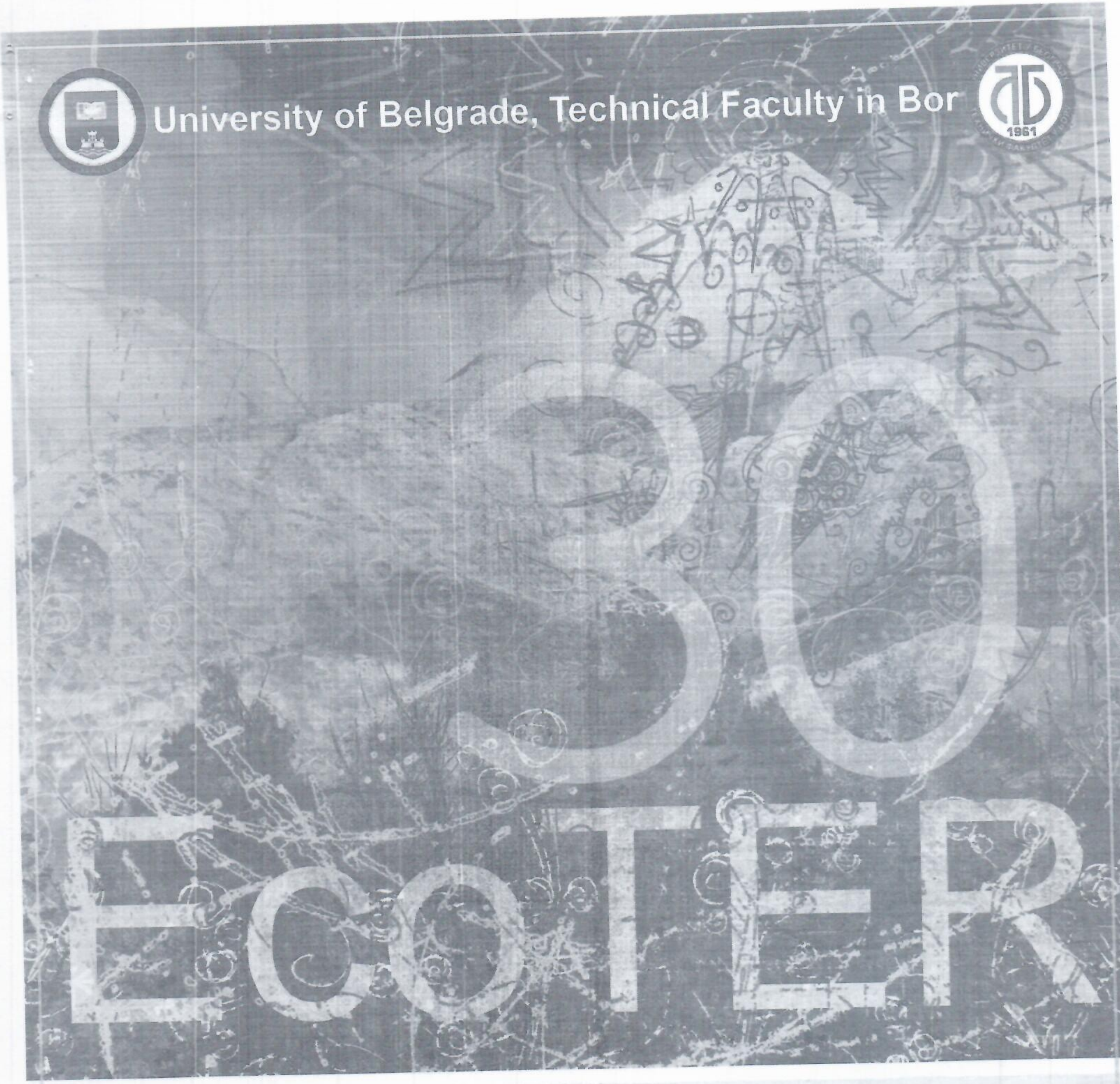

30th International Conference Ecological Truth & Environmental Research 2023

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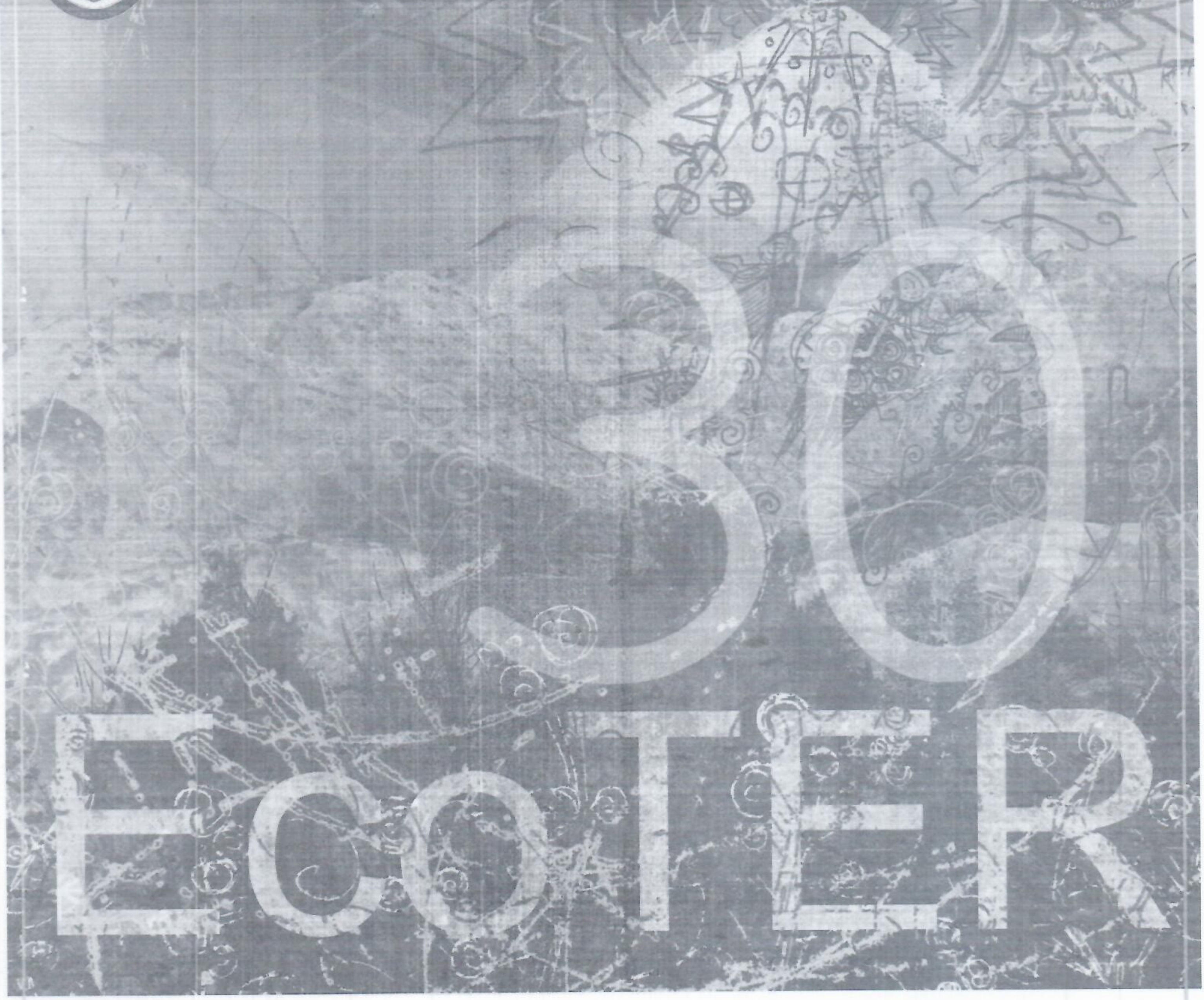

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RADIOACTIVITY IN SOIL AND MOSSES FROM THE SPECIAL NATURE RESERVE OF ZASAVICA IN 2021

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Abstract

Soil and moss samples were collected in the Special Natural Reserve (SNR Zasavica) in August 2021 from 12 localities. Determination of the specific activity of natural radionuclides (^{226}Ra, ^{232}Th, ^{40}K) and artificial radionuclide (^{137}Cs) was performed using a germanium detector ORTEC-AMETEK, USA. The specific activity (Bq kg^{-1}) of ^{40}K in soil (moss) samples was from 633 (188) to 1022 (530), ^{226}Ra from 27.9 (16.6) to 48.6 (36.6), ^{232}Th from 35.4 (6.5) to 48.5 (25.7) and ^{137}Cs from 3.8 (1.7) to11.1 (65.0). The specific activity of radionuclides in soil and moss in SNR Zasavica were within the range of measured activity in soil and moss in Serbia.

Keywords: SNR Zasavica, radionuclides, soil, moss.

INTRODUCTION

The special natural reserve (SNR) Zasavica was put under state protection in 1997 as a natural reserve of the first category of extreme significance to the Republic of Serbia in order to preserve natural watercourses and wet habitats and its significant variety of flora and fauna. It is situated in Northeastern Serbia, in the region of south Vojvodina and northern Mačva, east of the Drina River and south of the Sava River, on the territory of the municipalities of Sremska Mitrovica and Bogatić, between settlements: Crna Bara, Banovo Polje, Ravnje, Radenković, Zasavica I and II, Salaš Noćajski, Noćaj and Mačvanska Mitrovica. Its area is 1852 ha and it spans the river Zasavica with a length of 33.1 km. The Batar stream runs through, and it includes the Jovac, Prekopac and Bogaz channels (the Bogaz channel links it with the Sava River). Zasavica has a subterraneous water supply from the Drina River and gravitationally from the Cer Mountain. The area of northern Mačva is bordered on the southern side by Cer and Iverak Mountains comprised of remnants of granite melt of magmatic rocks that include pegmatites, greisens and granodiorites composed of rare earth minerals and also uranium and thorium [1]. The reserve enjoys an internationally protected status: Ramsar area (No. 1783), botanically significant area (IPA), area significant for birds (IBA, RS008), and primary area for butterflies (PBA, 40) [2]. It is a member of the Europark federation. The reserve is looked after by the non-governmental organization "Pokret gorana" from Sremska Mitrovica.

All organisms on the planet Earth are exposed to radiation. Natural radioisotopes: ^{40}K, ^{232}Th, ^{226}Ra, ^{238}U, etc. located in the Earth's crust and formed during the nucleosynthesis process with a long half-life (10^5–10^{16} years) contribute the most to gamma irradiation (96%) in the environment. These radionuclides have different geochemical properties, types of radioactive half-life, irradiation intensity, isotopic abundance, expression, migration and geochemical cycles [3]. Radionuclides of an anthropogenic origin (^{131}I, ^{137}Cs, ^{90}Sr, ^{99}Tc, ^{239}Pu, etc.), deriving mostly from splitting heavy nucleus also contribute to gamma radiation. Pollution with these radionuclides usually has a regional character, but it can be wider in the case of strong nuclear explosions (Chernobyl, 26.4.1986) [4]. The Chernobyl accident (Ukraine) released a great amount of radionuclides into the environment of which 3.7×10^{16} Bq ^{137}Cs. Radio-cesium – 137, forms as a fission product or is produced in the production or testing process of nuclear weapons and in nuclear reactors. It is a toxic element and its physicochemical characteristics enable active incorporation into the food chain of humans and animals through plants, as it metabolically replaces potassium [4], has a long physical half-life (30.2 years), and the processed of radio-cesium adoption from the environment can be physical and chemical adsorption and ionic exchange. Land is one of the basic living conditions. Soil is the most significant and sensitive component of the environment and a complex, dynamic system in which different physic-chemical and biological processes occur [5]. Soil has different compositions, chemical, physical and biological properties. One of the physical properties is radioactivity. Natural ionizing radiation in the environment caused by ^{40}K, ^{232}Th, ^{226}Ra and ^{238}U varies from place to place and mainly depends on the geology and concentration of elements in rocks and soil. According to the UNSCEAR report (2000) average specific activities (Bq kg^{-1}) in soil in the World (min-max) are ^{238}U 35 (16–110); ^{226}Ra 35 (17–60); ^{232}Th 30 (11–64) and ^{40}K 400 (140–850) [6].

Moss is characterized with a particular structure (no root, trunk, leaf and they have a large body surface) and a specific ecology in relation to vascular plants. Their longevity, physiological activity and adaptability to different environmental conditions, possible accumulation of many materials in their body and retention of old part, and also wide prevalence make them good bioindicators and biomonitors of polluting substances. The localities of the SNR Zasavica showed the presence of 43 moss taxonomies (41 species and 2 varieties) grouped in 22 genuses and 14 families. Three taxonomies belong to the liverwort class, while 40 are members of real moss (9.09% flora Bryopsida Serbia) [7,8].

Measuring and monitoring activity levels in soil and moss samples from the environment has a great significance from the aspect of ecosystem protection as it is the basis for the formation of criteria for the radiological security of the biosphere. Radioactivity monitoring is necessary and significant to achieve environmental protection and radiological protection of the inhabitants of a certain region.

MATERIAL AND METHODS

Soil (S) and moss (M) samples were collected in the SNR Zasavica in August 2021 from 12 localities: (1) Ravnje, Zovik; (2) Radenković, Batar; (3) Glušci, Bitva, (4) Banovo polje, Trebljevine; (5) Hajdučki potok, Miline; (6) Parloge; (7) Lešnica; (8) Jadarska lešnica; (9) Badivinci; (10) Bradić; (11) Desić and (12) Ladjane. The moss type was not determined.

After the samples were brought to the laboratory they were cleaned to remove noticeable impurities, dried, homogenized and packed in Marinelli vessels with volumes of 0.5 and 1 L that were sealed with paraffin and left for 40 days in order to establish radioactive equilibrium between ^{226}Ra, ^{222}Rn and their short-lived descendants. The moss sample mass was up to 100g, while the soil sample mass was up to 600g. A semiconducting germanium high purity detector of the n-type produced by ORTEC-AMETEK, USA, with 8192 channels, resolution 1.65 keV and relative efficiency of 34% at 1.33 MeV for ^{60}Co was used to determine radionuclide activity levels. Detector calibration was performed using a reference radioactive material: silicon resin matrix, Czech Metrological Institute Praha (ČMI Praha). All samples were measured for 60000 s. Spectral analysis was performed using the Gamma Vision software package 32. The relative sample preparation and measurement uncertainty was up to 10%. The activity level of ^{226}Ra was determined based on the gamma line for: ^{214}Bi (609, 1120 and 1764 keV) and ^{214}Pb (295 and 352 keV), of ^{232}Th on the gamma line ^{228}Ac (338, 911 and 969 keV), of ^{40}K on the gamma line at 1460.8 keV, while for ^{137}Cs it was determined based on the gamma line at 661.6 keV.

RESULTS AND DISCUSSION

The specific activity of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs (Bq kg^{-1}) in soil and moss collected from SNR Zasavica in 2021 is presented in Table 1. From the values shown in Table 1, it follows that the specific activity of ^{40}K in soil samples was from 633 (locality 8) to 1022 Bq kg^{-1} (locality 7) and in moss samples from 188 (locality 9) to 530 Bq kg^{-1} (locality 2). The average value of the specific activity of ^{40}K in soil (moss) was 764 (353) Bq kg^{-1}. The results of this investigation show that the specific activity of ^{40}K in soil (moss) from Zasavica was higher in relation to our previous research 206–654 (130–438) [9,10]. The specific activity of ^{40}K in soil from SNR Zasavica are within the measured range of specific soil activity in Vojvodina (238–1000 Bq kg^{-1}) [11], but somewhat higher than values determined in the World (140–850 Bq kg^{-1}) [6]. The specific activity of ^{226}Ra in soil samples were from 27.9 (locality 4) to 48.6 Bq kg^{-1} (locality 2), and in moss samples from 16.6 (locality 12) to 36.6 Bq kg^{-1} (locality 10). The average value of the specific activity of ^{226}Ra in soil (moss) was 35.5 (22.5) Bq kg^{-1} (Table 1). This research has shown that the specific activity of ^{226}Ra in soil (moss) from investigated localities in Zasavica were higher compared to our previous measurements 32–37 (0.9–13.3) Bq kg^{-1} [9,10], but they are still within the measured values for soil from Vojvodina (9.7–49.1 Bq kg^{-1}) [11] and within the range of the values determined in the World (17–60) [6]. Table 1 follows that the specific activity of ^{232}Th in soil samples was from 35.4 (locality 8) to 48.5 Bq kg^{-1} (locality 7), while in moss samples it was from 6.5 (locality 3) to 25.7 Bq kg^{-1} (locality 2). The average value of the specific activity of ^{232}Th in soil (moss) was 40.3 (16.5) Bq kg^{-1}. This research has shown that the specific activity of ^{232}Th in soil (moss) from the investigated localities in Zasavica were higher when compared to our previous measurements 41–46 (3.9–14.8) Bq kg^{-1} [9,10], but they are within the range of measured values in Vojvodina soil (11.7–70.5 Bq kg^{-1}) [11], but somewhat higher than in the World (11–64) [6]. The specific activity of ^{137}Cs in soil samples was from 3.8 (locality 8) to 11.1 Bq kg^{-1} (locality 4), while in moss samples it was from 1.7 (locality 12) to

65.0 Bq kg^{-1} (locality 11). The average value of the activity of ^{137}Cs in soil (moss) was 7.0 (18.0) Bq kg^{-1}. This research has shown that the specific activity of ^{137}Cs in soil (moss) from the investigated localities in Zasavice was significantly higher than our previous measurements 6.5–13.1 (0.8–5.8) [9,10], but they are within the measured values of soil activity in Vojvodina (3.04–42.6 Bq kg^{-1}) [11]. Analysis of the obtained results enables the conclusion that the substrate collected on locality 7 has the most ^{40}K and ^{232}Th, while the substrate collected on locality 8 has the lowest ^{40}K, ^{232}Th and ^{137}Cs. Moss collected at locality 12 has the lowest ^{226}Ra and ^{137}Cs. Pearson correlation coefficients for ^{40}K-^{226}Ra, ^{40}K-^{232}Th, ^{226}Ra-^{232}Th in soil are 0.903; 0.842; 0.771, respectively and indicate a strong interdependence between the observed radionuclides, while for ^{40}K-^{137}Cs, ^{226}Ra-^{137}Cs and ^{232}Th-^{137}Cs they are -0.150; -0.052; 0.006 and indicate a very weak interdependence. High values of the Person coefficients between radionuclides of the uranium and thorium series in soil indicate their joint origin. Pearson correlation coefficients for ^{40}K-^{232}Th and ^{40}K-^{137}Cs in moss are 0.603; -0.607 and indicate a moderate interdependence between the observed radionuclides, while for ^{226}Ra-^{232}Th, ^{232}Th-^{137}Cs and ^{40}K-^{226}Ra they are 0.207; 0.203 and 0.214, respectively and indicate a weak interdependence, while for ^{226}Ra-^{137}Cs it is -0.008 and indicates a very weak interdependence.

***Table 1** Specific activity of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs in soil (S) and mosses (M) collected in August 2021 in Zasavica and transfer factors (TF)*

Locality	Sample type, TF	^{40}K (Bq kg^{-1})	^{226}Ra	^{232}Th	^{137}Cs
1	S	701	32.1	41.6	7.1
	M	461	19.7	17.1	2.7
	TF	0.66	0.61	0.41	0.38
2	S	953	48.6	41.4	6.4
	M	530	25.6	25.7	2.8
	TF	0.56	0.53	0.62	0.44
3	S	793	43.2	44.1	8.5
	M	309	21.5	6.5	1.9
	TF	0.39	0.50	0.15	0.22
4	S	640	27.9	36.4	11.1
	M	421	20.5	20.2	3.7
	TF	0.66	0.73	0.55	0.33
5	S	728	31.3	37.7	6.2
6	S	641	29.3	37.6	6.7
7	S	1022	43.3	48.5	6.1
8	S	633	28.2	35.4	3.8
9	M	188	22.6	12.7	40.9
10	M	359	36.6	17.8	25.2
11	M	265	17.2	21.4	65.0
12	M	288	16.6	10.3	1.70

The transfer factor (TF) for the introduction of any radionuclide from soil to moss that grows on that soil is defined as the ratio between specific activity of the analyzed radionuclide in moss (Bq kg^{-1}) and the activity level in soil (Bq kg^{-1}) [12]. Transfer of radionuclides from the substrate to moss depends on physical, chemical and biological factors that determine the radionuclide properties, moss type and soil characteristics. The calculated mean values of TF grow in the following order $^{137}Cs < ^{232}Th < ^{40}K < ^{226}Ra$ (0.34 < 0.43 < 0.57 < 0.59).

CONCLUSION

Radionuclides ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs are present in all soil and moss samples and they have partly appeared due to discharging from the Cer Mountain. The average value of the specific activity (Bq kg^{-1}) of ^{40}K in soil (moss) was 764 (353), ^{226}Ra 35.5 (22.5), ^{232}Th 40.3 (16.5) and ^{137}Cs 7.0 (18.0). Pearson correlation coefficient for ^{40}K-^{226}Ra, ^{40}K-^{232}Th, ^{226}Ra-^{232}Th in soil are 0.903; 0.842; 0.771, respectively and indicate a strong interdependence between the observed radionuclides and their joint origin. Pearson correlation coefficients for ^{40}K-^{232}Th and ^{40}K-^{137}Cs in moss are 0.603; -0.607 respectively and indicate a moderate interdependence between the observed radionuclides.

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