PROCEEDINGS OF SCIENCE

Seasonal Measurements of Indoor Radon Concentration Level in the Period of Summer at Technical College of Applied Sciences in Zrenjanin

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Radon concentration measurements were performed at Technical College of Applied Sciences in Zrenjanin during summer, as part of the "Radon level measurements" studies financed by the Provincial Secretariat for Higher Education and Scientific Research (the project is currently going on). The two lowest level rooms of the College building were examined, the basement and the ground floor. Measurements were performed with the active type radon detector based on alpha spectrometry (brand Airthings) which is capable of both long-term (up to 1 year) and short-term (a few days) continuous monitoring. The detector measured radon for 48 h in each of the rooms. The doors and the windows were closed during this period and the rooms were not ventilated for at least 12 h prior to the procedure. For short term measurements in 12 rooms radon level ranged from 10 Bq/m^3 to 36 Bq/m^3 with a mean value of 20 Bq/m^3. The results are compared with the previous results obtained in the same rooms during spring time measurements campaign. Spring time data were slightly higher and the ratio of the spring over summer medium radon concentration is 1.31 The maximum measured radon gas concentration at TCAS is below National Reference Level Limits of 400 Bq/m^3.

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1. Introduction

Ionizing radiation has ever been present in nature from the beginnings. Apart from the natural sources, today other man-made sources of radiation are present as well. Radon (Rn) is the dominat natural source of radiation [1]. It is an inert gas which has no color, smell or taste. The most important radon isotopes ^{222}Rn and ^{220}Rn [1] are radioactive and are produced by the decay of radium which comes from uranium and thorium series. Uranium in traces is present everywhere in rocks and soil. Radon can percolate through the soil and move to the surface. In the open air radon is diluted and its concentration is very small. When radon is trapped in a house or a buildings, its concentration can also reach higher levels. Radon daughters are not gasses and can easily be attached to dust and other particles which can be transported via air and then can be breathed in [2]. Radon can cause lung cancer [3], [4] and it is a much bigger threat for the smoking population [4], [5].

It is important to monitor indoor radon levels. Indoor radon levels are measured as part of the projects ("Radon level measurements") studies at Technical College of Applied Studies in Zrenjanin (TCAS) in summer 2022, which is financed by the Provincial Secretariat for Higher Education and Scientific Research. The analysis refers to ^{222}Rn, as the concentration of ^{220}Rn is usually much lower.

2. Detectors

We used two types of active radon detectors at TCAS, produced by Airthings. Those are Correntium Home Radon Detector [6] presented on Figure 1 and View Plus Radon Detector [7]. The Radon sensors inside the detectors are based on alpha spectrometry [8]. There is a passive diffusion chamber in which air flows in. A photo diode in the chamber measures the number of radon daughters. Fresh air flows into the chamber every 30 minutes. Chrome is used as a cage to retain unwanted particles. Special algorithm is developed that can discriminate radon and noise events. Measurements done every hour contribute to the average result as the detector provides average radon concentration after one, two or more days. The detector can continuously measure radon concentration up to one year. View Plus Detector has also WiFi and BlueTooth connections. It can be connected to applications on the mobile phone so the user can see the graphs of radon concentration over time. The data measured by View Plus can also be seen on PC via Airthings dashboard, a free online platform, from where it is possible to download and analyse raw data. The dashboard offers viewing of the archive of previous measurements. In addition, View Plus detector also measures air quality parameters like pressure, temperature, relative humidity, CO_2, VOC (chemicals from furniture and cleaning products) and the concentration of particulate matter PM2.5 and PM1 which can cause serious health problems. For both detectors the precision rate at 200 Bq/m^3 is 10% for 7 days measurements and 5% for two months measurements. Correntium Home Detector measures up to 9999 Bq/m^3, while View Plus can measure up to 20000 Bq/m^3.

Figure 1: Photo of Correntium Home Radon Detector by Airthings.

3. Measurements and Results

In houses and buildings, radon is measured in lower spaces like basements and ground floor where usually it accumulates the most. Significant amount of radon rarely occurs above the second floor where radon is mainly emitted from the building materials. The indoor radon concentration level can vary both daily and seasonally as the temperature, humidity, pressure changes and the atmospheric instability affects it all [9], [10.] In order to test radon levels, authors have performed short-term measurements of a few days at first. If high radon levels were discovered in some of the spaces, then long term (few months) measurements would be performed there.

At TCAS measurements were made in 12 rooms in the basement and ground floor levels with the surface of about 4000 m^2. Offices, labs, classrooms, a printing press office were all included there. Measurements were performed in rooms with closed doors and windows for two days. Before the start of the measurement, rooms were not ventilated for at least 12 h. Detectors were put at 1 m above the floor, far from doors and windows. The heating system was not in function. The obtained results are shown in Table 1. The authors estimated detector precision for these measurements to be 30%. The maximum value of radon concentration is 36 Bq/m^3 and the mean value is 20 Bq/m^3. Slightly higher values are obtained during spring measurements [11] in the same rooms at TCAS, when the maximum value was 42 Bq/m^3 and the mean value was 26 Bq/m^3. The ratio of the spring and the summer medium radon concentration is 1.31. Similar values were obtained in the case studies [12] at VINČA Institute of Nuclear Sciences where ratios of spring and summer radon concentrations were 1.31 and 1.35. Previous measurements of radon concentration level performed during Vojvodina radon mapping [17] showed that medium radon concentration in the city of Zrenjanin (where TCAS is placed) were in the range between 100 Bq/m^3 and 120 Bq/m^3.

In the open air radon concentration oscilates during the day as a consequence of changes of atmospheric stability [2]. Maximum values are reached in the early morning and during the night when temperature inversion happens and radon remains caged close to the ground. Minimum values are reached during the day when the sun heats the ground and the lower part of the atmosphere, so the vertical flow of air is present. Similar trend of radon variations were noticed in most of the studies in closed spaces where the ratio of daily maximum and minimum radon concentration was going up to 10. Sometimes due to natural or artificial ventilation it can happen that maximum is reached in an atypical part of the day [9], [13], [14], [15], [16]. In Figure 3 the plot of radon concentration level during 48 h in printing press office is shown as an example of daily variations of radon level measured during summer at TCAS. The maximum value is reached in the late afternoon and in the early morning. This room has a few badly insulated doors and holes, so the large morning values are the consequence of ventilation. The number near the plot is the medium value of radon concentration for this measurement.

Room	Radon concentration (Bq/m^3)
Basement, printing press office	36
Basement, lab for agricultural machinery	29
Basement, storage for technical equipment	21
Basement, lab for welding	12
Basement, lab for hybrid engines and vehicles	11
Ground floor, classroom 111	29
Ground floor, library	30
Ground floor, classroom 144	10
Ground floor, creativity studio	19
Ground floor, CIRT	13
Ground floor, classroom 137	12
Ground floor, students' club (138)	15

Table 1: Radon concentration levels measured during summer at TCAS.

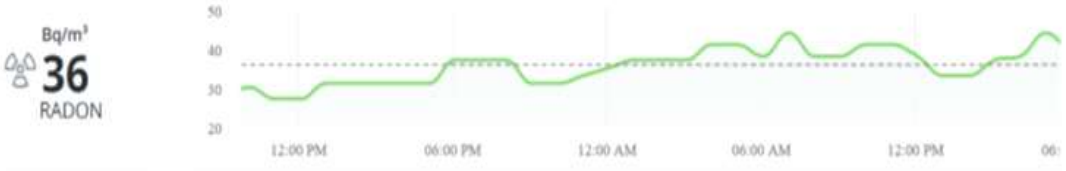

Figure 3: Plot of radon concentration level in printing press office measured during 48 h.

4. Conclusions

Serbia has adopted The Reference Level of Radon Concentration of 200 Bq/m^3 for new buildings and 400 Bq/m^3 for old buildings [18], [19]. The World Health Organization (WHO) assumes that radon concentrations greater than 100 Bq/m^3 are not recommendable. For high

indoor radon concentrations there are procedures of mitigation of radon, but daily ventilations are welcome for all spaces.

Radon concentrations measured at TCAS during summer 2022 are lower than WHO recommendations and National Reference Limits. It can be concluded that staying and working at TCAS is safe for everyone and there is no need for any space remedies. One of the future plans is to repeat the measurements during colder months.

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