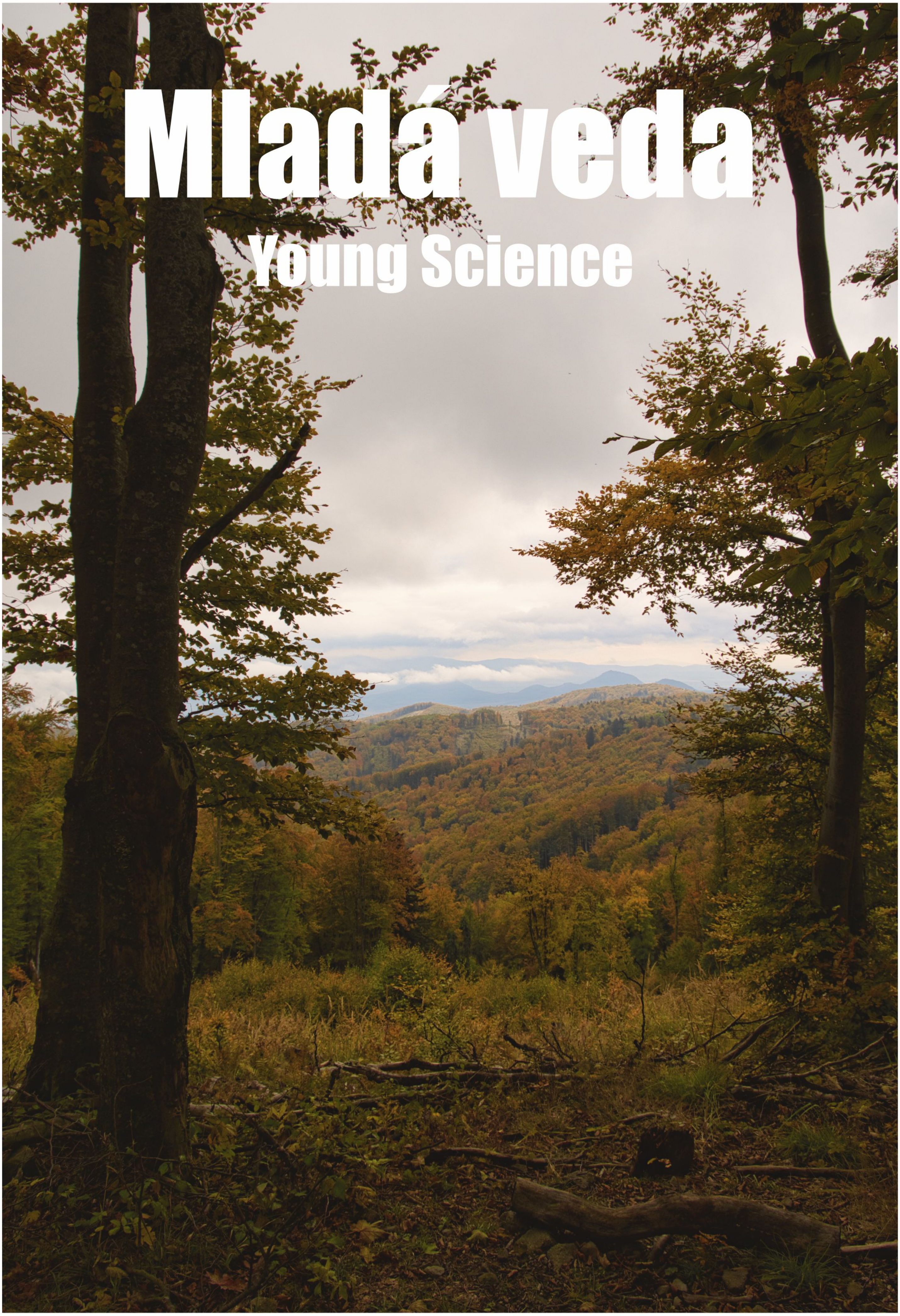
ISSN 1339-3189 5/2026

Mladá veda

Young Science



Mladá veda
Young Science

MEDZINÁRODNÝ VEDECKÝ ČASOPIS MLADÁ VEDA / YOUNG SCIENCE
Číslo 5, ročník 14., vydané v septembri 2026
ISSN 1339-3189, EV 167/23/EPP
Kontakt: info@mladaveda.sk, tel.: +421 908 546 716, www.mladaveda.sk
Fotografia na obálke: Pohorie Čergov. © Branislav A. Švorc, foto.branisko.at

VYDAVATEĽ
Inštitút pre vedu, kultúru a spoločenský rozvoj
IČO: 57728038, Bajkalská 12B, 080 01 Prešov, Slovensko
v spolupráci s vydavateľstvom UNIVERSUM-EU, spol. s r. o.

Mladá veda Young Science ISSN 1339-3189

Vol. 14 (5), pp. 40-51

AIR QUALITY IN SELECTED INDOOR ENVIRONMENTS IN BRATISLAVA (SLOVAKIA)

KVALITA OVZDUŠIA VO VYBRANÝCH POBYTOVÝCH PRIESTOROCH V BRATISLAVE

Richard Kopča, Andrej Mojzeš [1]

Richard Kopča is a student at the Faculty of Natural Sciences, Comenius University in Bratislava. His bachelor's thesis focused on indoor air quality and its relationship to the underlying geology. Andrej Mojzeš is an Associate Professor at the Department of Engineering Geology, Hydrogeology and Applied Geophysics, Faculty of Natural Sciences, Comenius University in Bratislava. His teaching and research activities are concerned with the application of radionuclide methods in geological issues, in both surface and borehole surveys.

Richard Kopča je študentom na Prírodovedeckej fakulte Univerzity Komenského v Bratislave. Vo svojej bakalárskej práci sa venoval problematike kvality vnútorného ovzdušia a jej vzťahu k geologickému podložiu. Andrej Mojzeš pôsobí ako docent na Katedre aplikovanej a environmentálnej geofyziky na Prírodovedeckej fakulte Univerzity Komenského v Bratislave. V pedagogickej i vedeckej praxi sa venuje aplikáciám rádionuklidových metód v geologickej problematike v povrchovom i vrtnom prieskume.

Abstract

This paper presents the results of an indoor air quality (IAQ) monitoring campaign carried out in four buildings of different age, construction type and geological setting in Bratislava, Slovakia. Using the Airthings Wave Plus monitor, the radon (^{222}Rn) activity concentration (RAC), carbon dioxide (CO_2) and volatile organic compounds (VOC) concentrations, temperature, humidity and air pressure were continuously measured, complemented by in situ gamma-spectrometric measurements of ^{40}K, ^{238}U and ^{232}Th concentrations in the topsoil around each building. Radon levels showed a clear dependence on the distance of the monitored room from the terrain surface, the age and insulation quality of the building, and the permeability of the underlying geological basement, reaching an extreme average of 920 Bq/m³ (maximum 1631 Bq/m³) in the poorly insulated cellar of an older house built on highly permeable fluvial sediments – more than three times the Slovak legislative reference level. In contrast, CO_2 and

[1] Workplace Address: Richard Kopča, Assoc. Prof. RNDr. Andrej Mojzeš, PhD., Comenius University in Bratislava, Faculty of Natural Sciences, Department of Engineering Geology, Hydrogeology and Applied Geophysics, Ilkovičova 6, 842 15 Bratislava, Slovak Republic
E-mail: richard.kopca@uniba.sk, andrej.mojzes@uniba.sk

VOC concentrations were primarily linked to ventilation rate and occupant activity rather than geology.
Key words: indoor air quality, radon, carbon dioxide, volatile organic compounds, geological subsoil, meteorological parameters, Bratislava

Abstrakt
Príspevok prezentuje výsledky monitorovania kvality vnútorného ovzdušia v štyroch budovách rôzneho veku, konštrukčného typu a geologického podložia na území Bratislavy. Pomocou zariadenia Airthings Wave Plus bola nepretržite meraná objemová aktivita radónu (^{222}Rn), koncentrácia CO_2 a VOC, teplota, vlhkosť a tlak vzduchu, doplnené in situ gamaspektrometrickými meraniami obsahu ^{40}K, ^{238}U a ^{232}Th v pôde v okolí jednotlivých budov. Koncentrácia radónu jasne závisela od vzdialenosti meraného priestoru od terénu, veku a kvality izolácie budovy a priepustnosti geologického podložia, pričom extrémna priemerná hodnota 920 Bq/m³ (maximum 1 631 Bq/m³) bola nameraná v nedostatočne izolovanej pivnici staršieho domu na vysokopriepustnom podloží – viac než trojnásobne nad rámec slovenského legislatívneho limitu. Naopak koncentrácie CO_2 (oxidu uhličitého) a VOC (prchavých organických látok) súvisia predovšetkým s intenzitou vetrania a aktivitou užívateľov priestorov, nie s geologickým podložím.
Kľúčové slová: kvalita vnútorného ovzdušia, radón, oxid uhličitý, prchavé organické látky, geologické podložie, meteorologické parametre, Bratislava

Introduction
People today spend on average 85 to 90 % of their time indoors – in homes, workplaces and schools. Indoor air quality (IAQ) is therefore one of the main factors affecting human health, comfort and productivity (Bluyssen, 2013), even though both public and expert attention has traditionally focused mainly on outdoor air pollution.

According to the World Health Organization, exposure to polluted indoor air – for example from heating, cooking or the use of chemical products indoors – can pose a serious health risk: worldwide, exposure to these substances is attributed to around 1.6 million deaths per year and roughly 3 % of the total disease burden, a greater impact than that of outdoor air pollution (WHO, 2010).

From a geological point of view, the most significant risk is posed by radon (^{222}Rn) – a natural radioactive gas generated by the decay of uranium in rocks and soil. After smoking, long-term exposure to elevated radon concentrations is the second most common cause of lung cancer, with the risk of lung cancer increasing by approximately 16 % for every 100 Bq/m³ increase in the long-term average radon concentration (WHO, 2023). Moreover, the ongoing modernisation of buildings, window sealing and facade insulation reduce natural air exchange, allowing radon – as well as other substances such as carbon dioxide (CO_2) and volatile organic compounds (VOC) – to accumulate indoors at higher concentrations.

The aim of this paper is to evaluate indoor air quality in selected indoor environments in Bratislava on the basis of our own field measurements, and to assess to what extent the measured concentrations of radon, CO_2 and VOC are related to the geological subsoil, the construction type and age of the building, the position of the room relative to ground level, and the activity of its occupants.

Legislative and regulatory framework

In Slovakia, air quality protection is addressed through a combination of legal regulations and recommended technical and health-related guidelines, with the legislative focus lying mainly on the protection of the outdoor environment and on radiation protection. Act No. 146/2023 Coll. on Air Protection focuses on protecting outdoor air and sets emission limits, but does not address limit values for indoor spaces.

Radon is addressed within radiation-protection legislation. Under Act No. 87/2018 Coll. on Radiation Protection, monitoring of the radon activity concentration is mandatory; the limit is set at 300 Bq/m³ for existing buildings, while for new buildings this limit is reduced to 100 Bq/m³. This value is consistent with the WHO recommendation (2023). Carbon dioxide has no defined limit for indoor air in Slovak legislation – according to international recommendations, the acceptable CO_2 concentration ranges from 800 to 1,000 ppm, above which the risk of fatigue and reduced concentration increases (Protronix). Likewise, VOCs have no defined exposure limits in Slovak legislation; their assessment relies on WHO recommendations, which set limit values for individual substances such as formaldehyde and benzene based on their toxicological properties (WHO, 2010). Table 1 summarises the main reference values used in interpreting our results.

Parameter	Reference / recommended value	Source
Radon activity concentration ^{222}Rn (RAC)	300 Bq/m³ (Slovakia, existing buildings)	Act No. 87/2018 Coll.
Radon activity concentration ^{222}Rn (RAC)	100 Bq/m³ (Slovakia, new buildings)	Act No. 87/2018 Coll.
Radon activity concentration ^{222}Rn (RAC)	100–300 Bq/m³ (recommended range)	WHO, 2023
CO_2 concentration	800–1000 ppm (international recommendation)	Protronix
VOC concentration	individual substance limits (e.g., formaldehyde, benzene)	WHO, 2010

Table 1 – Legislative and recommended reference values for the monitored parameters
Source: own elaboration based on the cited sources

Materials and methods

Indoor air quality monitoring was carried out using the Airthings Wave Plus smart device from the Norwegian manufacturer Airthings ASA (Fig. 1), which contains six sensors and, via passive air diffusion, continuously records the radon (^{222}Rn) activity concentration (RAC) (Bq/m³), CO_2 concentration (ppm), VOC concentration (ppb), temperature (°C), relative humidity (%) and air pressure (hPa) (Airthings, 2026). CO_2 is measured using an NDIR (Non-Dispersive Infra-Red) sensor, which evaluates the absorption of infrared radiation by the gas component of the sample (Lee and Kester, 2016); VOC is measured with a MOX (Metal-Oxide Semiconductor) sensor that responds to the presence of volatile substances through a change in electrical resistance (Pietraru et al., 2024); and radon is measured by alpha spectrometry in the device's diffusion chamber (Airthings, 2026).

Fig. 1 – Airthings Wave Plus indoor air quality sensor used for the measurements
Source: own photographic documentation

In addition, in situ measurements concentration of the radioactive elements ^{40}K, ^{238}U and ^{232}Th in the near-surface soil layer (down to a maximum depth of 0.5 m) were carried out at three points in the immediate vicinity of each studied building, using a PGIS2-1 field gamma spectrometer (Fig. 2; PicoEnvirotec Inc., Canada). The instrument is equipped with a 256-channel ADC converter, a scintillation detector with a 0.347 l NaI(Tl) crystal, and a 12-channel GPS receiver (PicoEnvirotec Inc., 2014).

Fig. 2 – PicoEnvirotec PGIS2-1 field gamma spectrometer
used for the in situ measurement of natural radioactivity
Source: own photographic documentation

The measurements were carried out gradually over the years 2023–2025 at four sites within Bratislava with different geological subsoil, construction type and building age (Fig. 3): site No. 1 – the Donnerova residential panel building (Karlova Ves); site No. 2 – the pavilion-type campus of the Faculty of Natural Sciences (FNS CU) of Comenius University on Ilkovičova Street, Karlova Ves; site No. 3 – a brick apartment building on Košická Street (Ružinov); and site No. 4 – a brick garden cottage in the Nové záhrady allotment area (Prievoz). According to the BRIX property database, the Donnerova apartment building was built in 1970–1971 (BRIX Application, 2020) and is constructed of lightweight-concrete panels 280 mm and 150 mm thick (Ministry of Construction and Regional Development of the Slovak Republic, 2008). The FNS CU campus was built in the 1970s–1980s from concrete, precast concrete elements, brick and metal structures. The apartment building on Košická Street is a 7-storey building, built in 1980–1982, made of brick with a reinforced-concrete load-bearing structure. The garden cottage at the Nové záhrady site is a single-storey brick building with a gable roof, built in the 1950s, partly with a cellar, and partly with a concrete and partly with a wooden floor. At each site, measurements were carried out successively in several rooms on different floors – from technical basements and cellars to offices, living rooms and garages – at intervals of approximately one month.

Fig. 3 – Map of the four studied sites in Bratislava
Source: mapy.com (edited)

Geological characteristics and natural radioactivity of the sites

The individual indoor environments stand on different geological subsoil, which can influence the measured concentrations, particularly of radon (Fig. 4). According to the Geological Map of Slovakia (SGIDŠ, 2013a), site No. 1 Donnerova lies at the boundary between the Neogene – the Jakubov Formation (conglomerates, sands) – and the Quaternary, formed by deluvial sandy-loamy slope gravels. The FNS CU campus (site No. 2) is situated in the Quaternary, at the boundary between fluvial gravels and sandy gravels of younger terraces covered by loess.

Site No. 3 Košická is situated on Quaternary deposits formed by fluvial sediments and floodplain loams. Site No. 4 Nové záhrady lies on Quaternary fluvial-organic sediments – fine sandy and clayey humic loams of former river channels (oxbows) and marshes, which are characterised by high permeability to soil gas.

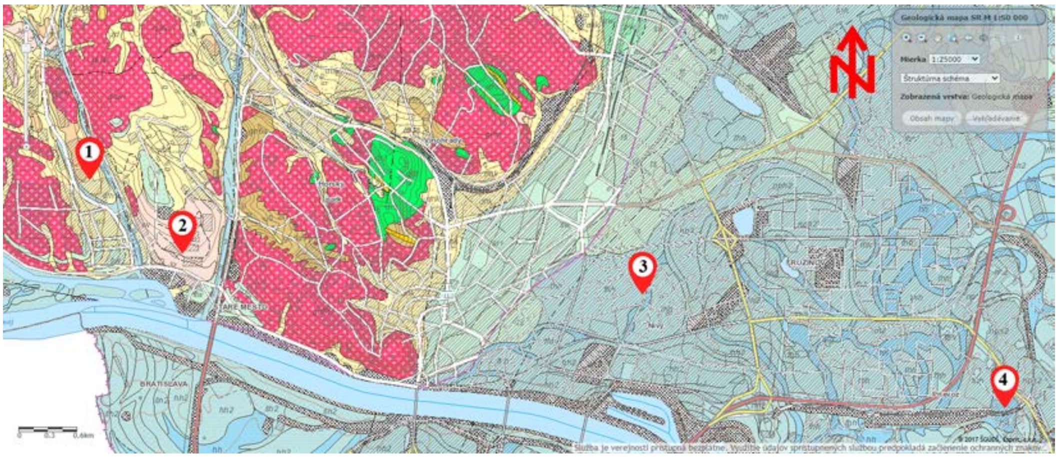


Fig. 4 – Map of the geological subsoil beneath the selected sites
Source: geology.sk (SGIDŠ, 2013a)

According to maps of natural radioactivity and geological radon risk (Fig. 5; SGIDŠ, 2013b), all four sites lie in a zone of low to medium radon risk. At the nearest measuring points (measured in 1992), the mean value of the volume activity of ^{222}Rn (VAR) was found to be 9 kBq/m³ around the Donnerova site (equivalent uranium concentration 2.3 ppm), 13 and 7 kBq/m³ around FNS CU (3.1 and 2.7 ppm eU), 6 kBq/m³ around Košická (2.7 ppm eU), and only 4 kBq/m³ around Nové záhrady (3.5 ppm eU). Interestingly, it is precisely the Nové záhrady site, where the extreme highest indoor radon concentrations were measured, that has the lowest natural radioactivity of the subsoil among all four sites according to the regional maps. This confirms that the main factor determining the extent of radon penetration into a building is not only the uranium content of the subsoil, but also the permeability of the rock environment combined with the condition and quality of the insulation of the particular building (Nunes et al., 2023). Radon enters buildings mainly through foundations, cracks and gaps in walls or floors, or through porous building materials (Cabáneková and Nikodemová, 2013), which corresponds exactly to the condition of the cellar at the Nové záhrady site, which has partially damaged walls and an uninsulated earthen floor.

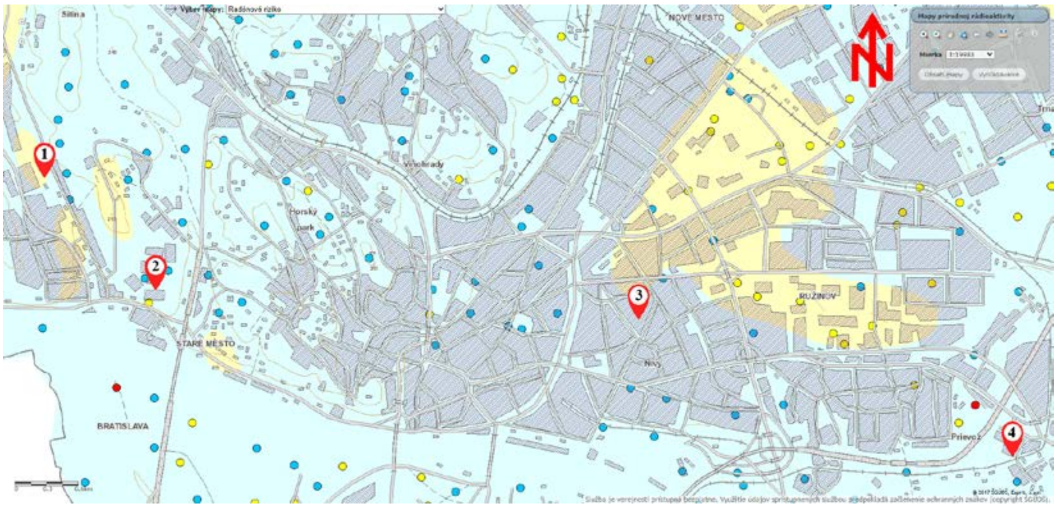


Fig. 5 – Map of radon risk at the studied sites
(light blue = low radon risk level, yellow = intermediate radon risk level)
Source: geology.sk (SGIDŠ, 2013b)

Results and discussion

The strongest dependence on geological subsoil, construction and room position was recorded for radon. Mean radon activity concentration (RAC) values at all four sites increased with decreasing distance of the measuring point from ground level and with increasing building age, or decreasing insulation quality (Table 2).

At site No. 1 Donnerova, where the panel building is likely well insulated from the subsoil, we recorded the lowest radon activity concentration values of all the studied buildings: an average of 7.6 Bq/m³ in the room on the 3rd floor, 25.5 Bq/m³ in the garage at ground level, and 35.3 Bq/m³ in the cellar below ground level. Sites No. 2 and 3, FNS CU and Košická, both situated on highly permeable fluvial sediments and gravels, showed higher RAC values in underground and basement spaces (63.7–293.9 Bq/m³), probably due to a combination of more permeable subsoil and lower insulation quality. The highest value within this pair of sites was measured in the technical basement of FNS CU at the –2nd floor level (293.9 Bq/m³), where radon accumulates due to minimal ventilation of the enclosed space.

An extreme case is represented by the garden cottage at site No. 4 Nové záhrady. While the mean RAC value in the living room at ground level reached 91.6 Bq/m³, in the cellar of the same partially damaged and poorly insulated 1950s building we measured a mean value of 920.8 Bq/m³ (maximum 1,631 Bq/m³) – more than three times the reference value of 300 Bq/m³ set by Slovak legislation (Table 1; Act No. 87/2018 Coll.). As noted in the previous section, this site paradoxically has the lowest regional natural radioactivity of all four studied sites, which clearly shows that the main factor behind such an extremely high indoor radon concentration is not the natural radioactivity of the subsoil alone, but also the permeability of the geological environment (sediments of old river alluvium) combined with the condition and quality of the insulation of the particular building.

	Donnerova 1970s	FNS CU 1970s–1980s	Košická 1980s	Nové záhrady 1950s
5th floor			15.7 ± 7.4	
3rd floor	7.6 ± 4.4	31.0 ± 19.9		
ground floor	25.5 ± 13.8			91.6 ± 31.6
1st basement	35.3 ± 13.6	63.7 ± 15.9 89.2 ± 37.7	203.9 ± 52.2	920.8 ± 249.6
2nd basement		293.9 ± 51.9		

Table 2 – Mean radon activity concentration RAC (Bq/m³ ± SD) in the studied buildings by floor, age and construction quality (SD – standard deviation)
Source: own elaboration

The time series of the measured parameters in the cellar at the Nové záhrady site (Fig. 6) also clearly documents the influence of meteorological parameters on radon concentration. When atmospheric pressure drops, a so-called suction effect occurs, whereby radon-rich soil air is drawn into the interior, manifesting as short-term increases in RAC that coincide with pressure drops or follow shortly afterwards – this phenomenon is most pronounced in our dataset precisely in the cellar spaces at the Nové záhrady site, similar to the study by Kashkinbayev et al. (2024), who demonstrated a clear relationship between pressure drops and increased indoor radon in a school building. Similarly, increased soil moisture after precipitation can temporarily restrict radon escape in saturated parts of the subsoil and redirect it towards less saturated areas beneath the building. We intend to devote a more detailed quantitative analysis of this relationship to further research.

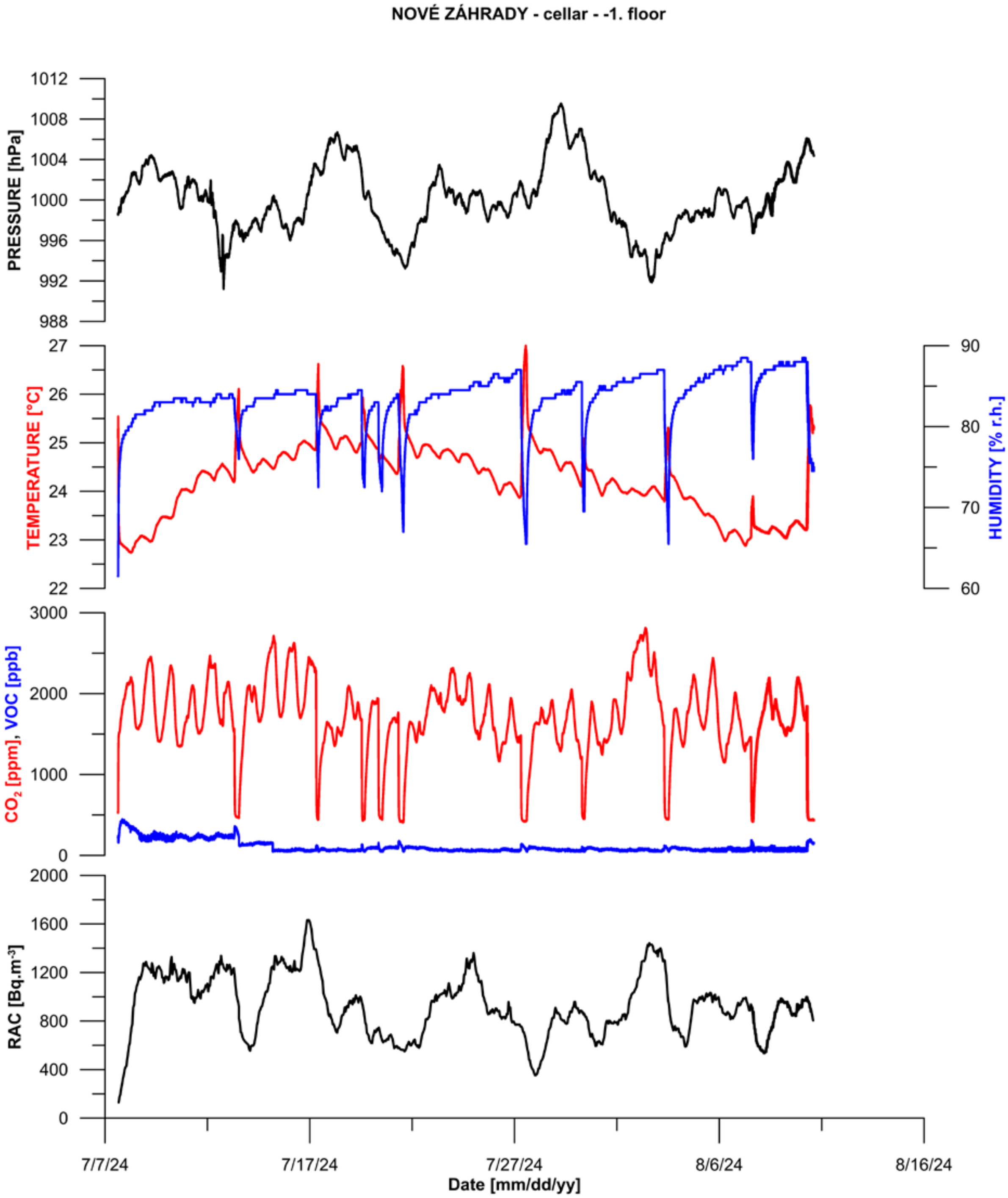


Fig. 6 – Time series of pressure, temperature, humidity, CO_2, VOC and RAC in the cellar of the Nové záhrady building
Source: own elaboration

In our measurements, carbon dioxide proved to be primarily an indicator of ventilation effectiveness and human activity intensity, rather than of geological subsoil (Table 3). At site No. 1 Donnerova, a regular nightly increase in CO_2 was recorded due to closed windows during sleep (maximum 2,039 ppm in the room on the 3rd floor). The highest mean CO_2 values (1,225.1 ± 711.7 ppm) were measured in the living room at site No. 3 Košická – in a flat with modern, highly airtight plastic windows and no systematic ventilation, where the recommended limit of 1,000 ppm was exceeded (Lowther et al., 2021). The overall highest mean CO_2 value (1,696.6 ± 474.1 ppm) was surprisingly measured in the cellar at site No. 4 Nové záhrady (Fig. 6), likely due to its traditional use for storing agricultural produce (potatoes, vegetables), the respiration of which produces CO_2. In contrast, in spaces with minimal human presence (the FNS CU technical basement, and the Košická and Donnerova cellars), mean CO_2 values mostly remained below 500 ppm, regardless of geological subsoil.

	Donnerova 1970s	**FNS CU 1970s–1980s**	**Košická 1980s**	**Nové záhrady 1950s**
5th floor			1225.1 ± 711.7	
3rd floor	612.4 ± 203.2	535.3 ± 155.5		
ground floor	452.2 ± 25.5			527.9 ± 40.3
1st basement	455.1 ± 29.7	482.1 ± 43.5 461.2 ± 31.5	481.6 ± 32.8	1696.6 ± 474.1
2nd basement		537.1 ± 54.9		

Table 3 – Mean CO_2 concentration (ppm ± SD) in the studied buildings by floor (SD – standard deviation)
Source: own elaboration

VOC concentrations showed mainly short-term maxima linked to specific activities. At site No. 1 Donnerova, higher maxima were recorded in the room due to the melting of plastic filament during 3D printing (2,167 ppb), and in the garage due to regular spikes caused by vehicle operation (maximum 1,172 ppb). At site No. 2 FNS CU, apart from one-off spikes caused by construction work or soldering in the laboratory, VOC values were within normal limits. Site No. 3 Košická shows the highest extremes measured of all the sites – the mean value in the living room reached 567 ± 747.6 ppb, with a maximum of almost 4,000 ppb, probably due to the use of chemical cleaning products. In contrast, at site No. 4 Nové záhrady, mean VOC values were low (116.1 ppb in the room, 106.1 ppb in the cellar), corresponding to low occupancy intensity. Mean VOC values across all spaces therefore showed no marked link to geological subsoil.

It is also worth noting that warm summer weather can indirectly affect all the monitored parameters at once – high outdoor temperatures increase the release of VOCs from building materials and furniture, while also leading people to spend more time in cooler basement and cellar spaces, which tend to have the highest radon concentrations; the use of air conditioning, in turn, recirculates indoor air without introducing fresh air, which concentrates both radon and CO_2 (Field, 2010).

Conclusion

Our own indoor air quality measurements at four sites in Bratislava confirmed that the radon concentration in indoor environments strongly depends on the distance of the room from the subsoil, the age and construction type of the building, and the permeability of the geological subsoil, while the level of natural radioactivity of the geological subsoil itself (determined both by in situ gamma spectrometry and by compiling regional SGIDŠ maps) differed only slightly between sites, and was in fact lowest at the site with the most extreme results. The highest and, from a human health perspective, most hazardous RAC values (mean 920.8 Bq/m³, maximum

1,631 Bq/m³) were recorded in the poorly insulated cellar of an older building on highly permeable subsoil, exceeding the Slovak legislative limit for existing buildings (300 Bq/m³) more than threefold, and the limit for new buildings (100 Bq/m³) more than ninefold.

Unlike radon, CO_2 and VOC concentrations proved to be primarily a function of ventilation intensity, window airtightness, the way the space is used, and specific human activity, rather than of geological subsoil. Our results also indicate a relationship between drops in atmospheric pressure and short-term increases in radon concentration due to the so-called suction effect, as well as between increased soil moisture and the movement of radon towards less saturated parts of the subsoil beneath the building. We intend to devote a more detailed quantitative analysis of this meteorological relationship, as well as expanding the set of studied sites, to further research.

This article was recommended for publication in the scientific journal Young Science by:
prof. RNDr. Roman Pašteka, PhD.

We would like to thank our families and colleagues, as well as the Department of Engineering Geology, Hydrogeology and Applied Geophysics of the Faculty of Natural Sciences, Comenius University, for their support and for providing the instrumentation needed to carry out the measurements. Thanks are also due to the Slovak scientific agencies for financial support within the framework of the research projects APVV-21-0159, VEGA1/0107/23 and VEGA1/0587/24.

References

1. Act No. 87/2018 Coll. on Radiation Protection and on Amendments to Certain Acts (Zákon č. 87/2018 Z. z. o radiačnej ochrane a o zmene a doplnení niektorých zákonov).
2. Act No. 146/2023 Coll. on Air Protection and on Amendments to Certain Acts (Zákon č. 146/2023 Z. z. o ochrane ovzdušia a o zmene a doplnení niektorých zákonov).
3. AIRTHINGS ASA, 2026. Wave Plus: Sensor Accuracy *[online]*. [accessed 28 February 2026]. Available at: https://help.airthings.com/en/articles/6320631-wave-plus-sensor-accuracy
4. BLUYSSEN, Philomena M., 2013. *The Healthy Indoor Environment*. London: Taylor & Francis Group. ISBN 978-0-415-62098-5.
5. BRIX Application, 2020 *[online]*. [accessed 28 February 2026]. Available at: https://brix.znalec.sk/statistics/
6. CABÁNEKOVÁ, Helena, and Dagmar NIKODEMOVÁ, 2013. *Usmerňovanie ožiarenia obyvateľstva radónom v pobytových priestoroch [Managing Population Radon Exposure in Indoor Spaces]*. Bratislava: Environment. ISBN 978-80-89384-05-1.
7. FIELD, Rebecca W., 2010. *Climate Change and Indoor Air Quality* [online]. Report for US EPA. [accessed 28 February 2026]. Available at: https://www.epa.gov/sites/default/files/2014-08/documents/field_climate_change_iaq.pdf
8. KASHKINBAYEV, Yerlan, Marat BAKHTIN, Petr KAZYMBER, Aliya LESBEK, Bibigul KAZHIYAKHMETOVA, Masahiro HOSHI, Nurlan ALTAEVA, Yasutaka OMORI, Shinji TOKONAMI, Hiroyuki SATO, and Dariya IBRAYEVA, 2024. Influence of Meteorological Parameters on Indoor Radon Concentration Levels in the Aksu School. In: *Atmosphere*. Vol. 15, no. 9, p. 1067. ISSN 2073-4433.
9. LEE, Reidy, and Walt KESTER, 2016. Complete Gas Sensor Circuit Using Nondispersive Infrared (NDIR). In: *Analog Dialogue*. Vol. 50. Available at: https://www.analog.com/en/resources/analog-dialogue/articles/complete-gas-sensor-circuit-using-nondispersive-infrared.html

10. LOWTHER, Scott D., Sotiris DIMITROULOPOULOU, Kerry FOXALL, Clive SHRUBSOLE, Emma CHEEK, Britta GADEBERG, and Ovnair SEPAI, 2021. Low Level Carbon Dioxide Indoors – A Pollution Indicator or a Pollutant? A Health-Based Perspective. In: *Environments*. Vol. 8, no. 11, p. 125. ISSN 2076-3298.
11. MINISTRY OF CONSTRUCTION AND REGIONAL DEVELOPMENT OF THE SLOVAK REPUBLIC, 2008. *Zásahy do nosných konštrukcií panelových bytových domov [Interventions in Load-Bearing Structures of Panel Apartment Buildings]* [online]. [accessed 28 February 2026]. Available at: https://www.technospol.sk/wp-content/uploads/2016/04/typy-panelovych-domov.pdf
12. NUNES, Leonel J. R., António CURADO, and Sérgio I. LOPES, 2023. The Relationship between Radon and Geology: Sources, Transport and Indoor Accumulation. In: *Applied Sciences*. Vol. 13, no. 13, p. 7460. ISSN 2076-3417.
13. PICOENVIROTEC INC., 2014. *PGIS-2 User's Quick Reference Manual*. Concord: PicoEnvirotec Inc.
14. PIETRARU, R. N., M. NICOLAE, Ş. MOCANU, and D. M. MEREZEANU, 2024. Easy-to-Use MOX-Based VOC Sensors for Efficient Indoor Air Quality Monitoring. In: *Sensors*. Vol. 24, no. 8, p. 2501.
15. PROTRONIX. CO2 – Oxid uhličitý [Carbon Dioxide] *[online]*. [accessed 6 December 2025]. Available at: https://www.cidla.sk/odborne-vyrazy/co2-oxid-uhlicity/
16. STATE GEOLOGICAL INSTITUTE OF DIONÝZ ŠTÚR, 2013a. Geologická mapa Slovenska M 1:50 000 [Geological Map of Slovakia M 1:50,000] *[online]*. Bratislava: ŠGÚDŠ. [accessed 28 February 2026]. Available at: https://app.geology.sk/gm50
17. STATE GEOLOGICAL INSTITUTE OF DIONÝZ ŠTÚR, 2013b. Prehľadné mapy prírodnej rádioaktivity M 1:500 000 [Overview Maps of Natural Radioactivity M 1:500,000] *[online]*. Bratislava: ŠGÚDŠ. [accessed 28 February 2026]. Available at: https://app.geology.sk/radio/
18. WORLD HEALTH ORGANIZATION, 2010. *WHO Guidelines for Indoor Air Quality: Selected Pollutants* [online]. Copenhagen: WHO Regional Office for Europe. [accessed 23 November 2025]. Available at: https://iris.who.int/server/api/core/bitstreams/202feb0d-06e8-418d-8e38-8927ec2d166b/content
19. WORLD HEALTH ORGANIZATION, 2023. Radon *[online]*. [accessed 23 November 2025]. Available at: https://www.who.int/news-room/fact-sheets/detail/radon-and-health

Mladá veda
Young Science

ISSN 1339-3189