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Distribution of the Land Factor Transfer - Wooden Periodic Plants in Pcinja District

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ABSTRACT

This paper presents the results of testing the transfer factors in the food chain of soil-woody perennial crops (bull, oak, mulberry, acacia, apricot, plum) in the Pcinja district. Transfer factors, as a quantitative measure of the process for all analyzed samples of woody perennial crops, were significantly lower by ^{226}Ra than by ^{232}Th and ^{40}K. The results of transfer factors showed that in some of the cereals in the Pcinja district, the ratio of the given radionuclides is harmonious and is most pronounced for the radionuclide ^{40}K. The aim of this paper was to obtain the first results of the transfer of land-cereal factors, which would be of great importance for farmers producing these types of cereals in this region.

Keywords: Transfer factor, Radionuclides, Soil, Woody perennial crops

INTRODUCTION

Natural radioactivity originates both from members of the radioactive arrays of which ^{232}Th, ^{238}U and ^{235}U are the originators, as well as ^{40}K. In addition to the natural ones, under the influence of technology (or human action), some artificial radionuclides have been released into the environment. One of them is ^{137}Cs (T1 / 2 = 30y), to which the occurrence in nature was largely caused by nuclear tests in the 60's and the Chernobyl accident in 1986 [1].

This forms the bond between the substrate and a given specimen. The transfer factor (TF) is used as a parameter for environmental transfer models that are useful in predicting the specific activity of radionuclides in agricultural crops [3]. The main factors that determine TF variability are the type of radionuclide, the type of plant, the type of soil (its characteristics) and the stable concentration of the element [4]. Factor transfer values depend on plant varieties and weather [5]. The results of research on transfer factors should show, provide a basis for theoretical explanations for the different adoption of elements that do not participate in physiological and biochemical processes in the plant [6]. Transport processes in the soil-plant system for the radionuclide group ^{226}Ra, ^{40}K, ^{232}Th, ^{238}U, ^{235}U and ^{137} Cs are not well known in the Pcinja region. The aim of this paper was to show the first results of transfer factors in some woody perennial plants that are very important in the food chain [7].

METHODOLOGY

This paper presents the results of transfer of ^{226}Ra, ^{40}K and ^{232}Th factors in perennial woody plants (beech, oak, mulberry, acacia, apricot, plum). The first tests in the Vranje region included sampling at three locations: Slivnica and Toplac during 2016. About 10 samples of arable forest land were sampled as well as 9 samples of woody perennial plants.

The preparation of soil samples involves the removal of mechanical impurities, stones and plant material, as well as drying at 105° for 24 h. The samples of the woody plant cultures were dried at room temperature and mineralized at 450°.

The radioactivity of the samples was determined by gamma spectrometry at the Institute for Nuclear Sciences Vinca in the Laboratory for Radiation and Environmental Protection.

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Table 1. List of soil samples and coordinates of sampling sites.

Location	Depth (cm)	Coordinates		Elevation (m)	Date of sampling
		north latitude	eastern geography		
Bujkovac	0-5	42°33'26"	22°00'35"	718	09.11.2016.
	0-10	42°33'26"	22°00'35"	718	09.11.2016.
	0-20	42°33'26"	22°00'35"	718	09.11.2016.
Slivnica	0-5	42°33'08"	22°05'35"	1043	11.11.2016.
	0-10	42°33'08"	22°05'35"	1043	11.11.2016.
	0-20	42°33'08"	22°05'35"	1043	11.11.2016.
Toplac	0-20	42°34'06"	21°56'58"	359	18.11.2016.
	0-40	42°34'06"	21°56'58"	359	18.11.2016.

The gamma spectrometry was performed on three high purity germanium (HPGe) detectors (CAN -BERRA) with relative efficiencies of 18 % (*n*-type), 20 % (*p*-type), and 50% (*n*-type). Resolution of all of the detectors was 1.8 keV at 1332 keV. Efficiency calibration for soil samples was performed using a reference radioactive material - a silicone resin matrix, Czech Metrological Institute, Praha, 9031-OL-420/12, total activity 41.48 kBq on 31. 08. 2012. (^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{203}Hg, ^{88}Y, ^{113}Sn, ^{85}Sr, 1^{37}Cs) [8].

The counting time was 60000 s. The results are presented with the expanded measurement uncertainty for the factor *k* = 2, with the level of confidence of 95% for normal distribution [8].

The TF was calculated according to eq. (1), defined as the ratio of specific activity of radionuclide in plant dry matter [Bq/kg] and specificactivity in soil [Bq/kg].

$$T_F = \frac{A_b}{A_z} \quad (1)$$

where A_b is the specific activity of the radionuclide in plant dry matter [Bq/kg] and A_z – the specific activity of the radionuclide in soil [Bq/kg].

The absorbed dose rate of gamma radiation from the natural radionuclides in soil was calculated according studies [9]

$$\dot{D}\left(nGyh^{-1}\right) = 0.462 \times C_{Ra} + 0.604 \times C_{Th} + 0.0417 \times C_K \quad (2)$$

where C_{Ra} is the specific activity of ^{226}Ra in soil, C_{Th} the specific activity of ^{232}Th in soil, and C_K the specific activity of ^{40}K in soil. The annual effective dose was calculated according to [9]

$$D_E(mSv) = 0.7SvGy^{-1} \times 0.2 \times 365 \times 24 \times \dot{D} \quad (3)$$

RESULTS AND DISCUSSION

Soil samples were taken from different depths, but the sampling depths were not the same at all locations. In some locations, soil samples were taken from a depth of 0-5 cm, 0-10 cm and 0-20 cm, Bujkovac; soil samples from the depth of 0-5 cm, 5-10 cm and 10-15 cm were taken at Slivnica site; while at the Toplac site, soil samples were taken from a depth of 0-20 cm and 0-40 cm **(Table 2)**.

At the given locations, the values of the specific activity of the detected natural radionuclides do not differ in depth; the differences present are within the measurement uncertainty of the measurement results. Even the specific activity values of the ^{137}Cs radionuclide produced do not differ in depth.

The specific activity values of the radionuclide ^{226}Ra at all sites are in the range of 22 to 45 Bq/kg, while for ^{232}Th they are in the range of 29 to 55 Bq/kg. In the case of ^{40}K, specific activity values at all sites are in the range of 460 to 730 Bq/kg, while specific activity values are ^{238}U in the range of 22 to 51 Bq / kg, and ^{235}U in the range of 1.1 to 2.7 Bq/kg. The specific activity values of the ^{137}Cs produced radionuclide are in the range of 7.2 to 17 Bq/kg. The cesium leaching and relocation processes can lead to a very uneven distribution of this radionuclide in one area. Regardless, the obtained specific activity values of ^{137}Cs are low, so obviously no accumulation of this produced radionuclide in the soil occurred. The specific activity ratio of ^{235}U/^{238}U corresponds to natural uranium.

All the detected values of natural radionuclides by location do not differ significantly.

Table 2. Specific activity of natural radionuclides and ^{137}Cs in the soil.

Bq/kg						
Depth (cm)	**^{226}Ra**	**^{232}Th**	**^{40}K**	**^{238}U**	**^{235}U**	**^{137}Cs**
Slivnica						
0-5	38 ± 3	52 ± 4	490 ± 30	35 ± 8	1.7 ± 0.1	10.1± 0.7
05-Oct	33 ± 2	48 ± 3	470 ± 30	34 ± 9	1.7 ± 0.2	7.9 ± 0.6
Oct-15	37 ± 3	50 ± 3	460 ± 30	34 ± 8	1.9 ± 0.2	7.2 ± 0.5
Toplac						
0-20	39 ± 3	52 ± 4	660 ± 40	35 ± 7	1.9 ± 0,3	7.6 ± 0.6
0-40	42 ± 3	54 ± 4	690 ± 40	50 ± 10	2.0 ± 0.2	7.6 ± 0.6
Bujkovac						
0-5	22 ± 2	30 ± 2	500 ± 30	25 ± 8	1.6 ± 0.2	17 ± 1
0-10	23 ± 2	30 ± 2	510 ± 30	25 ± 7	1.5 ± 0.1	18 ± 1
0-20	25 ± 2	29 ± 2	520 ± 30	22 ± 8	1.1 ± 0.1	17 ± 1

Minimum values of specific activity for ^{226}Ra, ^{232}Th, ^{238}U and ^{235}U were obtained at the Bujkovac location, and maximum values at the Toplac location. The obtained values of the specific activity of the detected radionuclides are characteristic of the soil and correspond to values from other areas of the former Yugoslavia [10]. The value of the specific ^{226}Ra activity is lower at the Bujkovac location compared to other locations.

Table 3 shows the results of the specific activity of the detected radionuclides in samples of woody plants in [Bq / kg] of dry matter. Samples of woody plants, tree, (beech, oak, apricot, mulberry, cherry, plum conifer, acacia and hornbeam) were taken from three locations: Bujkovac, Slivnica and Toplac. The altitudes of these samples are different, with the Slivnica location having the highest altitudes, as shown in **Table 1**.

Table 3. Gamma radiation adsorbed dose strength and effective gamma radiation dose of tested soil samples at given locations.

Sample (cm)	$\dot{D}(nGyh^{-1})$	$D_E(mSv)$	**$^{235}U/^{238}U$**
Slivnica			
0-5	69.39	0.085	0.048
5-10	63.84	0.078	0.05
10-15	66.48	0.081	0.056
Toplac			
0-20	76.95	0.092	0.054
0-40	80.79	0.104	0.040
Bujkovac			
0-5	49.13	0.061	0.064
0-10	50.75	0.062	0.06
0-20	50.01	0.061	0.05

Table 4. Specific activities of detected natural radionuclides and ^{137}Cs in samples of woody plants [Bq / kg] of dry matter.

	(Bq/kg)					
Types of sample	^{226}Ra	^{232}Th	^{40}K	^{238}U	^{235}U	^{137}Cs
Bujkovac						
Acacia wood	< 0.4	< 0.3	49 ± 4	< 1	< 0.08	< 0.06
Wood cer	1.0 ± 0.1	< 0.07	55 ± 4	< 0.7	< 0.04	< 0.02
Elm wood	< 1	< 0.7	120 ± 10	< 4	< 0.2	< 0.1
Mulberry tree	0.48 ± 0.09	< 0.2	99 ± 7	< 2	< 0.08	0.11 ± 0. 4
Pineapple plum	< 0.8	< 0.6	52 ± 4	< 3	< 0.1	0.09 ± 0.03
Oak tree	0.9 ± 0.2	1.0 ± 0.3	86 ± 8	< 3	< 0.2	0.4 ± 0.1
Beech wood	11 ± 1	< 1	84 ± 10	< 8	< 0.4	1.0 ± 0.3
Toplac						
Apricot tree	4.3 ± 0.5	< 0,9	42 ± 5	< 3	< 0.2	< 0.08
Slivnica						
Acacia wood	< 1	< 1	45 ± 5	< 4	< 0.2	0.28 ± 0.09
Beech wood	12 ± 2	< 1	80 ± 10	< 10	< 0.7	0.9 ± 0.3
Oak tree	0.5 ± 0.2	1.0 ± 0.4	75 ± 6	3 ± 1	0.16 ± 0.05	0.14 ± 0.06
Wood hornbeam	2.2 ± 0.4	3.4 ± 0.6	25 ± 3	3 ± 1	0.20 ± 0.05	0.10 ± 0.04

In samples of tested woody plants taken from locations (Bujkovac, Slivnica and Toplac) in the Pcinja region **(Table 4)**, the specific activity values of the detected ^{226}Ra radionuclides were in the range of 0.48 Bq/kg for mulberry tree up to 12 Bq/kg for beech wood; for ^{232}Th they are in the range of 0.6 Bq/kg for oak wood in the Bujkovac and Slivnica locations, up to 3.4 Bq/kg for hornbeam in the Slivnica location. For all other samples of woody plants, the specific activity of ^{232}Th is below the minimum detection limit.

In the case of radionuclides, the ^{40}K values of specific activity in wood samples are in the range of 25 Bq/kg (hornbeam tree in Slivnica) to 120 Bq/kg for elm tree in Bujkovac. The specific activity values of radionuclides ^{238}U, ^{235}U for all wood samples at Toplac and Bujkovac locations are below the minimum detection limit. At the Slivnica site in acacia and beech wood samples, the values of these radionuclides are also below the minimum detection limit.

Only at the Slivnica site, specific activity values of radionuclides ^{238}U and ^{235}U were detected in oak and hornbeam samples above the detection limit. The specific activity ratio of ^{235}U/^{238}U corresponds to natural uranium. In the case of the ^{137}Cs radionuclide produced, the value of the oak sample, the specific activity of this radionuclide has a minimum value of 0.16 Bq/kg.

specific activity is below the minimum detection limit in the apricot tree sample at the Toplac site, as well as in the acacia, cherry and elm tree samples at the Bujkovac site. The specific activity of the detected ^{137}Cs radionuclide for the apricot tree per is 47 Bq/kg which is much higher than in the apricot tree sample examined.

Unlike other wood samples, cera wood has the least activity-specific values for ^{232}Th, ^{40}K, ^{238}U, ^{235}U and ^{137}Cs. The maximum value of specific activity of ^{226}Ra of 12 Bq/kg was detected in the beech sample at the site Slivnica, while the minimum value of specific activity of this radionuclide was 0.48 Bq/kg was detected in the mulberry sample at the Bujkovac location. For ^{232}Th radionuclides, the maximum value of specific activity of 3.4 Bq/kg was detected in the gabbro sample at Slivnica site, and the minimum value of 1 Bq/kg was detected in oak at the same location.

The minimum value of specific activity of ^{40}K radionuclide of 25 Bq/kg was detected in the hornbeam sample at Slivnica site, and the maximum value of 120 Bq/kg was detected in the elm sample at Bujkovac site. A maximum activity value of ^{235}U of 0.2 Bq/kg at the Slivnica site was detected in the hornbeam sample. At the same location in the

The maximum value of ^{137}Cs specific activity was detected in the beech sample of 0.9 Bq / kg at the Slivnica site, while the minimum values of 0.09 Bq/kg were detected in the plum bean sample at the Bujkovac site.

The obtained values of transfer factor for woody plant samples are given **(Table 5)**.

Table 5. Values of transfer factors.

	Transfer factors			
Types of wood	**$^{226}Ra/^{226}Ra$**	**$^{232}Th/^{232}Th$**	**$^{40}K/^{40}K$**	**$^{137}Cs/^{137}Cs$**
Bujkovac				
Acacia	-	-	0.09	
Cer	0.04	-	0.11	
Elm wood	-	-	0.24	
Mulberry tree	0.02	-	0.19	0.01
Pineapple plum	-	-	0.10	0.01
Oak tree	0.04	0,03	0.17	0.02
Beech wood	0.46	-	0.16	0.06
Toplac				
Apricot tree	0.11	-	0.06	
Slivnica				
Beech wood	0.45		0.15	0.05
Oak tree			0.09	
Wood hornbeam	0.04	0.02	0.18	0.02
Beech wood	0.03		0.12	

In most samples of woody cultures, natural radionuclides ^{238}U and ^{235}U were not detected, that is, their specific activities are below the minimum detection limit. The transfer factor is only determined for: ^{40}K, ^{226}Ra, ^{232}Th. Higher transfer factor values were obtained by ^{40}K for samples of oak, plum, hay, elm, cherry and acacia compared to other radionuclides and ranged from 0.09 to 0.24 [11]. Higher values of transfer factors were obtained for ^{226}Ra in the beech sample, Bujkovac site, 0.46 compared to other woody plants.

CONCLUSION

Specific soil radionuclide activities at all sites ranged from 22 to 45 Bk/kg for ^{226}Ra, 29 to 55 Bk / kg for ^{232}Th, 460 to 730 Bk/kg for ^{40}K, 22 to 51 Bk/kg for ^{238}U, from 1.1 to 2.7 Bk/kg for ^{235}U, and 7.2 to 17 Bk / kg for ^{137}Cs. The differences between the specific activities of radionuclides in soil samples from different depths are within different ratios, and the specific activity values of radionuclides ^{235}U/ ^{238}U are of uranium origin.

The activities of the radionuclides tested do not differ in general from the values given by other authors in their tests [12].

The distribution of radionuclides from soil to soil and in the plant depends on the bioavailability of at least other quantities in the soil, root structure, habitat only, as well as the processes that take place in the plant. Which were the only ones that gave some significant results in the measurement. Examination of soil samples and woody perennials yielded results showing that the transfer factor behaves according to a certain probability distribution. It can be concluded that the transfer factor obtained for ^{40}K compared to other radionuclides has higher values. This means that the largest number of plants (tree trunks) absorb between 0.02-0.46%^{226}Ra and about 0.6-0.24%^{40}K [13].

These are the first studies of transfer factors for some cereals grown in the Pcinja district. Since the results of the transfer factors are determined only for some types of cereals taken from the soil of the type of manure, I suggest further

research, but for some other type of land, to make sure that the Pcinja district is a region that can produce healthy food.

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