CONTINUOUS MONITORING OF RADON ACTIVITY CONCENTRATION FOR WORKPLACES

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Abstract

Since the publication of the European Council Directive 2013/59/Euratom and implementation of its requirements in the Romanian legislation in 2018, a series of recommendations have been published regarding the radon exposure in workplaces. In this paper the authors would like to emphasize the importance of continuous monitoring of Radon activity concentration for workplaces in the optimisation of radiation protection. In order to better estimate the workers' exposure to Radon, the concentration of Radon activity during the occupancy times should be taken considered. The results of the pro-bono studies for continuous Radon activity concentration measurements at various workplaces in public and private institutes in Romania are presented.

Keywords: *Radon, Continuous measurement, Workplace*

Introduction

The first studies for determination of health effects due to Radon exposure were performed in workplaces such as underground mines, and based on these studies results, in 1988, the International Agency for Research on Cancer (IARC) classified Radon as a carcinogen element [1]. According to European Agency for Safety and Health at Work studies, at least 22 million workers were exposed to IARC group 1 carcinogens. The most common exposures were to the following sources: *solar radiation* (9.1 million workers exposed during at least 75% of their working time), *ETS* (7.5 million workers exposed during at least 75% of their working time), *crystalline silica* (3.2 million exposed), *diesel exhaust* (3.0 million), *Radon* (2.7 million) and *wood dust* (2.6 million) [2], making Radon one of the main carcinogen element at the workplace.

Because health at work is a very important issue in all companies and is regulated by national authorities and international organisations such as International Labour Organization (ILO), a series of international documents which address the Radon exposure in workplaces were published after the European Council Directive 2013/59/ Euratom was issued: Radiation Protection 188 – Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides [3] and Radiation Protection 193 – Radon in Workplaces [4].

All recommendations from the publications mentioned above and the recommendations in ICRP Publication 126, Radiological Protection against Radon Exposure from 2014 [5] emphasize on the optimization principle in radiation protection in Radon exposure.

However, it happens that many times when we think of the optimisation principle, we only talk about reducing the doses as low as achievable, without the ″reasonable″ and without taking into account the economic and social factors. There are cases when the indoor Radon activity concentration averaged over one year is higher than the national reference level, and the first measure of optimisation of the radiation protection is to apply costly building remediation solutions, when one of the simplest solutions is to optimize the occupancy of the room, the working hours and the internal organisation of the company, respectively

Most of workplaces have predictable working hours, predictable holidays (winter, summer, national holidays), mechanical ventilation or HVAC systems, and one first step in optimisation of radiation protection of Radon exposure is evaluating its activity concentration during the working hours. This can be achieved through continuous Radon activity concentration monitoring.

In this paper, a summary of the results obtained from 4 of the participants to the study organised by Dositracker for continuous Radon monitoring is presented. Preliminary results were also presented at the National Conference of the Romanian Society for Radiation Protection and published in the conference proceedings [6, 7]. The results show how the holidays, weekends and other periods when there is no activity at the workplace are highlighted through continuous Radon monitoring.

Methods and instruments

Dositracker's Laboratory for Environmental Measurements is approved by the National Commission for Nuclear Activities Control (CNCAN) for continuous radon activity concentration using Airthings WAVE detectors.

Table 1 presents the technical characteristics of the detectors.

Table 1. Technical characteristics of Airthings WAVE detectors, [8]

	**Airthings Wave** is a continuous monitoring detector from the category of ″smart sensors″. The detector measures simultaneously 3 indoor air quality parameters: - Radon activity concentration - Temperature; - Relative Humidity; Through the mobile app, the detector transmits real time measured data, including alarms.
Technical specifications	
Power supply:	2x AA alkaline (LR6) or Energizer L91 batteries
Dimensions:	Radius: 120 mm ; Height: 36 mm
Weight:	219 g (incl. 2 x L91 batteries)
Temperature:	+4 °C to +40 °C
Relative humidity:	< 85 %
Initial Accuracy/Precision at 100 Bq/m^3	7 days < 20 % ; 1 month < 10 %
Measurement range	5 Bq/m^3 to 50000 Bq/m^3

Starting from 2019, Dositracker Laboratory organized pro – bono studies for continuous radon monitoring using the Airthings Wave detectors. Until now, 33 public and private companies in Romania participated to this study.

The detector measures continuously the Radon activity concentration and the measured value is recorded hourly. The recorded data are used to create graphs of temporal variation, highlighting periods with high measured values. The Radon activity concentration values in the indoor air depend on the weather conditions (temperature, humidity, precipitation, etc.), the constructive characteristics of the building, the heating system of the building and the ventilation systems for heating/cooling and ventilation ways of the rooms.

In order to cover seasonal variations, weekly routines or holidays, proposed measurements have been performed continuously, for at least 3 months, with at least 2 months in the winter season.

Radon detectors were placed in regularly occupied rooms located at the lowest level of the building, meeting the following criteria:

- Radon detector location was selected to allow the workers to continue their activities without any inconvenience.
- Radon detector has been placed far from heat sources (radiators, stoves) and from air ventilation systems, and at a significant distance from doors/windows, allowing the measurement process to be carried out in good conditions (humidity < 65%, protected from direct sunlight).
- Radon detector has been placed at a distance of at least 0.50 m above the floor, as close as possible to the height at which a person breathes in the room.

Quality Assurance

The Airthings WAVE detectors were tested in reference conditions by Dositracker Laboratory at the National Institute for Nuclear, Chemical and Biological Protection, (Czech Republic) and Table 3 presents the Radon chamber parameters. The testing laboratory from Czech Republic is traceable to the National Metrology Institute – Physikaliche – Technische Bundesanstalt, PTB (Germany).

Table 3. Parameters of the Radon chamber
National Institute for Nuclear, Chemical and Biological Protection

Volume	10 m^3	
Parameters:	*From:*	*To:*
Radon Activity Concentration	100 Bq/m^3	2 MBq/m^3
Equilibrium factor	0.1	0.9
Unattached fraction f_p	0.02	0.3
Unattached fraction for ^{218}Po	0.05	0.9
Aerosol concentration	300 particles/cm^3	80000 particles/cm^3
Temperature	15 °C	25 °C
Relative Humidity	20 %	90 %

Airthings WAVE detectors were tested by exposure in Radon chamber at Radon activity concentrations from 200 Bq/m^3 to 2500 Bq/m^3. The detectors were exposed in Radon chamber for 7 days and the results showed that the performance requirements are fulfilled.

Results

Until now, results reported by 33 Radon detectors were analysed. Radon concentration was measured continuously for at least 3 months. Radon activity concentration averaged over the monitoring period was between 13 Bq/m^3 and 130 Bq/m^3. The hourly recording of Radon activity concentration allowed identification of the periods with higher concentration: weekends, holidays, COVID 19 pandemic period. Figs. 1 - 4 show examples of results that can be analysed using Airthings Wave detectors.

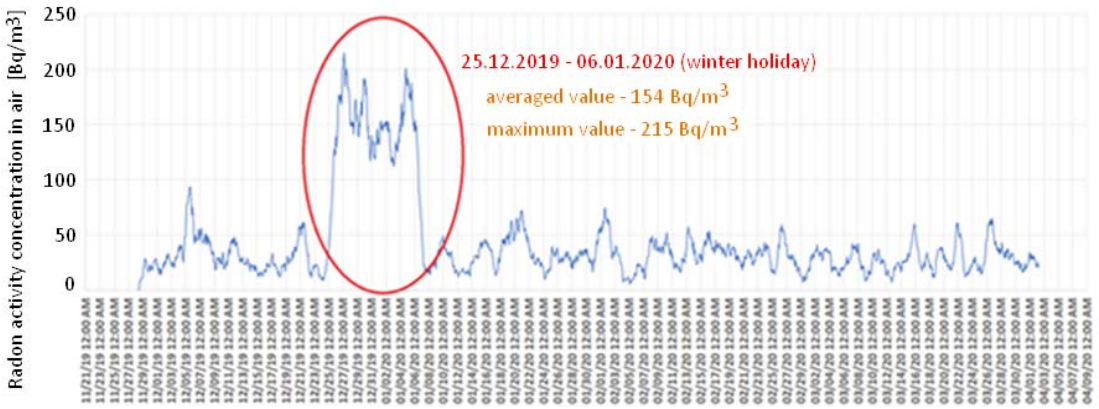


Fig.1. Evolution of indoor Radon activity concentration for one of the participants to the study
Monitoring period: 21.11.2019 – 09.04.2020

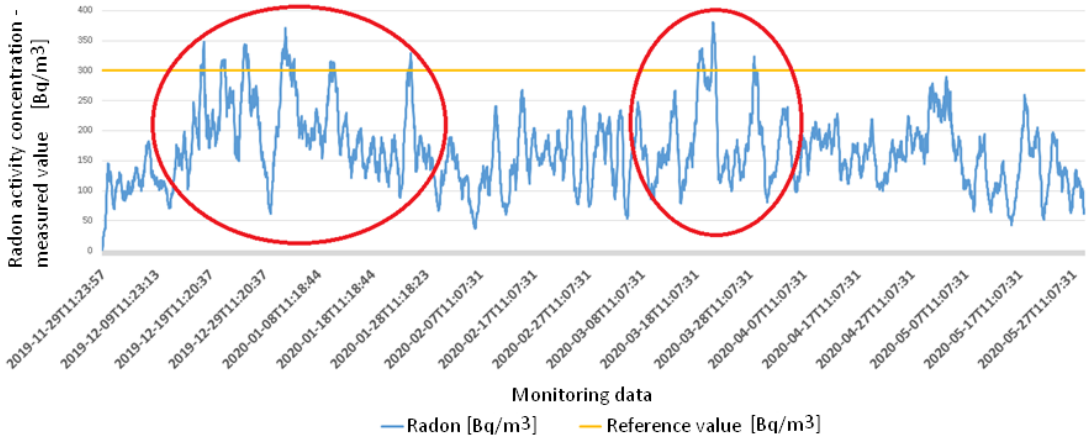


Fig.2. Evolution of indoor Radon activity concentration for one of the participants to the study, with highlights of the holiday periods and COVID-19 pandemics
Monitoring period: 29.11.2019-29.05.2020

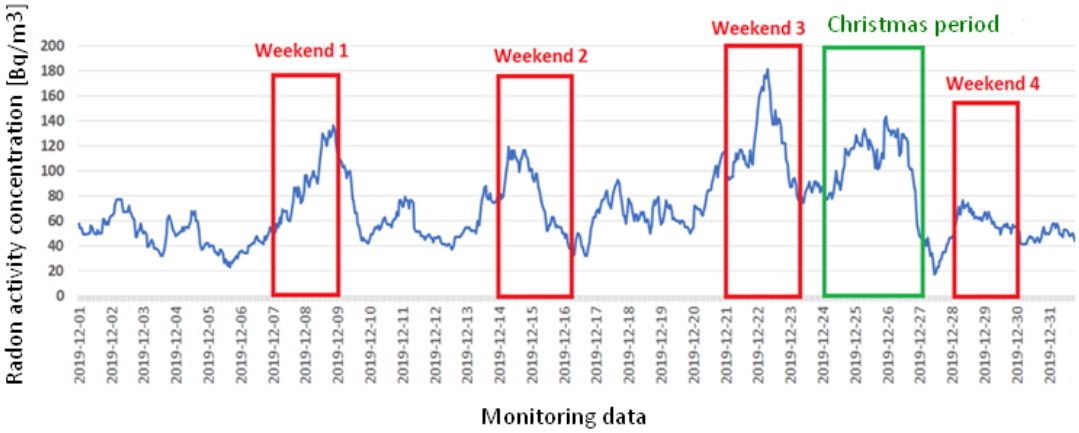


Fig.3. Evolution of indoor Radon activity concentration for one of the participants to the study, with highlights of the holiday periods and weekend.
Monitoring period: 01.12.2019 – 31.12.2019

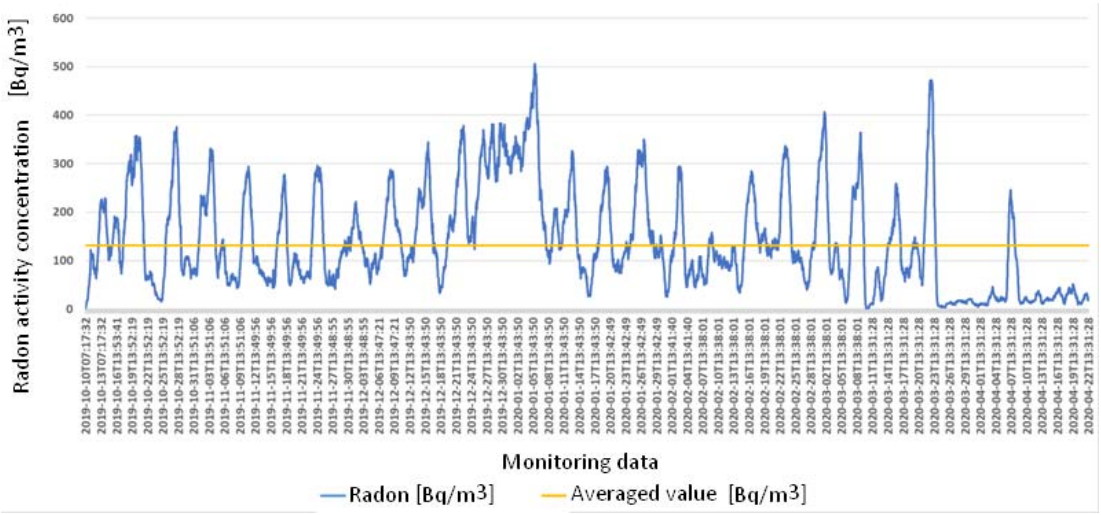


Fig.4. Evolution of indoor Radon activity concentration for one of the participants to the study
Monitoring period: 10.10.2019 –11.05.2020

A summary of the results from Fig.1 are presented below:
- Type of workplace: research institute
- Monitoring period: 21.11.2019-09.04.2020
- Radon activity concentration averaged over monitoring period: ***42 Bq/m^3***
- Maximum measured value: ***215 Bq/m^3*** measured on 27.12.2019
- During the winter holiday, 25.12.2019 – 06.01.2020, the detector measured the highest values from all the monitoring period: Radon activity concentration averaged over the winter holiday – ***154 Bq/m^3***; Maximum value – ***215 Bq/m^3***.

A summary of the results from Fig.2 are presented below:
- Type of workplace: dental radiology laboratory
- Monitoring period: 29.11.2019-29.05.2020
- Radon activity concentration averaged over monitoring period: ***167 Bq/m^3***
- Maximum measured value: ***380 Bq/m^3*** measured on 21.03.2020
- During the winter holiday, 21.12.2019 – 05.01.2020, the detector measured some of the highest values from all monitoring period: Radon activity concentration averaged over the winter holiday – ***234 Bq/m^3***; Maximum value – ***371 Bq/m^3***.
- During COVID 19 pandemics when the professional activities were closed, 13.03.2020 – 29.03.2020, the detector measured the highest values: Maximum Radon activity concentration: **380 Bq/m^3**.

A summary of the results from Fig.3 are presented below:
- Type of workplace: general hospital (medical doctor's office)
- Monitoring period: 26.11.2019 – 14.05.2020
- Radon activity concentration averaged over monitoring period: ***50 Bq/m^3***
- Maximum measured value: ***181 Bq/m^3*** measured on 22.12.2019
- During the winter holiday, 08.12.2019 – 31.12.2019, the detector measured the highest values from all the monitoring period: Radon activity concentration averaged over the winter holiday – ***77 Bq/m^3***; Maximum value – ***181 Bq/m^3***.

A summary of the results from Fig.4 are presented below:
- Type of workplace: general hospital (medical physicist's office)
- Monitoring period: 10.10.2019-11.05.2020
- Radon activity concentration averaged over monitoring period: ***131 Bq/m^3***
- Maximum measured value: ***506 Bq/m^3*** measured on 05.01.2020
- During the winter holiday, 25.12.2019 – 05.01.2020, the detector measured some of the highest values from all the monitoring period: Radon activity concentration averaged over the winter holiday – ***325 Bq/m^3***; Maximum value – ***506 Bq/m^3***
- The spikes represent the weekends. An example of the Radon activity concentration during one week is presented in Fig.5.

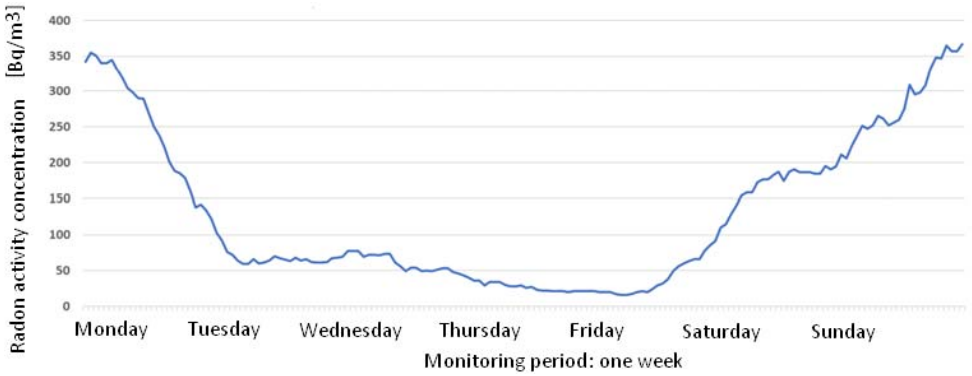


Fig.5. An example of the Radon activity concentration during one week (from the data presented in Fig.4)

Conclusions

The preliminary results presented in this paper show that the periods with no professional activities at the workplace can be highlighted using continuous Radon monitors such as Airthings WAVE. The detectors measure Radon activity concentration continuously and the measured results are reported hourly, allowing the user to evaluate Radon activity concentration averaged over the working hours.

Radon activity concentration continuous monitoring is a more suitable method for Radon exposure evaluation in workplaces as it offers a better estimate than the integrating method with the track etches detectors. Moreover, in workplaces with mechanical ventilation, HVAC systems or ventilation systems with fresh air intake, using the Radon activity concentration averaged over the working hours as an estimate of the annual activity concentration could prevent unnecessary and costly building remediation measures.

The continuous monitoring is also a method in line with the technical recommendations published by the European Commission in [3]: ″before mitigation is considered, it may be appropriate to undertake Radon measurements to identify if there are significant cyclic variations in the Radon concentrations that would affect the dose assessment. Concentrations could follow a diurnal pattern and/or reflect regular periods (e.g. weekends) when the workplace is not occupied″ [3].

Also, from the experience in Finland, described in the recommendations published by the European Commission in [4], the continuous method is used to better estimate annual average Radon activity concentration in workplaces: ″if the ratio between average during working hours versus the week average, multiplied with the long term average is less than the reference level, it can be concluded that the reference level is not exceeded″ [4].

Acknowledgement

We would like to thank all our partners who participated or are currently participating in our studies and they are providing us with valuable information for better estimating the radon exposure in workplaces.

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