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PARALLEL HALF-YEAR-LONG RADON CONCENTRATION MEASUREMENT AT TCAS IN ZRENJANIN, SERBIA

Iris Borjanović Trusina[1]*, Milica Rajačić[2]

[1]Technical College of Applied Sciences in Zrenjanin, Zrenjanin, Serbia
[2]Vinča Institute of Nuclear Sciences, National Institute of the Republic of Serbia, University of Belgrade, Belgrade, Serbia

Abstract. *Radon is a radioactive gas originating from the ground which can permeate enclosed spaces and pose serious health risks for humans when inhaled chronically. At the Technical College of Applied Sciences in Zrenjanin continuous measurements of radon concentration were undertaken during the summer and autumn of 2023. Radon concentrations were monitored in four rooms located in the basement and ground floor levels, covering an area of approximately 4000 m², where previous short-term tests had indicated the highest radon concentrations. Detectors were positioned approximately 1 meter above the ground and away from doors, windows, walls and heating sources. These rooms remained in normal use throughout the measurement period. Two types of detectors were utilised simultaneously, placed in close proximity to each other. Radon concentrations were assessed using active-type radon detectors branded as Airthings, alongside CR39 track detectors. The radon concentration values obtained with CR39 detectors demonstrated good agreement with the results obtained using Airthings detectors. The statistical Z-test was employed for analysis.*

Keywords: *Airthings radon detector, CR39 tack detector, indoor radon measurement*

1. Introduction

Ionizing radiation surrounds us everywhere on Earth, originating from both, natural and man-made sources. Radon is the dominant source of radiation from natural sources [1]. It is a noble gas. Radon isotopes are unstable and the most important naturally occurring isotope is ^{222}Rn [1]. It originates from the ^{238}U, which is present in stones and soil in minor concentrations. Radon isotopes decay through alpha decay, and their progenies, also radioactive, can attach to dust particles in the air and be inhaled in by humans [2].

Radon can escape from the ground into the atmosphere, where its concentrations are low. It can also enter houses through holes and cracks coming from the ground, or originate from building materials, water and gas. In closed spaces like basements or places with no proper ventilation, radon can accumulate in higher concentrations, posing hazards when inhaled or ingested [3], [4]. Thus, monitoring radon concentrations in living and working environments is important.

At the Technical College of Applied Sciences in the Zrenjanin (TCAS), we initially conducted short term tests of ^{222}Rn concentrations [5]-[8] in the two lowest level building rooms (basement and ground floor) by performing two-day radon concentration measurements. Later, we initiated continuous six-months radon concentration measurements during summer and autumn of 2023, as presented in this paper. The goal was to monitor radon concentrations over longer periods. We also conducted measurements with different types of radon detectors simultaneously to verify the reliability of the obtained results. This work was part of the projects "Parallel Yearly Radon Level Measurement at TCAS in Zrenjanin", funded by Provincial Secretariat for Higher Education and Scientific Research.

2. Detectors

For radon concentration measurements at TCAS, we utilized Airthings radon detectors and CR39 track detectors simultaneously.

2.1. Airthings detectors

Airthings radon detectors are active-type radon detectors based on alpha spectrometry [9]. Two models, the Corentium Home radon detector [10] and the View Plus radon detector [11] were used for ^{222}Rn concentration measurements in this study (see Figure 1).

These detectors detect alpha particles from radon decay. The fresh air enters the passive diffusion chamber, where a photodiode is located, every half an hour.

The photodiode acts as a digital version of the film used to reconstruct events from radon decay. Chromium is used to remove unwanted particles and particular algorithm was developed to eliminate "noise" events. Hourly measurements contribute to the average

* iris@ipb.ac.rs

concentrations. These detectors can perform both continuous measurements lasting a few days and measure radon over longer periods of up to one-year. The detector accuracy is 10% at 200 Bq/m^3 for measurements lasting seven days and 5% at 200 Bq/m^3 for two-month-long measurements. The View Plus radon detector is a “smart” version with Wi-Fi and Bluetooth connections. It also measures other air-quality parameters, namely temperature, humidity, pressure, particulate matter, volatile organic compound and carbon-dioxide. The Correntium Home model can measure up to 9999 Bq/m^3, while the View Plus can detect up to 20000 Bq/m^3.

Figure 1. Photo of Corentium Home radon detector.

2.2. CR39 track detectors

FIDO track detectors [12] (see Figure 2), produced by Niton srl, were also used to measure ^{222}Rn concentration in the air.

Figure 2. Photo of FIDO track detector.

FIDO track detectors are passive detectors. They are CR39 type detectors (Solid State Nuclear Track Detectors) and have a cylindrical shape (with diameter of 4 cm and a height of 2 cm). They are made of plastic polymers. Inside the detector, there is a small diffusion chamber made from conductive material. Due to exposure to radiation, the plastic is etched by passing particles. After being exposed to the air for a certain period, detectors are sent to certified laboratories where they are treated with sodium hydroxide and analyzed with optical microscopes and appropriate software which count the radon tracks. The optimal time of FIDO detector exposure is from 2 to six months. After the six-months exposure at TCAS, FIDO track detectors were sent to Niton Lab for analysis.

3. Measurement and Results

In closed spaces, radon is dominantly accumulated in the lowest building (or house) level like the basement and ground floor. Only when radon originates from building material does it make sense to measure radon concentration above the second floor. Radon fluctuates both daily and seasonally, because temperature, humidity, and pressure changes influence it [13], [14]. Therefore, it was planned to do a one-year-long measurement at TCAS via two consecutive six-months-long measurements. The first measurement took place from July till December 2023 and is described below. Measurements were performed in four rooms located in the basement and ground floor levels (covering an area of about 4000 m^2), where previous short-term tests [5]-[8] had indicated the highest radon concentration. In each room, two type of detectors (CR39 and Airthing) were simultaneously utilized in close proximity to each other. In the office 138 a View Plus radon detector (brand Airthings) was placed, while in other rooms measurements were performed with Correntium Home radon detector (brand Airthings). Detectors were placed on the table (approximately one meter above the floor) and away from heating sources, walls, doors and windows. The rooms remained in normal use during the measurement period.

Measured concentrations with associated uncertainties at a 95% confidence level (k=2) are shown in Table 1. The maximum measured radon concentration with the Airthings detector during the six-months long period was 49 Bq/m^3, while the maximum value obtained with the CR39 detector was 42 Bq/m^3. During the Vojvodina radon mapping [15], the median measured radon concentrations in the city of Zrenjanin, where TCAS is located, were between 100 Bq/m^3 and 120 Bq/m^3.

The statistical Z-test [16] was also applied to estimate the statistical difference between results obtained with the two mentioned type of detectors. The Z-test also takes into account the uncertainties of the measured results, so the Z was calculated using formula (1):

$$Z = \frac{c_{CR39} - c_{Airthings}}{\sqrt{u^2_{c_{CR39}} + u^2_{c_{Airthings}}}} \qquad (1)$$

where c_{CR39} and $c_{Airthings}$ are radon concentrations measured with CR39 and Airthings radon detectors, respectively, while $u^2_{c_{CR39}}$ and $u^2_{c_{Airthings}}$ are their corresponding uncertainties. Confidence interval of α=0.05 (critical value -1.96 < $Z_{0.05}$ <1.96) was used. All the calculated Z values (see Table 1) are below 1.96, which means that there is a good agreement between the two sets of measurements obtained with Airthings and CR39 radon detectors.

Table 1. Radon concertation measured simultaneously with CR39 track detectors and with Airthings radon detectors during a continuous six-months-long period (summer and autumn 2023.) at TCAS in Zrenjanin. The authors estimated Airthings detector precision for these measurements. Applied statistical Z-test results are also shown.

Room	Airthings radon concentr. (Bq/m³)	CR39 radon concentr. (Bq/m³)	Z-score
Library (ground floor)	31 ± 1	28 ± 7	0.42
Storage for technical equipment (basement)	36 ± 1	34 ± 8	0.25
Creativity studio (ground floor)	47 ± 1	42 ± 9	0.55
Office 138 (ground floor)	48 ± 1	32 ± 8	1.5

Medum monthly radon concentrations in Office 138 (with largest measured 6-months-long radon concentration) measured with Airthings View Plus radon detector are presented in Table 2.

Table 2. Monthly. radon concertation in Office 138 at TCAS measured with Airthings View Plus radon detectors.

Month	Monthly radon concentration (Bq/m³)
July	39 ± 3
August	46 ± 3
September	27 ± 2
October	46 ± 3
November	60 ± 4
December	70 ± 5

Slightly higher monthly radon concentration values are obtained in November and December compared to previous summer months as the windows were also kept less time open. The ratio of autumn to summer medium radon concertation is 1.57, similar to value obtained in a case study [17] at VINČA Institute of Nuclear Sciences where the obtained ratio was about 1.27.

4. Conclusion

According to our national legislation [18] intervention levels of radon concentration are set at 200 Bq/m³ for new buildings, 400 Bq/m³ for old buildings, and 1000 Bq/m³ for working places. These values should be harmonized with international recommendations. European Union regulations [19] require intervention level below 300 Bq/m³ in all living and working spaces. The World Health Organization (WHO) suggests even stricter limits [4] of 100 Bq/m³ in residential dwellings and propose that the national reference level should not exceed 300 Bq/m³.

Radon concentration values measured with Airthings radon detectors and CR39 track detectors at TCAS during the six-months period are within safe limits according to both national and international recommendations. Only regular ventilation is needed as a measure of radon elimination, and it is safe for both students and employees to stay and work at TCAS.

There is a good agreement between the results of radon concentration measurements obtained with both types of radon detectors (Airthings and CR39) that were used simultaneously. This was also demonstrated by the results of the statistical Z-test that was applied. Z-test results increase confidence in the used measurement methods.

Currently, the second parallel six-months measurement (which started in January 2024) is ongoing and after it ends on July 2024 we plan to estimate annual radon concentrations.

Found concentrations are objectively quite low compared to those in some problematic places (with some kBq/m³), due to the Panonian geology with usually low geogenic radon potential.

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