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Studies of ^{137}Cs Contamination of Some Plants from Eastern Poland

J. Solecki, S. Chibowski, J. Szczypa

Department of Chemistry and Colloid Chemistry, Faculty of Chemistry, Maria Curie-Sklodowska University, 20-031 Lublin, pl. M. Curie-Skłodowskiej 3, Poland

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Abstract

This paper presents the results of investigations of grass contaminated by ^{137}Cs in eastern Poland. The influence of the site, potassium ion content, soil type and caesium from soil to plant transfer coefficient (TF) were examined.

Keywords: ^{137}Cs, grass, soil, transfer coefficient

Introduction

Many papers devoted to ^{137}Cs and ^{134}Cs investigations have appeared due to nuclear explosions and nuclear power plant breakdowns.

Radioactive particles that settle on the upper layer of soil are adsorbed by root systems of plants, often very developed. (A single rye plant may have a root system surface as big as 600 m^2). It was estimated that radioactive isotopes are absorbed by plants in the following order: Sr>I>Be>Cs, Ru>Ce>Pm, Zr>Pu [1]. The total concentration of elements in the plant is a sum of the isotopes absorbed by the roots and above -ground parts. These ways have different kinetics and the faster adsorption goes by plant leaves.

Results of the radionuclide transfer examinations are generally presented as a transfer or discrimination coefficients [2, 3]. The transfer coefficient (TF), is defined as equal to dry plant activity in Bq/kg, divided by dry soil activity (also in Bq/kg).

The discrimination coefficient K_d of caesium towards potassium is defined as a quotient ^{137}C to K activity measured in plant and soil.

$$K_d = [^{137}Cs/K] \text{ (in plant)} / [^{137}Cs/K] \text{ (in soil)}$$

The transfer coefficient describes the behavior of a specific isotope in the environment. For TF>1, plant accumulates the isotope (the concentration of the isotope in the plant is bigger than in the soil). Because TF values are the function of many variables, these can vary from hundredth part to hundreds in extreme cases. The greatest factors having an influence on TF are soil type [3-7], soil element contents (especially potassium and calcium) pH of the soil [7-9] agricultural treatments [2, 10] and the climate conditions (participation, soil humidity and temperature) [2].

So many factors influencing the TF make the description of it as a function of them all very difficult.

Considering the above, this paper presents only ^{137}Cs and ^{134}Cs isotope contents in over-ground parts of grass in eastern Poland. For all samples transport coefficient was calculated. Because of a short half-life period of ^{134}Cs (2.06 years), this isotope was noticed merely in a few samples, as much as a few Bq/kg, where ^{137}Cs content was high.

Methods

For the examination of eastern Poland territory (so called Eastern Wall) contamination by gamma emitters, the whole area was divided along the length and breadth in 15 km squares [7,13,14]. The samples were collected at 282 points of 334 that formed lattice. Soil and plant samples (grass) were collected from the same points. According to IAEA procedure the plant was cut 2 cm above ground [11]. All samples were taken between spring and autumn 1992.

The samples were air dried in laboratory, then cut in Fritsh mill and fraction below 1mm was collected to measurements.

A volume 0.5 dcm^3 of each sample was placed in Marinelli's vessel, to standarize geometry, and measured after 10 days. The radioactivity was measured with Silena gamma spectrometer with IGC-13 germanium detector by Princeton Gamma Tech, equipped with a 4096 channel analyzer. The resolution of the detector was 1.75 keV for 1.33 MeV peak and the counting yield was equal to 15%. Measurement error ranges from 0.01 to 27.1 Bq/kg and was no bigger than 5% of the measured value. SIMCAS II software, ver. 4.11 was applied to the quantitative and qualitative analysis of the data.

Obtained results in Bq/kg of dry sample were calculated on the year of their collection, that is 1992, are discussed below and presented in Tables 1 and 2.

Results and Discussion

As mentioned earlier, gamma emitters were examined in 282 grass samples. For 46 samples ^{137}Cs content was below its detection level (LLD), so we assumed the activity of isotope equal to zero. The greatest activity, 1691 Bq/kg, was detected in sample number 90 from a meadow near Choroszcz village, the Bialystok region. Other samples from point numbers 39, 88, 30 and 95 also revealed high activity - 697.1, 672.2, 483.7, and 340.1 Bq/kg, respectively (Tab. 1). Generally the highest values were obtained for northeastern Poland, especially from grasslands and forests. Simultaneously, many samples from the same area had activity below the detection level. One can assume that the above situation results from different radioactive fallout and various soil types.

In 25 samples the presence of ^{134}Cs was detected on the level 0.2 -67 Bq/kg. It must be emphasized that ^{134}Cs was discovered in all samples having high ^{137}Cs concentrations.

The activity statistics of examined samples was as follows:

^{137}Cs activity below its detection level (LLD) - 46 samples
^{137}Cs activity between 0.1 and 10 Bq/kg - 179 samples
^{137}Cs activity between 10 and 50 Bq/kg - 30 samples
^{137}Cs activity between 50 and 100 Bq/kg - 7 samples
^{137}Cs activity higher than 100Bq/kg - 20 samples.

Tab.1. presents results of activity measurements for 45 samples. For all of them, TF is higher than 1, meaning that ^{137}Cs is cumulated in the plant. The highest values were detected for samples taken from forests (TF = 126.7 for point 39) and grasslands (TF = 249 for point 88).

The above results confirm ^{137}Cs transfer dependence on the quality of the soil, and especially the weight of organic substance contents and mineral colloid fraction for caesium adsorption [2]. Plant samples originated from forest or grasslands, where the soil contains more organic particles, reveal higher radioactive con-

Table 1. The radioactivity of grass samples caused by ^{137}Cs for selected points from southeastern Poland, soil to plant transfer coefficient (samples collected in 1992).

Sample number	Geographical coordinates	Site	^{137}Cs activity in Bq/kg	TF ^{137}Cs
1	54° 22' N; 22° 52' E	plough field	17.5	1.20
5	54° 14' N; 22° 11' E	forest	100.0	1.36
13	54° 06' N; 21° 56' E	wasteland	48.3	5.30
14	54° 06' N; 22° 11' E	forest	123.4	1.61
30	53° 58' N; 23° 31' E	forest	483.7	11.25
38	53° 50' N; 23° 06' E	forest	7.3	1.10
39	53° 50' N; 23° 29' E	forest	697.1	126.70
46	53° 42' N; 22° 37' E	forest	382.0	29.40
56	53° 34' N; 22° 37' E	forest	122.0	6.13
62	53° 26' N; 21° 33' E	forest	15.2	5.85
65	53° 26' N; 22° 10' E	forest	20.0	3.00
72	53° 18' N; 21° 38' E	wasteland	112.4	9.61
75	53° 18' N; 22° 10' E	wasteland	8.5	1.20
80	53° 18' N; 23° 30' E	forest	263.5	2.73
82	53° 18' N; 23° 46' E	wasteland	58.8	4.20
83	53° 10' N; 21° 42' E	plough field	107.3	6.54
85	53° 10' N; 22° 06' E	forest	144.1	2.96
86	53° 10' N; 22° 10' E	meadow	23.3	1.05
87	53° 10' N; 22° 21' E	meadow	172.8	10.41
88	53° 10' N; 22° 37' E	meadow	672.2	249.00
90	53° 10' N; 23° 06' E	meadow	1691.0	121.00
93	53° 10' N; 23° 40' E	forest	263.2	5.73
95	53° 02' N; 21° 52' E	meadow	340.1	29.31
96	53° 02' N; 22° 06' E	plugh field	39.5	1.90
98	53° 02' N; 22° 21' E	meadow	16.3	3.02
111	52° 54' N; 23° 21' E	forest	261.8	12.1
112	52° 54' N; 23° 30' E	meadow	21.9	2.41
124	52° 46' N; 23° 52' E	meadow	4.2	1.17
126	52° 38' N; 22° 28' E	meadow	33.6	2.82
127	52° 38' N; 22° 37' E	meadow	13.0	2.65
132	52° 38' N; 23° 40' E	forest	132.0	4.16
139	52° 30' N; 23° 27' E	meadow	53.5	4.78
145	52° 16' N; 22° 07' E	meadow	72.4	5.06
151	52° 08' N; 22° 07' E	wasteland	43.5	12.43
153	52° 08' N; 22° 30' E	forest	210.7	1.87
158	52° 05' N; 23° 38' E	meadow	22.8	2.45
187	51° 33' N; 22° 30' E	forest	172.6	21.2
190	51° 33' N; 23° 09' E	meadow	22.4	1.10
254	50° 37' N; 22° 15' E	wasteland	84.0	2.64
258	50° 37' N; 23° 07' E	forest	4.7	2.5
264	50° 28' N; 21° 49' E	forest	139.0	6.84
268	50° 28' N; 22° 41' E	wasteland	90.5	1.78
269	50° 28' N; 22° 54' E	wasteland	29.3	4.64
291	50° 12' N; 22° 40' E	forest	21.2	14.8
297	50° 04' N; 22° 27' E	wasteland	18.2	2.28

Table 2. ^{137} Cs and ^{40}K transfer coefficients for the selected samples of grass from eastern Poland (collected in 1992)

Number	Geographical coordinates	TF ^{137}Cs	TF ^{40}K
3	54° 14' N; 21° 42' E	0	5.15
6	54° 14' N; 22° 22' E	0	0.30
12	54° 06' N; 21° 42' E	0	1.40
17	54° 06' N; 22° 52' E	0	0.96
19	54° 06' N; 23° 22' E	0	0.60
22	53° 58' N; 21° 42' E	0	1.06
23	53° 58' N; 21° 56' E	0	2.26
24	53° 58' N; 22° 11' E	0	1.98
26	53° 58' N; 22° 38' E	0	0.42
27	53° 58' N; 22° 52' E	0	2.33
34	53° 50' N; 22° 10' E	0	0.16
60	53° 34' N; 23° 30' E	0	2.61
101	53° 02' N; 23° 06' E	0	5.48
228	51° 01' N; 23° 34' E	0	2.27
230	51° 01' N; 24° 00' E	0	1.30
30	53° 58' N; 23° 31' E	11.25	0.18
39	53° 50' N; 23° 29' E	126.70	0.73
46	53° 42' N; 22° 37' E	29.40	0.28
56	53° 34' N; 22° 37' E	6.13	0.72
87	53° 10' N; 22° 21' E	10.40	1.87
89	53° 10' N; 22° 51' E	249.00	0.45
90	53° 10' N; 23° 06' E	121.00	1.53
95	53° 02' N; 21° 52' E	29.30	0.63
111	52° 54' N; 23° 21' E	12.10	0.40
151	52° 08' N; 22° 07' E	12.43	2.74
187	51° 33' N; 22° 30' E	21.20	2.23
291	50° 12' N; 22° 40' E	14.80	6.00

tamination as a result of faster kinetics of caesium desorption. That is because this element is adsorbed weaker by organic colloids [12]. The lack of agricultural treatment of soil also helps the roots adsorb caesium, as its penetration is weaker through the compact subsoil.

Based on the obtained results, the statistical comparison of TF values was performed for the rest of the samples. For 28 samples TF varied from 0.5 to 1. In this group, 3 samples came from forests, 3 from plough field vicinity and the rest, 22, from meadows and wastelands. For 88 samples TF was in the range 0.1-0.5. In this group 45 originated from grasslands, 5 from forests and 38 from wastelands, balks and paths near the fields. 121 samples revealed the lowest TF values, ranged from 0.0 to 0.1. Among them 4 came from forests, 38 from grasslands and 78 from nonplough areas near fields. The presented comparison does not let us explain all factors involved in ^{137}Cs isotope circulation in analyzed grass samples, but for the majority of them taken from forests and meadows the observed amounts of caesium were greater than for those collected from other sites.

The lowest radioactivity was observed for samples collected from close vicinity of plough lands. One can assume the changes in ion balance of the soil, made by fertilization. It is well known that fertilization delivers a surplus of ions for the plant's physiological needs [2, 10]. Probably for that reason TF>1 was observed only for three points (number 1, 83 and 96), from plough lands, i.e., 1.2, 6.54, and 1.90, respectively (Tab. 1).

The considerable differentiation can be observed for geographical provenance of the samples. Generally, a lowering of TF values can be observed towards southeastern direction. Beside the reasons proposed above, the different TF of the grass samples may be caused by various kinds of soil, as was measured for the same territory earlier [7].

In Table 2, the extreme TF values for ^{137}Cs are presented with ^{40}K transfer coefficient, to illustrate whether the latter had the influence on the TF value of ^{137}Cs [2]. This presentation shows that there is no proportional relation between TF od ^{40}K and TF of ^{137}Cs. That confirms earlier observations that ^{137}Cs transportation from soil to plant is more complex.

To summarize we can state as follows.

1. In majority of the examined samples the transportation of radioactive caesium from soil to plant was noticed.
2. The level of grass contamination depends on sample location (forest, meadow, field, wasteland).
3. The consequence of the influence of potassium ions cannot be explained uniquivocally from available data.
4. Measurements confirm greater contamination of northeastern regions of Poland.
5. The comparison of the soil-plant transfer factor and activity of examined samples with the map of soils of Poland confirms the influence of soil type on the level of radioactive contamination of plants by caesium.

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