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EcoTER'22

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Prof. Dr Snežana Šerbula

21-24 June 2022, Hotel Sunce, Sokobanja, Serbia

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THE DISTRIBUTION OF THE MASS CONCENTRATIONS OF K, Th AND U IN THE SOILS OF THE TEKIJA REGION, THE NP ĐERDAP

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Abstract

Soil samples (27) were collected in June in the period from 2018 to 2020 on the territory of the National park Đerdap (Tekija region, from 4 governing units). Mass concentrations of potassium, thorium and uranium calculated based on measured gamma spectrometric radionuclide activity are shown in this work. The mean value of mass concentration of the analyzed elements in soil samples in the investigated three year period were 1.84% potassium, 3.17 mg kg^{-1} uranium and 10.15 mg kg^{-1} thorium. The strength of the absorbed gamma radiation dose originating from radionuclide activity was calculated. The total and also annual effective doses were in the range of average values determined in the World.

Keywords: NP Đerdap, mass concentration, potassium, thorium, uranium

INTRODUCTION

A National Park (NP) is a protected region with large numbers of diverse natural ecosystems of national significance, landscape features and cultural heritage where man lives in accordance with nature [1]. The first NP in the World was founded in 1872 in the Yellowstone region (USA), while in Europe the first NP was founded in 1909 (Sarek, Sweden). The first NP was founded in 1924 on the territory of former Yugoslavia in the Triglav lake valley. In 1948 the United Nations formed the International Union for Conservation of Nature (IUCN). Since the XIV century Serbia has worked on environmental protection (Dušan's Code, article 123). The oldest NP in Serbia was founded in 1960 (Fruška gora), followed by: Đerdap (1974), Kopaonik (1981), Tara (1981) and Šar-planina (1986). The procedure for protecting Stara Planina and Kučaj-Beljanice as a NP started in 2022. All NPs in Serbia cooperate with the independent non-governmental organization EUROPARC – Federation of Nature and National Parks of Europe [2]. NP Đerdap is located in the North-Eastern part of Serbia and covers part of the area of the Đerdap gorge (Iron Gate) in the middle flow of the Danube. It includes parts of the Severni Kučaj, Miroč and Štrbac massive 2-10 km wide, and also parts of the Danube belonging to the Republic of Serbia [1]. The very complex relief in NP Đerdap, specific climate, large number of relic species and phytocenosis, and also a great variety in the lithological composition of rocks, genetic affiliation and geological age have caused the formation of a variety of soil types with different properties and production potential [2,3]. Land is a dynamic system in which different physico-chemical and biological processes occur. It is composed of two components: mineral and organic. Rocks that are part of the Earth crust contain a certain concentration of natural radionuclides (uranium, radium, thorium and potassium) that are also present in the soil formed when they decompose and their contribution to natural radioactivity in the environment is the highest [4]. According to the UNSCEAR report (United Nations Scientific Committee on the Effects of Atomic Radiation) average mass concentrations (concentration range) (mg kg^{-1}) of uranium, radium, thorium, and potassium (%) in soil in the World are: 2.82 (1.29–8.87); 3.18 (1.53—5.45); 7.32 (2.68–15.61) and 1.54 (0.54–3.28), respectively [5]. The behavior of radionuclides depends on interactions with other soil components and their interrelations can be used to evaluate different processes in soil. Knowledge of their distribution and concentration plays a significant role in radiation protection.

External radiation of the population mainly originates from gamma radiation formed after the decay in radioactive series of uranium, thorium and potassium. Other radionuclides of natural origin are present in small amounts and to not contribute very much to population radiation [6].

Continual measurement and monitoring of basic activity levels of samples from the environment has a fundamental significance from the aspect of ecosystem protection, as this is the basis for building criteria of radiological security of the biosphere. In order to obtain a realistic picture of soil radioactivity, the most significant and sensitive component of the environment, soils samples were collected in NP Đerdap, in the Tekija region in the period 2018-2020 and the obtained results are presented in this work.

MATERIAL AND METHODS

Soil samples (27) were collected in the Tekija region, NP Đerdap, from 4 management units (MU) (Faca Tekija, Dafin, Đerdap and Štrbačko korito), up to the depth of 10 cm, in June 2018–2020. Localities were carefully chosen based on the results obtained for bioindicator radioactivity in previous years [7–9]. After arrival to the laboratory, the samples were cleaned by removing visible impurities, dried, mechanically chopped, homogenized and packed into Marinelli vessels with a volume of 0.5 L, hermetically sealed with paraffin and left to sit for 40 days in order to establish a radioactive stability of post-radon series members ^{238}U, prior to gamma spectrometric analysis. The sample mass was up to 600g. A semiconducting germanium high purity detector of the n-type, ORTEC – AMETEK, USA, with 8192 channels, resolution 1.65 keV and relative efficiency of 34% at 1.33 MeV for ^{60}Co. Spectra were analyzed using the Gamma Vision 32 software package [10].

Specific activity of ^{40}K, ^{238}U and ^{232}Th were converted into mass concentrations of potassium, uranium and thorium elements [11], respectively using the equation (1):

$$F_E = \frac{M_E \times C}{\lambda_{E,i} \times N_A \times f_{E,i} \times A_{E,i}} \qquad (1)$$

where: F_E – participation of element E in the sample, M_E – atomic weight (kg mol^{-1}), $\lambda_{E,i}$ – constant of the radioactive decay of isotope i of element E (s^{-1}), $f_{E,i}$ – representation of isotope i in the nature, $A_{E,i}$ – measured specific activity (Bq kg^{-1}) of radionuclides (^{40}K, ^{238}U, ^{232}Th), N_A – Avogadro number (6.023 × 10^{23} atom/mol) and C – constant with values in 10^{6} for U and Th (mass concentration mg kg^{-1}) or 100 for K (mass concentration in %).

According to the recommendation of UNSCEAR [5], the absorbed dose strength (D) at 1 m above ground can be calculated based on measured activity levels ($A_{U,Th,K}$) (Bq kg^{-1}) of natural radionuclides in investigated soil samples according to equation (2) with the assumption that all progeny are in equilibrium with their precursors and that radionuclides insignificantly contribute to the total dosage due to external exposition, using the conversion factors for ^{238}U, ^{232}Th and ^{40}K 0.462; 0.604 and 0.042 (nGyh^{-1}/(Bq kg^{-1}) respectively:

$$D\ (nGyh^{-1}) = 0.462A_U + 0.604A_{Th} + 0.042A_K \qquad (2)$$

If the total absorbed radiation dose strength (D) is known then equation (3) can be used to calculate the yearly effective radiation dose for an adult H (mSv):

$$H\ (mSv) = D \times 0.7 \times 0.2 \times 8760 \qquad (3)$$

where: 0.7 (SvGy^{-1}) is the conversion coefficient (ratio between the yearly effective dose received by the population and the absorbed dose in air); 0.2 – is the exposition factor for external irradiation (it is assumed that on average the population spends about 20% time outside in the open); 8760 – number of hours in a year [5].

RESULTS AND DISCUSSION

The natural radioactivity of soil depends on the type of radiation and geological structure of the area. Table 1 shows mass concentrations of potassium (%), uranium and thorium (mg kg^{-1}) in soil, minimal and maximal values, collected from 2018 to 2020 in the Tekija region.

Analysis of data shown in Table 1 enabled calculation of average values of mass concentrations of potassium present in soil collected in 2018 of 1.96%, 2019 2.02% and 2020 of 1.55%. These values are somewhat higher compared to our research conducted in previous years [7–9], but in the range of values determined in the World [5]. The average value of the mass concentration of uranium in soil was: 2018 3.24 mg kg^{-1}, 2019 3.35 mg kg^{-1} and 2020 2.92 mg kg^{-1}. These values are in the range of values obtained in our previous research [7–9] and in the World [5]. The average value of mass concentration of thorium in soil was: 2018 9.68 mg kg^{-1}, 2019 10.68 mg kg^{-1} and 2020 9.97 mg kg^{-1} and they are somewhat higher compared to our previous research and in the range determined in the World [5,7–9]. The values of the Pearson coefficient among radionuclides in soil are similar: for U–Th 0.499; K–U (0.537) and K–Th (0.503) indicating their moderate linkage.

Table 1 *Mass concentrations, average, minimal and maximal values of potassium, uranium and thorium in soil collected in the period 2018–2020 in the Tekija region*

MU* (samples)	Year	K (%)		U (mg kg^{-1})		Th (mg kg^{-1})	
		A**	Min–max	A**	Min–max	A**	Min–max
Faca Tekija (2)	2018	1.82	1.72–1.91	2.99	2.16–3.81	9.92	9.85–9.98
Dafin (2)		1.63	1.58–1.68	3.22	2.84–3.60	10.25	9.90–10.59
Đerdap (4)		2.20	1.89–2.64	3.38	2.56–4.38	9.29	8.17–10.00
Đerdap (7)	2019	2.18	1.32–2.97	3.56	2.60–4.20	11.08	8.46–13.12
Š.korito (3)		1.65	1.48–1.88	2.87	2.58–3.17	9.75	9.17–10.49
Đerdap (6)	2020	1.49	1.00–1.88	2.84	2.06–3.15	9.07	5.41–10.59
Š. Korito (3)		1.67	1.45–1.98	3.08	2.52–3.40	11.77	9.34–13.73

*MU-management unit, A**-average value

The absorbed radiation dose strength per radionuclide and in total D (nGyh^{-1}) was calculated based on equation (2) as shown in Table 2. The average value of the radiation dose strength of potassium, uranium and thorium (nGyh^{-1}) in soil collected in the territory of the Tekija region was: in 2018 it was 25.73, 18.57 and 23.98, in 2019 26.52, 19.19 and 26.46, and in 2020 20.38, 16.71 and 24.69, respectively. The average value of the total absorbed dose strength (nGyh^{-1}) in soil collected in the period 2018-2020 was 68.27, 72.17 and 61.78. Knowing D (nGyh^{-1}), and based on equation (3) the average annual effective radiation doses in the Tekija region were calculated as: in 2018 0.084 mSv, in 2019 0.088 mSv, and in 2020 0.088 mSv. These values were higher than the average value determined in the World (0.070 mSv), but within the measurement range.

Table 2 *Absorbed radiation dose strength per radionuclide and in total (nGyh^{-1}), annual effective radiation dose (nGy h^{-1}) in the Tekija region in the period 2018–2020*

MU*	Year	Absorbed dose strength per radionuclide and in total				H
		K	U	Th	D	(mSv)
		(nGy h^{-1})				
Faca Tekija	2018	23.81	17.12	24.55	65.48	0.080
Dafin		21.36	18.46	25.37	65.19	0.080
Đerdap		28.87	19.35	23.00	71.22	0.087
Đerdap	2019	28.58	20.38	27.45	76.41	0.097
Š.korito		21.70	16.42	24.14	62.26	0.076
Đerdap	2020	19.58	16.26	22.46	58.30	0.071
Š. Korito		21.98	17.62	29.15	68.75	0.084

*MU-management unit

Based on the Guidelines [6] the annual effective dose for the population is increased if it is higher than 1 mSv for a year. The calculated average values show that the effective dose for the population in Tekija region is low.

CONCLUSION

The average mass concentration of potassium in soil samples collected from 2018 to 2020 in the Tekija region was 1.84%, while the uranium concentration was 3.17 mg kg^{-1}, and the thorium concentration was 10.15 mg kg^{-1}.

The values of Pearson coefficients between radionuclides in soil were similar: for U–Th (0.499); K–U (0.537) and K–Th (0.503) indicating moderate linkage.

The absorbed gamma radiation dose strength originating from radionuclide activity in soil was calculated. Total and also annual effective doses were also calculated and they were in the range of average values in the World.

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