ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Medico-Ecological Characteristic of the Biogeochemical Status in the Khemchiksky Basin (Western Tuva).

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ABSTRACT

The results of analysis of the chemical substances content in the soil, surface waters and floristic complexes of the Khemchiksky basin are described and the assessment of the medico-ecological situation in the region is presented. It was shown that the degree of the heavy metals movability in the soil does not demonstrate a strong correlation between the element mobility, soil grain-size distribution and high humus content and the chemical elements content is affected by the ecological-phytocenotic confinedness of the floristic complexes. At the same time the main factor determining the accumulation of the chemical elements is the habitat area. Thus, in particular, by changing of the habitat area within the same floristic complex the content of both the basic micro- and macro elements is increased. The biogeochemical situation in the Khemchiksky basin may be considered to be safe. There are separate elements in the soils (Cr, Cu, Pb) the content of which exceeds the maximum permissible concentrations. The characteristics of content of these elements in phytocenotic complexes do not depend on their content in the soils and it can be stated that in the initial link of the biological element circulation the plant communities absorb the concentrations that are not dangerous to a human and apparently to the other living organisms as well. Generally, the biogeochemical situation in the Khemchiksky basin cannot be the major factor in determining the distribution of diseases among the population except for the hypothyrosis determined by iodine deficiency.

Keywords: biogeochemistry, chemical substances content in the soils, heavy metals, floristic complexes, medico-ecological situation, population morbidity.

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INTRODUCTION

The health of population depends on the influence of the various factors: natural-climatic, genetic, social-economical, medical, etc. that differ from each other through their nature, orientation and power of influence. According to the WHO, in the cumulative impact on the population health 50% falls to the lifestyle, 20% to the living environment and inheritance and 10% — to the quality of the health care services. The domestic literature points to a wider range of factors determining the state of health: lifestyle — from 20 to 52%, inheritance — from 15 to 25%, environmental condition — from 18 to 50%, health care organization — from 10 to 15%, social-economic conditions — 25%, psychological factors — 15% [1, 2]. The ranges considered are of generalized nature and do not into account the specific features of particular regions of the Russian Federation.

Present state of the problem

In most of the modern studies the assessment of effect of the separate environmental factors on the particular population state indicators prevails [3, 4, 5, 6, 7, 8,]. At the same time the medico-ecological studies using the integral assessment of the environmental status and the health of population of the particular regions of Russia are performed [9, 10, 11, 12].

A. V. Puzanov [13] referred the Khemchiksky basin to the Western-Sayan landscape-geochemical province and distinguished the Alash biogeochemical province with the increased content of Cu, W, Pb, Ni, Co, Cr.

The purpose and objectives of the research

The work objective is the study of the chemical substances in the soil, surface waters and floristic complexes of the Khemchiksky basin as well as medico-ecological characteristic of the territory.

In order to achieve the objective assigned the following tasks are solved:

- Analysis of the macro- and micro element composition of the natural environment and the main phytocenosis of the Khemchiksky basin.
- Medico-ecological characteristic of the territory and identification of health risks.

MATERIAL AND METHODS

The Khemchiksky basin where the analysis was performed is the South-Western tip of the central Tuva basin. It is the territory with industrial-residential complexes in the West, extremely sharp continental climatic indices that is located frontally to the global air masses and is convenient for the comparative integrated study of the issue.

Field study procedure

The field studies were performed at the 11 representative key sites. The objects of the study were the soils, flora and surface waters.

The sampling points were set for all landscape types – alpine eluvial, mid-mountain transition and accumulative plain steppe one (Table 1). Separate samples were taken in the area of effect of the residential complexes in the three districts – Bay-Tayginsky (the area of fall of the detachable pieces of the “Proton” launch vehicles), Barun-Khemchiksky (Ak-Dovuraksk asbestos industrial complex) and Dzun-Khemchiksky (Chadansky coal strip mine). We have referred the Sut-Kholsky district to the one that is not susceptible to the technogenic pollution of the area.

The gross content and the movable forms of Cu, Mn, Co, Zn, Pb, Cd, Ni, Al, Ba, Cr, Fe, Li, Mg, Sr and Ca as well as P, K, Na, I, N_2 (ammonium ions and nitrates), humus, pH, the soil texture were determined. Totally, more than 300 soil samples from the complete soil profiles (54) and from the root-inhabited soil layer (up to 50 cm, 120 surface water samples and 250 collections of the aerial portions of the main phytocenosis have been taken and analyzed. The herbage was cut from 1 m^2 of the sites. 320 geobotanical sites designed for the plant material sampling at the site of 10 m^2 were described.

Laboratory analysis

The analysis of the soil samples was carried out at the agrochemical laboratory "Tuvinskaya" of the Tyva Republic, the shared use center of the Siberian federal university, the shared use center of the Tuva State University. In order to identify the elemental composition of the environment we used: atomic absorption spectrometers Analyst 600 and Analyst 800 фирмы Perkin-Elmer and Sollar 6M by Thermoscientific; atomic emission spectrometers Optima 5300 фирмы Perkin-Elmer and ICAP 6500 by Thermoscientific. In order to specify and/or identify the organic substances of different origin we used: the mass-spectrometer by Agilent, spectrophotometers Cary 100, Cary 5000 Esclipse фирмы Varian, IR-spectrometer Nicolet by Thermoscientific, spectrofluorometers LS 55 and spectrophotometers Lambda 950 by Perkin-Elmer.

Mathematical statistics techniques

In order to investigate the correlation relationships of the gross composition and movable forms of the main macro- and microelements including heavy metals the linear multiple regression models with the minimum number of the independent factors were selected. For this purpose we used the method of the "stepwise factor inclusion-exclusion" (the STEPWISEFIT function of the math package MATHLAB used). The principle of the method consists in the fact that we compose the regression model that is the simplest in terms of the number of independent variables on the one hand and the best in terms of quality on the other hand. For this purpose we use the dedicated quick procedure of inclusion and exclusion of the factor model. The calculations were performed on the super-computers of the Computing center of the Tuva State University.

The results obtained were processed by the statistical methods with the use of the Statistica program – Version 6.1.

Table 1: Main landscapes and floristic complexes of the Khemchiksky basin

Sampling pointsб		Landscapes and plant communities (eco-systems)	Main soil types
No.	Topological names		
1	Smoothed steppe to the North-West from Ak-Dovurak, the valley of the Edegey river	Accumulative steppe. Bluegrass meadow at the point bars (Edegey). Mixed herbs pedati-sedge stony meadow steppe (Sut-Khol'). Mixed herbs wheatgrass true steppe (Chadan)	Chestnut steppe
2	The left bank of the river Khemchik, district Sug-Aksy, Kara-Chyraa and Kysyl-Tayga		Light-brown steppe
3	Plain smoothed steppe to the North-East from the Chadan mountain		Light-brown steppe
4	The valley of the river Ustuu-Ishkin downstream the cap Ara-Oy to the North-West of the Ishkin village	Transition mid-mountain (Alash plateau at the height of 1500-1800 m above sea level, dissected by the deep river valleys with the mixed forest). Mixed herb	Mountain-steppe chestnut

5	Stony mixed herb steppe at the slopes of the Sothern exposure (district of the Khondelen village)	gramineous-iris mixed forests. Larch gramineous-iris communities	Mountain-steppe chestnut
6	The spur of the Western ridge Tannu-Ola (Adar-Tosh pass)		Mountain-steppe liver-colored
7	Surroundings of the Sut-Khol Lake	Eluvial high-mountain (the shoots of the Western Sayan with the absolute height up to 2400-2800-3100 m). Cedar-larch taiga with the high-mountain tundras combined with cryophyte sub-alpine steppes	Meadow liver-colored
8	Surroundings of the Kara-Khol Lake		Mountain-meadow chernozem-like
9	The area of influence of the Ak-Dovurak asbestos industrial complex	Ak-Dovurak mountain and the 5-km area away from the settlement including ruderal and halophytic flora. Often identified as feather grass-cold-vermouth communities	Light-chestnut steppe light-textured soils
10	The middle reach of the mountain river Monagy (basin of the Kara-Khol lake)	Taiga forest with sub-alpine meadows, brushes, high-mountain tundras	Mountain-meadow with moors and humic soils
11	Chadan coal pit (10 km to the North from the Chadan mountain)	Mixed herb wheat grass sheep fescue true steppe here and there changing to the Caragana bush mixed herb low bush grass true steppe	Chestnut and light-chestnut

RESULTS

Soil biogeochemistry

The soil landscape of the basin is non-uniform and V. A. Nosin [14] distinguishes the following main soil categories: the groups of the steppe (light-, dark-brown, common and southern chernozems, mountain chernozems), taiga-forest (grey forest, dark-grey mountain-forest, sod-taiga and podzolic) and high-mountain (rocky juvenile, mountain-tundra) pedogenesis that are subdivided into smaller units. The basin soils are characterized by the small thickness of the soil profile because of the shallow penetration of the soil-forming processes, low intensity of the chemical processes and prevalence of the physical ones. These features of the soils are determined by the sharp continental climate and the extremely short period of the functional (biological) soil activity during the short vegetation season. The biogeochemical situation is affected by the peculiarities of formation of the local climate in particular by the amount of precipitations. The deficit of moisture in the basin is related to the effect of the Sayan ridge shielding the global atmospheric transport. The

ISSN: 0975-8585

situation is complicated by the Tannu-Ola Ridge that is fringing the basin from the North and is located frontally against the global air transfers and its shoots (the Adar-Tosh Ridge).

Biogeochemistry of the soils in the natural eco-systems

The analysis of micro elements, the gross concentrations of Cu, Zn, Pb playing a key role in metabolism make for the high-mountain soils 13,4-15,5; 26,9-35,3; 11,7-14,8 mg/kg of the air dry soil, respectively. The gross content of Pb in the root-inhabited soil layer of the high-mountain plant communities in the Bay-Tayginsky district (surroundings of the Kara-Khol Lake) slightly exceeds the background one, and Cu and Zn is accumulate in significantly lesser amounts than the background level. Definite decrease in the Pb content is typical for the soils covered by the spots of trees and shrubs that can be found in the high-mountain rocky steppes (surroundings of the Kara-Khol and Sut-Khol Lakes). In the high-mountain landscapes of the Sut-Kholsky district the content of all these elements is lower than the background one. This is with the exception of some samples taken in the area of burrowing by small mammals in the island high-mountain steppes and the sandy soil downstream the forest boundary where the concentration of Mn, Cu, Zn, Co, Mo slightly exceeds the background level. If we compare the similar communities in the flood plain and arena then we may note than in the soil covered by steppe trees and shrubs at the stage of joining at the arena the gross content of Cu is higher and in the flood plain – that of Zn and Pb. With increase of the age of the spots covered with trees and shrubs the gross content of all the elements under consideration increases. In the tree-shrub spots that are similar in the structure the increased concentration of all the movable forms of heavy metals in the soil by moving to the food plains of the Monagy, Alash and Ustuu-Ishkin rivers is observed.

In all soil types of the natural eco-systems in the basin of the Khemchik river no exceedance of the maximum permissible concentrations (MPC) and approximate permissible concentrations (APC) of the chemical elements from the heavy metals group that may be hazardous to the living organisms was observed. The exceedance of the MPC was observed only in respect of the gross cobalt. The exceedance of the movable cobalt forms was observed only in the Barun-Khemchiksky district (accumulative landscape). At the same place the exceedance of the MPC of the movable forms of manganese, zinc, nickel was observed. The exceedance of the chrome MPC was observed in all the soil types in the Barun-Khemchiksky, Bay-Tayginsky and Dzun-Khemchiksky districts and that of copper – in the Bay-Tayginsky (surroundings of the Kara-Khol Lake, upstream the lake in the taiga forest soils). The values of the cadmium content in most of the basin soils are close to the MPC (Table 2 of the Appendix 1). Pollution by chrome strongly affects the biological activity of the soil. The catalase activity of chernozem and the soil capacity to cellulose destruction are reduced. As the result of the reduced energy production against deterioration of the soil breathing the important biochemical processes are decelerated.

Chrome (in small amounts) stimulates the growth of the agricultural plants; however, the excess chrome causes different plant diseases. By entering the human body with the food chrome causes a lot of severe diseases including the secondary immunodeficiency [15]. The excess entry of copper results in the incorporation thereof into tissues (Wilson's disease). The hepatic cirrhosis, hepatolenticular degeneration are developed: a poorly soluble combination of copper with amino-acids is formed that is deposited in the lenticular brain core, liver, spleen cells, eye retina. The degenerative changes in the organs, photophobia are developed.

In all these types of the basin soils the extremely low iodine levels (from 0,15 to 0,29 mg/kg) are observed. These values are by 7-10 times lesser than the iodine content that is considered to be sufficient for the normal execution of metabolic processes in a human body (2 mg/kg) [16].

Biogeochemistry of the soils of residential complexes

As compared to the natural eco-systems the content of the most micro-elements including heavy metals in the technogenic landscapes is significantly increased. However, as a rule, the levels of these elements remain lower than the maximum permissible concentrations. The content of Ni, Mg, Co (gross) exceeding the MPC was observed in the soils of all technogenic landscapes. The As, Cd content over the MPC - the area of fall of the detachable pieces of the launch vehicles (Bay-Tayginsky district). At the same place the high content of Ba and Sr was observed. In the area of influence of the Ak-Dovuraksky asbestos industrial complex the content of Mg, movable forms of Ni, Zn, Co, Mn, Cu exceeding the MPC was recorded. In the area of influence of the Chadan coal pit the high content of magnesium, strontium (above MPC) is observed. The lead and barium content in the pit exceeds the background level in the basin.

Biogeochemistry of the surface waters

During the summer low-water period the water of all the water bodies is sweet, low-mineralized, of hydrocarbonate class of sodium group (over all years of observation) (Table 4 of the Appendix 1). Water of the rivers and lakes under investigation is classified by the total hardness values as "low-hardness (soft) water". The pronounced prevalence of calcium over magnesium is typical for the surface waters. The arid climate has determined the relatively weak migration of chemical elements, in particular, of calcium, the flora and fauna basically do not suffer from calcium deficiency.

The content of heavy metals in the surface waters depends mostly on the water pH, oxidation reduction potential, water hardness, phytoplankton maturity and other factors. The content of micro-elements in the surface waters varies steadily under the influence of many factors. The observations carried out during 2009–2014 revealed the common pattern for all the water bodies in the basin: increased content of magnesium, sodium, calcium. Most of the microelements of the heavy metal class as well as biogenic elements are represented in all the surface waters investigated in the trace amounts. Mineralization and ionic composition of the water bodies under consideration — Kara Khol and Sut-Khol lakes, Alash, Khemchik, Ustuu-Ishkin and Chadan river, formation of their chemical composition proceeds under the same conditions which determines a narrow range of indicators of the salt and biogenic relations.

Biogeochemistry of the aboveground photosynthesizing organs of the main plant communities

No direct correlation between the content in the soil (gross and movable forms) of the main macro- and microelements and the soil types was established (Table 5 of the Appendix 1). The accumulation of most of the chemical elements depends on the ecological-phytocenotic confinedness. There is a definite dependence of accumulation of macro- and microelements in the investigated floristic complexes on the type of the geochemical landscape. Most probably, a certain role belongs also to the functional accumulative features of the landscape. Thus, in particular, rather higher content of the main macro-elements N, P, K and some microelements – Mn, Ni, Fe, Mg is typical for floristic complexes of dry steppes. It can be seen from the Table 5 of the Appendix 1 (столбцы 7 и 8) that the content of certain macro - (K, Na) and microelements including those from the heavy metal group (Cu, Co, Zn, Pb and especially Mg) in the aboveground parts of the high-mountain floristic complexes is higher than in the middle-mountain and plain steppes. At the same time a high variability of the chemical element content in the high-mountain floristic complexes is observed which can be seen from the values of standard deviations from the mean value. The maximum values of the element content are mostly confined to the mountain-tundra complexes containing mosses and lichens.

The distinctive features of the floristic complexes of the middle-mountain areas (in the Table 5 data in the columns 4, 5, 6) are the low values as compared to the other floristic complexes, rather low variability of the macro- and microelement content.

The average values of the macro- and microelement content as well as the significant variability thereof is typical for the complexes of the plain steppes (columns 1, 2, 3 in the Table 5). Variability of content of the macro- and microelement composition of the plain-steppe floristic complexes is primarily related to the sufficient number of hole complexes with the peculiar physical and chemical parameters of the area of their influence. In terms of quantity the area occupied by them may reach up to 50% of the unit of area of the natural steppe eco-systems and it would be wrong to ignore their role in the determination of the chemical behavior of environment, in particular, of the plants. The chemical activity and physical parameters of such areas are determined by the burrowing activity of the digger mammals [17].

In the floristic complexes of technogenic landscapes the content of chemical elements exceeds in tens and hundreds of times the content thereof in the natural floristic complexes. In the flora some chemical elements that have not been detected in other plant associations were found in the trace amounts. They include Ba, Vi, As, Li, Sr, Ta. The values of content of some elements by many (tens of times) exceed the maximum permissible concentrations (MPC) and approximate permissible concentrations (APC) of the chemical elements that may be hazardous to the living organisms. The elements with the abnormal high content in the plant communities include Al, Ca, K, Na, Mg, Mn, Cu, many of which belong to the energy accumulation elements as the most important physiological ones. In the high-mountain areas arsenic and zinc are added to such elements. High content of chemical elements in them may be related to the composition of the plant cover. In technogenic landscapes the ruderal flora with inclusions of halophyte species is formed.

The content of Cu in the floristic complexes depending on the phytocenotic confinedness varies within the range from 4,7 to 13,3 mg/kg, Zn – from 9,9 to 20,4 mg/kg, Fe – from 1930 to 2325,2 mg/kg, Mn – from 11,4 to 20,9 mg/kg. The level of the natural Pb content in the floristic complexes falls within the range from 0,4 to 3,9 mg/kg, Cd – within the range from 0,05 to 0,36 mg/kg, Cr – from 1,12 to 3,9 mg/kg, Co – from 0,1 to 1,98 mg/kg, Mg – 0,10 up to 260,9 mg/kg and Ni – from 3,9 to 10,5 mg/kg (Table 5 of the Appendix 1).

The normal concentration of Cu in the plants is at the level of 0,2-20,0 mg/kg [18], Zn in the plants – 15-150 mg/kg [19], Fe – from 3,98 to 28,23 mg/kg, Mn – 20-300 mg/kg [20]. Despite the fact that Cr, Ni, Co, Pb, Cd has a physiological meaning for plants these elements are classified among the technophylic elements since the concentration thereof in the plants may increase as the result of technological impact [21]. The penetration of the increased quantities of these elements into the plants quite often results in a number of physiological and morphological changes. The natural levels of the lead content in the plants from unpolluted and barren areas falls within the range of 0,1-10,0 mg/kg of the dry weight at the average concentration of 2 mg/kg [22]. Normal Cd content in the plants – 0,05-0,2 mg/kg, estimated maximum content – 3 mg/kg [19].

The elemental chemical composition of the plants of the territory under consideration may be considered as representation of the biogeochemical situation of an ecologically clean region with the undisturbed natural biogeochemical cycles.

SUMMARY

The results that we have received in respect of the degree of the heavy metal movability in the soil do not demonstrate a strong correlation between the element mobility, soil grain-size distribution and high humus content. Definite correlation is observed between the content of the basic macro-elements (K, P, N) and physiologically-relevant elements. Under the same site conditions in the cedar and larch forests the soil contains different number of the gross and potentially movable forms of heavy metals and microelements. Completely different indicators of the chemical composition were recorded in the soils and plant cover (mosses and lichens) of the high-mountain landscapes in the Bay-Tayginsky district where some elements (As, Pb, Cd, Ba, Sr) showed high content in the soil (397,1; 197,7; 0,9; 185,7; 39,6) exceeding the MPC set for As, Pb, Cd manifold (the MPC values for Ba, Sr are not established) (Table 3 of the Appendix 1).

No direct correlation between the chemical element content in the soil, chemical activity of the surface waters and content in different types of plant communities can be established. The accumulation of most of the chemical elements depends on the ecological-phytocenotic confinedness. High content of chrome, magnesium, cobalt, zinc, lead, calcium, sodium, copper is typical for the high-mountain floristic complex (sergy dwarf birch and tussock sedge mixed herbed meadow). High content of the most chemical elements is typical for the intrazonal ruderal floristic complexes in the area of influence of residential complexes (area of influence of the Ak-Dovuraksky asbestos industrial complex, Chadan coal pit).

Thus, the chemical element content is affected by the ecological-phytocenotic confinedness of floristic complexes. At the same time the main factor determining the accumulation of the chemical elements is the habitat area. In particular, by changing of the habitat area within the same floristic complex the content of both the basic micro- and macro elements is increased. Such situation is typical for the area of the intensive hole digging small mammals of the floristic complexes regardless of the landscape confinedness (eluvial, transition, accumulative).

The biogeochemical situation in the Khemchiksky basin may be considered to be safe. There are separate elements in the soils (Cr, Cu, Pb) the content of which exceeds the maximum permissible concentrations. The characteristics of content of these elements in phytocenotic complexes do not depend on their content in the soils and it can be stated that in the initial link of the biological element circulation the plant communities absorb the concentrations that are not dangerous to a human and apparently to the other living organisms as well. At least, in the floristic complexes that are actively used for agricultural purposes no exceedance of the normal concentrations was recorded. The content of the toxic elements (especially As) in the high-mountain floristic complexes containing mosses and lichens arouses certain concern. Surely, these complexes are not the typical pastures for domestic animals and as a rule they are not directly included in the human food chain. However, the threat to the other living organisms and entry into a human body through the biological cycle cannot be excluded. Such situation is also typical for ruderal floristic complexes in the area of influence of residential complexes. They often include halophyte species that may be consumed by animals at the initial stages of ontogenesis and cannot be excluded from the list of the potentially hazardous ones.

The minimum iodine content in the soils causes special concern and the entire basin area may be classified as the biogeochemical province with the iodine deficiency provoking hypothyrosis.

Generally, the biogeochemical situation in the Khemchiksky basin cannot be the major factor in determining the distribution of diseases among the population except for the hypothyrosis determined by iodine deficiency.

Appendix 1

Table 2

CE*	Average content of chemical elements in different soil types, mg/kg								MPC
	1	2	3	4	5	6	7	8	
K	1140±363	142±14	654±12	440±31	233±62	270±46	506±43	215±15	-
Na	797±145	-	-	-	780±191	-	-	326±289	-
Ca	2210	13850	86480	14950	68440	27610	26940	5975	-
P	56±28	25±6	22±5	42±24	30±13	29±4	49±28	13±3	-
B	0,70±0,07	0,40±0,01	0,40±0,01	0,40±0,02	0,50±0,02	0,40±0,01	0,40±0,01	0,65±0,11	-
I	0,26±0,02	0,15±0,01	0,19±0,01	0,19±0,01	0,27±0,02	0,29±0,02	0,29±0,02	0,26±0,02	-
$Cu_{\text{в}}$	8,1±0,8	12,3±0,7	12,0±0,8	12,7±0,9	7,6±0,9	12,7±0,1	13,4±0,4	15,4±2,1	33
$Mn_{\text{в}}$	521±3	88±6	91±9	102±10	496±1	93±1	102±15	288±36	1500,0
$Co_{\text{в}}$	7,24±0,78	11,05±0,07	11,25±0,52	11,75±0,51	6,45±0,85	11,50±0,28	12,27±0,56	6,08±0,97	5,0
$Zn_{\text{в}}$	28,6±7,6	28,5±3,5	32,8±7,6	38,2±8,8	31,4±6,2	38,5±3,5	35,3±7,1	26,9±4,6	100,0
$Pb_{\text{в}}$	17,7±0,8	11,8±0,6	12,1±0,6	12,4±0,6	14,5±2,2	12,5±0,3	11,7±2,8	14,8±1,1	30,0
$Cd_{\text{в}}$	0,33±0,02	0,42±0,01	0,44±0,03	0,46±0,04	0,25±0,01	0,40±0,01	0,43±0,03	0,40±0,02	0,5
$Ni_{\text{в}}$	20,5±0,3	20,7±0,4	21,6±1,3	21, 8±0,9	18,8±0,9	20,6±0,2	23,0±1,5	19,4±1,4	85,0
$Fe_{\text{в}}$	24594	18330	26071	21842	24594	18240	16935	20208	
$Cr_{\text{в}}$	353±187	-	-	-	71±4	-	-	30±9	6,0
$Al_{\text{в}}$	15631	-	-	-	13746	-	-	7758	-
$Mg_{\text{в}}$	60617	-	-	-	23906	-	-	9195	-
$Cu_{\text{п}}$	0,23±0,05	0,06±0,01	0,09±0,04	0,14±0,04	0,12±0,04	0,12±0,02	0,18±0,03	19,19±7,7	3
$Mn_{\text{п}}$	26,08±0,52	4,3±0,141	4,46±0,27	4,75±0,22	19,58±1,77	4,75±0,07	5,05±0,63	19,18±7,69	1500
$Co_{\text{п}}$	0,12±0,01	0,04±0,01	0,07±0,02	0,12±0,03	0,08±0,02	0,09±0,01	0,14±0,02	0,12±0,07	5
$Zn_{\text{п}}$	1,28±0,06	0,63±0,09	0,87±0,19	1,03±0,42	0,90±0,27	0,82±0,02	1,19±0,44	1,12±0,66	23,0
$Pb_{\text{п}}$	1,37±0,17	0,65±0,19	0,90±0,21	1,05±0,42	0,56±0,16	0,97±0,06	1,06±0,50	1,10±0,42	30,0
$Cd_{\text{п}}$	0,030±0,002	0,050±0,0030	0,05±0,008	0,060±0,005	0,010±0,001	0,050±0,001	0,056±0,005	0,070±0,013	-
$Ni_{\text{п}}$	1,08±0,04	0,98±0,03	1,05±0,13	1,148±0,11	0,77±0,11	0,97±0,04	1,09±0,14	0,60±0,13	4,0
Humus	7,7±2,2	1,01±0,04	2,1±1,2	4,5±3,0	6,2±2,2	4,1±0,3	9,5±6,9	6,8±3,9	

Table 3

Chemical element	Average content of chemical elements in the soils of technogenic landscapes, mg/kg			MPC of the substance, mg/kg
	9	10	11	
K	170±123	275±33	184±120	560
Ba	34,3±14,8	185,6±121,0	38,3±18,3	-
P	9,7±1,5	29,5±3,0	12,7±2,4	-
B	0,83±0,86	0,41±0,01	0,65±0,13	-
I	0,147±0,005	0,293±0,015	0,269±0,034	-
Cu_{gross}	5,99±6,82	12,7±0,1	15,7±2,1	55*
$Cu_{movable}$	10,28±12,14	0,12±0,02	0,17±0,08	3
Mn_{gross}	45,8±44,1	92,8±1,0	289,2±35,0	1500
$Mn_{movable}$	277,5±332,3	4,7±0,1	18,7±7,9	60-100
Co_{gross}	5,6±2,4	11,5±0,2	6,4±1,0	5
$Co_{movable}$	4,70±1,65	0,09±0,01	0,11±0,07	5
Zn_{gross}	19,4±11,4	38,9±2,5	27,1±4,2	100*
$Zn_{movable}$	34,09±25,05	0,83±0,01	1,28±0,65	23
Pb_{gross}	6,4±4,1	12,5±0,2	14,7±1,0	32
$Pb_{movable}$	8,65±5,08	0,98±0,04	1,12±0,47	30
Cd_{gross}	0,23±0,22	0,406±0,005	0,399±0,011	0,5
$Cd_{movable}$	0,300±0,290	0,053±0,001	0,072±0,013	1,0*
Ni_{gross}	10,9±7,9	20,7±0,1	19,2±1,4	36*
$Ni_{movable}$	8,14±5,89	0,97±0,03	0,59±0,14	4
Al	13745,7±4308,4	7757,6±2254,6	15630,8±5514,5	-
Mg	60617,5±31176,8	23906,4±19509,2	9195,6±6898,2	1500
Sr	88,9±55,0	39,6±21,6	89,2±48,3	-

Table 4

Chemical elements	Average content of chemical elements in the natural surface waters, mg/l			
	Kara-Khol lake	Sut-Khol lake	Khemchik lake	Chadan river
Aluminum	0,12±0,01	0,086±0,07	0,11±0,10	0,06±0,04
Barium	0,004±0,002	0,016±0,010	0,041±0,019	0,018±0,010
Iron	0,129±0,320	0,185±0,150	0,222±0,177	0,082±0,067
Potassium	0,068±0,860	0,741±0,228	0,944±0,164	1,331±0,717
Calcium	17,68±11,93	17,86±8,54	15,77±5,36	25,91±14,50
Magnesium	2,88±0,95	3,62±2,01	4,72±1,02	9,18±6,32
Manganese	0,0060±0,0040	0,0090±0,0040	0,0090±0,0050	0,0009±0,0001
Sodium	10,17±7,33	7,76±4,99	10,25±2,69	11,25±6,76
Strontium	0,09±0,06	0,09±0,05	0,11±0,03	0,76±0,56
Chrome	0,0015±0,0011	0,0018±0,0014	0,0026±0,0012	0,0012±0,0007

Table 5

CE*	*n*	Average content of chemical elements in different plant communities, mg/kg							
		1	2	3	4	5	6	7	8
K	32	1,8±0,9	1,8±0,9	6,4±3,0	1,4±0,6	1,0±0,5	0,4±0,1	0,4±0,9	2,6±1,0
Na	32	0,35±0,20	0,22±0,12	0,70±0,40	0,03±0,01	0,24±0,17	0,03±0,02	169,50±29,40	241,20±33,50
Ca	32	1,11±0,36	0,57±0,53	0,71±0,27	0,52±0,10	0,71±0,33	0,48±0,11	0,75±0,43	1,70±1,04
P	32	0,80±0,08	0,12±0,03	0,30±0,12	0,06±0,03	0,14±0,06	0,25±0,16	0,85±0,23	0,20±0,10
B	33	22,4±1,6	18,5±1,2	21,6±3,1	19,2±1,6	18,5±2,9	22,1±4,2	22,5±4,2	22,4±1,5
Cu	33	4,6±1,1	7,0±2,5	7,2±0,3	4,8±2,3	4,7±1,3	8,1±3,5	12,8±3,2	13,3±2,5
Mn	31	20,9±8,3	13,3±1,9	11,4±1,1	14,1±1,3	16,3±8,8	12,9±1,0	11,7±6,7	18,2±8,8
Co	31	0,20±0,08	0,20±0,06	0,10±0,03	0,13±0,04	0,15±0,03	1,17±0,05	0,88±0,98	1,98±1,03
Zn	32	9,9±2,6	15,4±10,8	15,5±10,5	18,9±2,9	17,9±5,2	14,3±1,6	19,1±6,1	20,4±4,9
Pb	33	0,6±0,2	0,5±0,2	0,7±0,5	0,6±0,4	0,4±0,1	0,8±0,1	2,1±0,9	4,0±2,4
Cd	33	0,36±0,08	0,19±0,07	0,17±0,13	0,21±0,07	0,25±0,12	0,27±0,11	0,05±0,09	0,14±0,10
Ni	31	8,1±2,4	5,1±2,8	8,4±5,4	10,5±1,9	4,2±2,8	7,3±2,5	3,9±2,1	5,0±3,2
Fe	33	2325±454	1411±7	1545±119	2246±190	1574±290	1631±220	1784±108	1930±363
Cr	33	3,3±0,8	1,8±1,6	3,9±2,2	2,1±0,5	1,5±0,7	1,1±0,4	3,0±0,8	2,3±2,4
Al	33	0,07±0,03	0,02±0,01	0,04±0,02	0,03±0,01	0,03±0,01	0,03±0,01	0,03±0,02	0,04±0,02
Mg	32	0,5±0,2	0,3±0,2	0,3±0,1	0,1±0,1	0,4±0,1	0,3±0,1	157,4±87,4	260,9±110,2

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