, and Table 7 shows the evaluation of results obtained using Lucas cells.

Table 2. Radon concentration measurement results obtained by the participants using active monitors

Participant code	PT 1		PT 2		PT 3	
	C_{Rn}	U	C_{Rn}	U	C_{Rn}	U
	[kBq/m^3]					
A	14.70	0.03	0.371	0.030	0.916	0.006
B1	15.90	0.80	0.417	0.021	1.028	0.051
B2	14.00	0.70	0.307	0.015	0.746	0.037
C	Outside the range of monitor		0.458	0.023	0.977	0.049
D	15.46	0.77	0.455	0.023	1.022	0.051
E	15.30	0.05	0.359	0.003	0.712	0.008
F1	13.46	0.67	0.352	0.018	0.844	0.042
F2	17.40	0.87	0.455	0.023	1.084	0.054
G	13.83	0.05	0.356	0.050	0.886	0.050
H	14.89	0.74	0.404	0.020	0.969	0.048
I1	14.69	0.73	0.371	0.019	0.919	0.046
I2	14.37	0.72	0.366	0.018	0.905	0.045
J	14.60	0.73	0.377	0.019	0.925	0.046
K	14.92	0.75	0.373	0.019	0.924	0.046
Reference value	14.84		0.337		0.936	

Notes: C_{Rn} – radon concentration measured by the participant; U – extended uncertainty of the result.

Table 3. Radon concentration measurement results obtained by the participants using passive detectors

Participant code	PT 1		PT 2		PT 3	
	C_{Rn}	U	C_{Rn}	U	C_{Rn}	U
	[kBq/m^3]					
C	9.875	0.49	0.455	0.02	0.939	0.05
M	13.530	0.68	0.379	0.02	0.968	0.05
F1	12.808	0.64	0.453	0.02	0.854	0.04
D1	15.917	0.80	0.374	0.02	0.937	0.05
D2	12.080	0.83	0.344	0.03	0.823	0.06
N	16.590	0.76	0.609	0.02	1.212	0.04
L1	14.580	0.63	0.335	0.03	1.079	0.11
E	15.105	0.76	0.305	0.02	0.754	0.04

Notes: C_{Rn} – radon concentration measured by the participant; U – extended uncertainty of the result.

Table 4. Radon concentration measurement results obtained by the participants using Lucas cells (grab sampling)

Participant code	PT 1		PT 2		PT 3	
	C_{Rn}	U	C_{Rn}	U	C_{Rn}	U
	[kBq/m^3]					
L1	15.10	0.90	–	–	0.88	0.06
L2	14.70	1.10	–	–	0.83	0.07
D	14.80	1.50	–	–	0.93	0.10

Notes: C_{Rn} – radon concentration measured by the participant; U – extended uncertainty of the result.

In the case of radon measurements using active monitors, the Z_{score} test showed that there are no grounds for rejecting any result as unsatisfactory. Only two results of participant F in exposure No. 1 and participant E in exposure No. 3 were assessed as doubtful, but acceptable.

In the case of radon measurements with passive detectors, it was found that in one case – participant N in exposure No. 2 – the obtained Z_{score} value was >3; hence, this result should be considered unsatisfactory (bold underline in Table 6). In addition, two results – of participant C in exposure No. 1 and of participant N in test No. 3 – were assessed as doubtful, but acceptable (bold in the table).

In the case of radon measurements using Lucas chambers, i.e., instantaneous measurements, no unsatisfactory results were found. In one case, during exposure No. 3, participant L obtained a result that was assessed as doubtful, but acceptable.

Summary

Thirteen radon laboratories from Poland and one from abroad took part in comparative measurements of radon concentration in the air.

The participants used different types of active monitors, as well as passive methods (track detectors CR-39, LR-115 and PicoRad activated charcoal containers) for radon measurements. Active meters were mostly AlphaGUARD monitors, in which ionization chambers were installed. RAD7 monitors were

Table 5. Evaluation of the results of comparative measurements of radon concentration for active monitors

Participant code	$|Z_{score}|$ value			Quality of the result
	PT 1	PT 2	PT 3	
A	–0.133	+0.732	–0.188	+
B1	1.054	0.893	0.902	+
B2	–0.833	–1.562	–1.862	+
C	–	1.808	0.402	+
D	0.619	1.741	0.843	+
E	0.458	–0.402	**–2.195**	±
F1	–1.367	–0.558	–0.902	+
F2	**2.539**	1.741	1.451	±
G	–0.998	–0.469	–0.490	+
H	0.055	0.603	0.323	+
I1	–0.146	–0.134	–0.167	+
I2	–0.465	–0.246	–0.304	+
J	–0.237	0.000	–0.108	+
K	0.081	–0.089	–0.118	+

Table 6. Evaluation of comparative measurements of radon concentration for passive detectors

Participant code	$|Z_{score}|$ value			Quality of the result
	PT 1	PT 2	PT 3	
C	**–2.252**	1.363	0.024	±
M	–0.594	0.035	0.257	+
F1	–0.921	1.328	–0.659	+
D1	0.489	–0.052	0.008	+
D2	–1.252	–0.577	–0.908	+
N	0.795	**4.055!**	**2.217**	±
L1	–0.117	–0.734	1.149	+
E	0.121	–1.258	–1.462	+

Table 7. Evaluation of comparative measurements of radon concentration using Lucas cells

Participant code	$|Z_{score}|$ value			Quality of the result
	PT 1	PT 2	PT 3	
L1	1.256	–	–1.120	+
L2	–0.665	–	**–2.120**	±
D	–0.185	–	–0.120	+

also increasingly used, in which the semiconductor detector was used as the alpha spectrometer. Two laboratories (IFJ PAN, IMP) have accreditation of their method for measurement of radon in the air using track detectors (AB 788, AB 327). One of the laboratories (IFJ PAN) additionally has accreditation of the method for measurement of radon in the air using an active meter.

In >90% of cases, participants obtained positive results for all three exposures and all measurement techniques (see tables in the text). In terms of measurements with active methods, in two cases, the participants obtained doubtful but acceptable results. During the measurements with passive detectors, in two cases, the participants reported doubtful but acceptable results. Unfortunately, in the case of one exposure, the result given by the participant was unsatisfactory. In the case of measurements using the Lucas chambers, one participant obtained a doubtful result. A detailed list is provided in Tables 5, 6 and 7, and the descriptions are provided under the tables.

Conclusions

It has been proved in the presented PT exercises that the major results of radon measurements, achieved with active and passive monitors, were in agreement with reference values. Such results and cooperation of the members of the Polish Radon Centre (PRC) is an important issue due to the future implementation of National Radon Action Plan, accordingly to the Euratom/59/2013 Directive and Polish Atomic Law. It seems to be necessary to test all available radon sources as we found significant flaws in comparison of real activities with the respective certificates.

Acknowledgment. This work was supported by the Polish Ministry of Science and Higher Education within the statutory activity of the Central Mining Institute, contract no. 11050317-370 in the period 4.01.2017 – 31.12.2018.

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