FEATURES OF A PRIMARY DISTRIBUTION ^{137}Cs AND ^{90}Sr AT PROFILE AND AGGREGATE LEVELS OF SODDY-PODZOLIC SOIL

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Introduction

In spite of the fact that with accident history on Cemobyl NPP totals already more than 20 years, considerable territories of the Russian Federation remain polluted of radionuclides. For the postchemobyl period on behaviour studying pollutants extensive scientific researches have been carried out in soil for the purpose of possibility of forecasting of their behaviour in various ecosystems [1], but in details distribution pollutants in structures composing soil and a role of live plants in their redistribution are insufficiently studied.

In soil radionuclides interacted with its components, move in a horizontal direction and are transferred deep into a soil profile, join in biological cycles of migration. The great value in migration pollutants has sorption ability of soils which essentially increases with increase in dispersion of soil particles that is caused by more specific surface of small soil fractions, and distinctions in their mineralogical content. The basic share radionuclides in soil usually communicates the small fractions containing clay and silt particles and enriched by secondary minerals of groups montmorillonite, kaolinite and hydromicas. Appreciable influence on distributions radionuclides between soil components is rendered also by quantity and structure of organic substance [2].

In aggregate structure of top horizons of soils takes place accumulation of pollutants on surfaces of units of the different size which is caused by moving of a soil moisture to intermodular space and primary sorbtion interactions with a surface of aggregates. Presence of such effects accumulation and approaches to their research were discussed earlier [3, 6, 7].

The purpose of the given work - studying of primary vertical distribution radionuclides at washing of soil columns of different preparation by water, and also distributions ^{137}Cs and ^{90}Sr on soil aggregates.

Materials and methods

The data of laboratory experiences on soddy-podzolic silt soil formed on loam cover are resulted in the present investigation. Samples of not broken structure were selected from a 10-year-old idle occupied with meadow natural vegetation. Sampling of monoliths was made in wooden boxes by section 20x20 and in height to 30 cm. Monoliths were selected with an interval 1 year to make columns with soil of natural structure with live roots (for experience in a year of sampling), and with dead roots (for experience after 3 years dryings and storage in the conditions of laboratory). Modelling experiences spent in plastic columns-containers section 6x6 and in height 10 cm. From monoliths cut out corresponding to the size of a column the sample. Each of the parties of the sample serially paraffined then the sample was inserted into a column containing hot paraffin. This reception allowed to avoid solution course between walls and a monolith at a filtration through a column. The bottom of a column also paraffined, but in it apertures for a free filtration of solutions were drilled. Before the experience beginning all plants in a column from fresh soil have been cut off at level of a surface of soil. ^{137}Cs and ^{90}Sr in the form of solutions of nitrate in volume of 100 ml and the general activity 80 kBq and 20 kBq, respectively, were applicated on a monolith surface. These portions of solutions have been entirely absorbed at surface layer of soil. Water addition was carried out by portions with intervals in 2-3 days before occurrence of eluate. At such way all irrigation water was completely absorbed in soil. Then monoliths within 2-4 weeks were washed out by water in the norm equivalent of 200 mm of rainfalls. Experiences were spent in greenhouse at temperature 22-25°C. During washing the part of plants in a column with fresh soil began to grow. In a column with natural structure of soil and dead roots of growth of plants it was not observed. Similar experiment with column filled washed soil of broken structure without roots, fraction of 1 -2 mm was in parallel made. Upon termination of washing distribution ^{137}Cs and ^{90}Sr on length of columns, and also distribution on soil aggregates in columns of not broken structure was studied.

Thus, three soil columns have been made: 1 column - soil of natural structure with live roots; 2 column - soil of natural structure after long storage in a dry condition; 3 column - bulk, without roots. After washing of a column by the set norm of the distilled water soil deleted from columns, dried and cut on layers in the thickness 1 cm. Each layer is divided into fractions by a method of dry dispersion on sieves in the size: 10; 5; 3; 2; 1 and 0,5 mm, thus, divided soil into fractions: > 10; 5-10; 3-5; 2-3; 1-2; 0,5-1 and <0,5 mm. Samples of eluate evaporated and in the dry rest also defined activity ^{137}Cs and ^{90}Sr.

The radiocaesium activity measured on spectrometer Compugamma-1285 (LKB, Sweden), radiostrontium - on radiometer "Beta", using the special spacer, allowing to spend measurements with identical geometry. Activity of samples counted under standards with known activity. Statistical calculations of results carried out standard methods, using software package STATGRAF.

Results and discussion

The basic quantity ^{137}Cs and ^{90}Sr was revealed in the top parts of a profile, despite distinctions in absorption of these radionuclides soil of columns different in a condition (tab. 1, 2). For columns of natural structure it is a layer of soil of 0-3 cm, for bulk it is little bit less - 0-2 cm. For the sample of natural structure with live roots there was characteristic a big prolixity of radionuclide concentrations on a profile, in comparison with columns with dead roots, whereas in soils of the broken structure it was absent at all and practically all ^{137}Cs and ^{90}Sr (more than 99 %) have been found in the upper layers.

Such distribution can be caused influence of biological factors: presence of live roots in a column and spending channels on courses of died roots.

In the first case the live roots located in the upper layer of soil absorb a part radionuclides. Further there is their redistribution on depth as a result of movement pollutants on spending systems of roots.

The overall picture of profile distribution radionuclides is logically supplemented with data under their maintenance in eluate. The concentrations of ^{137}Cs and ^{90}Sr in eluate various columns had different values. The column filled with soil of not broken structure with live roots was characterised by the greatest concentration of two radionuclides in eluate. Biologically active components of soil promoting movement pollutants were absent in other columns, therefore in them sorption was above.

Thus, in migration radionuclides a leading role plays structure of soil and porosity, and also root systems of live plants which promote carrying over radionuclide downwards on a soil profile. In columns with live roots about 3 % from total activity ^{137}Cs it is revealed in the vegetative residues, and about 6 % of ^{90}Sr. It is obvious, that prolixity of radionuclides on a soil profile appears in many respects thanks to movement on roots of plants (tab. 1,2).

Table 1

Migration ^{137}Cs in soil columns of various structure

Layer, cm	Soil of natural structure with live roots			Soil of natural structure after long storage in a dry condition			Bulk column (from the sifted sample, fraction of 1-2 mm)		
	Activity, Bq	% from the total activity	Specific activity, Bq/g	Activity, Bq	% from the total activity	Specific activity, Bq/g	Activity, Bq	% from the total activity	Specific activity, Bq/g
	Distribution in soil without root residue								
0-1	61650±7400	79,4	1480±480	76340±9160	94,3	1520±328	59450±4760	75,5	1620±190
1-2	1660±610	6,0	110±20	760±80	1,0	20±4,8	17620±1590	22,4	410±50
2-3	3000±240	3,9	80±6	83,5±7	0,1	2±1	220±20	0,3	6±1
3-10	799±100	1,0	4±0,5	113±21	0,1	0,4±0,1	370±50	0,5	1,3±0,3
	Distribution in the root residue								
0-1	4970±450	6,4	4760±430	3600±390	4,4	5125±50	0	0	0
1-2	310±45	0,4	270±25	80±11	0,1	40,6±3,8	0	0	0
2-4	78±10	0,1	30±3	0	0	0	0	0	0
	Concentration in eluate								
-	2200	2,8	-	0	0	-	1040	1,3	-
Σ	77667	100	-	80897	100	-	78700	100	-

Table 2

Migration ^{90}Sr in soil columns of various structure

Layer, cm	Soil of natural structure with live roots			Soil of natural structure after long storage in a dry condition			Bulk column (from the sifted sample, fraction of 1-2 mm)		
	Activity, Bq	% from the total activity	Specific activity, Bq/g	Activity, Bq	% from the total activity	Specific activity, Bq/g	Activity, Bq	% from the total activity	Specific activity, Bq/g
	Distribution in soil without root residue								
0-1	9370±850	45,7	223±37	14590	73,2	400±44	16010±1700	76,5	380±41
1-2	4210±510	20,6	100±13,5	3170	15,9	90±9	3700±240	17,7	105±15
2-3	1270±150	6,2	30±3	430	2,2	14±3	280±35	1,3	7±2
3-10	1770±130	8,7	6±1	680	3,4	4±0,4	750±83	3,5	2,7±1
	Distribution in the root residue								
0-1	1870±200	9,2	2050±220	420	2,1	1050±100	0	0	0
1-2	656±71	3,2	250±20	400	2,0	580±65	0	0	0
2-4	96±15	0,5	80±8	80	0,4		0	0	0
	Concentration in eluate								
-	1200±135	5,9	-	160	0,8	-	200	1,0	-
Σ	20442	100	-	19930	100	-	20940	100	-

The migration second for intensity ^{137}Cs there was a column with soil of the broken structure. We assume, that in this case the raised level of migration in comparison with soil of natural structure, but with dead roots, is caused by movement ^{137}Cs with structure of silt fraction of soil which usually takes place in bulk columns at the initial stages of a filtration and accompanied by occurrence of a visible suspension of soil particles in eluate.

Effect primary accumulation of pollutant on a surface of units of soil estimated on concentration coefficient (C_c). Concentration coefficient represents the ratio of the toxicant concentration (or activity of radionuclide in case of radioactive compounds) in any isolated soil component (aggregate surface, a fraction of certain aggregate size, plant residues, etc.) to the mean concentration (or activity) in that part of the soil from which the component is isolated. [5]. The effect of accumulation in relation to the average maintenance of substance is observed, when $C_c > 1$.

For an estimation of accumulation of radionuclides in a surface of aggregates experimental definition of specific activity of soil on a surface and in structural separateness is necessary. There are various ways removing of surface layers of soil aggregates from internal volume: mechanical stratification [6], washing out of freezing in liquid nitrogen aggregates by water on a sieve [7], or without frosts [5], stratification by means of a sticky tape [4], radioautography [5] and dry sorting on sieves. In the given research we have used the last method, as the most simple and indicative. For distribution studying pollutants at aggregate level soil units from various layers of soil columns divided by method of dry dispersion on corresponding sieve. According [5] it is possible to assume, that ^{137}Cs and ^{90}Sr at fresh pollution will concentrate in surface of soil units, without dependence from their sizes. In tables 3, 4, 5, 6 the given distributions ^{137}Cs and ^{90}Sr in layers of soil columns of 0-1 and 1-2 cm at aggregate level as these layers of soil have appeared the most activity are presented.

In a soil column treated by ^{137}Cs with dead roots the difference of ^{137}Cs concentration in layer of 0-1 and 1-2 cm has appeared about 100 times, while for a column with live roots - only 37 times. It specifies to the significance role of live roots in moving radionuclide on a soil profile. The greatest specific activity of ^{90}Sr and ^{137}Cs has been found out at the smallest fraction <0,5 mm. It speaks large a specific surface of this fraction. Radiocaesium in more degrees is fixed by small fractions of soil in comparison with ^{90}Sr since has not exchange type of absorption (tab. 3, 4, 5, 6).

Table 3

Specific ^{137}Cs activity of various on the size soil aggregates.
A column with soil of natural structure with live roots

Fraction of aggregates, mm	Depth of selection of the sample in a column			
	0-1 cm		1 - 2 cm	
	Specific activity, Bq/g, a_i	C_c*	Specific activity, Bq/g, a_i	C_c
> 10	510±62	0,35	58±6	0,53
5-10	405±35	0,27	73±4	0,66
3-5	885±68	0,60	74±9	0,67
2 - 3	1070±83	0,72	96±8	0,87
1-2	1310±140	0,89	111±17	1,01
0,5 - 1	2090±250	1,41	148±29	1,35
<0,5	4090±270	2,76	210±33	1,91
$a_{av.}$ (average)	1480±480	-	110±20	-

* In tables 3 - 6 $C_c = a_i / a_{av}$

Table 4

**Specific ^{137}Cs activity of various on the size soil aggregates.
A column with soil of natural structure after long storage**

Fraction of aggregates, mm	Depth of selection of the sample in a column			
	0-1 cm		1 - 2 cm	
	Specific activity, Bq/g, a_i	C_c	Specific activity, Bq/g, a_i	C_c
> 10	240±23	0,16	3±1	0,15
5-10	790±90	0,52	13±2	0,65
3-5	1270±140	0,84	15±1	0,75
2 - 3	1500±170	0,99	20±3	1,00
1-2	1730±200	1,14	21±4	1,05
0,5 - 1	2320±230	1,53	24±2	1,20
<0,5	2790±280	1,84	44±5	2,20
$a_{av.}$ (average)	1520±328	-	20±4,8	-

Table 5

**Specific ^{90}Sr activity of various on the size soil aggregates.
A column with soil of natural structure with live roots**

Fraction of aggregates, mm	Depth of selection of the sample in a column			
	0-1 cm		1 - 2 cm	
	Specific activity, Bq/g, a_i	C_c	Specific activity, Bq/g, a_i	C_c
> 10	88±10	0,40	30±3	0,30
5-10	116±9	0,52	77±8	0,77
3-5	196±25	0,88	105±9	1,05
2 - 3	241±21	1,08	112±13	1,12
1-2	252±19	1,13	130±15	1,30
0,5 - 1	320±27	1,44	116±15	1,16
<0,5	348±43	1,56	130±10	1,30
$a_{av.}$ (average)	223±36,7	-	100±13,5	-

Table 6

**Specific ^{90}Sr activity of various on the size soil aggregates.
A column with soil of natural structure after long storage**

Fraction of aggregates, mm	Depth of selection of the sample in a column			
	0-1 cm		1 - 2 cm	
	Specific activity, Bq/g, a_i	C_c	Specific activity, Bq/g, a_i	C_c
> 10	325±38	0,81	75±7	0,83
5-10	233±32	0,58	58±4	0,64
3-5	383±24	0,96	67±7	0,74
2 - 3	392±29	0,98	92±15	1,02
1-2	383±43	0,96	100±12	1,11
0,5 - 1	476±53	1,19	113±12	1,26
<0,5	608±71	1,52	125±20	1,39
$a_{av.}$ (average)	400±44	-	90±9	-

Specific surface of these fractions considerably above, than at the others and concentration coefficient above by all experiences. This circumstance testifies about surfacing accumulation radionuclides by soil fractions.

Conclusions

1. Mobility ^{137}Cs and ^{40}Sr in soddy-podzolic silt soil is defined by its condition. Migration of these radionuclides in bottom layers of a soil profile above in not broken soil with live roots, hence roots of plants promote migration radionuclides downwards on a soil profile. Nevertheless, basic part pollutants remains in the upper layer of soils of 0-1 cm in not to dependence on their structure and presence of live roots of plants.

2. The small fraction of soil units <0,5 mm thanks to the greatest specific surface possesses the biggest specific activity in comparison with other larger fractions that confirms primary absorption radionuclides with a surface of soil aggregates.

Summary

Vertical migration of fresh contamination soils by radionuclides is defined by presence of live roots of plants in soil weight. Originally radionuclides are localised on surfaces of soil aggregates and in upper soil layers basically in 0-1 cm.

Bibliography

1. *Alexakhin R.M.* **Problem of radioecology: Evolution of ideas. Results. M: RIARAE, 2006.**

2. *Kruglov S. V., Vasileva N.A., Kurinov A.D., Aleksakhin R.M.* **Distribution of radionuclides Chernobyl contaminations on structure fractions of soddy-podzolic soils // Pochvovedenie. 1995. №5. P. 551-557.**

3. *Targuljan V. O, Sokolov T.A., Birina A. G., Kulikov A. V., Celischeva L.K.* **Organisation, structure and genesis of demovo-palevo-podzolic soil on integumentary loams. Analytical research. The X Int. congress of soil scientists. M., 1974.**

4. *Fokin A.D., Torshin S.P.* **Primary gradients of concentration and dynamics of a condition radionuclides in soils (on an example of ^{137}Cs). Int. seminar «Radioecology of a Chernobyl zone». Slavutich, 27-29 sept., 2006. P. 144-147.**

5. *Fokin A.D., Torshin S.P., Kaupenjohann M.* **An initial distribution of pollutants at aggregate and profile levels of soils. Int. conf. Biogeography of soils. Syktyvkar, 2002. P. 49-50.**

6. *Horn R.* **Die bedeutung der aggregierung fur die nahrstoffsorption in boden. Z. Pflanzenerenahr. Bodenk, 1987. V. 150. P. 13-16.**

7. *Kayser A.T., Wilcke W., Kaupenjohann* M, *Joslin J.D.* **Small scale heterogeneity of soil chemical properties. I A technique for rapid aggregate fractionation. Z. Pflanzenerenahr. Bodenk, 1994. V.157. P. 453-458.**