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Research Article

Ecology-Radio Biogeochemical Evaluation of the Soil-Plant Complex of Agro-Systems in Issyk-Kul Oblast

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Abstract

In the article are presented the results of researches of the concentration of radionuclide, macro- and microelements in the soil and seeds of grain crops of the Issyk-Kul region. The phytotoxicity of soil was determined in the agroecosystems by using cereals.

Keywords: Radionuclide; Microelements; Heavy Metals; Cereals; Agroecosystem

Introduction

The biogeochemistry of radioactive elements and heavy metals in the biosphere territory of Issyk-Kul is still one of the most problematic issues in the region. According to the estimates of biogeochemists and geochemists, the Issyk-Kul basin is a natural uranium biogeochemical province with higher concentration of uranium in the natural environment [1-3]. At the same time increasing environmental pollution with artificial radionuclide and heavy metals and a global character of distribution is a potential danger of their accumulation in various objects of the biosphere [4].

Materials and Methods

Ecology-radio biogeochemical investigations of the soil-plant complex of agroecosystem were conducted in the coastal zone of the Issyk-Kul region. There were founded 12 control places. The soil samples of the humus layer (0-20 cm) were sampled from each control site for ecology-radio biogeochemical researches, samples were taken from the winter wheat grain (*Triticum aestivum*), which was presented mainly in the local variety: “Intensive”, “Erythrosperum 80”, “Bezostaya 1”, “Kazakhstan 210” and spring barley (*Hordeum vulgare*) varieties “Nutans 89”, “Taalay”, “Kylym”, “Nadia”, “Combiner” and “Union”.

Sampling of soils and plants was carried out according to the methodological recommendations of B.M. Djenbaev (2014) and I.A. Sobolev, E.N. Belyaeva (2002). Analyzes of the determination of macro- and microelements were performed by X-ray fluorescence analysis in the laboratory of nuclear physical methods of the Institute of Nuclear Physics of the National Nuclear Center of the Republic of Kazakhstan and in the laboratory of biogeochemistry and radioecology of the Institute of Biology of the NAS of the KR using methods of atomic absorption on the MGA-915 spectrometer.

A gamma spectrometer "Canberra" (model GX4019 with software Genie-2000 S 502, S501 RUS) was used to determine the isotope composition of radionuclide in soil samples and plant ashes.

The quantity of gluten in wheat and the full technical analysis are made in the laboratory of the Grain Examination Center of the Ministry of Agriculture and Melioration of the Kyrgyz Republic.

Results and Discussion

The soil cover of the agroecosystems of the investigated region is represented by mountain-valley gray-brown, light-brown, light-chestnut and dark-chestnut soil, the composition is mostly light, medium and heavy loamy. Gray-brown and light-brown soils of the region are characterized by a low concentration of humus and availability of elements of mineral nutrition.

The amount of humus in light chestnut, chestnut and dark chestnut soils varies within the limits for typical soil types in the investigated regions. They are sufficiently provided with elements of mineral nutrition and mobile forms of phosphorus and potassium. The described soils are mostly slightly carbonate, the reaction of the soil solution is alkaline. Absorption capacity is low 10-20 mg. eq per 100 g, in some cases average.

It is known that humus consists of complex organic compounds that can bind heavy metals and radionuclide, which contributes to a decrease in their entry into plants and further along the biogeochemical chain.

The power of the natural radiation background at various points is from 13 to 23 micro R/hour, which does not exceed the accepted norm in the republic (30 micro R/hour). Variations of the natural background are associated with the inhomogeneous distribution of elements of the radioactive series of uranium and thorium in the earth's crust [5-8].

According to the biogeochemical classification for natural radionuclides (^{238}U, ^{226}Ra, ^{232}Th, ^{40}K) is feature a weak accumulation in the soil (from 2 to 10 clarks). The concentration of the artificial radionuclide (^{137}Cs) does not exceed the permissible intervention levels (NRB-99) in the soil.

On macro- and microelements was not obtained the same results on their concentrations in soils (Table 1). It is possible to divide them into several groups: with insufficient concentration (Ti, Cr, Mn, Fe, Ni, Ga, Sr, Y, Zr, Nb, Bi); within the norm (N, P, K, Ca, Cu, Zn, Ge, Br, Rb, Mo, Ba, La, Ce); with weak accumulation (V, As, Sb, Nd, Pb, U, Th, Ra) and average (Co, Cs, Se, Sn). According to our data and literature sources, pollution of heavy metals in soils in this province is mainly related to transport emissions. Also, when the coal is burned in the private sector, the work of various processing industries and natural biogeochemical processes (rocks, soils, plants and animals) contributes to increasing the concentration of heavy metals and radionuclides in the soil and other objects.

Place of selection	**Type of the soil**	**K, %**	**Ca, %**	**Ti, %**	**V,**	**Cr,**	**Mn, %**	**Fe, %**	**Co,**	**Ni,**	**Cu,**	**Zn,**	**Ga,**
Toru-Aygyr village	gray-brown	1,5 ± 0,4	0,9 ±0,18	0,3 ±0,05	< 220	45 ±11	0,060 ± 0,010	2,8 ± 0,19	< 44	14 ±5	18 ± 9	68 ± 9	18 ± 9
Chon-Sary-Oy village	light brown	1,5 ± 0,4	1,62 ±0,18	0,28 ±0,05	< 220	40 ±11	0,054 ± 0,010	3,0 ± 0,19	< 54	17 ±5	16 ± 9	65± 9	22 ± 9
Grigorievka village	light chestnut	1,8 ± 0,3	1,38 ±0,16	0,38 ±0,06	< 241	53 ±11	0,070 ± 0,011	3,7 ± 0,2	< 62	20 ±5	20 ± 8	64 ± 9	16 ± 8
Ananjevo village	chestnut	1,9 ± 0,3	1,78 ±0,16	0,33 ±0,06	< 230	48 ±11	0,060 ± 0,011	2,9 ± 0,2	< 46	18 ±5	25 ± 8	70± 9	27 ± 9
Chon-Oruktu village	light chestnut	1,6± 0,4	1,22 ±0,13	0,32 ±0,05	< 214	45 ±10	0,058 ± 0,009	2,7 ± 0,17	< 51	15 ±5	20 ±9	70 ± 9	23 ± 8
Tup village	light chestnut	1,5 ± 0,4	0,87 ±0,13	0,28 ±0,05	< 214	40 ±10	0,052 ± 0,009	2,82 ± 0,17	< 43	13 ±5	16 ± 9	67 ± 9	30 ± 9
Maman village	dark chestnut	2,0 ± 0,3	1,96 ±0,19	0,35 ±0,06	< 237	48 ±11	0,070 ± 0,011	4,0 ± 0,2	< 65	22 ±6	32± 10	77 ± 10	30 ± 9
Chirak village	dark chestnut	1,9 ± 0,3	2,4 ±0,19	0,30±0,06	< 220	51 ±11	0,065 ± 0,011	3,8 ± 0,2	< 46	20 ±6	27± 10	75 ± 10	28 ± 9
Saruu village	chestnut	1,6 ± 0,3	1,68 ± 0,16	0,33 ±0,06	< 235	44 ±11	0,059 ± 0,011	3,0 ± 0,2	< 63	17 ±5	23 ±8	73± 9	29 ± 9
Barskoon village	light chestnut	2,1 ± 0,3	2,8 ±0,2	0,35 ±0,06	< 239	49 ±11	0,064 ± 0.011	3,6 ± 0,2	< 64	16 ±5	22 ± 9	75 ± 10	24 ± 8
Ton village	light brown	1,6 ± 0,4	1,82 ±0,18	0,29 ±0,05	< 220	41 ±11	0,058 ± 0,010	3,10 ± 0,19	< 56	20 ±5	17 ±9	66 ± 9	26 ± 9
Shor-Bulak village	Grey-brown	1,6 ± 0,4	1,1 ±0,18	0,4 ±0,05	< 220	44 ±11	0,062 ± 0,010	3,0 ± 0,19	< 49	15 ±5	16 ± 9	65 ± 9	17 ± 9
Place of selection	Type of the soil	Ge,	As,	Se,	Br,	Rb,	Sr,	Y,	Zr,	Nb,	Mo,	Sn,	Sb,
Toru-Aygyr village	gray-brown	< 10	< 15	0,1	< 5	148 ± 12	175 ± 11	45 ± 5	205 ± 17	12 ± 3	< 3	< 265	< 250
Chon-Sary-Oy village	light brown	< 10	< 12	0,12	< 5	168 ± 12	168 ± 11	55 ± 5	265 ± 17	22 ± 3	< 3	< 273	< 255
Grigorievka village	light chestnut	< 11	< 10	0,13	< 6	138 ± 9	203 ± 13	29 ± 4	202 ± 14	11 ± 2	< 3	< 280	< 269
Ananjevo village	chestnut	< 10	< 13	0,15	< 5	137 ± 10	194 ± 14	25 ± 3	184 ± 12	10± 1,9	< 3	< 275	< 263
Chon-Oruktu village	light chestnut	< 11	< 11	0,07	< 6	134 ± 9	196 ± 13	34 ± 4	258 ± 17	12± 2	< 3	< 255	< 260
Tup village	light chestnut	< 10	< 15	0,09	< 5	147 ± 10	214 ± 14	23 ± 3	174 ± 12	11± 1,9	< 3.2	< 262	< 248
Maman village	dark chestnut	< 10	< 14	0,1	< 6	134 ± 9	171 ± 11	30 ± 4	194 ± 13	13 ± 2	< 3	< 257	< 274
Chirak village	dark chestnut	< 10	< 13	0,14	< 6	130 ± 9	165 ± 11	25 ± 4	185 ± 13	12 ± 2	< 3	< 269	< 264
Saruu village	chestnut	< 10	< 14	0,12	< 5	140 ± 10	196 ± 14	27 ± 3	186 ± 12	10± 1,9	< 3	< 265	< 255
Barskoon village	light chestnut	< 11	< 13	0,11	< 6	135 ± 9	198 ± 13	36 ± 4	260 ± 17	14 ± 2	< 3	< 268	< 273
Ton village	light brown	< 11	< 12	0,08	< 6	183 ± 12	165 ± 11	58 ± 5	270 ± 17	24 ± 3	< 3	< 270	< 260
Shor-Bulak village	Grey-brown	< 10	< 12	0,09	< 5	140 ± 12	175 ± 11	42 ± 5	185 ± 17	15± 3	< 3	< 278	< 250
Place of selection	Type of the soil	Cs,		Ba,	La,	Ce, мг/кг	Pr,	Nd,	Pb,	Bi,	U,	Th,	Ra, n×10^{-11}%
Toru-Aygyr village	gray-brown	< 51		642 ± 83	< 66	70 ± 44	< 70	< 72	29 ± 11	< 11	7 ± 4	13 ± 4	25
Chon-Sary-Oy village	light brown	< 55		652 ± 83	< 68	92 ± 44	< 67	< 67	36 ± 11	< 11	8 ± 4	14 ± 4	28
Grigorievka village	light chestnut	< 50		802 ± 91	< 69	77 ± 40	< 74	< 76	33 ± 11	< 11	7 ± 4	15 ± 4	32,5
Ananjevo village	chestnut	< 60		796 ± 91	< 66	72 ± 40	< 72	< 71	28 ± 11	< 11	7 ± 4	12 ± 4	30,5
Chon-Oruktu village	light chestnut	< 53		795 ± 91	< 66	75 ± 40	< 72	< 74	31 ± 11	< 11	7 ± 4	12± 4	30,5
Tup village	light chestnut	< 62		796 ± 88	< 65	< 61	< 67	< 70	26 ± 10	< 11	8 ± 4	13 ± 4	22,5
Maman village	dark chestnut	< 63		631 ± 80	< 68	76 ± 40	< 71	< 74	22 ± 11	< 11	< 7	14 ± 4	35
Chirak village	dark chestnut	< 59		621 ± 80	< 65	72 ± 40	< 67	< 70	18 ± 11	< 11	< 7	12 ± 4	28
Saruu village	chestnut	< 61		792 ± 91	< 67	65 ± 40	< 70	< 75	29 ± 11	< 11	7 ± 4	13 ± 4	29
Barskoon village	light chestnut	< 65		731 ± 86	< 69	88 ± 41	< 70	< 76	22 ± 10	< 11	< 7	13 ± 4	32,5
Ton village	light brown	< 67		672 ± 83	< 68	106 ± 44	< 73	< 73	46 ± 11	< 11	8 ± 4	24 ± 4	36
Shor-Bulak village	grey-brown	< 57		645 ± 83	< 69	75 ± 44	< 75	< 70	25 ± 11	< 11	7 ± 4	14± 4	23

Table 1: Concentration of chemical elements in the soils of the Issyk-Kul region (mg/kg).

The results of gamma spectrometric analysis for the determination of radionuclides in seeds of cereal crops are presented in table 2. All radionuclides are characterized by weak accumulation, with the exception of ^{40}K, the biological absorption coefficient is 5.3.

Place of selection	^{234}Th	^{226}Ra	^{214}Pb	^{214}Bi	^{210}Pb	^{228}Ac	^{224}Ra	^{212}Pb	^{212}Bi	^{227}Th	^{40}K	^{137}Cs
Toru-Aygyr village	8 ± 4	< 12	< 6	4 ± 2	28 ± 6	10± 3	< 10	3,7 ± 0,7	9	< 3	4264 ± 39	< 1
Chon-Sary-Oy village	< 10	< 14	< 8	< 3	50 ± 7	16± 4	< 9	2,8 ± 0,7	10	< 3	4700 ± 49	< 0,8
Grigorievka village	< 10	< 13	7 ± 1	5 ± 2	42 ± 8	11± 3	12 ± 7	1,5 ± 0,7	19	< 4	5459 ± 55	< 1,5
Ananjevo village	9 ± 4	< 12	6± 1	< 5	33 ± 5	8± 3	10 ± 5	2,3 ± 0,6	12	< 3	5142 ± 50	< 1,3
Chon-Oruktu village	< 9	< 10	< 7	< 9	19 ± 7	18± 3	< 8	1,9 ± 0,6	7	< 3	4915 ± 46	< 0,9
Tup village	< 10	< 12	< 2	< 3	70 ± 8	9 ± 3	< 11	1,7 ± 0,7	11	< 4	4104 ± 50	< 1,2
Maman village	9 ± 4	< 9	6± 1	4 ± 1	55 ± 6	< 4	< 8	< 0,8	8	< 3	4723 ± 37	< 0,8
Chirak village	< 10	< 10	< 5	4 ± 2	35 ± 6	12 ± 3	< 11	3,3 ± 0,7	8 ± 5	< 4	5200 ± 55	< 1,1
Saruu village	< 10	< 12	< 8	< 3	40 ± 5	15 ± 3	10 ± 5	2,1 ± 0,7	9	< 4	4663 ± 42	< 1,5
Barskoon village	< 9	< 12	8 ± 1	4 ± 2	53 ± 8	< 4	12 ± 7	4,2 ± 0,7	10	< 4	4134 ± 49	< 1,4
Ton village	< 9	14 ± 7	9 ± 1	9 ± 2	18 ± 7	22 ± 3	< 10	3,8 ± 0,7	18 ± 7	< 3	6519 ± 55	< 1,3
Shor-Bulak village	8 ± 4	< 12	< 7	< 4	31 ± 6	< 4	< 10	1 ± 0,5	10	< 3	5320 ± 50	< 1,2

Table 2: Specific activity of radionuclide in the wheat seeds, Bq/kg.

For some macro- and microelements are significant differences in their concentrations in the seeds of cereal crops. It is possible to highlight some groups: with insufficient concentration (Br, Sr, As, Co, Cs), within the norm (Ca, Na, Ag, Ba, Mn, Pb, Fe, Th, Sb, Sc, W) and accumulation (Zn, Mo, Ni, Cu, Cr, Rb).

The coefficients of biological absorption of isotopes of radioactive elements are less than 1 and they do not accumulate in the seeds of grain crops. The obtained results of the radionuclides do not exceed the permissible concentrations in the investigated plants, but in comparison with other background regions, the values are slightly higher. At present, due to the deterioration of the environmental situation everywhere, it is possible to receive pollutants with air currents and precipitation. They can also come into plants through the surface of the leaves.

Determination of soil phytotoxicity by some parameters of the study of cereal crops. The mass of 1000 seeds of the wheat and barley was researched. The values of the barley from 5 regions were in the range of 41-50.7 g. Actual discrepancy was 0.19-0.35. The indicator of wheat varies from 38.3 g to 45.52 g. The maximum value for the first cereal was observed in the Jety-Oguz region - 50.7 g and the minimum was in the Ton region - 41g.

During the research the seeds of wheat were grown in different agrocenoses and had a germination capacity of 85-98%, barley - 80-93% and low variability. Consequently, the seeds can be used for planting on seed targets.

There are 3-4 classes of varieties of cultivated wheat in agroecosystems of the Issyk-Kul region in all territories. The gluten in seeds is 19% in the Ton region, Ak-Suu - 19%, Issyk-Kul - 20%, which corresponds to class 4; Jety-Oguz district - 26%, Tup - 25% class 3.

One of the methods of biodosimetry is the method of cytogenetic analysis. In Figure 1 and 2 is shown the main types of chromosomal abnormalities in cells.

The total number of reviewed materials was 5000. Among 93 were identified violations of chromosome: 18.2% of pair fragments, 44% of single fragments, 5.4% of chromosomal bridges and 32.2% of chromatid bridges. The single fragments and bridges are chromatid in the spectrum of chromosome disturbances in cells of root meristems of barley seeds (*Hordeum vulgare*) and wheat (*Triticum aestivum*). It can be concluded about effecting mutagens in chemical nature.

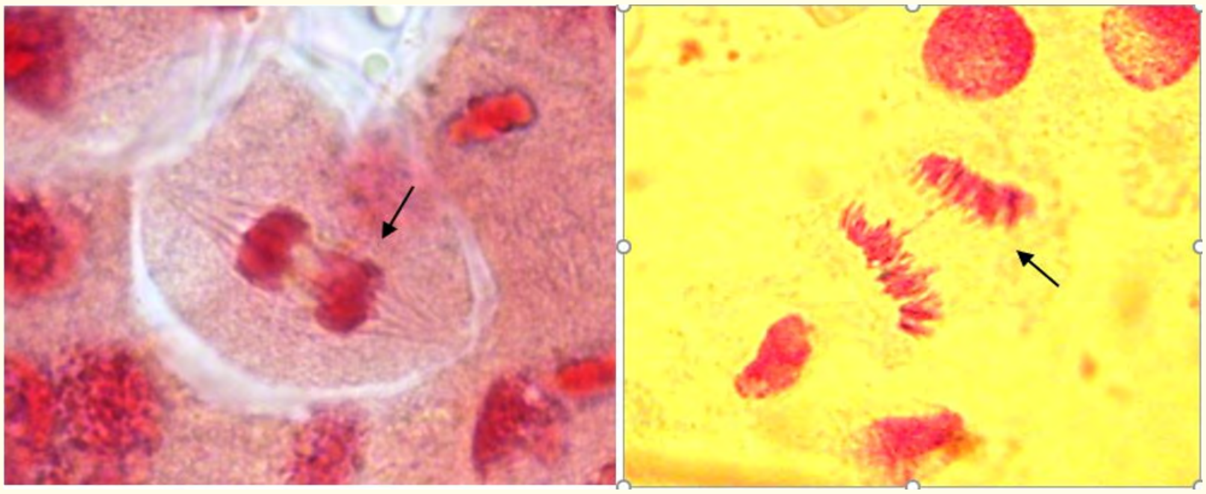

Figure 1: Ana-telophase plates:
a) Spring barley with a chromosome bridge,
b) Winter wheat with a chromatid bridge.

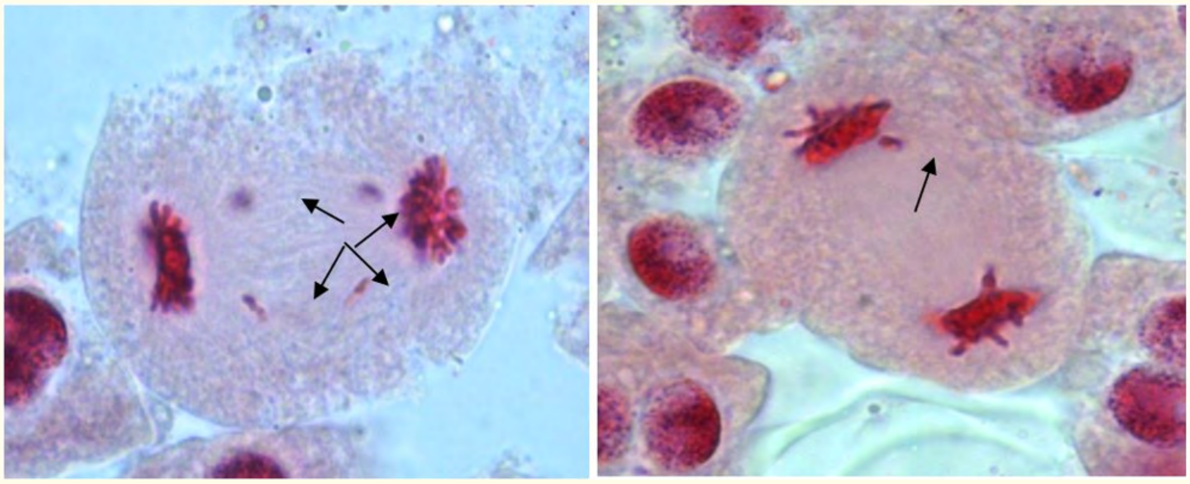

Figure 2: Ana-telophase plates:
a) Wheat with a pair fragment,
b) Barley with a single fragment.

The results of cytogenetic researches of seeds of cereal crops of the Agrisecosystems near the Issykkul was revealed the highest frequency of chromosomal disturbances for spring barley from the vicinity of the villages of Ton, in the winter wheat of the villages of Barskoon, Ananyevo and Tup. We associate this with the geochemical features of the Issyk-Kul intermountain basin. It is a uranium biogeochemical province, where uranium is enriched with rocks, soils, lake, river and groundwater, lake sediments and living organisms.

The frequency of chromosome aberrations in the cells of the root meristems of the seeds of spring barley (*Hordeum vulgare*) and winter wheat (*Triticum aestivum*) in the Issyk-Kul region was 1.4-2.2%, (1.86% on average). Apparently, chemical elements in combination with radionuclide interact synergistically with the genetic apparatus of cereal crops in the study areas.

Conclusion

It is established that the exposure radiation dose rate for gamma radiation in the investigated area of the agroecosystem of the Issyk-Kul biosphere territory is from 13 to 23 micro R/hour, which does not exceed the accepted norm of the republic (30 micro R/hour).

Here we can distinguish 4 groups among macro- and microelements in soils: with insufficient concentration (Ti, Cr, Mn, Fe, Ni, Ga, Sr, Y, Zr, Nb, Bi); within the norm (Ca, Cu, Zn, Ge, Br, Rb, Mo, Ba, La, Ce); with a weak accumulation (V, As, Sb, Nd, Pb, U, Th, Ra) and average (Co, Cs, Se, Sn).

Researched elements are also contained in various concentrations in the seeds of grain crops: an insufficient amount - Br, Sr, As, Co, Cs, within the norm - Ca, Na, Ag, Ba, Mn, Pb, Fe, Th, Sb, Sc, W, a weak accumulation is noted for elements such as Zn, Mo, Ni, Cu, Cr, Rb. Conducted corresponding analyzes of radioactive elements (^{238}U, ^{226}Ra, ^{232}Th, ^{40}K) show that radionuclide do not accumulate in the seeds of the researched cultures and do not exceed allowable concentrations, but in comparison with other background areas the values are slightly higher.

The number of chromosomal abnormalities in the cells of the root meristems of seeds of grain crops varies within natural values from 1.4 to 2.2%. The weight and germination of the seeds are also within normal limits. In terms of gluten concentration of the cereal crops of agroecosystems are classified as 3-4 classes of varieties (from 19 to 26%).

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