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# Effect of Seasonal Variation and Soil Parameters on Soil-Gas Radon Concentration in Ogbomoso, South Western Nigeria

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**ABSTRACT**

Radon $^{222}$Rn, an inert natural radioactive gas, a daughter product in the $^{238}$U natural decay series, a source of alpha radiation. It accounts for about 55% of the total radiation from natural sources. Radon is known for its substantial variations in concentration due to both seasonal changes and variations in soil parameters. Soil, fractures in rocks and water are the main source of radon and they are the routes through which individual is exposed to it, in which this study is aimed at examining the effects of seasonal variation, soil parameters, on soil radon concentration. A total of hundred (100) in-situ soil radon measurements were carried out for both seasons (wet and dry) in Ogbomoso using an active electronic device RAD 7. Soil parameters were measured using a 4-in-1 digital metre. The obtained experimental data were subjected to a statistical tool (SPSS) Version 23, with statistical significance set at $p < 0.01$. The result showed that the effect of seasonal variation on soil-gas radon concentration was discovered to be maximum during the dry season with the radon concentration of 1900.01 Bq/m$^3$ and minimum during the wet season with the radon concentration of 711.81 Bq/m$^3$.The mean value of radon in soil-gas was found to be 553.48 Bq/m$^3$ and 1366.34 Bq/m$^3$ for wet and dry season respectively. Soil parameters considered in this work have notable influence on soil gas radon concentration in both seasons. Thus, providing valuable insight into the dynamics of radon migration in the soil. The results will help to develop effective mitigation strategies by policies makers and reducing the risk of radon related lung cancer in the study area.

**Keywords:**
Soil radon,
Seasonal variation,
Soil temperature,
Soil moisture,
Soil pH.

## INTRODUCTION

Radon (Rn) is a decay product of radium (Ra), which is a member of the uranium (U) decay chain. The colourless, odourless, and tasteless characteristics of radon are its physical and chemical characteristics. It is difficult to detect without specialized equipment due to its radioactive nature. The decay series of uranium isotopes ($^{238}$U, $^{236}$U, and $^{235}$U), respectively, yields the three well-known isotopes of radon: radon ($^{222}$Rn), thoron ($^{220}$Rn), and actinon ($^{219}$Rn). The half-lives of the three radon isotopes—$^{222}$Rn, $^{220}$Rn, and $^{219}$Rn—are 3.82 days, 55.8 seconds, and 3.98 seconds, respectively (Guadie and Yetsedaw, 2021). One of the main causes of ionizing radiation is radon, which has been found to be harmful to human health. Approximately 55% of the background radiation dose that the environment receives comes from this primary source, and its concentration varies depending on the area and season (Belete and Shiferaw, 2022). The half-life of radon-222 makes it possible to swiftly identify its presence in water and in both indoor and outdoor air, which makes it a serious problem (Oni and Adagunodo, 2019). Various soil parameters play a pivotal role in modulating soil-gas radon concentrations. Moisture content, soil texture, organic matter, and pH levels have been identified as key factors affecting radon transport and emanation (Pulinets et al. 2024). The porosity of the soil, water-holding capacity, and organic matter content can influence radon diffusion and availability of radium, a precursor to radon numerous physical characteristics of soil, including radium contents, the internal structure of the soil, the size of the soil's grains, the type of mineralization, soil porosity, soil permeability, and emanation coefficient, affect radon concentration in the soil and radon exhalation from the soil surface etc. (Huynh et al. 2020). It was demonstrated that variations in the amount of radon present in the soil at a particular site over time are mostly caused by differences in

meteorological factors (Fijałkowska-Lichwa and Przylibski, 2023). Yang et al. (2019) stated that temperature differences between the air and soil, wind speed, relative humidity, and radon concentrations are all correlated, and also discovered that the most significant factor determining the quantity and variability of soil radon was found to be soil temperature. Moisture modesty also enhances radon emission (Yusuff et al. 2020). Some of the previous works on soil-gas radon concentration, seasonal variation and soil parameters (Taşköprü et al. 2023, Miklyaev et al. 2022, Smetanová et al. 2020, Nguyen et al. 2018, Al-Khateeb et al. 2017, Giagias et al. 2015, Duggal et al. 2014). Till now, no study has been able to check the influence of both seasons and soil parameter on the level of concentration in the soil in the study area, therefore this work pioneer it. This paper systematically examined the how seasonal variation coupled with varying soil parameters have impact on soil-gas radon concentration in Ogbomoso, South Western Nigeria.

## MATERIALS AND METHOD

### Study area

One of the well-known cities in southwest Nigeria is the study area, Ogbomoso metropolis, Oyo State. She had roughly 645,000 people living there in the 1991 census, but by 2005, that number had doubled to 1,200,000 people (Population City, 2015). Figure 1 shows map of the study area. The study area is between 8° 0′ and 8° 14′ north latitude and between 4° 6′ and 4° 23′ east longitude. The terrain elements of the Ogbomoso metropolis are slope, physiography, and geomorphology (Adabanija et al. 2014). In Ogbomoso, the dry season is typically overcast, muggy, and humid, while the rainy season is heavy, stifling, and heated. The rainy season has an average rainfall of 1247 mm (Adagunodo et al. 2019b). For more than thirty years, a steady stream of individuals from all six of Nigeria's geopolitical zones has been drawn to Ogbomoso, a peri-urban enclave in the southwest of the country. The study region hosts major institutions in Oyo State and other places including places of worship, marketplaces, and recreation centres.

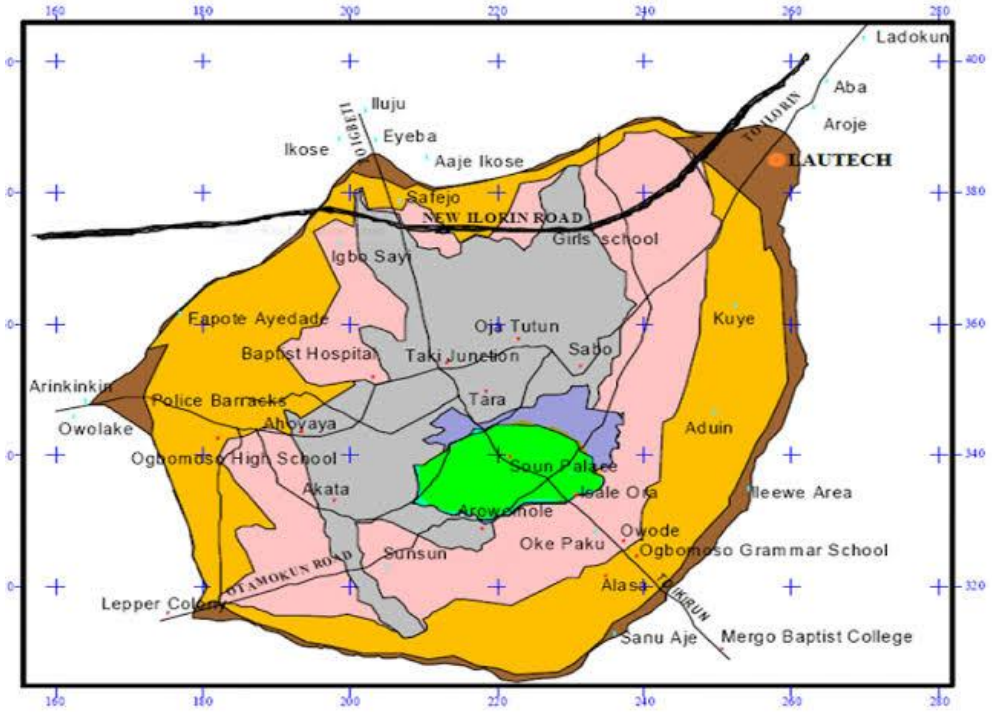


Figure 1: Map of the study area (Olaniyan et al. 2016)

In this study, measurements of radon concentration in the soil were made by using a portable electronic radon monitor RAD7 (Durridge Co. United States). A total of 100 in-situ soil-gas radon measurements were carried out for both seasons (wet season and dry season), at fifty (50) different locations in each season in Ogbomoso. In this study, the measurements of soil radon concentration were taken at a constant depth of 80cm using a stainless-steel soil gas probe, produced by Durridge Co. United States. A complete setup of the RAD7 detector is illustrated in Figure 2. The soil was drilled with a calibrated pilot rod of diameter 2 cm and a length of 100 cm. The stainless-steel soil gas probe was put into the soil opening and securely shut to stop air from leaking

out. According to the RAD7 protocol used, a grab-sample of soil gas is pumped into the RAD7 over 5 minutes. After $^{222}Rn$ and its daughters have reached equilibrium, the system waits five minutes before counting. Four measurements of the collected gas were made, each taking five minutes. When in sniff mode, the RAD7 uses only the $^{218}Po$ peak to calculate concentrations, allowing it to react quickly to variations in radon levels. According to the RAD7 procedure, each radon concentration stated is the mean concentration derived from the findings of the four independent measurements.

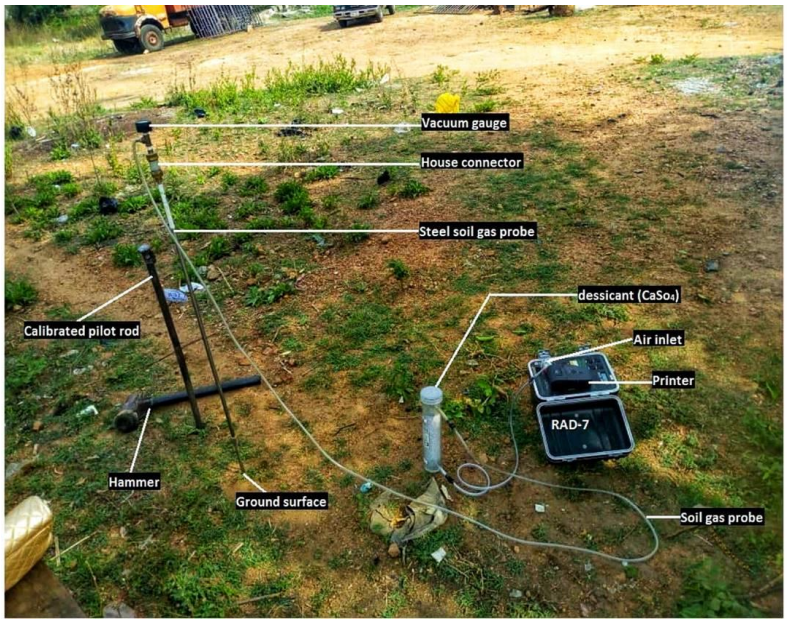


Figure 2: A complete setup of Rad 7 radon detector (Adagunodo *et al*., 2019b)

Soil parameters were measured using a 4-in-1 digital meter that may be used for temperature, pH, moisture content, and light testing. Its light sensor window and sensitive 200mm probe offer precise and accurate measured findings. It features a vivid LCD, a backlight, and automatic shut-off. The probe was submerged in the earth at a depth of 200mm, after which the soil parameters (soil pH, soil temperature, and soil moisture) were measured.

The correlation between soil radon concentration, seasonal variation and soil parameters were subjected to data analysis using IBM Statistical Packages for Social Sciences (SPSS) Version 23.

## RESULTS AND DISCUSSION

Results of radon concentration and other soil parameters measured in this work are presented in Table 1. Soil-gas radon concentration was found to vary from 181.50 $Bq/m^3$ to 711.81 $Bq/m^3$ in wet season, and 800.00 $Bq/m^3$ to 1900.01 $Bq/m^3$ in dry season respectively. The mean value of radon in soil-gas was found to be 553.48 $Bq/m^3$ and 1366.34 $Bq/m^3$ for wet and dry season respectively. The maximum allowed concentration level of radon in the soil is between 0.4-40 $kBq/m^3$. However, from the result presented, the obtained radon concentration values were within the maximum allowed concentration level of radon in the soil. The variation in radon concentration in different locations could be attributed to the uranium content in soil and other soil parameters (Cevik et al.,2011). In addition, the variation of radon could be attributed to the different lithology of the area and permeability of the soil. Though, it was observed that radon has high concentration during the dry season, which could be attributed to the opening of pores within the subsurface of the rock during the season, while, the low radon content during the wet season could be attributed to the assertions that when there is moisture in the soil, the mobility of radon weakens and is unable to spread across the pores, therefore when the soil is wet, there is less radon gas released on the surface of the earth (Cinelli et al., 2019)

Soil parameters (soil pH, soil temperature, and soil moisture) were measured and presented in Table 1. In the dry season, soil temperature varied between 39˚C to 45˚C and soil moisture was between 4 and 5, where 4 is dry and 5 is dry plus, the soil pH varied between 6.5 and 8.5. During the wet season, the soil temperature varied between 27˚C to 37˚C, soil moisture was between 1 and 3, where, 1 is normal, 2 is wet and 3 is wet plus. Also, the soil pH varied between 6.5 and 8.5. It was inferred that the effect of all the soil parameters considered alongside seasonal variation on the soil-gas radon concentration, was discovered to have had a significant effects on the soil-gas radon concentration during the

wet and dry seasons. Soil temperature and soil pH had significant effects during the dry season. While the soil moisture and soil pH had substantial effects on soil-gas radon concentration during the wet season.

Furthermore, the investigation conducted in the study area was carried out using partial correlation to test the significant relationships between the soil parameters (soil pH, soil temperature, and soil moisture), it was deduced that the soil temperature and soil pH were the parameters that were significantly associated with soil-gas radon at significant value of 0.01% during the dry season. Also, it was deduced that the soil moisture and soil pH were the parameters that were significantly associated with soil-gas radon at significant value of 0.01% during the wet season.

**Table 1: Soil-gas Radon Concentration and Soil Parameters for both seasons**

| Dry Season | | | | Wet Season | | | |
|---|---|---|---|---|---|---|---|
| **Soil pH** | **Temperature (˚C)** | **Moisture** | **Radon Concentration (Bq/m$^3$)** | **Soil pH** | **Temperature (˚C)** | **Moisture** | **Radon Concentration (Bq/m$^3$)** |
| 7.0 | 40 | 5 | 800.02 | 6.5 | 29 | 1 | 550.00 |
| 7.0 | 41 | 5 | 900.37 | 6.5 | 28 | 2 | 520.00 |
| 7.5 | 42 | 5 | 800.10 | 6.5 | 31 | 3 | 530.02 |
| 7.0 | 40 | 5 | 800.00 | 6.5 | 27 | 2 | 500.00 |
| 7.5 | 43 | 5 | 1200.26 | 6.0 | 28 | 1 | 700.10 |
| 7.0 | 39 | 5 | 1300.01 | 8.5 | 32 | 3 | 700.31 |
| 6.5 | 43 | 5 | 1300.50 | 7.5 | 33 | 2 | 700.01 |
| 7.0 | 40 | 5 | 1200.10 | 6.5 | 31 | 3 | 700.00 |
| 7.5 | 42 | 5 | 1000.57 | 8.0 | 33 | 1 | 700.03 |
| 7.0 | 44 | 5 | 1100.20 | 6.5 | 30 | 1 | 700.01 |
| 6.5 | 43 | 5 | 1000.56 | 7.0 | 29 | 2 | 600.00 |
| 6.5 | 42 | 5 | 1100.48 | 7.0 | 31 | 1 | 700.05 |
| 7.5 | 41 | 5 | 1700.30 | 5.5 | 28 | 2 | 440.40 |
| 8.0 | 39 | 4 | 1900.07 | 6.5 | 30 | 2 | 550.20 |
| 7.0 | 42 | 5 | 1900.01 | 9.0 | 29 | 3 | 530.35 |
| 6.5 | 40 | 5 | 1900.50 | 7.0 | 33 | 2 | 510.15 |
| 8.5 | 43 | 5 | 1100.72 | 7.0 | 32 | 3 | 530.22 |
| 7.0 | 45 | 5 | 1100.19 | 6.5 | 37 | 3 | 600.10 |
| 7.0 | 42 | 5 | 1200.58 | 6.5 | 37 | 2 | 560.15 |
| 7.5 | 42 | 5 | 1100.02 | 7.0 | 35 | 3 | 560.28 |
| 7.0 | 40 | 5 | 1400.11 | 7.5 | 29 | 1 | 181.50 |
| 7.5 | 41 | 5 | 1500.42 | 6.5 | 30 | 2 | 532.16 |
| 7.0 | 40 | 5 | 1500.61 | 7.0 | 31 | 2 | 427.09 |
| 7.0 | 41 | 5 | 1500.00 | 6.5 | 27 | 1 | 462.47 |
| 7.5 | 42 | 5 | 1200.72 | 6.0 | 28 | 1 | 441.09 |
| 7.0 | 40 | 5 | 1200.45 | 8.0 | 32 | 3 | 510.16 |
| 8.0 | 43 | 5 | 1200.51 | 7.5 | 33 | 2 | 537.95 |
| 7.0 | 39 | 5 | 1200.68 | 6.5 | 31 | 3 | 553.16 |
| 8.0 | 45 | 5 | 1500.03 | 8.0 | 33 | 2 | 515.71 |
| 7.0 | 40 | 5 | 1500.59 | 7.5 | 30 | 2 | 462.47 |
| 7.5 | 42 | 5 | 1400.04 | 7.0 | 29 | 2 | 526.95 |
| 7.0 | 44 | 5 | 1500.91 | 7.0 | 31 | 2 | 547.93 |
| 6.5 | 43 | 5 | 1500.74 | 7.5 | 28 | 2 | 574.50 |
| 6.5 | 42 | 5 | 1500.22 | 6.5 | 30 | 2 | 688.31 |
| 7.5 | 41 | 5 | 1200.18 | 8.5 | 29 | 3 | 711.81 |
| 8.0 | 39 | 4 | 1200.30 | 7.0 | 33 | 2 | 676.16 |
| 7.0 | 42 | 5 | 1200.05 | 7.0 | 32 | 2 | 695.79 |
| 6.5 | 40 | 5 | 1200.83 | 7.5 | 37 | 3 | 422.41 |
| 7.5 | 43 | 5 | 1500.14 | 7.0 | 37 | 2 | 364.66 |
| 7.0 | 41 | 5 | 1500.62 | 7.0 | 35 | 3 | 415.37 |
| 7.0 | 42 | 5 | 1600.55 | 7.0 | 31 | 2 | 434.14 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7.5 | 42 | 5 | 1500.10 | 7.5 | 29 | 2 | 456.10 |
| 7.0 | 40 | 5 | 1800.16 | 6.0 | 28 | 1 | 532.49 |
| 7.5 | 41 | 5 | 1900.78 | 8.0 | 30 | 2 | 498.73 |
| 7.5 | 42 | 5 | 1800.32 | 7.5 | 33 | 2 | 498.26 |
| 7.0 | 44 | 5 | 1900.01 | 8.0 | 31 | 3 | 611.29 |
| 6.5 | 43 | 5 | 1600.19 | 8.0 | 33 | 2 | 571.40 |
| 6.5 | 42 | 5 | 1600.17 | 7.5 | 30 | 2 | 679.81 |
| 7.5 | 41 | 5 | 1600.81 | 7.0 | 29 | 2 | 619.18 |
| 8.0 | 39 | 4 | 1200.00 | 7.0 | 31 | 2 | 642.47 |

The comparison of some measured radon concentration and seasonal variation is presented in Table 2. The results from the study area agrees with the study by Smetanová et al. (2020) which stated that radon level was at its peak during the summer (dry) season and lower during the winter (wet) season. However, negates the study by Giagias et al. (2015) and Duggal et al. (2014) who stated that radon concentration level was maximum during the winter (wet) season and minimum during the summer (dry) season.

**Table 2: The comparison of measured radon concentration and seasonal variation**

| Place of study | Detection techniques | Radon concentration | Seasonal variation | References |
|---|---|---|---|---|
| Athens | CR-39 solid state nuclear tracking detectors | 137.5 $Bqm^{-3}$<br>96.10 $Bqm^{-3}$ | Maximum of 137.5 $Bq/m^3$<br>In the winter and a lower concentration of 96.10 $Bq/m^3$ in summer. | Giagias et al. (2015) |
| Sri Ganganagar district of Rajasthan | Solid state nuclear track detectors (LR-115 type II) | 1.54 ± 0.29 $Bqm^{-3}$<br>1.48 ± 0.35 $Bqm^{-3}$ | Seasonal changes had minimum values in the dry season and maximum values in the wet season. | Duggal et al. (2014) |
| Važecká Cave (Northern Slovakia) | Rad 7 radon monitor | 3600–42200 $Bqm^{-3}$<br>1300–27700 $Bqm^{-3}$ | Radon level was at its peak during the summer season and lower during the winter season | Smetanová et al. (2020) |

## CONCLUSION

In this paper, the study demonstrated the effect of seasonal variation and soil parameters on soil-gas radon in Ogbomoso, south western Nigeria. Soil parameters, including soil pH, soil temperature, and soil moisture was measured. Also, the seasonal variation of soil-gas radon was measured. It was observed that the seasonal variation and the soil parameters considered in this study causes notable effects on soil-gas radon dynamics. There was a positive correlation between the soil parameters, seasonal variation and soil-gas radon concentration. This study revealed that seasonal variation significantly affects soil-gas radon concentration. Also, the soil parameters; soil moisture, soil pH, and soil temperature have significant effects on the soil-gas radon concentration at different seasons.

## REFRENCES

Adabanija, M.A., Afolabi, A.O., Olatunbosun, A.T. and Kolawole, L.L. (2014). Integrated approach to investigation of occurrence and quality of groundwater in Ogbomoso North, Southwestern Nigeria. *Environmental Earth Sciences*, **73**(1), 139– 162. https://doi.org/10.1007/s12665-014-3401-8

Adagunodo, T.A., Sunmonu, L.A., Adabanija, M. A., Omeje, M., Odetunmibi, O.A. and Ijeh, V. (2019b). Statistical assessment of radiation exposure risks to farmers in Odo Oba, Southwestern Nigeria. *Bulletin of the Mineral Research and Exploration*, **159**, 201–217. https://doi.org/10.19111/bulletinofmre495321 .

Al-Khateeb, H. M., Nuseirat, M., Aljarrah, K., Al-Akhras, M. A. H., and Bani-Salameh, H. (2017). Seasonal Variation Of Indoor Radon Concentration in A Desert Climate. *Applied Radiation and Isotopes*, **130**, 49-53. https://doi.org/10.1016/j.apradiso.2017.08.017

Belete, G. D., and Shiferaw, A. M. (2022). A review of studies on the seasonal variation of indoor radon-222 concentration. *Oncology Reviews*, **16**, 10570. https://doi.org/10.3389/or.2022.10570

Cevik, U., Kara, A., Celik, N., Karabidak, M., & Celik, A. (2011). Radon survey and exposure assessment in

Karaca and Çal Caves, Turkey. *Water, Air, & Soil Pollution*, *214*, 461-469. https://doi.org/10.1007/s11270-010-0437-6

Duggal, V., Rani, A. and Mehra, R. (2014). A Study of Seasonal Variations of Radon Levels in Different Types of Dwellings in Sri Ganganagar District, Rajasthan. *Journal of Radiation Research and Applied Sciences*, **7**(2), 201-206. https://doi.org/10.1016/j.jrras.2014.02.007

Fijałkowska-Lichwa, L. and Przylibski, T. A. (2023). Monthly and quarterly correction factors for determining the mean annual radon concentration in the atmosphere of underground workplaces in Poland. *Environmental Geochemistry and Health*, **45**(5), 1475-1498. https://doi.org/10.1007/s10653-022-01280-2

Giagias, V., Burghele, D. and Cosma, C. (2015). Seasonal Variation of Indoor Radon in Dwellings from Athens, Greece. Rom. *J. Phys*, **60** (9-10), 1581-1588. https://www.researchgate.net/profile/Burghele-Bety-Denissa/publication/288242690_Seasonal_variation_of_indoor_radon_in_dwellings_from_Athens_Greece/links/5f7af3fd299bf1b53e0e46b6/Seasonal-variation-of-indoor-radon-in-dwellings-from-Athens-Greece.pdf

Guadie, D.B. and Yetsedaw, A.A. (2021). General Overview of Radon Studies in Health Hazard Perspectives, Article ID 6659795, https://doi.org/10.1155/2021/6659795

Huynh, N. P., Thu, N., Van, T. and Le, C. H. (2020). The effects of some soil characteristics on radon emanation and diffusion, *Journal of Environmental Radioactivity*, Volume **216**, 106189. https://doi.org/10.1016/j.jenvrad.2020.106189

Miklyaev, P. S., Petrova, T. B., Shchitov, D. V., Sidyakin, P. A., Murzabekov, M. A., Tsebro, D. N. and Gavriliev, S. G. (2022). Radon transport in permeable geological environments. *Science of the Total Environment*, **852**, 158382. https://doi.org/10.1016/j.scitotenv.2022.158382

Nguyen, P. T. H., Vu, N. B., and Le Cong, H. (2018). Soil radon gas in some soil types in the rainy season in Ho Chi Minh City, Vietnam. *Journal of environmental radioactivity*, **193**, 27-35. https://doi.org/10.1016/j.jenvrad.2018.08.017

Olaniyan, O. S., Akeredolu, D. A., Showale, O. S., & Akolade, A. S. (2016). Assessment of microbial quality of some selected shallow wells in Ogbomoso, South Western Nigeria. *American Journal of Water Resources*, *4*(2), 30-34. doi: 10.12691/ajwr-4-2-1.

Oni, E. A., and Adagunodo, T. A. (2019). Assessment of radon concentration in groundwater within Ogbomoso, SW Nigeria. *Journal of Physics: Conference Series* Vol. **1299**, No. 1, p. 012098. doi: 10.1088/1742-6596/1299/1/012098

Pulinets, S., Mironova, I., Miklyaev, P., Petrova, T., Shitov, A. and Karagodin, A. (2024). Radon Variability as a Result of Interaction with the Environment. Atmosphere, **15**,167. https://doi.org/10.3390/atmos15020167

Smetanová, I., Holý, K., Luhová, Ľ., Csicsay, K., Haviarová, D. and Kunáková, L. (2020). Seasonal variation of radon and CO in the Važecká Cave, Slovakia. Nukleonika, **65**(2), 153-157. doi: 10.2478/nuka-2020-0025

Taşköprü, C., İçhedef, M. and Saç, M. M. (2023). Diurnal, monthly, and seasonal variations of indoor radon concentrations concerning meteorological parameters. *Environmental Monitoring and Assessment*, **195**(1), 25. https://doi.org/10.1007/s10661-022-10596-6

Yang, J., Busen, H., Scherb, H., Hürkamp, K., Guo, Q. and Tschiersch, J. (2019). Modeling of radon exhalation from soil influenced by environmental parameters. *Science of the Total Environment*, **656**, 1304-1311. doi: 10.1016/j.scitotenv.2018.11.464

Yusuff, I.M., Oni O.M., Aremu, A.A. (2020). Computational Model for Prediction of Soil-Gas Radon-222 Concentration in Soil-Depths and Soil Grain Size Particles. World Academy of Science, Engineering and Technology International, *Journal of Chemical and Molesscular Engineering* **14**, 5. Computational Model for Prediction of Soil-Gas Radon-222 Concentration in Soil-Depths and Soil Grain Size Particles (researchgate.net)