РАДИОЭКОЛОГИЯ. ЭКОЛОГИЧЕСКИЙ МОНИТОРИНГ

GENERAL REGULARITIES OF ^{90}SR DISTRIBUTION IN SYSTEM SOIL–PLANT UNDER NATURAL CONDITIONS

Gudelienė I.[1], Marčiulionienė D.[1], Petrošius R.[2]

[1]Institute of Botany, Vilnius, Lithuania, radeko@ar.fi
[2]Institute of Geology and Geography, Vilnius, Lithuania

^{90}Sr distribution in system „soi l –underground part of plant – aboveground part of plant" was investigated. It was determined that ^{90}Sr activity concentration in underground and aboveground part of plants and in mosses was not dependent on its activity concentration in soil. There was direct dependence of ^{90}Sr activity concentration in aboveground on underground parts of plants. ^{90}Sr transfer factor from soil to underground part of plants and mosses was directly dependent on this radionuclide activity concentration in them.

INTRODUCTION

^{90}Sr is one of the most toxic technogenic radionuclides. It gets into the plants in two ways: from atmosphere depositions through aboveground parts of plants and through roots from soil, within water and other mineral substances. The amount of ^{90}Sr which gets into plant from atmosphere is less up to 200 times than its intake from soil, therefore in field researches the amount of this radionuclide intake from the atmosphere usually is considered as insignificant [1].

^{90}Sr distribution in system soil–plant is affected by many factors: such as ionic capacity and moisture of soil, distribution of plants rootage zone in soil, different mineral nutrition of plants, competitive relationships between plants and etc. According to many authors, from 30 to 90 percent of ^{90}Sr in soil is in easily assimilating form. Therefore, this radionuclide takes part in metabolism of plants, integrates in their tissues, and can negatively affect whole plant [2, 3]. Thus, the assessment of radiation influence on nature is one of the most important goals of radioecological researches.

The researches of ^{90}Sr distribution in system soil–plant ordinary cover only analysis of this radionuclide mobility in soil or investigations of ^{90}Sr distribution in system soil–aboveground part of plant [4, 5], It is not enough attention paid to this radionuclide accumulation in underground part of plant.

The main aim of present work – to assess ^{90}Sr activity concentration in underground and aboveground parts of treated plants species from different biotopes and in soil of their habitats; to determine the accumulation of this radionuclide in plants in dependence on ^{90}Sr activity concentration in soil, on mineral matter content in plants and on their roots type; to estimate general regularities of ^{90}Sr distribution in system „soil–underground part of plant–aboveground part of plant".

MATERIALS AND METHODS

Samples of underground and aboveground parts of plants and soil of their habitats were collected in 2002, in National parks of Lithuania. Samples were collected in three different biotopes: forest (*Vaccinium myrtillus* L.*, Calamagrostis arundinacea* (L.) Roth.*, Hylocomium splendens* (Hedw.) Shimp), grassland (*Hypericum perforatum* L.*, Dactylis glomerata* L., *Amblystegium serpens* (Hedw.) Schimp. *Campylium protensum* (Brid.) Kindb.) and wetland (*Calluna vulgaris* (L.) Huul*, Ledum palustre* L.*, Sphagnum* sp.). Samples were dried in the room temperature (~20 °C) and burned at 610°C. Mineral matter content coefficient in underground and aboveground parts of plants and in soil was evaluated – it is the ratio of dry/ash weight, expressed in relative units (rel. unt.); the higher coefficient value, the less mineral matter content in sample.

^{90}Sr extraction was performed by radiochemical method [6], and its activity was measured by liquid scintillation spectrometer (Tri-Carb 3170TR/SL, registration efficiency – 37,2%). ^{90}Sr activity concentration was expressed in Bq/kg dry weight (d.w.). ^{90}Sr transfer factor in system „soil–underground part of plant–aboveground part of plant" was evaluated (the ratio of ^{90}Sr activity concentration in underground part of plants or mosses and in soil; and the ratio of ^{90}Sr activity concentration in aboveground part of plants and in underground part of plants, expressed in rel. unt.).

RESULTS AND DISCUSSION

The investigation of ^{90}Sr accumulation and distribution in system „soil–underground part of plant–aboveground part of plant" under natural conditions showed that ^{90}Sr activity concentration in soil varied from 0.7 to 20.9 Bq/kg d. w. The highest this radionuclide activity concentration in soil was in wetland biotope. It was 17.5-30.0 times higher than ^{90}Sr activity concentration in

soil of forest and grassland biotopes, which were similar with average value close to one (Table 1). High organic matter content in soil of wetland biotope could affect the ^{90}Sr activity concentration in it, because this radionuclide adsorbs to organic part of soil rather than to mineral part [7]. ^{90}Sr activity concentration in soil depended on mineral matter content in it (R^2 = 0.92).

Table 1

^{90}Sr activity concentration in underground and aboveground parts of plants and in soil of their habitats from different biotopes (g/kg d. w.) and their mineral matter content coefficients (relative unit)

Species	Soil of habitats		Underground part of plant		Aboveground part of plant	
	^{90}Sr activ. conc.	Min. matter cont. koef.	^{90}Sr activ. conc.	Min. matter cont. koef.	^{90}Sr activ. conc.	Min. matter cont. koef.
FOREST BIOTOPE						
Hylocomium splendens	1.1	1.3	–	–	12.4	28.0
Calamagrostis arundinacea	1.2	1.1	2.1	62.4	6.6	18.9
Vaccinium myrtillus	1.1	1.2	1.4	63.1	16.5	32.4
GRASSLAND BIOTOPE						
Grassland mosses	1.0	1.1	–	–	30,2	9.6
Dactylis glomerata	1.0	1.1	5.0	2.7	9.3	12.2
Hypericum perforatum	0.7	1.1	3.2	23.3	28.3	30.5
WETLAND BIOTOPE						
Sphagnum sp.	20.9	9.2	–	–	4.2	45.2
Calluna vulgaris	20.9	6.5	2.5	105.8	15.1	38.0
Ledum palustre	20.9	10.0	2.3	109.1	5.8	62.9

There was no dependence of ^{90}Sr activity concentration in underground and aboveground part of plants and in mosses on this radionuclide activity concentration in soil. (R^2 = 0.012, R^2 = 0.084 ir R^2 = 0,247, respectively). W. Shimmack et. al. [8] also did not determine dependence of ^{90}Sr activity concentration in plants on this radionuclide activity concentration in soil. Thus, it is appealing to suggest that there is regulating processes in plants, that control intake of ^{90}Sr. Beside, the dependence of ^{90}Sr activity concentration in plants on it activity concentration in soil can be influenced of different environmental conditions and factors – such as ionic capacity and moisture of soil, different mineral nutrition of plants, competitive relationships between plants and etc.

The results of investigation of ^{90}Sr distribution in plants showed, that activity concentration of this radionuclide in aboveground part of plant varied to 7.2 times, while in underground part – to 3.6 times. The highest ^{90}Sr activity concentration was determined in plants of grassland biotope: in underground part – in *D. glomerata*, and in aboveground part – in grassland mosses, respectively 5.0 and 30.2 Bq/kg d. w. (Table 1). ^{90}Sr activity concentration in plants of forest and wetland biotopes was quite similar. Also R. Dušauskienė Duž [9] determined that ^{90}Sr activity concentration in plants of grassland biotope is higher in comparison to other treated plants. These data point out, that ^{90}Sr activity concentration in plants is influenced by both plant species and its growth biotope.

The ^{90}Sr activity concentration in aboveground part of plants was 5.7 times higher than in underground part. The proportion of ^{90}Sr activity concentration in aboveground and underground parts of plants depended on plant species and varied from 1.8 (*D. glomerata*) to 11.6 (*V. myrtillus*) times. The ^{90}Sr activity concentration in underground part of plants with taproots (*H. perforatum, V. myrtillus, C. vulgaris, L. palustre*) and fibrous roots (*C. arundinacea, D. glomerata*) were similar. The activity concentration of this element in aboveground part of plants with taproots was 2.1 times higher than in these with fibrous roots. Thus, ^{90}Sr accumulation in aboveground part of plant may be influenced by the root type of the plant. There was determined the direct dependence of ^{90}Sr activity concentration in aboveground on underground parts of plants in both plants with taproots and fibrous roots (R^2 = 0.62 ir R^2 = 0.62, respectively).

The mineral matter content coefficients in Table 1 demonstrate that in both, underground and aboveground parts of plants, mineral matter content was the highest in treated plants of grassland biotope and the lowest in plants of wetland biotope. That kind of differences in mineral matter content in plants may be determined by different environmental conditions and different properties of plants – most of the treated plants in grassland biotope were grassy and in wetland biotope – ligneous plants. It is known that mineral matter content in plants leaves is higher than that in lignified part. It was determined the direct dependence between ^{90}Sr activity concentration in aboveground part of plants, with both, taproots and fibrous roots, and in mosses on the mineral matter content in them (R^2 = 0.75, R^2 = 0.62 ir R^2 = 0.66, respectively). Such dependence was not determined in underground part of treated plants (R^2 = 0,17). The dependence of ^{90}Sr activity concentration in underground part of plants on their mineral matter content may be affected by soil adhered to roots.

^{90}Sr transfer factor in system „soil–underground part of plant–aboveground part of plant" was reliant on plants species. This radionuclide transfer factor from soil to mosses varied from 0.2 to 31.0, this factor from soil to underground part of plant – varied from 0.1 to 4.6 and transfer factor from underground to aboveground part of plant – from 3.8 to 17.8 rel. unt. Both, ^{90}Sr transfer factor from soil to underground part of plant and this factor from underground to aboveground part of plant, was the least in *L. palustre*. The least this factor from soil to mosses was in *Sphagnum sp*. The highest ^{90}Sr transfer factor from soil to mosses was determined in grassland mosses, from soil to underground part of plant – in *H. perforatum* and *D. glomerata*, from underground to aboveground part of plant – in *V. myrtillus* (Fig. 1). These data point out, that ^{90}Sr transfer factor in system „soil–underground part of plant–aboveground part of plant" is much more influenced by plant species than by growth biotope.

^{90}Sr transfer factor from soil to underground part of plants and to mosses was directly dependent on this radionuclide activity concentration in them. In case of ^{90}Sr transfer factor from underground part of plant to aboveground part of plants such dependence was not determined (Fig. 2). There was no correlation between ^{90}Sr transfer factor in system „soil–underground

part of plant–aboveground part of plant" and this radionuclide activity concentration in soil, as well as ^{90}Sr transfer factor in treated system was not dependent on mineral matter content in plants and soil.

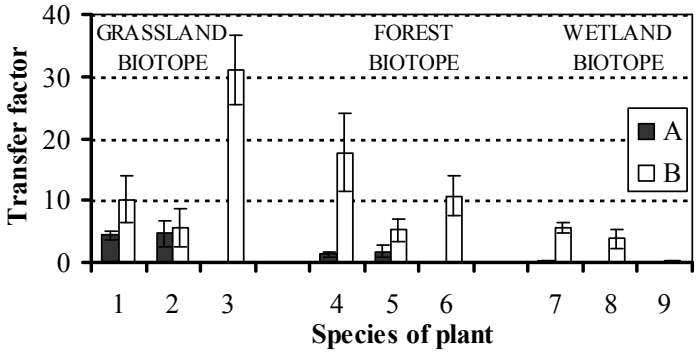

Fig. 1. The transfer factor of ^{90}Sr in system soil–underground part of plant–abovegroud part of plant from different biotopes: 1 – Hypericum perforatum; 2 – Dactylis glomerata; 3 – Grassland mosses; 4 – Vaccinium myrtillus; 5 – Calamagrostis arundinacea; 6 – Hylocomium splendens; 7 – Calluna vulgaris; 8 – Ledum palustre; 9 – Sphagnum sp.; A – underground part of plant; B – aboveground part of plant

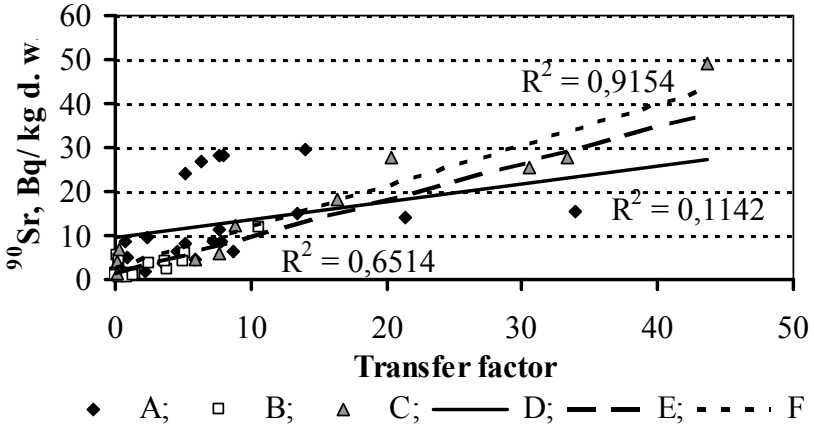

Fig. 2. The dependence of transfer factor of ^{90}Sr in plants on ^{90}Sr activity concentration in them: A – aboveground part of plants; B – underground part of plants; C – mosses; D – linear (aboveground part of plants); E – linear (underground part of plants); F – linear (mosses)

CONCLUSIONS

The investigation of ^{90}Sr distribution in system „soil – underground part of plant – aboveground part of plant" revealed that: ^{90}Sr activity concentration in soil depended on mineral matter content in it.

There was no dependence of ^{90}Sr activity concentration in underground and aboveground part of plants and in mosses on this radionuclide activity concentration in soil. There was direct dependence of ^{90}Sr activity concentration in aboveground on underground parts of plants. ^{90}Sr activity concentration in aboveground part of plants depended on their mineral matter content.

^{90}Sr transfer factor from soil to underground part of plants and to mosses was directly dependent on this radionuclide activity concentration in them. In case of ^{90}Sr transfer factor from underground part of plant to aboveground part of plants such dependence was not determined. ^{90}Sr transfer factor in treated system was not dependent on this radionuclide activity concentration in soil and on mineral matter content in underground and aboveground parts of plants and soil.

REFERENCES

1. Malek, M. A., Hinton, T. G., Webb, S. B. A Comparison of ^{90}Sr and ^{137}Cs Uptake in Plants Via Three Pathways at Two Chernobyl-Contaminated Sites. Environmental Radioactivity. – 2002. – 58(2–3). – P. 129–141.

2. Dušauskienė, Duž R. Biological Factors Determining ^{90}Sr Accumulation in Land Plants. Environmental and Chemical Physics. – 1999. – 21(3-4). – P. 30–35.

3. Tyson, M. J., Sheffield, E., Callaghan, T. V. Uptake, allocation, accumulation and ecological implications of ^{85}Sr in bracken (Pteridium aquilinum (L.) Kuhn). Environmental Radioactivity. – 1999. – 46(1). – P. 15–25.

4. Tsukada, H., Takeda, A., Takahashi, T., et. al. Uptake and Distribution of ^{90}Sr and Stable Sr in Rice Plants. Environmental Radioactivity. – 2005. – 81(2–3). P. 221–231.

5. Forsberg, S., Rosén, K., Bréchignac, F. Chemical Availability of ^{137}Cs and ^{90}Sr in Undisturbed Lysimeter Soils Maintained under Controlled and Close-to-Real Conditions. Environmental Radioactivity. – 2001. – 54(2). –P. 253–265.

6. Suomela, J. Methods for Determination of Strontium-90 in Food and Environmental Samples by Cerenkov Counting. SSI-rapport 93-11, Swedish Rad. Prot. Inst., 1993.

7. Wang, G., Staunton, S. Evolution of Sr Distribution Coefficient as a Function of Time, Incubation Conditions and Measurement Technique. Environmental Radioactivity. – 2005. – 81(2–3). P. 173–185.

8. Schimmack, W., Kracke, W., Sommer, M. Spatial Variability of Fallout-^{90}Sr in Soil and Vegetation of an Alpine Pasture. Environmental Rad. – 2003. – 65(3). P. 281–296.

9. Dušauskienė, Duž R., Marčiulionienė, D. Technogenic Radionuclide Accumulation in Aquatic and Terrestrial Plants. Envir. and Chemical Physics. – 2004. – 26 (3). –P. 129–137.

ОСОБЕННОСТИ РАСПРЕДЕЛЕНИЯ ^{90}Sr В СИСТЕМЕ ПОЧВА–РАСТЕНИЕ В НАТУРАЛЬНЫХ УСЛОВИЯХ

Гуделене И., Марчюленене Д., Петрошиус Р.

Было изучено распределение ^{90}Sr в системе «почва – подземная часть растения – надземная часть растения». Установлено, что удельная активность ^{90}Sr в подземной и надземной частях исследованных растений, а также во мху не зависела от удельной активности этого радионуклида в почве. Между удельной активности ^{90}Sr в подземной и надземной частях растений установлена прямая пропорциональность. Коэффициент накопления ^{90}Sr из почвы в подземную часть растений и в мох был прямопропорционален удельной активности этого радионуклида в исследованных растениях.

INVESTIGATION OF PLUTONIUM BEHAVIOUR IN ARTIFICALLY CONTAMINATED SOIL

Lukšienė B., Druteikienė R.

Institute of Physics, Vilnius, Lithuania, bena@ar.fi.lt

The vertical migration and transformation of plutonium chemical forms artificially supplied to sandy loam columns after its exposure to natural conditions for about one year was investigated. An analysis of artificially contaminated samples after one year had shown that 81% of $^{239}Pu^{4+}$ and 44% of $^{239}Pu^{3+}$ were accumulated in the 0-5 cm layer of sandy loam. The data of sequential analysis of the same type of soil at the adequate artificial contamination level after one month exposure under laboratory conditions are presented as well. ^{239}Pu binding to soil geochemical fractions was rather uneven. The largest amount of ^{239}Pu (60 %) was determined in the residual fraction. Consequently, it can be assumed that organic substances and some inorganic compounds, which usually are the main components of a residual fraction, affects the retention and migration of plutonium in the soil.

Investigation of plutonium as most hazardous and radiotoxic element behavior in the environment from radioecological and geophysical point of view is of particular concern. The diversity of the chemical forms being released form different sources – from insoluble oxides to soluble inorganic salts and organic complex compounds – is characteristic for plutonium. Because of the high temperature during the nuclear explosion, insoluble plutonium oxides, mixtures of oxides or compounds with the constructive elements ($PuO_x \cdot MO_x$; $PuO_x \cdot U_3O_8$) are predominant. The soluble forms of plutonium ($PuO_x \cdot nH_2O$; $Pu(NO_3)_x$, Pu organic complex compounds) are basically released to the environment from the nuclear technological cycle (1, 2). The physico-chemical forms of released radionuclides determine their interactions with soils and, thus, the degree to which soils can act as a sink or a diffuse source of contaminants (3)

Processes of migration and accumulation of plutonium in that environmental system are in tide connection with the stability and transformation of it chemical compounds because of a reciprocity between components of investigative soil and plutonium chemical species (4-7).

The aim of the present study was to determine vertical migration of ^{239}Pu in artificially contaminated sandy loam depending on the radionuclide initial chemical form and to evaluate ^{239}Pu binding to soil geochemical fractions.

MATERIAL AND METHODS

Three series of field experiments with three columns of non-destroyed sandy loam were carried out. Experiments were designed as follows: the plastic columns (diameter-10cm, length-20cm) were stuck into the soil at all length. The sandy loam surface in a separate column was artificially contaminated with ^{239}Pu (30 Bq) in the form of $^{239}Pu(NO_3)_4$, $^{239}PuCl_3$ or $^{239}PuO_2$. The arranged experimental system retained the original microbiological and mechanical properties of soil. The interaction and vertical migration of added Pu species (III, IV) in a sandy loam has been followed as a function of contact time (326 days).After exposition each column was divided into 4 layers (5cm). The soil was dried at room temperature, the plants and roots were separated from soil. The soil was precisely ground and mixed. The amount of organic matter in the soil sample was obtained by a loss-on-ignition analysis (550°). The soil reaction (pH) was measured with a glass electrode in the 25 ml 1M KCl solution