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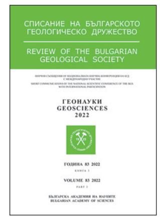

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# Dynamics in the radon index measurements at a specific test site

# Динамика в измерванията на радоновия индекс на определена тестова площадка

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**Abstract.** The study deals with the evaluation of the dynamic of the radon index in one pilot site based on second-time pilot investigations of the radon index in Bulgaria. In situ measurements of the radon concentration in soil gas, and soil permeability at three polygons: one over and two – close to fault zone have been performed in October 2020 and October 2022. The results show that higher radon content is detected in the fault zone in both cases.

**Keywords:** radon dynamics, *in situ* measurements, geology, fault, Bulgaria.

## Introduction

The naturally occurring radioactive element radon (Rn222) is a noble gas and is a daughter product of radium (Ra226) of the radioactive uranium (U238) family, which is found in every rock and soil in the lithosphere. The half-life of radon is sufficient (3.82 days) for it to pass from the terrestrial environment to the surface. This process can be more intensive because gas migration to the Earth's surface is strictly linked to preferential degassing pathways, such as faults or fracture systems (Etiope, Martinelli, 2002). The physical properties of the terrestrial environment, especially its permeability, can also affect the flux of Rn222 (Porstendorfer, 1994; Neznal, Neznal, 2005). Therefore, the geological structure is one of the main factors influencing the indoor radon variation and thus the radon concentration in buildings and radon exposure (Appleton, Miles, 2010). In this regard, the geogenic radon potential (GRP) of the terrain is the probability of the presence of high radon concentration in a building, the genesis of which is directly related to the influence of the earth's surface, and not *e.g.* from building materials. The concept of radon index is used to characterize GRP. One of the approaches for quantifying the radon index is based on a multivariate cross-tabulation, which includes two parameters – radon concentration in soil gas and gas permeability of the earth layer (MRDPW, 2019).

Within the framework of a research project, combined measurements have been started to determine the radon index of sites with a specific geological structure. The article aims to compare the data obtained from pilot combined measurements at a specific site (Botanical Garden – BAS) in October 2020 (Antonov et al., 2020) and those performed this year in October, in order to assess the dynamics of radon index.


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## Materials and methods

### *Study area*

The first site is located on the territory of the Botanical Garden at the National Academy of Sciences, and the chosen location is due to the presence of the so-called Vitosha fault, part of the Iskar fault zone (Zagorchev et al., 1994). The geological structure is represented by the lower volcanogenic-sedimentary association in depth, covered by a general deluvial-proluvial fan, the latter being subject to landslide processes (Tsenkov, Ivanov, 2004). The aim of the research is evaluation of the dynamic of the radon index, i.e. combined measurements of the radon index, including in situ determination of the concentration of radon in soil and the gas permeability of the respective soil layer at points possessing same coordinates falling on and away from the fault zone (Fig. 1).

### *Equipment*

In October 2020, the spatial position of the fault was determined by geophysical measurements performed with PQWT-TC300 instrument developed by Hunan Puqi Geologic Exploration Equipment Institute. The method is based on the measurement of the electric field caused by various mostly natural sources. After establishing the location of the fault violation, three polygons were selected – one in the range of the fault, and the other two to the north and south of it (Fig. 1). The distances between the polygons are as follows: between polygons T1 and T2 is 23.7 m, and between T2 and T3 – 31.5 m. The approximate area surveyed is 652 $m^2$. Gas permeability of the soil was measured both times (*October 2020 and October 2022*) by RADON-JOK system manufactured by Radon v.o.s, Czech Republic. The theoretical framework for measuring soil gas permeability is based on the Darcy equation (Neznal et al., 2004). The measurement range is from 2.0E-11 to 5.0E-17 [$m^2$]. Radon concentration in a soil gas was measured (*both times*) by an RM-2 system of the company Radon v.o.s, Czech Republic. The range of radon measurements in soil gas is between 3 and 900 kBq/$m^3$, air temperature +5 to +40 °C and humidity ≤70%. Direct gamma dose rate measurements were performed at each test site according to standard operating procedure with a Rados-RDS 110 portable dosimetry device (*both times*).

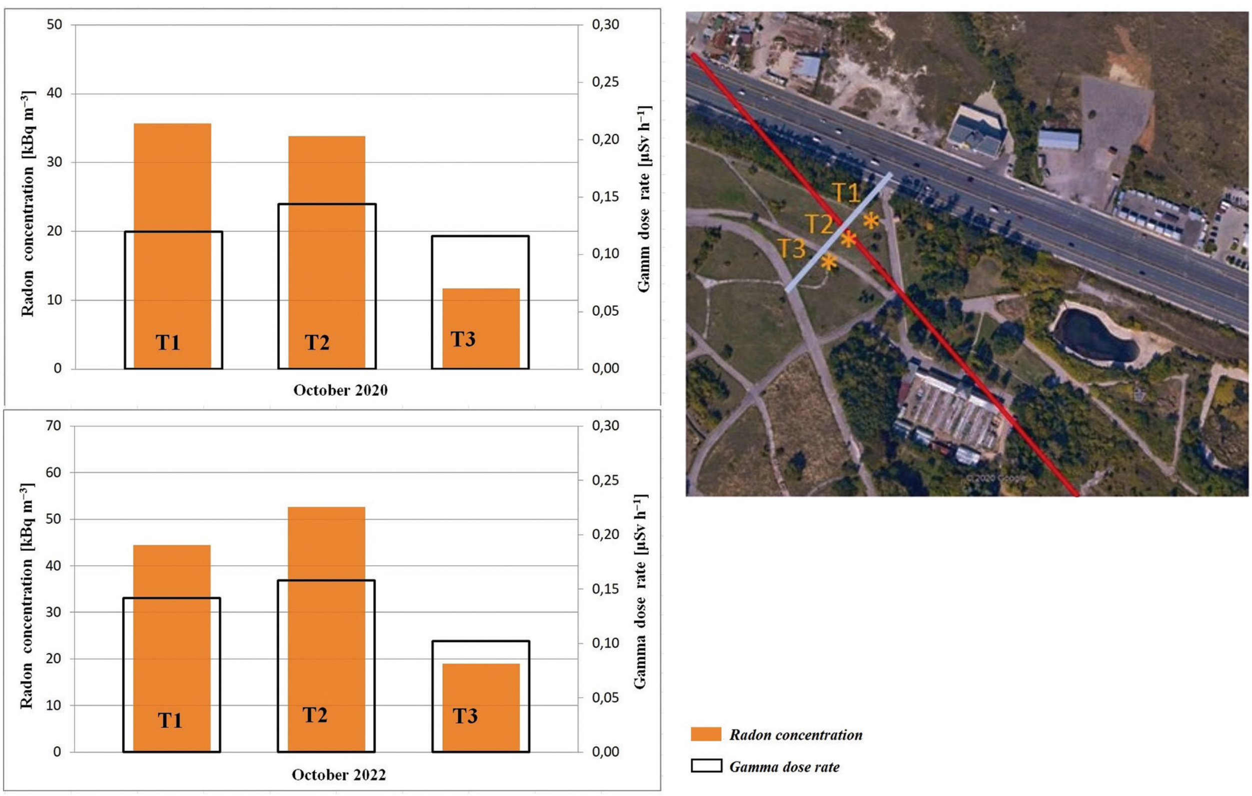


**Fig. 1.** Location of the selected polygons (the Vitosha fault is given by a red line), and the results of the radon concentration in the soil gas (according to the values of the third quartile) and the gamma dose rate in both campaigns

*Table 1. Polygon measurements of radon concentration in soil gas, soil permeability, gamma dose rate and determined radon index in both October 2022 and October 2020 campaigns*

| Polygon № | Coordinates | Radon concentration in soil [kBq/m$^3$] | Soil permeability [m$^2$] | Gamma dose rate [μSv/h] | Radon index |
|---|---|---|---|---|---|
| T1 | 42°38'46.0" 23°18'01.8" | 23.2±1.59 (24.1±1,6)* | 1.80E–12 (1.80E–12) | 0.17±0.02 (0.13±0.02) | high (medium) |
| | | 41.5±2.13 (35.7±2.0) | 1.90E–12 (1.50E–12) | 0.14±0.02 (0.12±0.02) | |
| | | 36.9±2.00 (26.3±1.7) | 1.70E–12 (2.05E–12) | 0.15±0.02 (0.12±0.02) | |
| | | 44.2±2.19 (24.2±1.6) | 2.00E–11 (8.50E–12) | 0.13±0.02 (0.13±0.02) | |
| | | 44.5±2.20 (55.0±2.4) | 2.00E–11 (8.00E–13) | 0.12±0.02 (0.12±0.02) | |
| **Third quartile** | | **44.4±2.20 (35.7±2.0)** | **2.00E–11 (4.00E–12)** | N/A | |
| T2 | 42°38'45.5" 23°18'00.6" | 50.3±2.34 (29.6±1.8) | 6.00E–12 (5.00E–12) | 0.18±0.02 (0.18±0.02) | high (high) |
| | | 53.4±2.41 (31.0±1.8) | 1.80E–13 (3.00E–12) | 0.17±0.02 (0.15±0.02) | |
| | | 48.7±2.30 (35.6±2.0) | 1.90E–13 (2.00E–11) | 0.16±0.02 (0.12±0.02) | |
| | | 46.4±2.25 (31.2±1.8) | 7.00–12 (2.00E–11) | 0.13±0.02 (0.11±0.01) | |
| | | 51.2±2.54 (33.8±1.9) | 1.70E–13 (8.00E–12) | 0.15±0.02 (0.16±0.02) | |
| **Third quartile** | | **52.3±2.39 (33.8±1.9)** | **6.50E–12 (2.00E–11)** | N/A | |
| T3 | 42°38'45.0" 23°18'00.6" | 17.6±1.38 (9.2±1.0) | 2.00E–11 (1.50E–11) | 0.09±0.01 (0.10±0.01) | medium (medium) |
| | | 18.2±1.41 (14.0±1.2) | 2.00E–11 (8.00E–13) | 0.10±0.01 (0.11±0.01) | |
| | | 19.7±1.46 (2.6±0.5) | 2.00E–11 (7.50E–14) | 0.11±0.01 (0.13±0.02) | |
| | | 17.0±1.36 (10.5±1.1) | 2.50E–12 (2.00E–11) | 0.10±0.01 (0.12±0.02) | |
| | | 17.5±1.38 (11.7±1.1) | 2.00E–12 (2.00E–11) | 0.11±0.01 (0.12±0.02) | |
| **Third quartile** | | **18.9±1.43 (11.7±1.1)** | **2.00E–11 (2.00E–11)** | N/A | |

***** *Note*: All data in brackets are from October 2020 campaign

## Results

In October 2022, the performed measurements were done at exact same polygons' positions according to the coordinates of 2020. All polygons have an area of about 100 m$^2$, and on each of them, 5 measurements of the parameters were made: permeability of the soil, and radon concentration in soil gas. Soil permeability ranges from 2.00E-11 to 7.00E-14 [m$^2$]. The gamma dose rate in air is in the range of 0.09 to 0.18 μSv/h and is within the natural gamma dose rate background. The radon concentration in soil gas varies from 17.0 to 53.4 kBq/m$^3$. The determined radon index of the polygons (according to the values of the third quartile) is respectively: T1 – high, T2 – high and T3 – medium (Table 1).

## Conclusion

The performed as repetition of the field measurements in October 2022 at the same specific test site (the Botanical Garden – BAS) showed that the gamma dose rate and the concentration of the radon in the soil are definitely increased (Fig. 1). Two of the three polygons remain with the same radon index to that one of October 2020, and there is a variation at one of the polygons, and namely T1. The latter's index "increased" from "medium" to "high". One of the reasons could be the presence of sub-faults and their influence over the radon concentration at T1. Therefore, in future investigations of the radon index in the territory with appearing faults systems, a very detailed survey of the site's geology is needed.

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