Assessment of radioactivity levels in soil samples on Zlatibor mountain

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Abstract: This study aimed to investigate the presence and activity concentrations of natural radionuclides and cesium in soil samples collected from the Zlatibor region. A total of ten soil samples were collected from various locations across the Zlatibor area. The analysis was performed using gamma spectrometry to measure the activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs. Additionally, ^{137}Cs was found in big amounts in some of the samples, indicating its dispersion in the environment. The activity concentrations of the detected radionuclides were calculated, and their potential radiological implications were assessed. The obtained data from this study contributes to the baseline information on the natural radioactivity levels in the Zlatibor region, which is essential for environmental monitoring and radiation protection purposes. Furthermore, the presence of ^{137}Cs highlights the importance of continued monitoring to assess potential radiological risks to the local population and environment.

Keywords: natural radionuclides, soil samples, Zlatibor

1. Introduction

In recent years, the investigation of natural radionuclides and anthropogenic radionuclides has become a crucial area of research due to their potential implications for human health and the environment. Radionuclides are radioactive isotopes that emit radiation as they decay, and their presence in the environment can arise from both natural and human-made sources. Among the anthropogenic radionuclides, cesium-137 (^{137}Cs) has gained particular attention due to its association with nuclear accidents and nuclear weapons testing [1, 2, 3].

The Zlatibor region, known for its scenic landscapes and environmental significance, has also been subject to scrutiny concerning potential radionuclide contamination.

Understanding the distribution and levels of radionuclides in this area is essential for assessing the radiological risk to the local population and ecosystems. Consequently, gamma spectrometry, a powerful and non-destructive analytical technique, has been widely employed for the detection and quantification of radionuclides in environmental samples [4].

The presence of ^{137}Cs in the soil can lead to its uptake by plants and subsequent transfer through the food chain, ultimately reaching humans and wildlife. Long-term exposure to elevated levels of ^{137}Cs can increase the risk of cancer, especially in organs that accumulate radiation, such as the thyroid and gastrointestinal tract. Moreover, exposure to gamma radiation from ^{137}Cs can also cause other health effects, including genetic mutations and damage to cells.

The significance of this research lies in providing comprehensive data on radionuclide contamination in the Zlatibor region. Such information is critical for the development of effective environmental monitoring strategies and the implementation of appropriate remediation measures, if necessary.

2. Material and methods

2.1 Collection and preparation of samples

Ten soil samples were collected from various locations in the Zlatibor region to ensure representativeness of different soil types. The collected samples were air-dried to remove any moisture content and ground into a fine powder using a mill. The powdered soil samples were then sieved to obtain a homogenous particle size distribution. Subsequently, the homogenized samples were divided into ten separate aliquots, with each aliquot carefully labeled and stored in airtight containers to prevent contamination. To achieve a secular equilibrium between ^{226}Ra and its short-lived decay products, the samples were hermetically sealed for a period of four-to-six weeks.

2.2 Gamma spectrometry

The activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, and ^{137}Cs were measured using a coaxial HPGe detector (GEM30-70, ORTEC) with an energy resolution (FWHM) of 1.85 keV at 1.33 MeV (^{60}Co) and a relative efficiency of 30%. To minimize background interference, the detector was housed within a 10 cm lead shield during measurements. Each sample was exposed to the detector for a timed duration of 172,800 seconds, and background corrections were applied. Data analysis was conducted using the computer software MAESTRO 2. For the determination of ^{226}Ra activity concentration, gamma lines of ^{214}Pb and ^{214}Bi (at 351.9 keV, 609.3 keV, and 1764.5 keV) were utilized. The specific activity of ^{232}Th was estimated by examining gamma lines at 338.3 keV, 911.1 keV, and 583.0 keV (corresponding to ^{228}Ac and ^{208}Tl). For ^{137}Cs activity concentration, the gamma line at 661.6 keV was monitored. Moreover, the photopeak at 1460.7 keV was utilized to estimate the activity concentration of ^{40}K in the soil samples.

2.3 Activity concentration of soil samples

Specific activity of radionuclides can be calculated as [5]:

$$AC = \frac{N_L}{\varepsilon \cdot m \cdot t \cdot P_\gamma}, \quad (1)$$

where: AC is the activity concentration (Bq kg^{-1})
N_L is the net area of the photopic
m is the sample mass (kg)
ε is counting efficiency for a specific energy
P_γ is the emission probability of the measured gamma-ray
t is the counting time (s).

3. Results and discussion

Activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) and anthropogenic ^{137}Cs measured in soil samples are presented in Table 1.

Table 1. Table of Radionuclide Activity Concentrations in Soil Samples from Zlatibor Region (in Bq kg^{-1}).

Sample No	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
S1	3.6 ± 0.2	5.2 ± 0.3	72.6 ± 3.6	610 ± 30
S2	5.5 ± 0.3	7.2 ± 0.4	118.7 ± 5.9	870 ± 40
S3	3.3 ± 0.2	5.2 ± 0.3	89.0 ± 4.5	660 ± 30
S4	3.9 ± 0.2	6.4 ± 0.3	115.8 ± 5.8	490 ± 30
S5	4.9 ± 0.2	6.9 ± 0.3	102.4 ± 5.1	780 ± 40
S6	3.8 ± 0.2	6.0 ± 0.3	95.1 ± 4.8	590 ± 30
S7	6.2 ± 0.3	7.8 ± 0.4	120.1 ± 6.0	930 ± 50
S8	4.3 ± 0.2	6.2 ± 0.3	98.8 ± 4.9	720 ± 40
S9	4.0 ± 0.2	5.5 ± 0.3	81.3 ± 4.1	660 ± 30
S10	5.9 ± 0.3	7.6 ± 0.4	116.9 ± 5.8	890 ± 50

The measured activity concentrations of ^{226}Ra ranged from 3.3 Bq kg^{-1} (Sample S3) to 6.2 Bq kg^{-1} (Sample S7). These values are within the typical range found in soil samples from various geological regions. The presence of ^{226}Ra in soil can be attributed to the natural decay series of uranium and its abundance in the Earth's crust. For ^{232}Th, the activity concentrations varied from 5.2 Bq kg^{-1} (Sample S3) to 7.8 Bq kg^{-1} (Sample S7). The activity concentrations of ^{40}K were found to be in the range of 81.3 Bq kg^{-1} (Sample S9) to 120.1 Bq kg^{-1} (Sample S7). Furthermore, the anthropogenic radionuclide ^{137}Cs was detected in all samples, with activity concentrations ranging from 490 Bq kg^{-1} (Sample S4) to 930.0 Bq kg^{-1} (Sample S7). The observed elevated activity concentrations of ^{137}Cs in the soil samples from the Zlatibor region can potentially represent a radiological risk to the environment and human health. The radiological risk associated with ^{137}Cs stems from its long half-life of approximately 30 years. This means that even though it is considered a short-term hazard due to its high radioactivity, it can persist in the environment for an extended period. ^{137}Cs emits gamma radiation, which can penetrate the body and pose a risk to human tissues and organs if exposure levels are significant [6].

3. Conclusion

The analysis of soil samples from the Zlatibor region revealed the presence of both natural radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) and anthropogenic radionuclide ^{137}Cs. The elevated levels of ^{137}Cs indicate a potential radiological risk to the environment and human health. Continuous monitoring and mitigation strategies are crucial to ensure the safety and sustainable development of the region, minimizing the potential impacts of ^{137}Cs on the ecosystem and local population. Public awareness and education on radiological risks are essential in fostering responsible practices and safeguarding the well-being of the community.

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References

[1] SRBATOM (2021) http://www.srbatom.gov.rs/srbatomm/posledice-akcidenta-u-fukusimi-na-srbiju/?lang=en

[2] G. Steinhauser, A. Brandl, T.E. Johnson, *Comparison of the Chernobyl and Fukushima nuclear accidents: a review of the environmental impacts,* Science of The Total Environment, 470–471 (2014) 800–817.

[3] UNSCEAR (2008) Report to the general assembly. Sources and efects of ionizing radiation, vol II. United Nations, New York

[4] M. M. Janković, Rajačić, M., Jelić, I., Krneta-Nikolić, J. D., Vukanac, I., Dimović, S., Sarap, N., M.Ž. Šljivić-Ivanović, *Distribution of Natural Radionuclides and 137Cs in Urban Soil Samples from the City of Novi Sad, Serbia - Radiological Risk Assessment*, Toxics, 11(4) (2023) 345.

[5] A. Jose, J. Jorge, M. Cleomacio, V. Sueldo, D.S. Romilton, *Analysis of the 40K levels in soil using gamma spectrometry,* Brazilian Archives of Biology and Technology 48 (2005) 221-228.

[6] Kabata-Pendias A., Trace elements in soils and plants, 4thedn. CRC Press, (2011) New York