SITUAÇÃO DE RADIAÇÃO EM TERMOS DA PRESENÇA DE ^{90}SR E ^{137}CS NA REPÚBLICA DE ALTAI

RADIATION AMBIANCE ON THE CONTENT OF ^{90}SR AND ^{137}CS IN THE REPUBLIC OF ALTAI

РАДИАЦИОННАЯ ОБСТАНОВКА ПО СОДЕРЖАНИЮ ^{90}SR И ^{137}CS В РЕСПУБЛИКЕ АЛТАЙ

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RESUMO

A contaminação radioativa é considerada como contaminação física, uma vez que a introdução de uma fonte de energia em um ambiente se manifesta em um desvio da norma de suas propriedades físicas. As substâncias radioativas depositadas na superfície do solo podem se mover na direção horizontal e vertical sob a ação de vários processos. Como resultado, o solo, corpos d'água e as plantas acumulam substâncias perigosas, que também podem entrar no corpo humano. Portanto, o objetivo principal do estudo é determinar a situação de radiação no que diz respeito a conteúdo de ^{90}Sr e ^{137}Cs na República de Altai. Mais de 100 fatias de solo e cerca de 50 espécies de plantas foram estudadas para o estudo. Os autores apresentaram dados sobre o conteúdo de radionuclídeos artificiais (^{137}Cs, ^{90}Sr) no sistema solo-planta. A concentração de nuclídeos em diferentes tipos de solos, desenvolvidos sob condições de zoneamento vertical, foi determinada. O acúmulo de elementos radioativos pelas plantas depende do seu conteúdo no solo, do tipo e das propriedades dos solos e das espécies de plantas. Foi estabelecido que o conteúdo de ^{137}Cs e ^{90}Sr no sistema solo-planta na área de estudo é fixado em ou abaixo dos valores máximos admissíveis.

Palavras-chave: *coeficiente de acumulação, radiostrontium, radiocesium, circulação biológica, condições de paisagem e geoquímicas.*

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ABSTRACT

Radioactive contamination refers to the physical contamination, since the introduction into the environment of a source of energy, manifested in a deviation from the norm of its physical properties. Radioactive substances deposited on the soil surface can move in the horizontal and vertical direction under the action of various processes. This leads to the accumulation of hazardous substances in the soil, waterbodies, plants, which enter the human body. Therefore, the main objective of the work is to determine the radiation ambiance on the content of ^{90}Sr and ^{137}Cs in the Altai Republic. More than 100 soil sections and about 50 plant species were analyzed for the study. The authors represented the data on the content of artificial radionuclides (^{137}Cs, ^{90}Sr) in the soil-plant system. The content of nuclides in different types of soils developed under the conditions of vertical zonation has been determined. The accumulation of radioactive elements by plants depends on their content in soils, the type of soil, and properties of soils, and the species of plants. It has been established that the content of ^{137}Cs and ^{90}Sr in the soil-plant system of the unexplored territory is fixed at the level and below the limit permissible values.

Keywords: *accumulation coefficient, radiostrontium, radiocesium, biological circulation, landscape-geochemical conditions.*

АННОТАЦИЯ

Радиоактивное загрязнение относят к физическому загрязнению, поскольку привнесение в окружающую среду источника энергии, проявляющееся в отклонении от нормы ее физических свойств. Радиоактивные вещества, отложившиеся на поверхности почвы, могут перемещаться в горизонтальном и вертикальном направлении под действием различных процессов. Это приводит к накоплению опасных веществ в грунте, водных объектах, растениях, которые попадают и в организм человека. Поэтому основная цель работы заключается в определении радиационной обстановки по содержанию ^{90}Sr и ^{137}Cs в Республики Алтай. Для исследования было изучено более 100 почвенных срезов и около 50 видов растений. Авторами представлены данные о содержании искусственных радионуклидов (^{137}Cs, ^{90}Sr) в системе почва-растение. Определено содержание нуклидов в разных типах почв, развитых в условиях вертикальной поясности. Накопление радиоактивных элементов растениями зависит от содержания их в почвах, типа и свойств почв и видовых принадлежностей растений. Установлено, что содержание ^{137}Cs и ^{90}Sr в системе почва-растение не изучаемой территории фиксируется на уровне и ниже предельно допустимых значений.

Ключевые слова: *коэффициент накопления, радиостронций, радиоцезий, биологический круговорот, ландшафтно-геохимические условия.*

INTRODUCTION

Radioactivity and attendant to it ionizing radiation are not new phenomena. They existed long before the birth of life on Earth and were present in space before the appearance of the planet itself. Living organisms receive the main part of the irradiation from the natural radiation, the sources of which are natural formations, as well as the industrial enterprises which are leading the extraction and deep processing of ores, and CHP plants operating on coal, combustible shale and peat with a high content of radioactive elements. The development of the atomic industry and atomic energy, the testing of nuclear weapons lead to the fact that radioactive substances become components that pollute the environment, and their ionizing effect acts as a negative of environmental factor (Daus and Kharchenko, 2018; Yergobek *et al.*, 2018).

The behavior of radioactive elements and their compounds in ecosystems is diverse and difficult. Once the radionuclides fall into in the atmosphere and on the earth's surface, they migrate, joining into the biological cycle of the circulation of substances.

The greatest biogeochemical interest among long-lived radionuclides is the behavior of ^{137}Cs and ^{90}Sr as indicators of past radioactive pollution of the environment associated with testing nuclear devices. Radioactive strontium undergoes β-decay, consistently forming radioactive yttrium and stable zirconium. Radiostrontium is biologically dangerous, affects bone tissue and bone marrow, being an analog of calcium. The radiocaesium beta and gamma emitter, a daughter nuclide of radioactive iodine, decays to stable barium. Cesium interacts with rubidium and potassium, easily replacing them in compounds (Moiseev and Ramzaev, 1975).

The migration paths of nuclides depend on the natural and climatic conditions of the region and the physicochemical properties of the soil. The heterogeneous lithochemical composition of Mountain Altai predetermined the initial spatial diversity in the content of radioactive elements in soils. Climate plays an important role in the redistribution of artificial radionuclides. In Northern Altai, the climate is milder and more humid than in other parts of the mountainous country, which favors the formation of forest vegetation and soils with a wash type of water regime, which ensures the migration of elements. The climate of the South-Eastern Altai is dry and sharply continental. It contributes to the development of dry-steppe vegetation and soils with a non-flushing type of water regime. Central Altai is climatically diverse. Here various soils with different properties are formed, which is reflected in the behavior of technogenic radioactive elements (Modina, 1997).

Vegetation plays a prominent role in the circulation of radionuclides. The directivity of soil formation and the movement of elements in the soil stratum depend on it. In the vegetation cover of Mountain Altai, vertical zonality is clearly expressed. With the height of the terrain, the kinds of vegetation are successively replaced: steppe, forest, and high-mountain (alpine) (Kuminova, 1960).

Vertical zonality is inherent in the soil cover of the Mountain Altai. Depending on the height and exposure of the slopes, mountain-tundra, mountain-meadowб and mountain-meadow-steppe soils, which conjunction with the high-mountains (1600–3500 m), were formed here; mountain-forestry soils, covering the heights of 600-2500 m; forest-steppe, which are occupying the heights less than 600 m above sea level. In addition to the vertical zones in the study area, inter-zones areas (intermontane basins and river valleys) with steppe soils are distinguished (Kovalev, 1973).

On the territory of the Republic of Altai, studies on the ^{137}Cs content in environmental objects have been carried out for many years. Radiostrontium is less studied.

The assessment of the prevailing ecological-geochemical situation with respect to artificial radioactive elements in the Altai Republic is of great theoretical and applied importance.

METHODOLOGY

Studies on the content of long-lived radioactive elements (strontium-90 and cesium-137) in environmental objects were carried out throughout the whole Mountain Altai. The material was collected in the period from 2004 to 2018 during the complex expeditions. More than 100 soil sections, about 50 plant species from more than 20 families, were examined for the content of radioactive elements.

The field work consisted of routing surveys of the soil cover and included the following stages: selection of the location of the lay of the geomorphological profile (catena), selection of the points of sampling, make sampling. In the geomorphological profile, all elements were studied – a watershed (mountain tops), slopes, terraces, floodplains of the rivers.

The virgin lands have more informativeness about the pollution caused by technogenic radionuclides. Soil samples were selected by layers every 5 cm (from the upper horizons) and lower along the genetic horizons. If soil studies on nuclide content were carried out on arable land, then one sample was taken at each point till the depth of plowing (0-20 cm).

To assess the radiation situation on the territory of the Altai Republic, ^{137}Cs and ^{90}Sr activities were studied in the soils of the low-mountains, middle-mountains and high-mountains of the region (mountain-tundra, mountain-taiga, mountain-meadow, mountain-meadow-steppe, mountain-forestry gray, mountain-forestry brown, mountain-forestry chernozem-like, mountain-forestry sod-deeply-podzolic, and also the soils of intermountain hollows and river valleys – ordinary chernozem, southern and chestnut soils). In addition, the migration ability of nuclides in the soil-plant system was investigated.

Samples of soil, aerial mass and plant roots were dried to the air-dried state. Movable forms of radionuclides from soil samples were extracted with distilled water and with 1N solution of CH_3COONH_4 (Moiseev and Ramzaev, 1975). To calculate the accumulation coefficients (CA) and proportionality (Cp), data on the content of radioactive elements in the corresponding soils (at a depth of 0-25 cm) were used.

Soil properties were determined by generally accepted methods (Arinushkina, 1970), the content of radioactive elements was determined by gamma spectrometry at the Gamma Plus universal spectrometry complex (Methods of measuring…, 2003).

RESULTS AND DISCUSSION:

The climatic and landscape-geochemical conditions of the study area largely determined the present density of the distribution of radionuclides in the environment of the region (Pavlotskaya, 1974).

The holistic picture of the migration of ^{90}Sr and ^{137}Cs on the territory of the Republic of Altai allows compiling a long-term study of their behavior in the soil cover, using the catena method (Moiseev and Ramzaev, 1975; Modina, 1997; Kuminova, 1960; Soils…, 1973; Arinushkina, 1970; Methods of measuring…, 2003).

The variability of the spatial distribution of the density of radioactive contamination of the soils of the Altai Republic is explained by the diversity of its natural zones (Malgin, 2000; Puzanov, 2000; Aleinikova, 2000; Kuznetsova, 2000; Kuznetsova, 2001; Kuznetsova, 2002). The contamination density of ^{90}Sr and ^{137}Cs of the studying soils of the Altai Republic is contrast: for ^{90}Sr – from 8 to 42 mKu/km^2, for ^{137}Cs – from 15 to 62 mKu/km^2 (Table 1).

In assessing the contamination of the investigated territory adhered to the magnitude of global background, determined for the Altai Territory and the Altai Republic at 56-60 mKu/km^2 (Silantyev, 1983).

Local contamination by ^{137}Cs, exceeding the global background was detected only in some places of the region. As a rule, the points with the maximum values of the nuclide activity are located on the tops of the ridges and along the edges of the hollows. Radiostrontium is contained in soils at the level of background. Stocks of radioactive elements vary considerably in the soils of one natural zone of the Altai Mountains Country. In the soils of high-mountains and humid landscapes, the activity of nuclides is quite high. The soils of the bottoms of dry steppe hollows and river valleys contain minimal concentrations of ^{137}Cs and ^{90}Sr. The present situation of the spatial distribution of ^{90}Sr and ^{137}Cs in the soils of the studied territory is presented in Figures 1-2. The obtained data are recalculated according to the law of radioactive decay until 2023.

More than sixty years have passed since most of radionuclides hit the soil of the Altai Republic (Malgin, 1995; Dubasov, 1994). With a long stay of radioactive elements in the soil, their forms are redistributed. Radionuclides become less mobile due to their strong binding to the clay minerals of the soil (Pavlotskaya, 1974; Polyakov, and Kader, 1971). The processes of precipitation and ion exchange also impede their movement along the soil profile. The mechanisms and speed of redistribution of mobile, exchangeable, and related forms of nuclides are different (Pavlotskaya, 1974; Gulyakin, 1962). In the studied soils of the Altai Republic in the period from 2004 to 2018, was determined the decreasing in the content of movable ^{137}Cs by almost in 2 times and insignificantly for 90Sr (Figure 3). The average content of movable radionuclides in this time interval is up to 4% for ^{137}Cs and up to 20% – for ^{90}Sr. It can be assumed that radiostrontium with time in smaller quantities transfers to the firmly fixed condition, than ^{137}Cs.

The ratio between the water-soluble, exchange, and non-exchange states of the studied radionuclides vary in soils of the same type and for an individual nuclide in the soils, which are different by composition (Figure 4). In most cases, the average content of water-soluble forms of ^{90}Sr in soils is higher, than ^{137}Cs. The percentage of movable nuclides increases from heavy loamy soils to light loamy soils. The sorption of long-lived radionuclides is influenced by the content in the soils of mobile calcium and potassium ions associated with ^{90}Sr and ^{137}Cs respectively. With an increase in their concentration in an aqueous soil solution, the amount of radionuclides bound by the solid phase of the soil decreases (Figure 5).

The mechanism of migration, diffusion and convective transfer over the soil profile of radionuclides depends on the physicochemical properties of the soil, the type of soil formation and the position of the soil in the landscape (Pavlotskaya, 1974; Perelman, 1966). Intra-profile distribution ^{137}Cs and ^{90}Sr studied in several hundreds of soil cuts on virgin soil and arable land (Figure 6). The behavior of nuclides in the soil profile depends on their genesis. Homogeneous and flooded peaty soils of high-mountains and middle-mountains of the Altai Republic differ more uniformly distributed of ^{90}Sr

by the depth of profile. In sod-podzolic and leached chernozem, nuclide migrates till the upper part of the alluvial horizon.

In the soils of the intermontane hollows and river valleys of the high-mountains the radiostrontium is retained in the upper layer of the soil horizon, and on the saline plots in the salt crust. In chestnut soils of high-mountain steppes, with a poorly developed sod layer due to deflation weathering, the reserves of ^{90}Sr are insignificant.

In mountain-forest soils (gray, brown, chernozem-like) there is also an ambiguous pattern of its distribution along the profile. Despite the slightly acidic reaction of the soil solution of mountain-meadow and meadow-steppe soils of high-mountains, characterized by an unsaturated absorbed complex due to the conditions of the flushing mode, the radionuclide is concentrated in the upper 10 cm layer.

Radiocaesium is distributed more evenly along the profile in soils with a leaching type of water regime and the acid reaction of the medium. Convective transfer by type from regressive-accumulative to accumulative-eluvial-illuvial for ^{137}Cs was defined in mountain-forest gray and brown soils developed in different natural conditions of the region. Mountain-forest chernozem-like soils are also characterized by contrast in the content and distribution of ^{137}Cs. Their high absorption capacity and organic substance are the screen, that limiting the migration capacity of radiocaesium in chernozem.

In the plowed soils of the hollows of the Republic of Altai, the nuclide is evenly distributed in the topsoil. In the profile of southern chernozem, the distribution of the element is regressive-accumulative.

There is no clear regularity between the content of radionuclides, physical clay and silt in the soil. The values of the correlation coefficient are varied widely, both in the case of a direct and inverse relationship. The percentage of the high positive relationship between pH values and the content of radiocesium is a quarter of the pairs studied, which is slightly lower than at ^{90}Sr. In 80% of cases, a positive linear relationship was determined between the absorption capacity and the activity of the nuclides.

Radionuclides, entering plants through the roots of the aquatic environment and soil, are included in food chains. The accumulation of radioactive elements by plants depends on their content in the soil, on the properties of the soils (pH, particle size distribution, hummus), their accessibility, type of plant, the phase of its development, naturally-climatic conditions (Gulyakin, 1962).

Radioactive elements in the soil are transferred to plants and accumulate in the bark, wood, leaves, needles, grass, and roots. Radionuclides accumulated by leaves of trees and grasses enter the biological circulation faster. The transition of radionuclides through the soil-plant link to other biological objects is determined to a greater extent by the properties of the soil. The accumulation coefficient of ^{137}Cs of plants varies from n 10^{-3} to n 10^{-1}. Its entry into plants from the soil is on average 5-10 times less than that of other long-lived radionuclides (Aleksakhin, 1992). ^{90}Sr is more intensively absorbed by plants from the soil environment. It accumulates in the leaves and stems (Gulyakin, 1962). The accumulation of ^{137}Cs by the plants depends on the type and properties of the soil and varies on average 20-30 times (Gulyakin, 1962). In order of decreasing the entry of radioactive cesium into soil plants, it can be arranged in the following sequence: sod-podzolic, red soils, meadow-carbonate, chernozem and sierozem. It was established that the ^{137}Cs content in the wheat grain on sod-podzolic sandy loam soil exceeded 12 times its amount in the harvest on leached chernozem (Gulyakin, 1962). The accumulation of ^{90}Sr in the vegetative part of the plant decreases in the order: sandy loam, loam, sierozem, alkaline soil, peat, black soil (Polyakov, and Kader, 1971).

Well, accumulate ^{137}Cs potassium-loving plants. With an increase in the content of exchange potassium in soils, the accumulation of ^{137}Cs in plants decreases (Aleksakhin, 1992). The maximum absorption of ^{137}Cs by plants is observed at a pH close to neutral. When ^{90}Sr is transferred from soil into the plants, the discrimination of radiostrontium towards calcium is happened (Gulyakin, 1962). The accumulation of ^{90}Sr by plants is inversely proportional to the content of exchangeable calcium in the soil, and the high content of potassium contributes to its dilution with ions in a ^{137}Cs soil solution. On the surface of the roots between ions arises a "competition" for a place of sorption (Ilyin, 1996). The entry of ^{137}Cs into plants is determined by the strength of its fixation in the mechanical fractions. Most strongly bind ^{137}Cs the mudflats fractions of the soil and drastically reduce the accumulation of nuclide in plants (Pavlotskaya, 1974; Gulyakin, 1962; Aleksakhin, 1992; Lima *et al.*, 2018).

The absorption of radioactive elements depends on the biological characteristics of the plant. The accumulation of ^{137}Cs by different plant species changes 10 times. Varietal differences in the absorption of radiocaesium by plants do not exceed 1.5–2 times (Gulyakin, 1962). Legumes absor^{137}Cs and ^{90}Sr more than grains; and the root crops more than tuber crops. As plants grow, the relative content of nuclides in terrestrial organs increases, which can ensure their transition through the soil-plant link to other biological objects (Prokhorov, 1963).

The results of our research indicate that among the studied plants, species with a high content of radionuclides were not found. The maximum activity of ^{137}Cs is determined in the marsh tea, ^{90}Sr – in the yellow Lucerne. In other plants, the content of elements is less or is beyond the detection limits of the method used (Table 2).

The main bulk of radioactive cesium is accumulated by plant roots (Figure 8). In the above-ground parts of plant samples, the activity of ^{137}Cs varies from 0-45 Bq / kg, and in the roots from 0-49 Bq/kg. Significant ^{137}Cs concentrations are determined in forestry vegetation litter – up to 200 Bq/kg. Radiostrontium is more concentrated in the stems of plants (from 2 to 10 Bq/kg) (Figure 8).

A direct interrelation was revealed between the accumulation of ^{137}Cs by plants and the content in the soils of the ooze fraction (Figure 9). The remaining properties of the soil correlate with the accumulation of radiocesium negatively. In the future, we plan to study the relationship between the content of ^{90}Sr and soil properties.

CONCLUSIONS

1. The density of ^{137}Cs and ^{90}Sr contamination of the soil cover of the Republic of Altai is at the level of global background. Local pollutions, confined to the tops of the mountains, saddlebacks, the upper parts of the forested mountain slopes, to the places with the maximum precipitation.

2. The nature of the distribution of radionuclides depends on the physicochemical properties of the soil and the position of the soil in the landscape.

3. The level of ^{137}Cs and ^{90}Sr content in the studied plants of the Altai Republic varies significantly. This is due to the species, growing conditions.

4. Assessing the current radiation-ecological situation in the Mountain Altai for long-lived nuclides, it should be noted that it is quite satisfactory for human habitation and economic activity.

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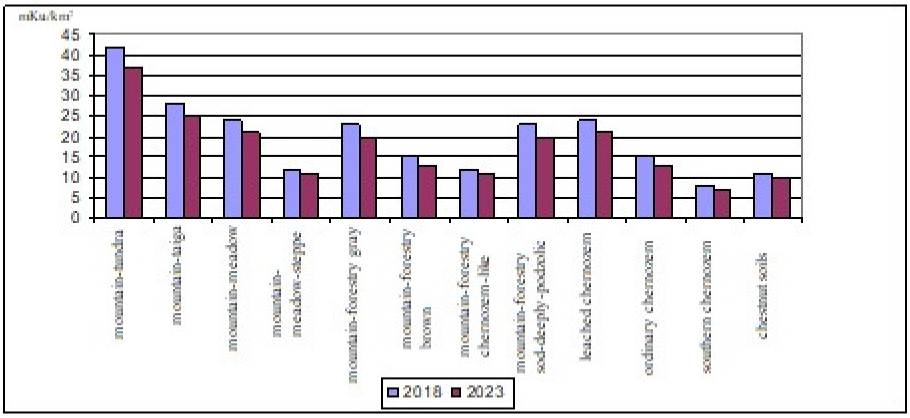


Figure 1. *The density of soil pollution in the Republic of Altai with ^{90}Sr for 2018-2023 years*

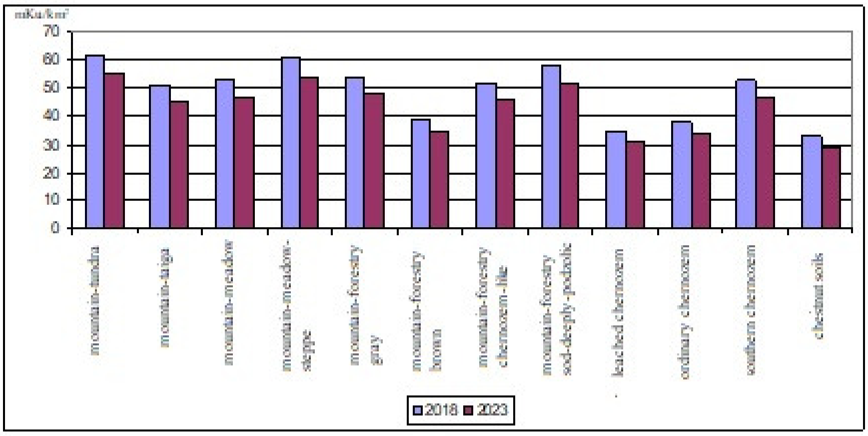


Figure 2. *The density of soil pollution in the Republic of Altai with ^{137}Cs for 2018-2023 years*

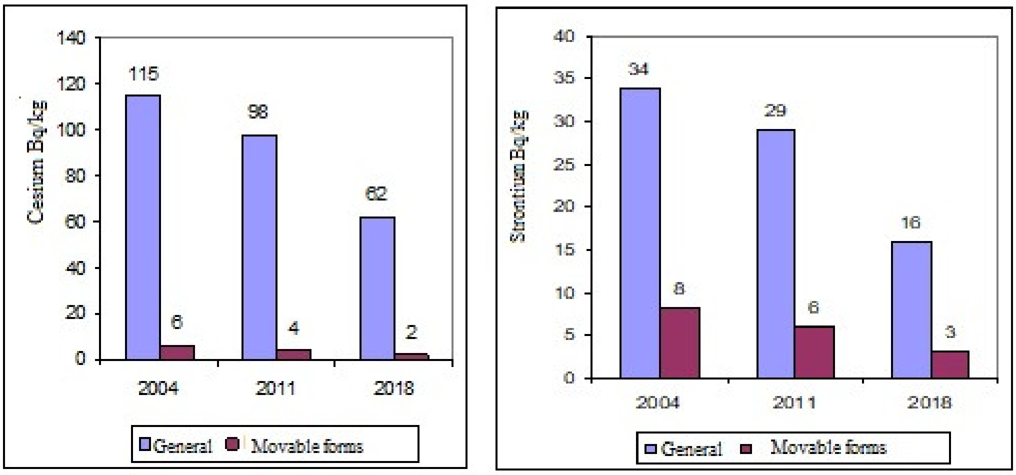
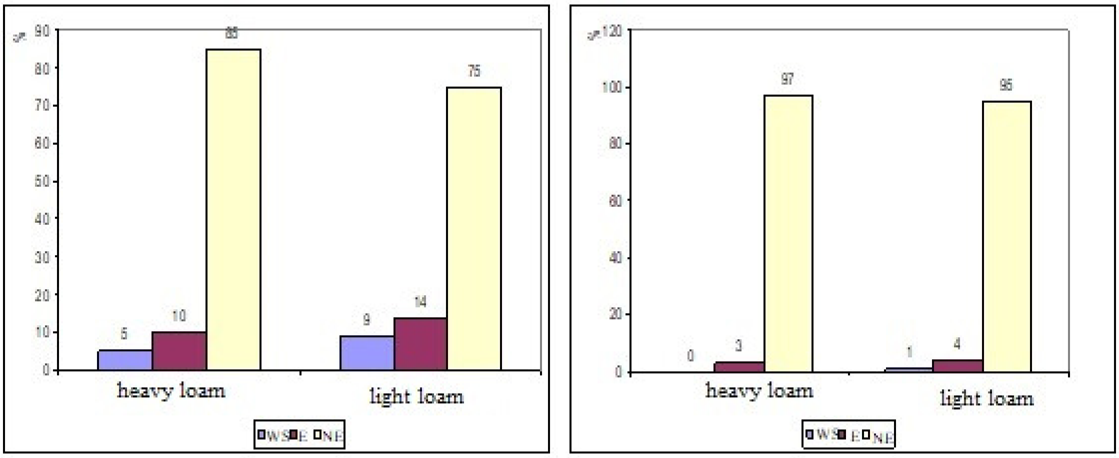


Figure 3. The *average content of general and movable forms of radionuclides in the soils of the Republic of Altai*



a b

Figure 4. *The average content of water-soluble (WS), exchange (E) and non-exchange (NE) forms ^{90}Sr (a) and ^{137}Cs (b) in soils of different composition of the Altai Republic*

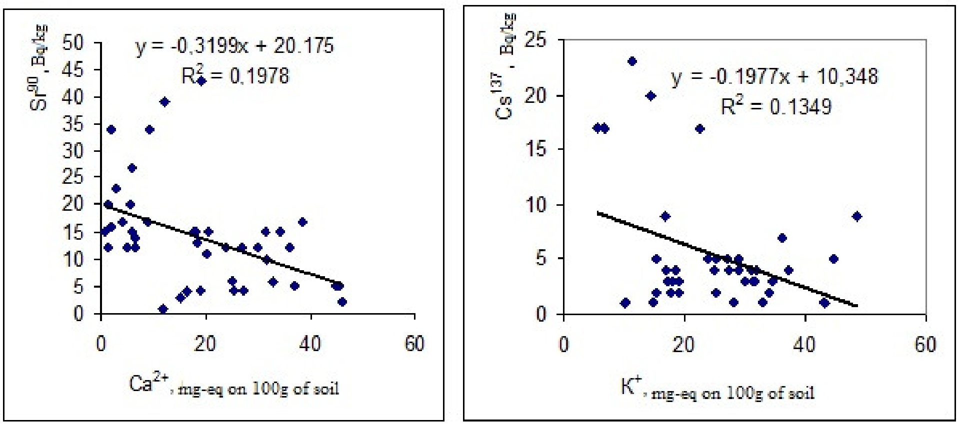


Figure 5. *The interrelation between the content of calcium and potassium ions in an aqueous solution and the content of associated radionuclides in the soils of the Republic of Altai*

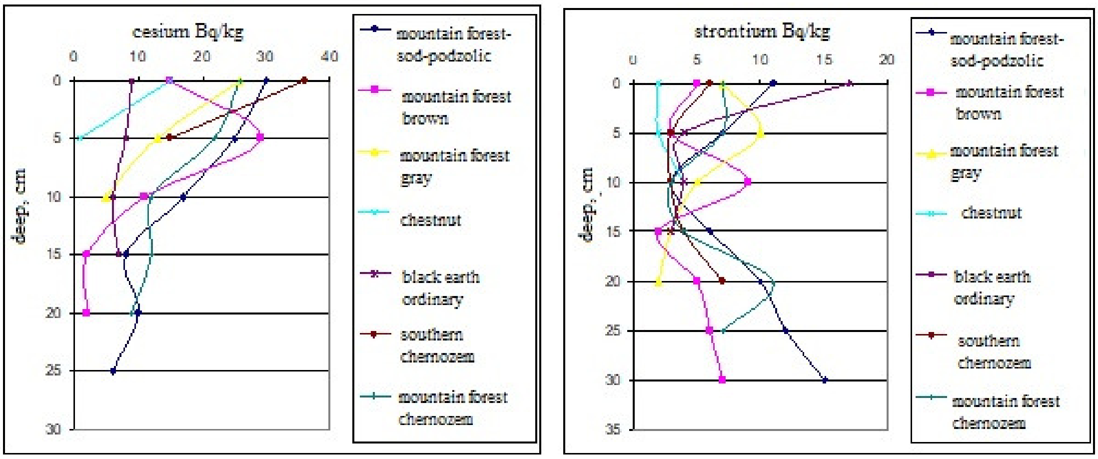


Figure 6. *Intra-profile distribution of ^{137}Cs and ^{90}Sr in certain types of soils of the Altai Republic*

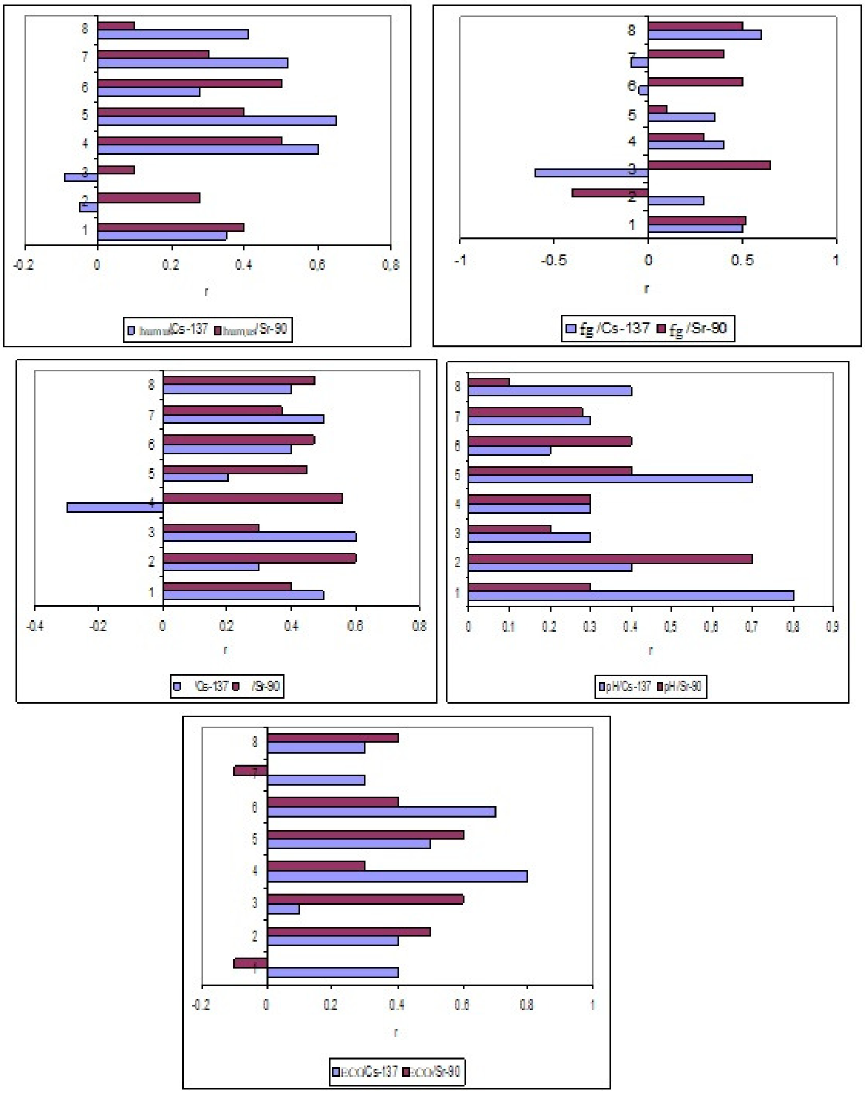


Figure 7. *Dependence of radionuclide content on the physicochemical properties of the soils of the Altai Republic (1 – mountain-tundra; 2 – mountain-taiga; 3 – mountain-meadow, meadow-steppe; 4 – mountain-forestry chernozem-like; 5 – leached chernozem, podzolized; 6 – ordinary chernozem; 7 – southern chernozem; 8 – chestnut soils)*

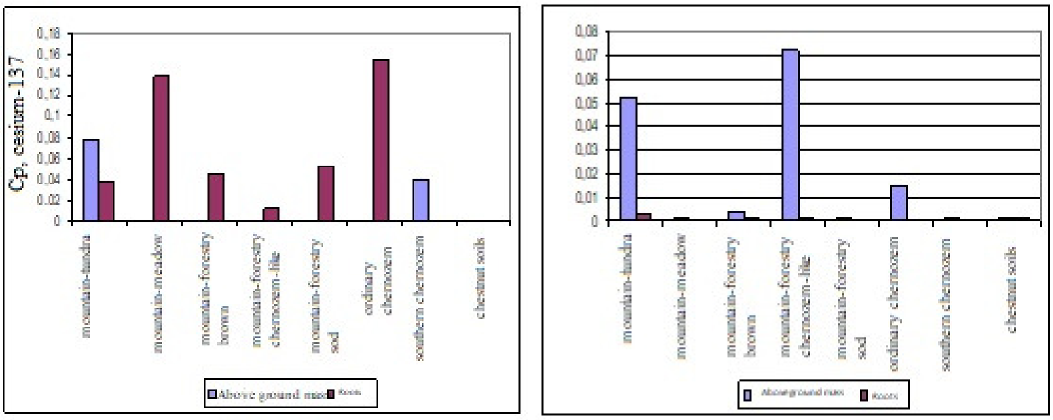


Figure 8. *The value of the coefficient of proportionality for ^{137}Cs and ^{90}Sr in plants of the Republic of Altai*

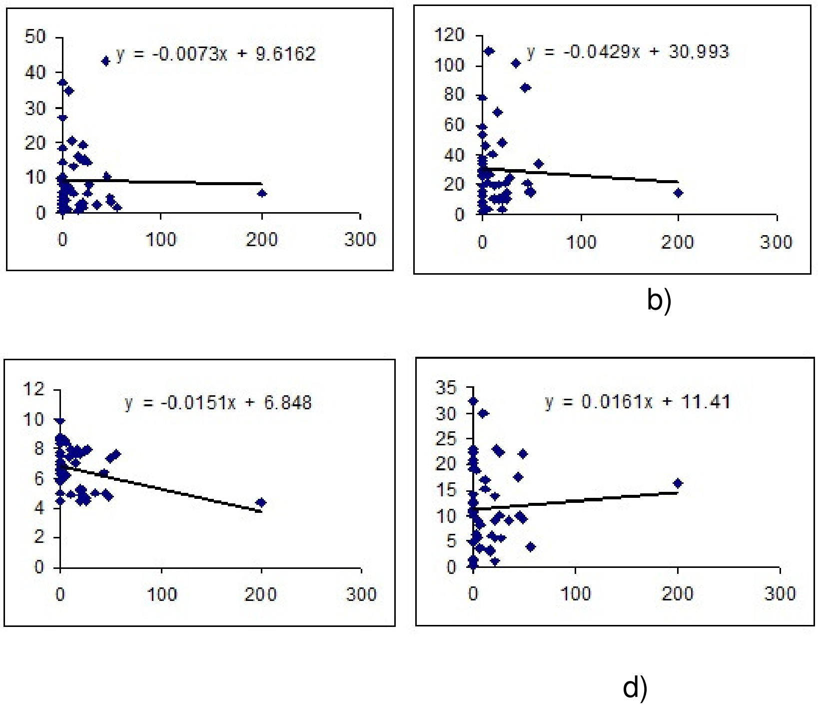


Figure 9. *The dependence of the content of radiocaesium in plant objects on some physicochemical properties of the soils of the Altai Republic: A – from humus, B – from ooze, C – from pH, D – from the absorption capacity*

Table 1. *The content of radioactive elements in some soils of the Altai Republic*

Soil	The number of cuts	^{90}Sr, mKu/km^2	^{137}Cs, mKu/km^2
Mountain-tundra	15	42	62
Mountain-taiga	10	28	51
Mountain-meadow	10	24	53
Mountain-meadow-steppe	8	12	61
Mountain-forestry gray	10	23	54
Mountain- forestry brown	10	15	39
Mountain- forestry chernozem-like	15	12	52
Mountain- forestry sod-deeply-podzolic	10	23	58
Leached chernozem	5	10	25
Ordinary chernozem	10	15	38
Southern chernozem	8	8	15
Chestnut soils	10	11	27

Table 2. *The content of radioactive elements (Bq / kg) in some plants of the Altai Republic*

Family	Type	^{137}Cs	^{90}Sr
Cereal family(Gramineae)	Chiy *brilliant*	1-11	N.d
	Barley	N.d	N.d
	Awnless wheat	N.d	2
	Bluegrass	1	2
	Feather grass	2-8	1
	Timothy grass	1	1
	Brome	N.d	N.d
	small reed	N.d	N.d
Legumes (Fabaceae)	*yellow* sweet clover	3	2
	Licorice	N.d	3
	Yellow Lucerne	2-4	3-15
	Clover red	N.d	1
Buckwheat family (Polygonaceae)	Buckwheat	N.d	1
	Horse sorrel	N.d	N.d
	Highlander	N.d	1
Rose family (Rosaceae)	Kuril tea	0,2-3	1
	Meadowsweet	N.d	N.d
John's wort family (Hypericaceae)	Common Saint-John's wort	N.d	1-3
Umbelliferous (Umbelliferae)	Thorough-wax *scorzonerifolium*	N.d	N.d
	Cumin *ordinary*	N.d	N.d
	Angelica	N.d	2
	Dill	N.d	N.d
Composite family (Acteraceae)	Sagebrush	1-11	N.d
	Pharmaceutical camomile	N.d	N.d
	Sunflower	N.d	N.d
	Yarrow	N.d	2
	Coltsfoot	N.d	3
Labiate family (Labiatae)	Sage-leaf mullein	N.d	2
	Garden burnet	N.d	2
	Mint	N.d	4
	Common origanum	2-3	1
	Thyme	3	N.d
	Ziziphora	3-4	N.d
Plantain (Plantaginaceae)	Plantain *large*	N.d	2
Sinyukhovye (Polemoniaceae)	Greek-valerian *polemonium*	N.d	3
Nettle family (Urticaceae)	Common nettle	N.d	3
Crowfoot family (Ranunculaceae)	Little meadow rue	N.d	N.d
Saxifrage family (Saxifragaceae)	Bergenia	13	2
Peony family(Paeoniaceae)	Peony *amphibological*	2	3
Heath family (Ericaceae)	Marsh tea	24-28	2-5
Goosefoot family (Chenopodiaceae)	Pigweed *white*	N.d	2
Clusterberry family (Vacciniaceae)	Cowberry	4-16	2
Primrose (Onagraceae)	Rosebay	N.d	N.d
Ephedra family (Ephedraceae)	Ephedra	7	2
Madder family (Rubiaceae)	Bedstraw	3	2
Sedge family (Cyperaceae)	Sedge	1-27	2

N.d. – not defined (below the detection limit)