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Original Research

The Examination of the Roztocze Region Environment. Radioisotope Monitoring of Soils and Plants The Heavy Metal Content in Soil

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Abstract

This paper present the results of investigations of the level of contamination by radioactive isotopes of grass and soil of the Polish and Ukrainian Roztocze area. Heavy metal contents in soil were also measured. The highest level of radioactivity was found in the Northwestern part of Roztocze which may be explained by the close vicinity of industrial centers.

The presence of caesium gave from 0.6 to 22% of the total soil activity at Polish side and from 1.5 to 11% at Ukrainian. The Chernobyl nuclear power plant failure is the main source of radioactive contamination of soil. For most samples 100% of this caesium came from this source. The mean ^{40}K contents made 57% of the total radioactivity in Polish Roztocze and 54% in Ukrainian. Radionuclides of thorium and uranium series gave 20 to 35% of total activity. The activity of ^{40}K in grass gave about 80% of the total radioactivity in Polish Roztocze and 73% in Ukrainian. Other radioisotopes present in grass are mainly ^{7}Be and ^{137}Cs. Heavy metal contents in plough land soil universally, except two points, do not exceed acceptable levels.

Keywords: radioactive isotopes, soil, plant, Chernobyl

Introduction

The main sources of radiochemical contaminations comes from the application of radioactive elements and substances for industrial and military purposes. Some amounts of radionuclides are liberated in mineral mining and coal combustion processes.

The environment may be polluted both by artificial radionuclides (^{137}Cs, ^{134}Cs, ^{90}Sr, ^{106}Rb, ^{144}Ce, ^{95}Zr), and by natural radioactive elements, especially uranium and thorium series and ^{40}K.

Among them, most important are ^{226}Ra and ^{224}Ra because products of their decay – radioactive gases ^{222}Ra and ^{220}Ra together with derivatives (^{214}Pb, ^{210}Pb, ^{212}Pb, ^{212}Bi, ^{214}Bi) – have essential meaning in the annual dose of ionizing radiation absorbed by human organisms.

A very important radionuclide, having big physiological meaning is ^{40}K, that is an essential constituent of the earth's crust. From soil this radionuclide goes to plants and animals and finally to our food.

The artificial radionuclide which has an important contribution in earth core pollution is ^{137}Cs. This isotope originated from global fallout after nuclear test explosions and nuclear power plant failures [1,2]. Other substantial, artificial radionuclides are ^{90}Sr and ^{239}Pu and ^{240}Pu, [3,4]. The detection of these isotopes is very difficult but it must be performed permanently because they are very dangerous to human beings.

The other kind of the soil pollution that ought to be taken into account concerns heavy metals (metal elements above atomic number 20).

Having in mind the above, the main purpose of this paper was to describe the total gamma emitter activities, the determination of ^{137}Cs origins in soil and grass samples from the territory of Polish and Ukrainian Roztocze region as well as determination of heavy metal contents in the soils of the examined area.

Materials and Methods

The measurements were performed in the Roztocze region, which covers the southeastern part of Poland (Zamość region) and the adjoining western part of Ukraine (Fig 1). From this territory 47 samples of upper layer of soil (0 - 10 cm deep), as well as grass

samples, were collected from the area of 8 km grid. All samples were collected according to IAEA and CLOR recommendations concerning soil monitoring [5].

In the laboratory, the samples of soils were air dried, then sieved through 1 mm screen, to remove stones and other impurities. The grass samples, after drying, were cut in Fritsh pulverisator. Then, 0.5 dm3 of the soil or grass sample was weighted to Marinelli type vessel to guarantee standard geometry of the measurements. Before the measurements, the samples were stored for three days to achieve radon equilibrium. All measurements were performed using SILENA gamma spectrometer with IGC-13 Princeton Gamma-Tech germanium detector, cooled with liquid nitrogen and 4096 channel analyzer. The detector resolution was 1.75 keV and the efficiency was 15% for 1.33 MeV peak. The data were analyzed by means of SIMCAS II ver.4.11 computer program.

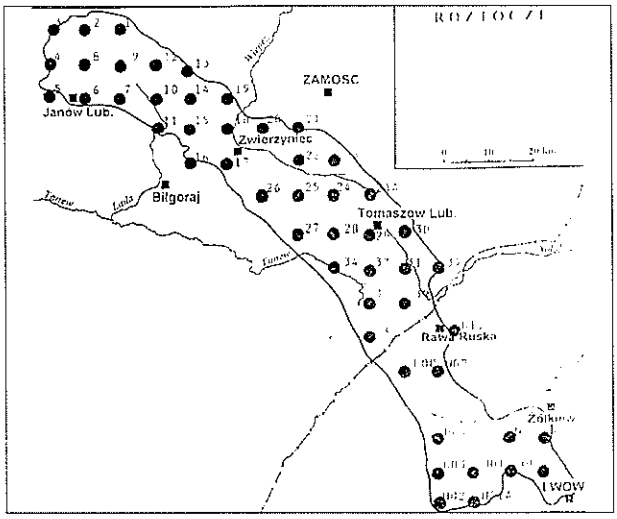


Fig. 1. Soil and grass samples collection points on Roztocze region

Standard deviation for the measured radioactivity of the soil samples ranged from 0.1 to 13 Bq/kg, depending on isotope activity. The measuring error was smaller than 5%. For grasses standard deviation ranges from 0.5 to 46 Bq/kg and measuring error was smaller than 10%.

Detected in the samples gamma emitters were divided in two following groups: natural, and long-lived artificial isotopes that come from nuclear power plant failures and nuclear experiments. The location of sample collecting points is depicted in Fig.1. For the construction of the drawings a Surfer software and 8 km sampling net was applied, enabling three dimensional surface of the contamination of the examined territory.

The heavy metal contents in Roztocze soil was measured by XRF Canberra fluorescent spectrometer, equipped with Si(Li) detector and Canberra 1510 a/d converter. For X-ray activation ^{55}Fe, ^{109}Cd and ^{241}Am were used. Quantitative analysis of the obtained data was performed using Canberra S-100 and AXIL software.

Results and Discussion

The total level of radioactivity of the examined area is formed by the natural isotopes originating from ^{238}U, ^{235}U and ^{232}Th decay and by the presence of ^{40}K as well as by the artificial radionuclides resulting from industrial or military human activities. Results of measurements are presented in Tables 1-10 and Figures 1-7.

As can be seen from the data presented in Tables 1 and 2 the level of the radioactivity of the examined area on both sides of the Polish-Ukrainian border is formed mainly by the presence of ^{40}K isotope. The level of radioactivity arises from its natural content in the crust of the earth estimated at about 0.0119% potassium, which makes the mean radioactivity level about 370 Bq/kg of the soil [2,6].

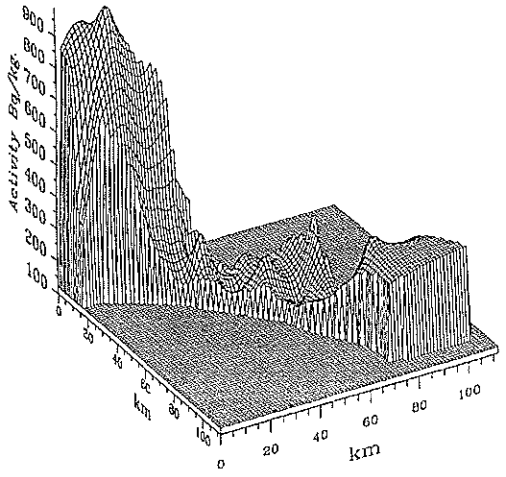


Fig. 2. Total activity of soil Bq/kg.

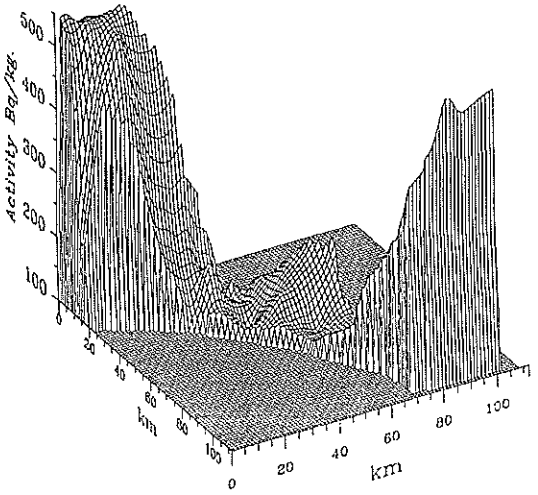


Fig. 3. Activity of K-40 in soil Bq/kg.

Table 1. ^{134}Cs, ^{137}Cs, ^{40}K, contents in Roztocze region soil (Poland side, July, 1995)

No	Site	Activity [Bq/kg]				Activity ^{137}Cs [Bq/m^2]	$^{134, 137}Cs$ fraction [%]	^{40}K fraction [%]
		Total γ activity	^{134}Cs	^{137}Cs	^{40}K			
1	Wola Ponkiewska	872.1	1.36	10.02	536.2	534.1	1.3	61.5
2	Batorz	939.7	1.39	20.30	530.4	1126.7	2.3	56.4
3	Brzozówka	860.4	1.16	20.04	558.1	1065.4	2.5	64.9
4	Wojciechów	788.1	1.07	15.61	497.2	813.8	2.1	63.1
5	Borownica	276.0	1.09	58.67	142.9	1798.6	22.4	53.5
6	Zofianka	672.4	1.03	43.26	418.9	2263.9	6.6	62.3
7	Kocudza Górna	762.9	1.22	16.23	509.4	724.8	2.3	66.8
8	Zdziłowice	842.0	1.34	15.00	524.3	805.1	1.9	62.3
9	Kolonia Otrorz	990.6	1.43	7.59	536.7	427.8	1.0	54.2
11	Rzeczyce	341.1	0.60	16.01	237.3	1069.1	4.9	69.6
12	Gródki	872.1	1.39	10.63	555.4	628.0	1.4	63.7
13	Zaporze	881.1	1.14	11.56	586.0	630.8	1.4	66.5
14	Chłopków	739.3	0.77	32.29	434.3	1338.6	4.5	58.7
15	Trzesiny	313.8	0.48	3.24	210.1	200.0	1.2	66.9
16	Bukownica	176.3	0.21	15.70	102.7	1152.4	9.0	58.3
17	Szozdy	317.5	0.43	8.10	172.7	456.7	2.7	54.4
18	Topolcza	207.1	0.49	23.35	130.0	1238.5	11.5	62.8
19	Szperówka	901.9	1.33	24.51	542.2	1134.4	2.9	60.1
20	Kosobudy	136.8	<LLD	5.92	101.2	429.3	4.3	73.9
21	Zarzecze	176.7	0.27	4.78	117.6	302.7	2.9	66.6
22	Parnia	212.1	<LLD	9.27	126.0	604.0	4.4	59.4
23	Hutków	197.3	0.42	5.77	141.1	382.4	3.1	71.5
24	Zielone	217.0	0.36	3.57	164.3	234.0	1.8	75.7
26	Borowina	120.5	0.34	12.94	81.2	841.1	11.0	67.3
27	Oseredek	272.5	0.51	11.69	137.0	744.4	4.5	50.3
28	Wólka Łosieniecka	213.2	0.42	13.89	150.2	835.0	6.7	70.5
29	Rabinówka	281.8	<LLD	3.10	184.5	189.1	1.1	65.5
30	Przeorsk	547.4	0.85	7.95	313.2	446.2	1.6	57.2
31	Zatyk	451.6	0.34	5.05	165.8	310.2	1.2	36.7
32	Potoki	124.9	<LLD	12.43	94.2	778.7	9.9	75.4
34	Młynki	150.6	<LLD	3.25	96.6	222.4	2.1	64.1
35	Wola Wielka	221.8	<LLD	30.65	116.8	1587.6	13.8	52.7
36	Nowiny Horynieckie	198.3	0.34	0.85	123.7	61.6	0.6	62.4

Table 2. ^{134}Cs, ^{137}Cs, ^{40}K, contents in Roztocze region soil (Ukrainian side, July, 1995)

No	Site	Activity [Bq/kg]				Activity ^{137}Cs [Bq/m^2]	$^{134,137}Cs$ fraction [%]	^{40}K fraction [%]
		Total γ activity	^{134}Cs	^{137}Cs	^{40}K			
U01	Iwano Frankowo	446.7	0.59	13.67	289.0	814.7	3.2	64.7
U01a	Wielikopole	260.2	0.73	30.10	120.4	1008.4	11.8	46.3
U02	Dobrostany	359.9	0.54	6.98	255.5	409.0	2.1	71.0
U03	Nowojaworskoje	869.6	1.16	13.15	556.7	714.1	1.7	64.0
U04	Wiereszczyca	428.0	0.78	23.00	278.5	1145.4	5.5	65.0
U05	Borki	734.8	1.00	42.55	379.8	1914.8	5.9	51.7
U06	Jasniska	417.4	0.90	6.19	159.2	342.9	1.7	38.1
U07	Majdan	814.7	1.44	22.30	467.2	1081.3	2.9	57.3
U08	Wolobracin	402.2	0.84	8.64	226.3	521.0	2.3	56.3
U09	Sieriedkiewiczi	190.1	0.32	11.37	134.8	799.3	6.2	70.9
U10	Mokrotin	769.9	1.02	2.61	473.8	148.2	0.3	61.5
U11	Rawa Ruskaja	268.9	0.43	13.03	146.4	707.5	5.0	54.4

Potassium as well as uranium and thorium isotope contents in the soil depends on geochemical processes that lead to formation of the bed rock from which the soils are formed, the mineral contained in these rocks and soil forming processes relate to the pH of soil, the mobility of water in soil, dissolution and washing out the components of soil by soil solution. The natural isotope contents in upper layer of the soil is changing because of precipitation and sorption processes. The main source of these contaminations are industrial emissions from coal combustion and strip mine actions. An additional factor increasing the level of soil radioactivity is made by the application of phosphatic fertilizers produced from the natural phosphatic deposits that contain ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K.

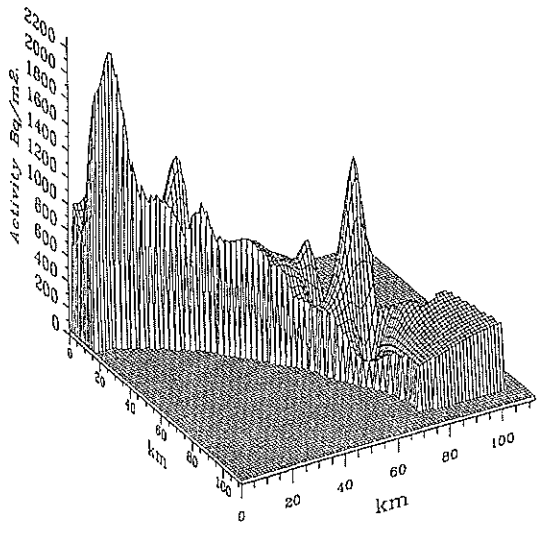


Fig. 4. The activity of Cs-137 in soil, Bq/m^2

As can be seen from Tables 1 and 2, about 54% of total radioactivity on Polish territory and 54% on Ukrainian is caused by the presence of ^{40}K in Roztocze soils, with minimum and maximum values 95-580 Bq/kg and 120-560 Bq/kg in both countries respectively. The differences may result from unlike soil formation processes, as well as from industrial and agricultural activity performed on the territory. Additionally ^{40}K, amount in upper layer of the soil may depend on colloidal particles content, exchangeable potassium content in sorption complexes and the presence of some metals such as Fe, Cr, Mn, Zn, and the like.That is the reason for the lower ^{40}K content in sandy soil than in clay type soils. Another factor that can increase the amount of ^{40}K is made by precipitation of the dust and ashes from hard coal burning. The radioactive potassium contents in hard coal may reach 50 Bq/kg and after burning its concentration increases 10 times in the ash.

Another important natural isotope is ^{226}Ra. Its average activity in examined samples was about 5% of the whole. This radionuclide is of great importance as it turns into ^{222}Rn, heavy gas emitter that is breathed in. This isotope, together with ^{220}Rn that comes from ^{224}Ra, increases the annual of radioactivity dose for Polish inhabitants. In 1991 almost 46% of the adsorbed dose came from these radioactive gases and products of their decay [7].

The other natural radionuclides that form from 20 to 35% of total radioactivity of the area are as follows:^{228}Ac, ^{212}Bi, ^{212}Pb, ^{224}Ra, ^{228}Th, ^{208}Tl, ^{214}Pb, ^{234}Th, and ^{210}Pb. Their concentration is connected with uranium and thorium series decay, as well as the kind and the type of soil. Close to the upper layer, industrial activity may also have an influence on the radioactivity

Table 3. ^{137}Cs contents from Chernobyl and global fallout in soil samples from Roztocze region (Polish side, July, 1995)

No	Site	Chernobyl origin ^{137}CS activity [Bq/kg]	"Chernobyl" ^{137}Cs [%] contribution	World fallout ^{137}Cs activity [Bq/kg]	World fallout ^{137}Cs [%] contribution
1	Wola Ponkiewska	10.02	100	0	0
2	Batorz	20.30	100	0	0
3	Brzozówka	20.04	100	0	0
4	Wojciechów	15.61	100	0	0
5	Borownica	34.63	59	24.34	41
6	Zofianka	32.72	75	10.90	25
7	Kocudza	16.23	100	0	0
8	Zdziłowice	15.00	100	0	0
9	Kolonia Otrocz	7.59	100	0	0
11	Rzeczyce	16.01	100	0	0
12	Gródki	10.63	100	0	0
13	Zaporze	11.56	100	0	0
14	Chłopków	24.46	75.3	8.03	24.7
15	Trzesiny	3.24	100	0	0
16	Bukownica	6.67	42.14	9.16	57.86
17	Szozdy	8.10	100	0	0
18	Topolcza	15.56	66.24	7.93	33.76
19	Szperówka	24.51	100	0	0
21	Zarzecze	4.78	100	0	0
23	Hutków	5.77	100	0	0
24	Zielone	3.57	100	0	0
26	Borowina	10.80	82.70	2.26	17.3
27	Oseredek	11.69	100	0	0
28	Wólka Łosieniecka	13.89	100	0	0
30	Przeorsk	7.95	100	0	0
31	Zatyk	5.05	100	0	0
36	Nowiny Hryniecki	0.85	100	0	0

level. This is well demonstrated by the higher radioactivity of the northwestern part of Roztocze region in comparison with the rest of examined Polish area. Such industrial centers as Tarnobrzeg or Stalowa Wola may be responsible for this state, as they emit some amounts of natural isotopes of uranium and thorium series together with ^{40}K isotope. That is probably why in this part of the region, mentioned isotope content is three times higher than for the rest of Polish Roztocze.

It can be noticed that the mean total soil activity of Polish Roztocze region is lower (420 Bq/kg) than in Ukrainian part (540 Bq/kg). In southeastern part of Polish Roztocze, adjoining to Ukraine, mean total activity is only 235 Bq/kg of soil. As can be seen from Tables 1 and 2 this radioactivity is formed mainly by natural isotopes, because artificial isotope content is low and reaches as much as 13-17 Bq/kg. As the kind of soil is very similar on both sides of the border the higher radioactivity of Ukrainian territory might result from its industrial contamination by aerosols containing natural isotopes.

An important part of examinations was determination of artificial isotope contamination that is made by ^{134}Cs and ^{137}Cs. ^{137}Cs, which appeared as a result of nuclear explosions and nuclear plant failures is a very important and dangerous isotope, with a half life of 30 years; ^{134}Cs half life is only 2.06 years.

The strong sorption ability of caesium makes its migration in the soil profile very slow, and in this way it is responsible, to some extent, for higher radiation of the upper layer of the soil [8,9]. The migration rate of caesium, above all, depends on basic mineral composition of the soil. But it is hard to find a simple relation, describing migration rate, just because from a chemical

Table 4. ^{137}Cs contents from Chernobyl and global fallout in soil samples from Roztocze region (Ukrainian side, July, 1995)

No	Site	Chernobyl origin ^{137}Cs activity [Bq/kg]	"Chernobyl" ^{137}Cs [%] contribution	World fallout ^{137}Cs activity [Bq/kg]	World fallout ^{137}Cs [%] contribution
U01	Iwanowo Frankowo	13.67	100	0	0
U01a	Wielikopole	30.10	77	6.9	23
U02	Dobrostany	6.98	100	0	0
U03	Nowojaworskoje	13.15	100	0	0
U04	Wiereszczyca	22.99	100	0	0
U05	Borki	42.55	74.7	10.8	25.3
U06	Jasniska	6.19	100	0	0
U07	Majdan	22.30	100	0	0
U08	Wolobracin	8.64	100	0	0
U09	Sieredkiewiczi	11.37	92.2	0.9	7.8
U10	Mokrotin	2.60	100	0	0
U11	Rawa Ruskaja	13.03	100	0	0

point of view, soil is too complicated a system. However, it is well known that the quality of the soil is, besides the magnitude of the fallout, the dominant factor in radioactive distribution.

The caesium content in soil of Roztocze region is presented in Tables 1-4 and in Fig.4.

It can be noticed that from 0.6 to 22% of the whole radioactivity on the Polish side of examined area results from caesium presence [2,10]. For comparison, on the Ukrainian side the same element gives from 1.5 to 11% of the whole radioactive contamination of soil. The maximum contamination reaches 2264 and 1915 Bq/m^2, respectively.That suggests a rather low level of Chernobyl fallout in this territory. In 1995, ^{134}Cs contribution to the contamination of examined area was small and reached from 0.3 to 1.4 Bq/kg of the soil of the whole Roztocze. This isotope in analyzed samples might come only from Chernobyl fallout. Because it was noticed in the most samples (except six points in Poland), the origins of ^{137}Cs could be estimated. Using decay law, the dependence between decay constant and half-life period [8] and knowing the ^{134}Cs to ^{137}Cs ratio on the first days after the catastrophe (0.528) [9], the quantitative and percentage contribution of Chernobyl, and global fallout, ^{137}Cs in the total caesium content in the soil samples was determined. The data are presented in Tables 3 and 4. On the basis of the obtained data, authors stated that in 21 of 33 samples in Poland side and 9 of 11 in Ukraine 100% of ^{137}Cs comes from Charnobyl fallout. This means that the same isotope from the global fallout migrated during the last 30 years, when superpowers ceased nuclear

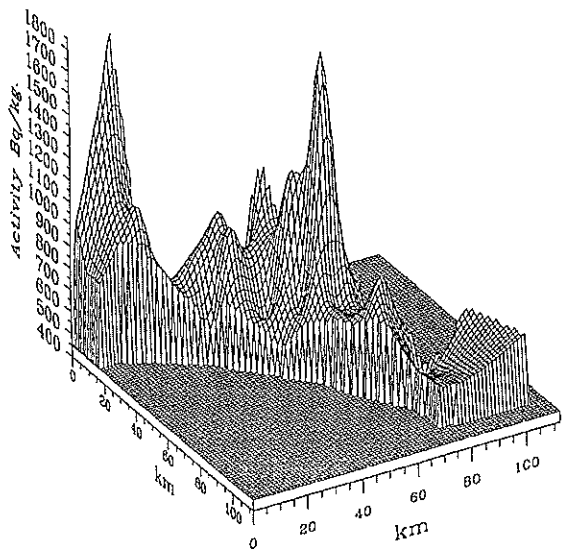


Fig. 5. Total activity of grass Bq/kg

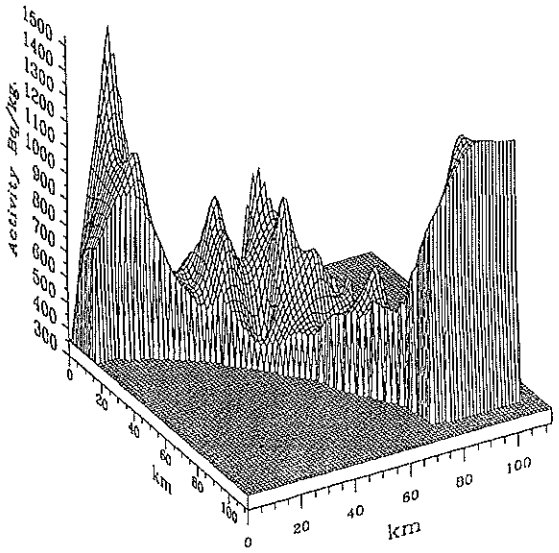


Fig. 6. The activity of K-40 in grass Bq/kg

Table 5. ^{134}Cs, ^{137}Cs, ^{40}K, contents in Roztocze region grass (Poland side, July, 1995)

No	Site	Activity [Bq/kg]					$^{134, 137}Cs$ fraction [%]	^{40}K fraction [%]
		Total γ activity	^{134}Cs	^{137}Cs	^{40}K	^{7}Be		
1	Wola Ponkiewska	2023.4	<LLD	2.05	1715.6	65.9	0.1	84.8
3	Brzozówka	969.1	7.15	254.13	260.7	265.7	27.0	27.0
4	Wojciechów	768.0	<LLD	4.07	683.9	80.0	0.5	89.0
7	Kocudza Górna	1238.5	<LLD	<LLD	1116.4	122.1	-	90.0
9	Kolonia Otrorz	1127.8	<LLD	5.91	1050.0	71.3	0.5	93.2
11	Rzeczyce	786.2	<LLD	<LLD	673.9	111.2	-	85.7
12	Gródki	441.5	<LLD	3.42	438.1	<LLD	0.8	99.2
15	Trzesiny	895.0	<LLD	6.95	611.8	276.3	0.8	68.4
16	Bukownica	603.3	<LLD	39.79	544.6	<LLD	6.6	90.3
17	Szozdy	1029.0	<LLD	<LLD	804.3	224.7	-	78.2
18	Topolcza	1059.6	<LLD	2.19	921.1	27.4	0.2	86.9
19	Szperówka	889.8	<LLD	<LLD	717.0	142.7	-	81.7
20	Kosobudy	766.4	<LLD	<LLD	530.0	226.3	-	69.2
21	Zarzecze	1439.6	<LLD	<LLD	1183.7	255.9	-	82.2
22	Parnia	988.2	<LLD	12.99	818.6	156.7	1.3	82.8
23	Hutków	737.2	<LLD	9.60	637.3	90.3	1.3	86.4
24	Zielone	1132.3	<LLD	34.10	973.2	125.0	3.0	85.9
25	Wólka Husińska	1265.1	<LLD	2.98	951.7	310.4	0.2	75.2
26	Borowina	955.1	<LLD	102.20	397.1	129.0	15.6	60.6
27	Oseredek	770.4	<LLD	2.32	621.9	146.2	0.3	80.7
28	Wólka Łosieniecka	1851.9	<LLD	7.49	758.5	264.9	0.4	41.0
29	Rabinówka	735.9	<LLD	<LLD	575.5	111.6	-	78.2
30	Przeorsk	989.1	<LLD	<LLD	838.3	156.2	-	84.8
31	Zatyk	797.4	<LLD	<LLD	688.6	108.8	-	86.4
32	Potoki	608.7	<LLD	29.70	429.7	149.3	4.9	70.6
34	Młynki	779.1	<LLD	18.26	476.3	238.1	2.3	61.1
35	Wola Wielka	728.4	<LLD	7.09	594.3	123.4	1.0	82.0
36	Nowiny Hrynieckie	941.2	<LLD	<LLD	803.3	137.9	-	85.3
37	Machnów	1329.1	<LLD	<LLD	1157.7	175.4	-	86.8

Table 6. ^{134}Cs, ^{137}Cs, ^{40}K, contents in Roztocze region grass (Ukraine side, July, 1995)

No	Site	Activity [Bq/kg]					$^{134, 137}Cs$ fraction [%]	^{40}K fraction [%]
		Total γ activity	^{134}Cs	^{137}Cs	^{40}K	^{7}Be		
U01	Iwano Frankowo	1246.5	<LLD	5.31	981.6	259.6	0.4	78.7
U01a	Wielikopole	828.2	<LLD	10.36	615.9	201.9	1.3	74.4
U02	Dobrostany	1711.7	<LLD	2.40	1416.5	289.3	0.1	82.8
U03	Nowojaworskoje	880.0	<LLD	15.47	609.7	251.2	1.8	69.3
U04	Wiereszczyca	1775.6	<LLD	11.70	1372.1	391.9	0.6	77.3
U05	Borki	1406.8	<LLD	19.66	1011.3	375.8	1.4	71.9
U06	Jasniska	1040.2	<LLD	<LLD	710.4	305.8	-	68.3
U07	Majdan	832.5	<LLD	7.24	498.3	307.3	0.9	59.9
U08	Wolobracin	507.7	<LLD	2.43	357.3	148.0	0.5	70.4
U09	Sieriedkiewiczi	754.0	<LLD	<LLD	426.4	189.4	-	69.2
U10	Mokrotin	615.8	<LLD	<LLD	426.4	189.4	-	69.2
U11	Rawa Ruskaja	826.5	<LLD	<LLD	681.5	180.9	-	79.0

Table 7. Transfer coeficient of ^{137}Cs for Roztocze region grass (Polish side, July, 1995)

No	Site	TF
1	Wola Ponkiewska	0.207
3	Brzozówka	12.618
4	Wojciechów	0.260
9	Kolonia Otrorz	0.773
12	Gródki	0.320
15	Trzesiny	2.125
16	Bukownica	2.514
18	Topólcza	0.094
22	Parnia	1.389
23	Hutków	1.648
24	Zielone	9.467
25	Wólka Husińska	0.304
26	Borowina	7.825
27	Oseredek	0.197
28	Wólka Łosieniecka	0.537
32	Potoki	2.371
34	Młynki	5.584
35	Wola Wielka	0.229

Table 8. Transfer coeficient of ^{137}Cs for Roztocze region grass (Ukrainian side, July, 1995)

No	Site	TF
U01	Iwano Frankowo	0.386
U01a	Wielikopole	0.342
U02	Dobrostany	0.341
U03	Nowojaworskoje	1.169
U04	Wiereszczyca	0.482
U05	Borki	0.459
U07	Majdan	0.324
U08	Wołobracin	0.281
U09	Sieriedkiewiczi	0.340

explosions, deeper than 10 cm. No samples deeper than 10 cm were collected. If Charnobyl catastrophe had not happened in 1986 then in many places of the upper layer of the Roztocze soil ^{137}Cs would not have been presented at all.

In complex investigations of the Roztocze environment the measurements of grass contamination by the radioactive isotopes occurred. Appropriate data are inserted in Tables 5 and 6 and Figures 5-7. It is concluded from measurements, that grass takes ^{40}K, ^{137}Cs,^{7}Be from air and soil above all, and in some points also ^{212}Pb, ^{214}Pb and ^{226}Ra. The amounts of lead and radium are, however, inconsiderable, and form only a fraction of percent of total activity. The isotope that determines the level of grass radioactivity is ^{40}K. Its activity contribution reaches 80% in Polish part of Roztocze and 73% in Ukrainian. The lowest and the highest values are: 250 and 1715 Bq/kg of dry grass on the Polish side and 350 and 1416 Bq/kg in the Ukraine. The high level of ^{40}K in grass arises from the fact that this isotope is biologically active and plants absorb it very intensely. The amount and the kind of the ion absorbed by a plant depends on the kind of plant and, to some extent, on its root system. Generally, plants have programmed in advance a request for the particular ion.[11]. In consequence, when the concentration of this ion in soil is too low, the plant absorbs other ions of the same sign. For example, in a potassium ion shortage other ions from the first group may be absorbed i.e. caesium.

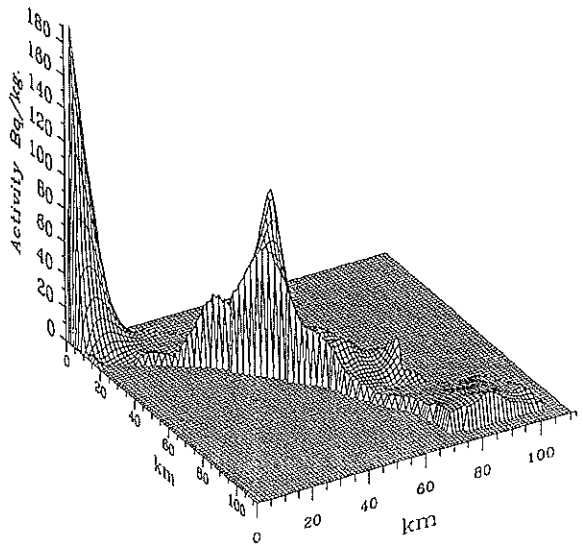


Fig. 7. The activity of Cs-137 in grass Bq/kg

Another isotope present in bigger amounts in the grass samples is ^{7}Be. This isotope comes from space, so plants absorb it by leaves, not roots. Besides, falling down in an aerosol form, ^{7}Be may settle down on the surface of their leaves, increasing radioactivity.

The activity of grass results from the presence of artificial isotopes, i.e. ^{137}Cs (as ^{134}Cs practically was not detected) ranged from 0 to 254 Bq/kg of the dry mass in Polish Roztocze and from 0 to 20 Bq/kg in Ukrainian Roztocze. The high activity of ^{137}Cs in point No. 3, from Brzozówka village (254.1 Bq/kg of dry mass) is surprising, as the soil from this territory reaches only 20.0 Bq/kg, whereas potassium activity was rather high, reaching 554.1 Bq/kg. The reason for this may be plant physiology, the dispersion of radionuclides adsorbed by plants and physical and chemical structure of the soil.

To investigate the influence of ^{137}Cs content in soil on the amount of absorbed caesium by grass, a transfer coefficient of ^{137}Cs to grass was calculated according to the equation:

$$TF = \frac{\text{Cs-137 activity of grass [Bq/kg]}}{\text{Cs-137 activity of soil [Bq/kg]}}$$

Table 9. Selected heavy metal contents in soil samples of Roztocze region (Polish side, July, 1995).

No	Site	Concentration [ppm]						
		Mn	Fe	Cu	Zn	Pb	Cr	Ba
1	Wola Ponkiewska	409.4	10280.0	28.4	38.1	27.7	164.0	415
2	Batorz	503.0	12040.0	31.9	48.2	28.4	ND	394
3	Brzozówka	687.1	11390.0	36.7	44.4	44.5	NNND	411
4	Wojciechów	635.5	9329.2	32.0	46.6	31.8	ND	386
5	Borownica	102.6	3528.7	23.4	99.8	53.0	ND	138
6	Zofianka	436.5	10030.0	18.6	60.0	50.3	<147.2	355
7	Kocudza Górna	628.9	10520.0	31.2	57.6	36.0	ND	406
8	Zdziłowice	302.1	11660.0	26.1	37.4	30.1	ND	396
9	Kolonia Otrorz	453.4	12580.0	30.3	41.6	28.7	222.7	393
10	Zastawie	619.4	11650.0	35.2	55.6	31.7	222.8	413
11	Rzeczyce	311.0	3835.8	<13.5	30.3	21.2	ND	218
12	Gródki	418.2	15880.0	28.6	41.0	32.7	ND	388
13	Zaporze	582.1	16560.0	41.6	76.6	34.5	<176.4	408
14	Chłopków	667.5	9996.5	39.54	115.6	34.7	ND	390
15	Trzesiny	123.5	4097.4	18.6	23.6	22.2	ND	205
16	Bukownica	438.2	2369.7	18.7	24.3	21.3	224.5	120
17	Szozdy	194.1	6366.3	19.5	30.3	17.0	ND	116
18	Topolcza	159.9	4589.3	22.0	28.68	20.8	ND	133
19	Szperówka	596.1	143.4	31.9	28.6	27.7	246.7	409
20	Kosobudy	158.2	1342.5	19.0	23.2	14.2	ND	99
21	Zarzecze	165.9	1963.1	24.6	23.3	17.4	ND	130
22	Parnia	110.4	3485.7	23.7	30.8	23.6	ND	123
23	Hutków	230.4	3488.8	<15.4	15.9	20.4	ND	146
24	Zielone	326.8	2447.1	29.1	23.6	14.8	ND	145
25	Wólka Husińska	221.1	4312.7	19.1	25.5	22.5	ND	148
26	Borowina	<74.8	938.2	17.0	10.0	20.9	ND	81
27	Oseredek	198.5	6017.0	28.3	26.3	26.3	ND	124
28	Wólka Łosieniecka	229.7	5645.0	17.8	53.2	30.7	ND	139
29	Rabinówka	<86.6	5957.8	17.5	35.0	15.4	249.9	174
30	Przeorsk	303.4	16200.0	<21.2	68.0	27.3	ND	192
31	Zatyk	146.8	4687.9	<17.6	20.9	15.5	ND	120
32	Potoki	<96.8	974.7	21.6	15.6	20.8	ND	85
34	Młynki	<90.8	3193.6	17.1	14.5	19.9	ND	84
35	Wola Wielka	95.4	2616.5	26.8	16.3	28.4	<139.7	106
36	Nowiny Horynieckie	201.7	3111.2	20.7	20.6	13.3	ND	101
37	Machnów	108.1	5173.3	28.4	28.7	21.3	ND	147

Table 10. Selected heavy metal contents in soil samples of Roztocze region (Ukrainian side, July, 1995).

No	Site	Concentration [ppm]						
		Mn	Fe	Cu	Zn	Pb	Cr	Ba
U01	Iwano Frankowo	237.3	7386.0	21.5	33.4	20.1	ND	228
U01a	Wielikopole	161.4	8225.8	21.8	41.3	39.2	ND	225
U02	Dobrostany	191.4	3815.3	17.8	24.1	15.1	ND	212
U03	Nowojaworskoje	502.5	4545.1	17.7	38.4	24.6	ND	225
U04	Wiereszczyca	689.1	6037.6	29.0	55.2	32.9	ND	289
U05	Borki	164.1	3863.0	22.3	18.0	18.2	ND	137
U06	Jasniska	1427.6	8716.6	21.6	72.21	36.2	ND	155
U07	Majdan	517.9	8517.6	<14.7	32.8	ND	347.0	
U08	Wolobracin	691.6	6793.6	24.2	42.4	24.1	202.0	219
U09	Sieriedkiewiczi	145.6	4633.8	<13.3	38.3	19.8	ND	288
U10	Mokrotin	225.2	9724.7	25.4	34.1	26.6	ND	356
U11	Rawa Ruskaja	177.0	7903.9	83.7	46.7	146.1	ND	166

Respective results are collected in Tables 7 and 8. Obtained values of TF coefficient differ much and vary from 0.09 to 12.6.

Maybe such a different transfer coefficient is caused by the kind of soil, its pH values, organic substances content, leaching parts of the soil content, the type and size of minerals, the presence of some cations, soil humidity, degree and the rate of the plant development, kind of plant organ and nutritious substance content in the soil [12].

The measurements of heavy metal content in soils of Roztocze were performed to develop our knowledge of the environment of the region. Relevant data are inserted in Tables 9 and 10. From among 14 heavy metals detected in the examined samples, special attention was played to those which reveal very big (Cu, Cr, Zn, Pb) or big (Mn, Fe, Ba) accumulation coefficients. All elements mentioned in the first group are especially dangerous to the chemical balance in biosphere, if are introduced to the environment in greater amounts [13]. Also, the elements having smaller accumulation coefficient are harmful to the organisms when their concentration in the environment would increase. The harmfulness of heavy metals to the environment results from their biochemical and chemical properties. Looking at the obtained results one may state, that in any sample point at Polish side of Roztocze the admissible level was not exceeded. On the Ukrainian side, in point U11 in Rava Ruska city 146 ppm of lead was detected, while 100 ppm is the maximum admissible level [13]. Above contaminations are connected with local industrial activity.

Generally, the rather low concentration of heavy metals in Roztocze soils arises from the absence of chemical industry (artificial fertilizers, paper and cellulose production). The range of influence of industrial emission often exceeds 50 km but the greatest changes of chemical composition of soil take place closest to emitters [13]. The permanence of metal elements absorption that were introduced to soil, depends on their chemical structure as well as on structure, composition and properties of soil. The exceeding of heavy metal admissible level is observed in Poland only for soils of big agglomerations and industrialized regions.

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