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Hydrochemical background of ^{222}Rn of three geological units of Lower Silesia




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Introduction

Radon, the heaviest element in the helium group, has four natural isotopes: ^{218}Rn, ^{219}Rn, ^{220}Rn, and ^{222}Rn, which exhibit radioactive properties. When analyzing water radioactivity, only ^{222}Rn is significant due to its half-life, which is more than 3.8 days.

The migration capacity of radon in geospheres (lithosphere, hydrosphere, atmosphere, and biosphere) and between them is very high [1-3]. Radon is formed in the lithosphere, especially in rocks containing increased concentrations of U and/or Ra in the mineral structures, or in rocks containing U and/or Ra compounds that precipitate secondarily on the surfaces of certain minerals in a water-rich environment, including groundwater reservoir rocks.

Due to its solubility in water, radon easily moves from the lithosphere to the hydrosphere. It can be found in groundwater as well as in surface waters, from where it can be easily released into the atmosphere [2,4-6]. Research results for surface waters are often focused on investigating groundwater inflows to surface waters [7,8] or vice versa. Radon (^{222}Rn) is frequently utilized as a tracer to assess the infiltration of surface water into groundwater [9]. The available data on surface water tests for ^{222}Rn activity concentration are relatively limited compared to the data for groundwater. This motivated the authors to conduct research on three geological units located in the region of Lower Silesian Voivodship: Sudetes, Fore-Sudetic Block and Fore-Sudetic Monocline.

Methodes

The authors initiated the research in May 2022, which lasted until February 2023. Within this timeframe, a total of 131 surface water samples were collected from rivers flowing through the Lower Silesian Voivodeship area. At each measurement point, 10 cm^3 of water samples were collected into pre-prepared vials, which also contained 10 cm^3 of the Insta-Fluor Plus scintillator.

The Ultra Low Level Liquid Scintillation Spectrometer α/β Quantulus 1220, was used to measure the activity concentration of ^{222}Rn. The spectrometer operates based on two phenomena: scintillation and external photoelectric effect. Due to the difference in the duration of individual pulses, it is possible to distinguish between α and β particles. The spectrometer also enables reducing the background of β radiation. An important aspect is that both the sample and the detector are isolated from the influence of the radiation sources that do not originate from the mixture in the scintillation vial. This is crucial considering the low values of ^{222}Rn activity concentration expected in surface water samples, as indicated by the authors. Therefore, achieving the lowest possible detection limit (LLD) becomes imperative.

The initial step in establishing the hydrochemical background of involved verifying the obtained data and eliminating gross errors. Each geological unit, was represented by over 25 data points, which prompted the use of the Graf test. In the subsequent stage, the authors identified and excluded outliers and extreme values. The final step of the statistical analysis involved verifying the remaining results for normality of distribution using the Shapiro-Wilk W test. This test is widely recognized for assessing normality, particularly when dealing with small sample sizes [10].

Results

As a result of the conducted research, the authors obtained 131 measurements of the activity concentration of ^{222}Rn (Fig. 1). Out of these, 48 samples were collected from the Sudetes area, 42 samples from the Fore-Sudetic Block, and 41 samples from the area of the Fore-Sudetic Monocline. Based on the statistical analysis, a total of 26 results were rejected (12 from the Sudetes area, 4 from the Fore-Sudetic Block, and 8 from the Fore-Sudetic Monocline). It is important to emphasie that the obtained outliers of ^{222}Rn activity concentration are not a result of improper sampling or measurement techniques. These anomalous results are particularly interesting due to their higher values, which may be associated with groundwater inflows or rocks within the riverbed.

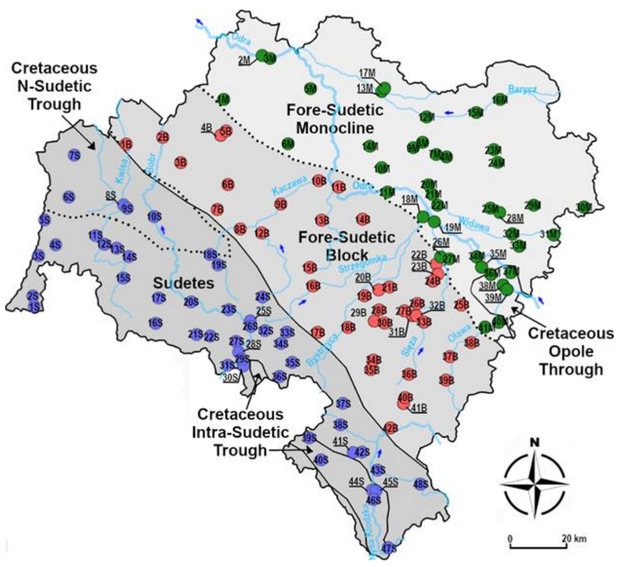

Figure 1. Division of the Lower Silesian Voivodship into three areas corresponding to SW: the Sudetenland, the Fore-Sudetic Block and the Fore-Sudetic Monocline. Sampling points of rivers from the area of: Sudetes (1S-48S), Fore-Sudetic Block (1B-42B) and Fore-Sudetic Monocline (1M-41M) are marked

The average activity concentration of ^{222}Rn in rivers within the Sudety Mountains was determined to be 1.94 Bq/dm^3. In the case of the Fore-Sudetic Block, the average radon content was found to be 0.80 Bq/dm^3, while in the Fore-Sudetic Monocline, the average value was 0.52 Bq/dm^3.

Based on the analysis of the results, it was determined that their distribution follows a normal pattern, thus obviating the need for data transformation. Regarding the hydrochemical background of the analyzed geological units, the highest values were observed in the Sudetes region (ranging from 0.26 to 1.33 Bq/dm^3), intermediate values in the area of the Fore-Sudetic Block (ranging from 0.18 to 0.92 Bq/dm^3), and the lowest values in the area of the Fore-Sudetic Monocline (ranging from 0.12 to 0.48 Bq/dm^3). Concurrently, the ranges of measured values for these geological units were as follows: for the Sudetes, 0.21 to 24.44 Bq/dm^3; for the Fore-Sudetic Block, 0.08 to 4.27 Bq/dm^3; and for the Fore-Sudetic Monocline, 0.09 to 3.37 Bq/dm^3.

Conclusions

The hydrochemical background values in surface (river) waters are as follows: Sudetes with a range of 0.26–1.33 Bq/dm^3 (measured values ranging from 0.21–24.44 Bq/dm^3), the Fore-Sudetic Block with a range of 0.18–0.92 Bq/dm^3 (measured values ranging from 0.08–4.27 Bq/dm^3), and the Fore-Sudetic Monocline with a range of 0.12–0.48 Bq/dm^3 (measured values ranging from 0.09–3.37 Bq/dm^3). These values indicate that the determined background levels and the ranges of measured values for surface waters align with the decreasing proportion of crystalline rocks in the surface structure and the increasing thickness of the sedimentary rock cover.

The range of measured values for ^{222}Rn activity concentration across the entire Lower Silesian Voivodeship is 0.08–24.44 Bq/dm^3, consistently lower than the parametric value of 100 Bq/dm^3. This demonstrates that the analyzed waters fulfill the radiological requirements for water intended for human consumption.

Acknowledgments

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