THE RADIOACTIVITY OF VOJVODINA AGRICULTURAL SOIL

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ABSTRACT

The widespread public belief that during the bombardment Vojvodina also was contaminated with depleted uranium makes the perceiving of the state of agricultural soil radioactivity very actual. Based on gamma-spectrometric analysis of 50 soil samples taken from the region of Vojvodina one can conclude that there is no increase of radioactivity that could endanger the food production. Measured activity concentrations of ^{137}Cs, taking in account the transfer factors of this isotope into plants, should not endanger the health safety of the produced food.

Key words: soil contamination, measurements, gamma spectroscopy

INTRODUCTION

The soil of Vojvodina is subject to radioactive contamination from a number of sources. First of all, these are the reactors of nuclear power plants in the South East Europe region that could contaminate a broader environment by their emission into air and water. As second, the use of phosphate fertilizers with high uranium concentration may cause a gradual increase of the uranium series activity concentration in soil. The widespread public belief that during the shelling Vojvodina also was contaminated with depleted uranium makes the perceiving of the state of agricultural soil radioactivity very actual.

The concentration of uranium and thorium in Earth's crust is 1.1 – 10 ppm [1] for uranium and 10 ppm [2] for thorium, what corresponds to range of activity concentration of 13.5 – 123 Bq/kg for ^{238}U and 39.4 Bq/kg for ^{232}Th. The distribution of uranium and thorium in the lithosphere is diffuse, that is, there are no ore deposits specific for these radioactive elements.

The anthropogenic radionuclides reach the soil by dispersion and it, as a powerful sorbent, represents a permanent reservoir from which the radionuclides get by ingestion into human organism through the nutrition chain. The intensity of the processes of sorbtion/desorbtion, migration, retention and translocation is influenced by the nature of the given radionuclide, as well as by the type of soil and type of crops raised on it.

METHOD OF MEASUREMENT

The soil samples were dried at 105°C to constant mass and transferred to sample holders. Due to urgency of this research, there was not enough time to establish the radon equilibrium in these samples. To achieve this equilibrium, a time period of at least 30 days is needed. Due to the method applied, measured concentrations of ^{226}Ra were smaller by about 20%. Gamma-spectrometric measurements were performed with the high-resolution HPGe gamma-spectrometer made by ORTEC. The nominal detector efficiency exceeds 36%, while the resolution is less than 1.9 keV. The detector has an increased energy range of measurement (GMX-type) such that it can detect also low-energy γ- and X-radiation. The metallic parts of the detector were made of materials tested for high radiopurity. The detector was placed in a special low background protection chamber with iron walls 25 cm thick. The chamber is made of pre WW II cast iron, so that it does not contain admixtures of man-made radioactivity and it reduces the background radiation level for about 1000 times. The spectra were led through the preamplifier-amplifier chain (the latter of CANBERRA-type) to the CANBERRA Series 35+ multichannel analyzer with two analog-to-digital converters, and with a memory containing 8192 channels. The multichannel analyzer is directly connected to a personal computer where the spectra were processed and stored. A modified version of the SAMPO program was used to process the spectra, in such a way that, besides the identified gamma-lines, it always presents spectral intensities of 20 selected isotopes. The samples were measured in cylindrical geometry, placed in sample containers with 67 mm diameter and 62 mm height. The detection efficiency for this geometry was determined with primary calibration point sources made by AMERSHAM, with calibrated voluminous sources made by NBS and OMH, as well as with a phosphate-ore sample of known activity concentration. The consistency of the calibration results was checked with a modified version of the SOLANG computer program. Typical measurement time was 80 ks. The measurement uncertainties were presented at the 95% confidence level, what means that the probability for obtaining a result laying outside the presented limits in a repeated measurement of the same sample is less than 5%. Activity concentrations of fission and corrosion products (except ^{137}Cs) were below the detection limits, so that in the final results only the activity concentrations of ^{137}Cs, of natural radioactive series of ^{238}U and ^{232}Th, and of the natural radionuclide ^{40}K were presented.
A special procedure developed in the Novi Sad laboratory enables the determination of ^{238}U activity concentration from gamma-lines of the first descendent of this radionuclide, ^{234}Th. Besides the ^{238}U activity concentration determined this way, activity concentrations of the ^{226}Ra member of the uranium series are presented also. The comparison of these two measured data is very important for the detection of the presence of depleted uranium. Namely, in materials contaminated with depleted uranium the equilibrium ratio of uranium to radium is substantially disturbed.

RESULTS OF MEASUREMENT AND DISCUSSION

Activity concentration of all measured radionuclides, except ^{137}Cs, are below the detection limit. The radionuclide ^{137}Cs is present in all soil samples. This radionuclide originates from the accident of the nuclear power plant 'Lenin' in Chernobyl in 1986. Due to the long half-life of this radionuclide of 30 yr, it will be relocated, washed out and redistributed, but it will be present for a long time in the Vojvodina ecosystem. The large standard deviation and the large difference between the minimum and maximum ^{137}Cs activity concentrations

show typical features of a man-made contaminant. The results are presented in Table 1. Mean values of activity concentration are presented in Table 2, while their distributions are presented in Figures 1 and 2.

Table 1. Activity concentration of radionuclides in soil samples from Vojvodina

location	Bečejski rit	Nadalj	Srbobran	Palić	Čoka Crna Bara	Tornjoš
code	LIVZ1	LIVZ2	LIVZ3	LIVZ4	LIVZ9	LIVZ10
date	07.05. 2001.	07.05. 2001.	08.05. 2001.	08.05. 2001.	10.05. 2001.	10.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.20	<0.3	<0.3	<0.4	<0.3	<0.4
^{144}Ce	<1.2	<2.0	<1.9	<2.2	<2.4	<2.5
^{141}Ce	<0.17	<0.6	<0.7	<0.5	<0.5	<0.8
^{125}Sb	<1.1	<0.6	<0.9	<1.4	<1.0	1.2±1.0
^{7}Be	<1.8	<7	<4	<2.0	<4	<4
^{103}Ru	<0.21	<0.3	<0.27	<0.4	<0.5	<0.3
^{134}Cs	<0.26	<0.4	<0.28	<0.4	<0.4	<0.29
^{124}Sb	<0.17	<0.3	<0.8	<0.4	<0.05	<0.11
^{106}Ru	<1.9	<2.8	<5	<2.8	<2.9	<6
^{110m}Ag	<0.21	<0.8	<0.28	<0.27	<0.26	<0.4
^{137}Cs	8.8±0.7	13.3±1.2	9.0±1.3	8.3±0.9	12.0±1.0	10.0±1.1
^{95}Zr	<0.4	<1.0	<1.1	<1.3	<0.4	<0.4
^{95}Nb	<0.5	<0.12	<0.7	<0.3	<0.6	<0.6
^{58}Co	<0.23	<0.4	<0.27	<0.4	<0.28	<0.6
^{160}Tb	<1.8	<2.0	<1.2	<1.2	<1.5	<1.2
^{60}Co	<0.27	<0.5	<0.21	<0.3	<0.4	<0.3
^{238}U	60±30	54±17	48±16	24±9	42±16	58±17
^{226}Ra	26.8±1.4	44.1±1.9	39.2±2.5	19.9±1.8	35.3±1.4	43±3
^{232}Th	51.7±2.5	52±3	49.4±2.5	23.5±2.6	53.3±2.6	54±3
^{40}K	720±30	553±29	515±26	310±20	619±27	492±27

location	Bačko novo selo	Srpski Miletić	Orlovat	Kikinda	Trandža-ment	Kać
code	LIVZ11	LIVZ12	LIVZ13	LIVZ14	LIVZ15	LIVZ16
date	10.05. 2001.	11.05. 2001.	12.05. 2001.	12.05. 2001.	12.05. 2001.	13.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.12	<0.5	<0.14	<0.7	<0.8	<0.6
^{144}Ce	<1.6	<2.3	<2.3	<3	<6	<2.3
^{141}Ce	<0.4	<0.3	<2.2	<1.6	<1.0	<1.1

^{125}Sb	<0.6	<1.2	<0.8	<1.6	<1.4	<1.0
^{7}Be	<2.2	<2.7	<2.2	<6	<6	<6
^{103}Ru	<0.20	<0.3	<0.3	<0.4	<0.3	<0.4
^{134}Cs	<0.28	<0.6	<0.8	<0.5	<0.28	<0.4
^{124}Sb	<0.13	<0.3	<0.4	<0.25	<0.27	<0.22
^{106}Ru	<2.1	<5	<2.9	<4	<7	<3
^{110m}Ag	<0.20	<0.7	<0.3	<0.3	<0.4	<1.2
^{137}Cs	6.0±0.7	6.4±0.8	9.6±0.8	11.7±1.3	13.8±1.6	8.1±1.1
^{95}Zr	<0.23	<1.1	<0.4	<1.0	<0.20	<0.8
^{95}Nb	<0.3	<0.5	<0.4	<0.9	<0.8	<0.6
^{58}Co	<0.27	<0.4	<0.7	<0.6	<0.3	<0.4
^{160}Tb	<1.9	<1.3	<1.0	<1.9	<4	<3
^{60}Co	<0.4	<0.4	<0.4	<0.29	<0.25	<0.6
^{238}U	35±11	64±29	53±15	43±18	60±18	56±27
^{226}Ra	30.2±1.9	40.5±2.7	37.0±2.5	29.0±2.8	42.2±2.0	44.1±2.6
^{232}Th	36.7±2.3	57±3	54.7±2.8	55.9±2.9	62±3	48±3
^{40}K	464±21	580±30	630±30	710±40	590±30	600±30

location	**Sakule**	**Boka**	**Sanad**	**Kula Lipar**	**Parage**	**Rivica**
code	**LIVZ17**	**LIVZ18**	**LIVZ19**	**LIVZ20**	**LIVZ21**	**LIVZ22**
date	**13.05. 2001.**	**13.05. 2001.**	**14.05. 2001.**	**15.05. 2001.**	**15.05. 2001.**	**16.05. 2001.**
radionuclei	**A_S [Bq/kg]**					
^{75}Se	<0.8	<0.29	<0.25	<0.5	<0.4	<0.20
^{144}Ce	<6	<2.1	<1.6	<2.6	<2.3	<1.5
^{141}Ce	<1.0	<0.6	<0.9	<0.7	<0.21	<0.8
^{125}Sb	<2.2	<1.3	<1.5	<1.5	<0.5	<0.7
^{7}Be	<9	<3	<4	<6	<8	<4
^{103}Ru	<0.6	<0.9	<0.3	<0.4	<0.4	<0.3
^{134}Cs	<0.9	<0.4	<0.06	<0.3	<0.9	<0.20
^{124}Sb	<0.6	<0.3	<0.4	<0.7	<0.4	<0.06
^{106}Ru	<5	<4	<3	<3	<3	<2.7
^{110m}Ag	<0.8	<0.8	<0.23	<0.4	<0.7	<0.26
^{137}Cs	7.2±1.1	10.3±1.1	9.3±1.2	7.8±1.3	9.4±1.4	8.5±0.7
^{95}Zr	<1.1	<0.8	<1.0	<0.17	<0.3	<2.1
^{95}Nb	<1.3	<0.9	<0.24	<0.9	<0.6	<0.5
^{58}Co	<0.9	<0.5	<0.4	<0.3	<0.3	<0.25
^{160}Tb	<4	<1.2	<1.1	<0.8	<1.2	<1.5
^{60}Co	<0.4	<0.6	<0.3	<0.4	<0.5	<0.4
^{238}U	41±19	53±18	49±14	56±23	66±19	63±16
^{226}Ra	21.3±2.4	44.2±2.1	34.9±2.0	43.2±2.3	45.5±2.9	45.2±2.8
^{232}Th	34±4	64±4	51±3	54±3	57±4	63±3
^{40}K	350±26	550±30	640±40	493±27	560±30	560±30

location	Višnjićevo	Maglić	Šid	Vršački breg	Crepaja	Gakovo
code	LIVZ25	LIVZ26	LIVZ27	LIVZ28	LIVZ29	LIVZ30
date	17.05. 2001.	17.05. 2001.	18.05. 2001.	18.05. 2001.	19.05. 2001.	20.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.29	<0.17	<0.24	<0.24	<0.27	<0.25
^{144}Ce	<2.6	<4	<1.6	<2.5	<2.0	<2.0
^{141}Ce	<0.9	<0.6	<0.9	<0.6	<0.5	<0.7
^{125}Sb	<1.0	<0.4	<0.7	<1.9	<0.6	<1.4
^{7}Be	8±4	<7	<5	<5	<4	<4
^{103}Ru	<0.6	<0.4	<0.26	<0.5	<0.26	<0.4
^{134}Cs	<0.4	<0.4	<0.4	<0.4	<0.4	<0.8
^{124}Sb	<0.08	<0.3	<0.29	<0.3	<0.25	<0.3
^{106}Ru	<3	<4	<2.8	<2.7	<2.1	<2.8
^{110m}Ag	<0.19	<0.15	<0.3	<0.3	<0.25	<0.5
^{137}Cs	8.1±1.1	5.7±0.9	7.5±0.7	12.6±1.4	17.5±1.4	7.0±0.9
^{95}Zr	<2.0	<1.8	<1.1	<0.4	<0.6	<0.8
^{95}Nb	<0.5	<0.8	<0.4	<1.0	<0.6	<0.3
^{58}Co	<0.6	<0.4	<0.3	<0.3	<0.21	<0.3
^{160}Tb	<2.1	<2.4	<1.2	<1.0	<1.0	<0.9
^{60}Co	<0.4	<0.24	<0.3	<0.7	<0.4	<0.5
^{238}U	55±17	39±15	69±16	50±20	44±24	55±16
^{226}Ra	51.0±2.1	40.6±2.5	44.4±2.2	31.9±2.2	36.4±2.3	41.6±2.5
^{232}Th	63±3	52.3±2.8	59±3	59±4	50.7±2.5	52±3
^{40}K	610±30	513±28	567±28	580±30	480±30	475±25

location	Zrenjanin Mihajlovo	Padina	Deliblato	Rimski Šančevi	Bogojevo	Rusko Selo Vojvoda Stepa
code	LIVZ31	LIVZ32	LIVZ33	LIVZ34	LIVZ35	LIVZ36
date	21.05. 2001.	21.05. 2001.	22.05. 2001.	22.05. 2001.	22.05. 2001.	23.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.23	<0.18	<0.22	<0.13	<0.4	<0.29
^{144}Ce	<1.5	<2.1	<1.7	<1.9	<1.9	<2.6
^{141}Ce	<0.7	<0.7	<1.4	<0.9	<0.6	<0.6
^{125}Sb	<0.3	<0.9	<0.8	<0.9	<0.9	<0.6
^{7}Be	<5	<6	<4	<4	<2.8	<5
^{103}Ru	<0.3	<0.5	<0.5	<0.3	<0.3	<0.29
^{134}Cs	<0.3	<0.3	<0.5	<0.07	<0.6	<0.3
^{124}Sb	<0.7	<0.25	<0.5	<0.3	<0.15	<0.07
^{106}Ru	<2.1	<2.1	<2.1	<3	<20	<4.2
^{110m}Ag	<0.09	<0.16	<0.3	<0.9	<0.9	<0.5

location	Zrenjanin Mihajlovo	Padina	Deliblato	Rimski Šančevi	Bogojevo	Rusko Selo Vojvoda Stepa
code	LIVZ31	LIVZ32	LIVZ33	LIVZ34	LIVZ35	LIVZ36
date	21.05. 2001.	21.05. 2001.	22.05. 2001.	22.05. 2001.	22.05. 2001.	23.05. 2001.
radionuclei	A_S [Bq/kg]					
^{137}Cs	8.5±1.1	12.3±1.1	28.2±1.9	6.9±1.4	9.2±1.0	19.7±1.2
^{95}Zr	<0.7	<0.6	<0.4	<1.8	<0.13	<0.8
^{95}Nb	<0.5	<0.16	<0.6	<0.3	<0.5	<0.3
^{58}Co	<0.24	<0.5	<0.25	<0.4	<0.4	<0.26
^{160}Tb	<0.8	<1.1	<2.0	<1.3	<1.3	<1.5
^{60}Co	<0.20	<0.4	<0.5	<0.4	<0.27	<0.6
^{238}U	49±23	55±22	51±14	52±16	42±17	53±14
^{226}Ra	40.4±1.8	41.0±2.4	41.5±2.7	40.5±2.6	37±3	34.9±1.5
^{232}Th	50.1±2.4	55±3	54.3±2.9	54±3	48.2±2.8	54±3
^{40}K	526±25	534±29	501±23	610±30	543±28	730±40

location	Morović	Ruma Irig	Aleksa Šantić	Bavanište	Pećinci Popinci	Ruski Krstur
code	LIVZ41	LIVZ42	LIVZ43	LIVZ44	LIVZ45	LIVZ46
date	25.05. 2001.	25.05. 2001.	26.05. 2001.	26.05. 2001.	26.05. 2001.	27.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.3	<0.25	<0.26	<0.4	<0.16	<0.24
^{144}Ce	<1.7	<2.3	<1.5	<2.6	<2.0	<2.5
^{141}Ce	<1.3	<0.9	<0.4	<2.2	<0.7	<0.8
^{125}Sb	<0.6	<0.7	<1.8	<0.7	<1.6	<1.1
^{7}Be	<4	<3.4	<2.2	<3	<3	<4
^{103}Ru	<0.26	<0.3	<0.27	<0.4	<0.3	<0.29
^{134}Cs	<0.5	<0.3	<0.3	<0.9	<0.4	<0.13
^{124}Sb	<0.27	<0.3	<0.4	<0.23	<0.08	<0.23
^{106}Ru	<2.1	<6	<2.4	<3	<5	<2.7
^{110m}Ag	<0.25	<0.17	<0.4	<0.9	<0.6	<0.26
^{137}Cs	7.8±0.7	7.7±0.9	6.7±0.7	55±3	11.5±1.6	7.7±0.7
^{95}Zr	<0.4	<0.5	<1.2	<0.6	<1.3	<1.4
^{95}Nb	<0.3	<0.22	<0.5	<0.5	<0.8	<0.6
^{58}Co	<0.28	<0.6	<0.4	<0.3	<0.26	<0.3
^{160}Tb	<1.5	<2.7	<0.8	<2.8	<0.7	<0.8
^{60}Co	<0.20	<0.6	<0.29	<0.25	<0.6	<0.24
^{238}U	56±18	50±16	60±17	59±17	56±16	56±15
^{226}Ra	50.9±1.8	50.4±2.0	46.6±2.4	43±4	39.4±2.9	48.6±2.0
^{232}Th	59±3	60±3	54.4±2.7	55.2±2.9	56±3	53.7±2.6
^{40}K	571±26	557±29	470±30	550±30	534±28	523±24

location	Žednik	Horgoš	Ilandža	Novi Kozjak	Žabalj	Margita
code	LIVZ5	LIVZ6	LIVZ7	LIVZ8	LIVZ37	LIVZ38
date	08.05. 2001.	09.05. 2001.	09.05. 2001.	09.05. 2001.	23.05. 2001.	24.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.4	<0.4	<0.6	<0.15	<0.4	<0.20
^{144}Ce	<3.2	<1.8	<2.3	<2.1	<1.8	<2.6
^{141}Ce	<0.6	<0.7	<1.3	<2.1	<0.8	<0.8
^{125}Sb	<1.1	<1.4	<0.8	<1.7	<0.6	<0.8
^{7}Be	<2.3	<1.5	<6	<3	<2.7	<2.6
^{103}Ru	<0.3	<0.18	<0.5	<0.3	<0.4	<0.25
^{134}Cs	<0.6	<0.20	<0.8	<0.6	<0.25	<0.4
^{124}Sb	<0.4	<0.28	<0.3	<0.17	<0.4	<0.20
^{106}Ru	<4	<3	<4	<2.5	<4	<2.6
^{110m}Ag	<0.6	<0.12	<0.5	<0.18	<0.18	<0.4
^{137}Cs	11.1±1.5	1.1±0.3	18.4±1.5	15.5±1.3	10.5±1.0	48.7±2.4
^{95}Zr	<0.5	<0.3	<0.4	<1.9	<1.5	<0.5
^{95}Nb	<0.3	<0.10	<0.7	<0.4	<0.5	<0.25
^{58}Co	<0.27	<0.18	<0.26	<0.3	<0.3	<0.24
^{160}Tb	<1.4	<0.8	<2.3	<1.4	<1.0	<1.6
^{60}Co	<0.5	<0.18	<0.3	<0.4	<0.29	<0.25
^{238}U	49±22	31±9	57±20	52±16	45±17	30±24
^{226}Ra	40.1±2.6	19.7±1.0	42.3±2.4	40.1±2.7	41.8±2.4	26.2±1.7
^{232}Th	50.5±2.6	22.0±1.5	57±3	50.1±2.7	59±3	54.8±2.8
^{40}K	488±28	238±13	550±40	500±30	640±30	551±23

location	Begejci	Banatsko Aranđelovo	Torda	Kumane	Donji Tovarnik	Obedska Bara
code	LIVZ47	LIVZ48	LIVZ49	LIVZ50	LIVZ39	LIVZ40
date	27.05. 2001.	28.05. 2001.	28.05. 2001.	29.05. 2001.	24.05. 2001.	24.05. 2001.
radionuclei	A_S [Bq/kg]					
^{75}Se	<0.3	<0.25	<0.3	<0.20	<0.3	<0.27
^{144}Ce	<1.7	<2.3	<2.6	<2.2	<2.3	<2.4
^{141}Ce	<1.3	<0.9	<0.9	<0.5	<0.9	<0.6
^{125}Sb	<0.6	<0.7	<0.24	<0.6	<0.5	<1.7
^{7}Be	<4	<3.4	<5	<2.1	<8	<5
^{103}Ru	<0.26	<0.3	<0.4	<0.25	<0.4	<0.4
^{134}Cs	<0.5	<0.3	<0.3	<0.4	<0.4	<0.20
^{124}Sb	<0.27	<0.3	<0.10	<0.20	<0.5	<0.5
^{106}Ru	<2.1	<6	<3	<4	<2.7	<3
^{110m}Ag	<0.25	<0.17	<0.24	<0.4	<0.6	<0.7
^{137}Cs	7.8±0.7	7.7±0.9	15.5±1.3	6.8±0.6	9.4±1.1	11.9±1.1

location	Begejci	Banatsko Aranđelovo	Torda	Kumane	Donji Tovarnik	Obedska Bara
code	LIVZ47	LIVZ48	LIVZ49	LIVZ50	LIVZ39	LIVZ40
date	27.05. 2001.	28.05. 2001.	28.05. 2001.	29.05. 2001.	24.05. 2001.	24.05. 2001.
radionuclei	A_S [Bq/kg]					
^{95}Zr	<0.4	<0.5	<0.11	<0.7	<0.8	<0.6
^{95}Nb	<0.3	<0.22	<0.6	<0.6	<0.8	<0.9
^{58}Co	<0.28	<0.6	<0.3	<0.21	<0.7	<0.3
^{160}Tb	<1.5	<2.7	<1.5	<0.8	<1.1	<2.0
^{60}Co	<0.20	<0.6	<0.28	<0.22	<0.5	<0.5
^{238}U	56±18	50±16	55±16	49±22	50±23	72±21
^{226}Ra	50.9±1.8	50.4±2.0	40.3±2.0	37.9±2.0	40±3	43.3±2.5
^{232}Th	59±3	60±3	59±3	55.0±2.7	62±3	62±3
^{40}K	571±26	557±29	660±30	720±30	600±30	630±30

location	Inđija	Sr. Mitrovica
code	LIVZ23	LIVZ24
date	16.05.2001.	17.05.2001.
radionuclei	A_S [Bq/kg]	
^{75}Se	<0.27	<0.3
^{144}Ce	<3	<1.9
^{141}Ce	<1.0	<0.8
^{125}Sb	<0.8	<0.8
^{7}Be	<4	<4
^{103}Ru	<0.5	<0.20
^{134}Cs	<0.15	<0.18
^{124}Sb	<0.5	<0.4
^{106}Ru	<6	<2.6
^{110m}Ag	<0.4	<0.24
^{137}Cs	6.7±0.9	5.9±0.6
^{95}Zr	<0.9	<0.19
^{95}Nb	<0.4	<0.5
^{58}Co	<1.0	<0.25
^{160}Tb	<1.3	<1.0
^{60}Co	<0.4	<0.4
^{238}U	57±23	49±15
^{226}Ra	44±3	39.9±2.4
^{232}Th	59±3	55±3
^{40}K	580±30	536±24

Table 2. Arithmetic mean values, standard deviations, minimum and maximum activity concentrations of radionuclides on the Vojvodina territory

Radionuclide	$\bar{A}_s$ [Bq/kg]	$\sigma\bar{a}_s$ [Bq/kg]	$A_{s(min)}$ [Bq/kg]	$A_{s(max)}$ [Bq/kg]	Location (min)	Location (max)
^{137}Cs	11.8	9.2	1.1	55.0	Horgoš	Bavanište
^{238}U	51.4	9.3	24.0	72.0	Palić	Obedska Bara
^{226}Ra	39.3	7.2	19.7	51.0	Horgoš	Višnjićevo
^{232}Th	53.2	8.3	22.0	64.0	Horgoš	Boka
^{40}K	554	92	238	730	Horgoš	Rusko Selo Vojvoda Stepa

Because the ^{238}U activity concentration in all samples is at the usual level, and because the ^{238}U/^{226}Ra ratio is not substantially changed, one can conclude that in the measured samples there is no indication of depleted uranium presence. The activity concentration of the natural radioactive series of ^{232}Th, and the natural radionuclide ^{40}K are within usual limits.
If we compare the obtained results with previous measurements [4, 5, 6, 7], we note a decreasing tendency of activity concentrations after 1988, while in the region of Vršac and Novi Sad the values are slightly higher than in 1989. (Table 3). This difference might be due to sampling micro locations different for previous and this year. The precipitation process of ^{137}Cs after the Chernobyl accident is obviously very ununiform.

Table 3. Measured activity concentrations of ^{137}Cs for the regions of Subotica, Vršac and Novi Sad

	activity concentration ^{137}Cs [Bq/kg]		
region	1988.[4]	1989.[4]	2001.
Subotica	9.0(12)	6.5(9)	4.7(25)
Vršac	44(6)	23(3)	31(13)
Novi Sad	8.7(14)	6.6(13)	8.2(7)

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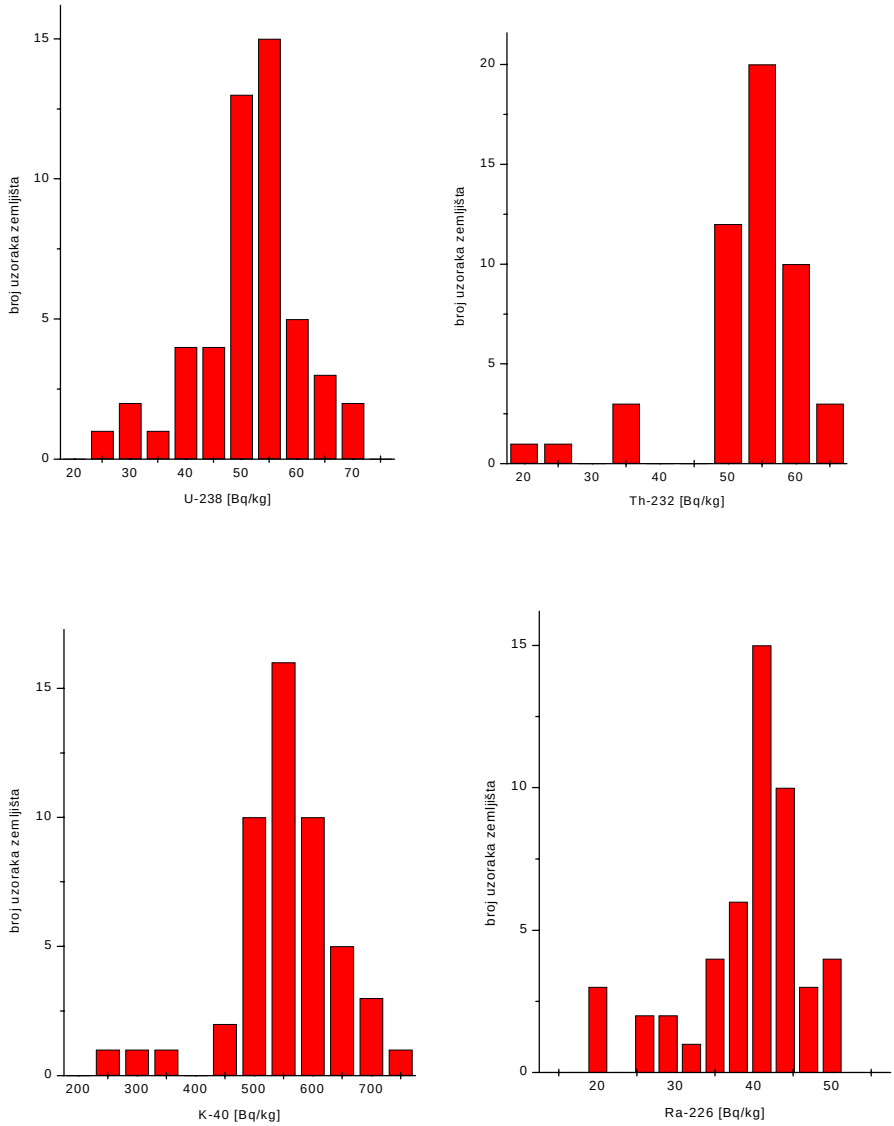

Figure 1. Distribution of activity concentrations of ^{238}U, ^{236}Ra, ^{232}Th and ^{40}K in soil samples

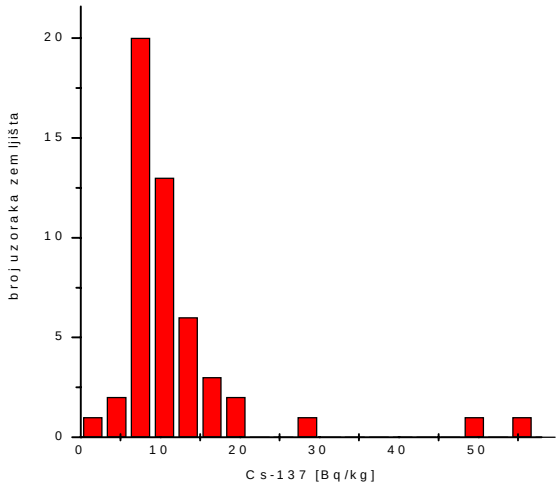

Figure 2. Distribution of ^{137}Cs activity concentration in 50 soil samples

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