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[1,2]Otarov A., [1]Ibraeva M., [1]Ustemirova A.

ACCUMULATION OF RADIONUCLIDES BY PLANTS AND THEIR BIOLOGICAL CIRCULATION CAPACITY

[1]Kazakh Research Institute of Soil Science and Agrochemistry after U.U. Uspanov, 050060, Almaty, 75 V al-Farabi avenue, Kazakhstan, e-mail: azimbay@bk.ru

[2]Scientific-Research Center for Ecology and Environment of Central Asia, 050060, Almaty, 75 V al-Farabi avenue, Kazakhstan

Abstract. The research results on accumulative ability of main dominating types of vegetation in the low reaches of the river Ili, are presented. It is determined that all explored types of plants mainly accumulate Sr^{90} rather than Cs^{137}. Classification of crops is performed according to radionuclides accumulation ability. The degree of radionuclides, involved into biological cycle, is very significant and ranges within hundredths, thousandth share of percentage of their level in soil.

Key words: ancient Akdala-Bakanas delta, soil-plant, accumulation rates, ratio ^{137}Cs:^{90}Sr, removal of radionuclides.

INTRODUCTION

Among the large number of artificial radionuclides, which form in fission of heavy nuclei, ^{90}Sr and ^{137}Cs, being chemical analogous of such biologically important elements as Ca and K, in large quantity are concentrated in plants. Accumulation coefficients ^{90}Sr and ^{137}Cs can reach 20, and ^{134}Cs and ^{137}Cs - 2 [1].

In the soil-plant system, ^{90}Sr has great biological mobility in comparison with ^{137}Cs [2]. One of major reasons for this difference is the process of "aging" of radionuclides, which is most specific for ^{137}Cs. The "aging" process represents a complex of crystal-chemical reaction with possible entry of radionuclide into crystal cell of secondary clay minerals [3, 4]. There is no consensus on fixation mechanisms of ^{137}Cs in soil. Preference is given to possible entry of ^{137}Cs into inter-packet spaces of layered clay secondary minerals [5, 6], though other types of crystal-chemical reaction of ^{137}Cs in soil are not excluded, when application of muscovite in soil and increased contact time of mineral with radionuclide solution has not affected the strength of sorption of ^{137}Cs with soil [7]. However, quite a lot of works [8-10] testify in favor of the theory of crystal-chemical sorption of ^{137}Cs.

In regard to the above mentioned, the assessment of radionuclide accumulating ability by main types of vegetation in the lower reaches of the Ili river and calculation of values of their radionuclide accumulation coefficients is one of the urgent problems.

OBJECTS AND METHODS

The research object is soil-vegetation cover of the lower reaches of Ili river that occupies the southwestern part of Balkhash-undrainage depression. The main part of the research object begins at the foot of Tasmurun mountain near the Bakbakty village. In the northeast, it has boundary with sandy massif Sary-Ishik-Otrau, in the north-west with sandy area Taukum and in the north – with water area of the lake Balkhash (Figure 1).

Formation of soil-plant cover of ancient delta is closely linked with the history of formation of the river delta. A number of researchers [11, 12] believe that initially the whole Balkhash depression looked like a sandy desert, and then later Ili river has been introduced, and as a consequence of increased moisture in the cavity water-marsh and meadow terrains have formed. The combination of desert regime and high humidity created an exceptional contrast and diversity of soil and vegetation cover of the downstream.

The choice of this region is justified by the fact that it is the object in the whole Ili-Balkhash basin, which is most heavily exposed to anthropogenic impact. The lower reaches of the rivers are almost always the final area of geochemical flow, and natural complexes are environmentally very vulnerable. In addition, Akdala rice growing area is located in the ancient Akdala-Bakanas delta. It is known that the increased rates of fertilizers, herbicides, pesticides, and other crop protection chemicals are applied on rice due to its biological features. All of them as impurities constantly, unfortunately, contain a considerable amount of heavy metal salts, radionuclides and other pollutants.

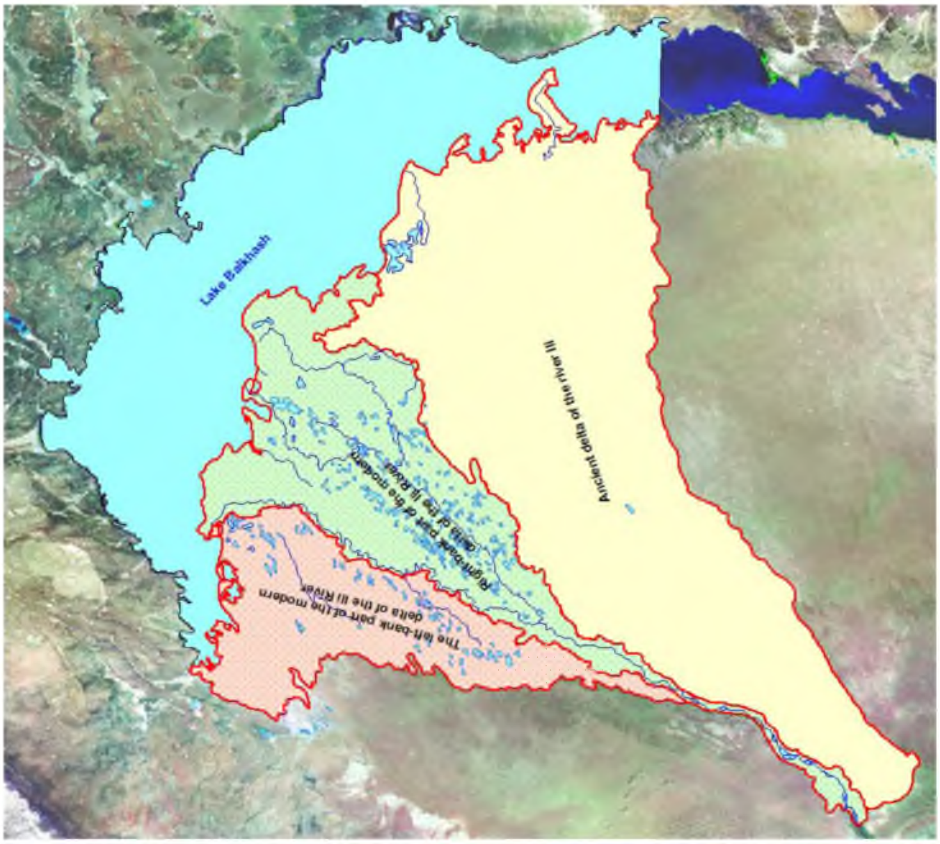

Figure 1 – Research object scheme of the lower stream of Ili river

In addition, due to large volume and high salinity there is a sharp problem of polluted return water, which often exceed the design standards both in composition and in volume. The return drainage sewage water becomes more polluted due to the increasing pressures on the environment. In addition, there is another negative natural factor – a factor of almost wide spread saline soils in the lower reaches of Ili river.

In this regard, we are consider the lower stream of the Ili river as anthropogenic and natural source, significantly influencing on ecological well-being of southern Balkhash area and Balkhash lake.

Artificial radionuclides have been determined by radiochemical method. The essence of radiochemical analysis method, in general, is as follows. To extract radiochemically pure ^{90}Sr and ^{137}Cs from solution, their stable inactive isotopes, so-called "isotope carriers" are used. It is necessary to observe the following conditions: - first, the quantity of carrier must be sufficient for complete extracting of the element - second, for reducing self-absorption and self-scattering effect in measuring the activity of the extracted element, the quantity of carrier should be minimal, especially in low activeness. To determine ^{90}Sr and ^{137}Cs in plant and soil samples were used methodological developments, which allow determining ^{90}Sr and ^{137}Cs from one sample. ^{137}Cs has been determined by antimony-iodine method and ^{90}Sr by oxalate method. In both cases, methods of deposition of radionuclides with carrier have been used. ^{137}Cs was deposited with a saturated solution of antimony trichloride in presence of ammonium iodide, and then the activeness of deposit was measured. Chemical output of carrier was determined by gravimetric method. ^{90}Sr was deposited by concentrated ammonia in presence of oxalic acid. Then, after separation of Fe, La and Y (separation time was recorded) ^{90}Y daughter product of ^{90}Sr and activeness was determined by it.

Activeness of preparations was measured on device of small background UMF-1500 with counter the SBT-13.

Method of determination of ^{90}Sr and ^{137}Cs in plant samples after ashing is similar to method of determining soil samples.

RESULTS AND DISCUSSION

In order to assess accumulation capacity of main types of vegetation in lower reaches of the Ili river with respect to radionuclides, their accumulation rates were calculated, which are expresses by ratio between radionuclide content in dry plant mass unit and their content in soil (Table 1).

Table 1 – Accumulation coefficients (AC) of radionuclides by main types of vegetation in the lower reaches of the Ili river

Soils	Plants	AC	
		^{90} Sr	^{137} Cs
Alluvial- meadow-tugai	Meadow grass	0,3	0,1
	Licorice «*Glycyrrhíza*»	0,4	0,1
	Brunets «*Poterium*»	0,4	0,04
Alluvial- meadow	Meadow grass	2,8	2,2
	Chingil «*Halimodendron*»	0,2	0,8
Swamp- meadow	Reed «*Phrágmites*»	0,06	0,09
	Licorice «*Glycyrrhíza*»	0,6	0,09
Swamp- meadow- drying	Reed «*Phrágmites*»	0,1	0,4
Meadow-swamp	Reed «*Phrágmites*»	0,4	0,1
	Meadow grass	4,5	1,1
Peat-swamp	Reed «*Phrágmites*»	0,06	0,2
Saline meadow	Tamarisk «*Tamarix*»	1,1	0,6
	Reed «*Phrágmites*»	0,04	0,01
	Camel-thorn «*Alhagi*»	3,5	0,4
	Sweda «*Suaeda*»	0,5	0,03
Saline crust-puffy	Black saxaul «*Halóxylon aphyllum*»	0,6	0,1
	Biyurgun «*Anabasis salsa*»	2,3	0,2
	Sarsazan «*Halocnémum*»	0,8	0,4
	Karabarak «*Halostachys belangeriana*»	0,2	0,1

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Takyr like	Biyurgun «*Anabasis salsa*»	1,8	0,7
	Keireuk «*Salsola orientalis*»	3,4	0,3
Dust- sandy	Wormwood «*Artemísia*»	1,1	0,1
	Teresken «*Ceratoides*»	1,0	0,1
	Kokpek «*Atriplex alba*»	0,4	0,2
	White saxaul «*Halóxylon persicum*»	1,3	0,3

Results of analyzes of accumulation coefficient values indicate the presence of significant differences between radionuclides and between plants. Almost all explored plants largely accumulate Sr^{90} rather than Cs^{137}. In most cases, the accumulation rates of Sr^{90} are higher than AR Cs^{137}. The largest accumulation ability in relation to Sr^{90} was shown by meadow grass (4.5), camel thorn (3.5), keireuk (3.4), and the lowest – reed with accumulation rate 0.06.

In relation to Cs^{137} it was found only one plant (meadow grass) which has accumulation coefficient greater than one. It has been also revealed that accumulation capacity depends on soil conditions of plant habitat. For example, meadow herbs which grow on different soils have different accumulation coefficients - on alluvial-meadow tugai soils 0.3, on alluvial-meadow soils 2.8 and on meadow-marsh soils 4.5.

From the above facts it can be concluded that the removal of radionuclides by plants in lower reaches of Ili river depends on plant biological characteristics and soil physical and chemical properties as well as radionuclides themselves. Consequently, radionuclides accumulation coefficient value also depends on soil and plant properties and properties of radionuclide itself. The obtained data on concentration of radionuclides in soil, plants and accumulation coefficients may be used to evaluate radio-ecological situation of the lower reaches of Ili river and forecasting estimates.

Correlations between ^{137}Cs : ^{90}Sr in atmospheric precipitation, which have been observed or long-term period in different parts of the globe, are relatively constant and estimated by figure 1.6 [13]. After falling on the earth surface this ratio depending on terrain-geochemical, soil and other conditions may vary in one or another direction, and can serve as a measure of evaluation of migration ability of these radionuclides in certain terrain components.

In comparing ratio ^{137}Cs : ^{90}Sr in soils and by certain plant species, it can be seen that in transition of radionuclides from soil to plants, this ratio is greatly disturbed, and in most cases becomes narrow, i.e. plants more intensively remove ^{90}Sr rather than ^{137}Cs. It was also determined that the ratio ^{137}Cs : ^{90}Sr in plants, as well as in case with soil, fluctuates quite widely reaching 55.5 multiple values. The maximum value of this ratio was typical for reed as a leading dominant of meadow vegetation and is estimated by figure 11.1, and minimum value 0.2 belongs to brunts as representative of meadow vegetation. Consequently, in transition from soil to plants in relation to these radionuclides, selective ration is shown from various plant species.

Furthermore, it was determined that this ratio also depends on soil conditions of plant habitat. For example, range of ratio ^{137}Cs : ^{90}Sr in aboveground mass of reed, depending on soil conditions is 6.5 times of value, while in meadow grass this range is 1.8 (Table 2).

Table 2 – The ratio ^{137}Cs : ^{90}Sr in main soil types and plant species of the lower reaches of Ili river

Soils	^{137}Cs : ^{90}Sr In soil	Plants	^{137}Cs : ^{90}Sr In plants
Alluvial- meadow-tugai	1,59	Meadow grass	0,9
		Licorice «*Glycyrrhíza*»	0,4
		Brunets «*Poterium*»	0,2
Alluvial- meadow	1,9	Meadow grass	0,9
		Chingil «*Halimodendron*»	3,8
Swamp- meadow	1,7	Reed «*Phrágmites*»	5,5
		Licorice «*Glycyrrhíza*»	0,5
Swamp- meadow- drying	3,8	Reed «*Phrágmites*»	11,1
Meadow-swamp	4,7	Reed «*Phrágmites*»	1,7
		Meadow grass	1,6
Peat-swamp	2,9	Reed «*Phrágmites*»	7,5
Saline meadow	3,9	Tamarisk «*Tamarix*»	1,8
		Reed «*Phrágmites*»	8,0
		Camel-thorn «*Alhagi*»	0,4
		Sweda «*Suaeda*»	0,6
Saline crust-puffy	3,4	Black saxaul «*Halóxylon aphyllum*»	0,9
		Biyurgun «*Anabasis salsa*»	0,3
		Sarsazan «*Halocnémum*»	1,5
		Karabarak «*Halostachys belangeriana*»	1,6
Takyr like	2,0	Biyurgun «*Anabasis salsa*»	1,2
		Keireuk «*Salsola orientalis*»	0,3
Dust- sandy	3,6	Wormwood «*Artemísia*»	0,2
		Teresken «*Ceratoides*»	0,4
		Kokpek «*Atriplex alba*»	1,64
		White saxaul «*Halóxylon persicum*»	0,6

On this basis, it can be concluded that the removal and accumulation of radionuclides by plants, along with other factors, also largely depends on specific features of plant, soil conditions of their habitats and properties of radionuclides.

By magnitude of this ratio the explored dominant vegetation types in the lower reaches of Ili river, it can be conditionally divided into the following groups: - plants, preferably accumulating ^{137}Cs – reed, chingil, tamarisk, karabarak kokpek; - plants which accumulate almost same quantity of ^{137}Cs and ^{90}Sr - meadow grass, sweda, saksaul; - plants, preferably accumulating ^{90}Sr - brunets, licorice, wormwood, keireuk, teresken and camel thorn.

Currently radionuclides accumulated in soil are fully involved in biogeochemical cycles of circulation of substances and reach humans through food chain. Currently, artificial radionuclides, particularly ^{90}Sr and ^{137}Cs are found in organism of all inhabitants of the planet, including humans. The migration intensity rate, active involvement in food chain depends on properties, vegetation cover characteristics, geochemical activity of radionuclides and depending on "optimal" combination of these factors, their content in foods can vary by hundreds or thousands times. In this regard, the issue of exploring the degree of their involvement into substance biogeochemical cycle is one of topical issues of soil-plant cover radiation ecology.

The survey results show that in the lower reaches of Ili river, despite the significant content of radionuclides in soil and plant dry matter, the degree of their involvement in biological cycle is very small and is ranging in hundredths and thousandths share of a percent of their content in soil (Table 3).

Table 3 – Removal of radionuclides by main types of vegetation in the lower reaches of Ili river

Soils	Plants	Removal by plants from 1 ha			
		^{90}Sr		^{137}Cs	
		Бк	%	Бк	%
Alluvial- meadow-tugai	Meadow grass	1974	0,012	1690	0,006
	Licorice «*Glycyrrhíza*»	462	0,003	176	0,001
	Brunets «*Poterium*»	480	0,003	80	0,0003
Alluvial- meadow	Meadow grass	29800	0,187	3892	0,021
	Chingil «*Halimodendron*»	364	0,002	1372	0,007
Swamp- meadow	Reed «*Phrágmites*»	262	0,002	1441	0,004
	Licorice «*Glycyrrhíza*»	462	0,004	242	0,001
Swamp- meadow- drying	Reed «*Phrágmites*»	1260	0,006	13986	0,016
Swamp- meadow	Reed «*Phrágmites*»	2035	0,027	3515	0,007
	Meadow grass	14125	0,188	22875	0,046
Peat-swamp	Reed «*Phrágmites*»	758	0,007	5685	0,024
Saline meadow	Tamarisk «*Tamarix*»	1210	0,008	2112	0,004
	Reed «*Phrágmites*»	138	0,001	1104	0,002
	Camel-thorn «*Alhagi*»	3111	0,020	1139	0,002
Saline crust-puffy	Biyurgun «*Anabasis salsa*»	646	0,004	437	0,001
	Sarsazan «*Halocnémum*»	440	0,003	660	0,001
	Karabarak «*Halostachys belangeriana*»	154	0,001	252	0,0004
Takyr like	Biyurgun «*Anabasis salsa*»	840	0,008	980	0,003
	Keireuk «*Salsola orientalis*»	1332	0,013	360	0,001
Dust- sandy	Wormwood «*Artemísia*»	300	0,004	70	0,0003
	Teresken «*Ceratoides*»	336	0,004	96	0,0005
	Kokpek «*Atriplex alba*»	595	0,007	374	0,002

Despite this, in analysis of their absolute value expressed in Becquerel, logical dependence of the amount of radionuclides involved in biological cycle on plant species features and soil conditions of their habitat has been determined.

For example, among explored plant species maximum capacity of biological cycle of radionuclides, representatives of meadow formations, especially meadow grass have been outlined. Moreover, grasses which grow in alluvial soils group have higher capacity. Also, general tendency of more migration ability in ^{90}Sr is observed rather than in ^{137}Cs.

CONCLUSIONS

Results of analyses of accumulation coefficient values indicate the presence of significant differences both between radionuclides and between plants. Almost all explored plants largely accumulate Sr^{90} rather than Cs^{137}. In most cases, accumulation coefficients of Sr^{90} are higher than AC Cs^{137}.

Degree of involvement of explored radionuclides in small biological cycle depends on plant species features, soil conditions of their habitats and radionuclides properties.

Both ^{90}Sr and ^{137}Cs have low degree of participation in small biological cycle.

The obtained data on concentration of radionuclides in soils, plants and accumulation coefficients may be used to evaluate radio-ecological situation of the lower reaches of Ili river and in forecasting calculations.

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ТҮЙІН

[1,2]Отаров А., [1]Ибраева М., [1]Устемирова А.

ӨСІМДІКТЕРДІҢ РАДИОНУКЛИДТЕРДІ БОЙЫНА ЖИНАУ БЕЛСЕНДІЛІГІ ЖӘНЕ БИОЛОГИЯЛЫҚ АЙНАЛЫМ СЫЙЫМДЫЛЫҒЫ

[1]Ө.О. Оспанов атындағы Қазақ топырақтану және агрохимия ғылыми-зерттеу институты, 050060, Алматы қ., әл-Фараби даңғылы, 75 В, Қазақстан, e-mail: azimbay@bk.ru

[2]Орта Азия қоршаған ортасы және экология ғылыми-зерттеу орталығы (Алматы), 050060, Алматы қ., әл-Фараби даңғылы, 75 В, Қазақстан

Мақалада Іле өзенінің төменгі ағысындағы доминантты өсімдіктердің радионуклидтерді бойына жинауын зерттеудің нәтижелері келтірілген. Барлық зерттелген өсімдіктердің Cs^{137}-ге қарағанда Sr^{90}-ды көп жинақтайтындығы анықталған, өсімдіктер радионуклидтерді бойына жинақтау қабілеті бойынша топтастырылған. Радионуклидтердің биологиялық айналымға қатысу мөлшері өте аз, топырақ құрамындағы мөлшерінің жүз және мың пайызындай ғана.

Түйінді сөздер: Ақдала-Бақанас ескі сағасы, топырақ-өсімдік, жинақталу жылдамдығы, ^{137}Cs : ^{90}Sr қатынасы, радионуклидтердің жойылуы.

РЕЗЮМЕ

[1,2]Отаров А., [1]Ибраева М., [1]Устемирова А.

ИНТЕНСИВНОСТЬ НАКОПЛЕНИЯ РАДИОНУКЛИДОВ РАСТЕНИЯМИ И ЕМКОСТЬ ИХ БИОЛОГИЧЕСКОГО КРУГОВОРОТА

[1]Казахский научно-исследовательский институт почвоведения и агрохимии имени У.У. Успанова, 050060, г. Алматы, проспект аль-Фараби, 75, Казахстан, e-mail: azimbay@bk.ru

[2]Научно-исследовательский центр экологии и окружающей среды Центральной Азии, 050060, г. Алматы, проспект аль-Фараби, 75, Казахстан

Приведены результаты исследования накопления радионуклидов основными доминантными видами растительности нижнего течения р. Или. Установлено, что все изученные виды растения в большой мере накапливают Sr^{90} чем Cs^{137}, произведено группировка растений по накопительной способности радионуклидов. Степень вовлечения радионуклидов в биологический круговорот очень незначительная и колеблется в пределах сотых и тысячных долей процента от их содержания в почве.

Ключевые слова: древняя дельта Акдала-Баканас, почва-растение, скорость накопления, отношение ^{137}Cs : ^{90}Sr, удаление радионуклидов.