Conference Paper

Content and Distribution of Biogenic and Toxic Elements in Soils and Vegetation of the Chulyshman River in the System of High-altitude Zone (Mountain Altai)

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Abstract

The content and distribution of nutrients (manganese, copper) and toxic elements (lead) in the soils and vegetation of the potentially recreational area of the Gorny Altai -- the r. Chulyshman. It was established that the level of total lead content in soils is characterized as ``low'', copper -- ``medium''. The content of mobile forms of copper and lead refer to the ``average'' gradation, which indicates the absence of contamination of the studied soils. Concentrations of the studied elements in the soils do not exceed the values of the APC and MPC adopted in Russia and abroad. Despite the obvious differences in the distribution of chemical elements in the soil profile, general patterns are also observed, due to the composition and properties of the soil. The biogenic accumulation of all elements, but especially of manganese and copper, is noted in mountain-brown podzolized soils. In mountainous chestnut-shaped soils containing little organic matter, having an alkaline reaction of the medium, an adsorption carbonate barrier is created, on which the precipitation of elements occurs. According to the content of elements, separate parts of plant associations on the studied soil types, except for the soils of the high-mountain belt, can be arranged in the following descending series: litter> roots> above-ground mass. The obtained data can be considered as a reference point for possible anthropogenic pollution.

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1. Introduction

The Chulyshman River is the largest tributary of Lake Teletskoye, whose basin is one of the main recreational areas of Gorny Altai, a UNESCO World Heritage Site (1998). Chulyshman gives about 70 % of the total inflow of the lake. It flows out of the high-mountain lake Dzhulukul at an altitude of 2200 m. The length is 241 km, the basin area is 16 800 km^2. The river divides two mountain systems of Altai: the Chulyshman Highland with altitudes from 1500 to 3110 m (in the east) and the Ulaganskoye plateau

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with altitudes from 2000 to 3446 m (in the west). The Chulyshman River basin is very picturesque, but at the same time, it is one of the most inaccessible and deserted areas of Altai. These places are distinguished by their ``wildness'', which gives them a special attraction. There are no permanent settlements in the upper course of the river, only one village is in the middle course, and two villages in the lower course. The lower reaches of the river are the most developed part of the Chulyshman valley. Here, parallel to the river, there is a road, and tourist bases are located along the banks. Part of the basin's territory belongs to the Altai State Natural Biosphere Reserve (AGPBZ), established in 1932, in order to preserve and study the unique natural complex of Lake Teletskoye and Priteletskaya taiga. Another part, especially in the summer period, is subjected to anthropogenic pressure as a result of the activities of the tourism industry, whose influence is increasing every year. Therefore, the assessment of the current biogeochemical state of this area is very relevant and extremely necessary. The intensive recreational load on natural resources causes a change in the directions and rates of migration of chemical elements included in the background composition of the soil and additionally from various sources of pollution. The purpose of these studies is to assess the biogeochemical state of the r. Chulyshman in the system of high-altitude.

2. Formulation of the Problem

To the priority tasks of modern biogeochemistry, which should be given priority attention, according to one of the leading Russian biogeochemists, V.B. Ilyina [1] is the study of the natural (background) content of chemical elements of pollutants in soils and plants and their distribution among the components of the soil and the organs of the plant organism. The obtained data can be used for the genetic characteristics of the soil and be considered as a point of reference, from which excess their pollution begins [2]. This is especially true for environmentally safe regions, where further strengthening of recreational activities is expected. Recreation is one of the main negative anthropogenic factors affecting natural ecosystems. Most of the works [3, 4] are devoted to the influence of recreational activities on forest ecosystems, namely, on the morphological, general physical, water-physical properties of the soil, on changes in the species composition of vegetation. But the steppe landscapes, and to a greater extent the river valleys ecosystems, are also exposed to recreational effects. Unfortunately, the alleged change in the elemental chemical composition of the landscape components, the disruption of translocation processes and the transformation of elements, both biogenic and toxic, are not cause for concern. Only in individual works is given a biogeochemical assessment of protected ecosystems [5, 6] In this paper, the content (gross and mobile forms), distribution over genetic soil horizons, in parts of plant associations (above ground mass, roots, litter) biogenic (manganese and copper) are considered. and toxic (lead).

3. Materials and Methods

When studying the processes of distribution, migration, transformation and accumulation of biogenic and toxic elements in landscapes of various taxonomic levels, both traditional approaches (comparative geographical, comparative genetic, biogeochemical) and approaches that take into account the specificity of the object under study (basin, landscape geochemical) were used. Such an integrated approach (including the basin one) in ecological and biogeochemical studies, along with a general assessment of the state of the environment, makes it possible to predict its changes in the future and determine ways to reduce the supply of toxicants to living organisms.

The objects of study were the main components of the landscape -- soil and vegetation.

Within the territory under consideration, the altitude-belt differentiation of the soil cover is determined by the presence of the following belts (from top to bottom): 1) mountain-tundra, mountain meadow-steppe soils of highlands; 2) mountain forest soils of middlelands; 3) steppe and mountain-steppe soils of middlelands. In the valley of the river. Chulyshman distributed floodplain and alluvial soil.

Sampling was carried out by methods generally accepted in soil science and agrochemistry. This paper presents the data on the content of chemical elements in the soil on genetic horizons. The elevated phytomass and litter were taken from an area of 1 m^2 in areas associated with soil cuts. Selection of plant samples was carried out in the flowering phase, when the maximum intake of chemical elements into the aboveground mass is noted. The roots were washed first in running water, then distilled. The determination of the content of heavy metals (manganese, copper, lead) was performed by the voltammetric method. The mobile forms of the elements were extracted with ammonium acetate buffer (pH 4.8). When processing the information received, the variation-statistical and correlation methods were used.

The content of chemical elements in the soil and their associated translocation into plants is a complex process that is influenced by many factors, which can be divided into 3 groups: 1) the composition and properties of the soil; 2) the needs and protective capabilities of the plant; 3) the properties and the biological role of the chemical element. The soil serves as a receiver for most of the elements involved in the biosphere, their main accumulator and migration regulator [7]. The leading role in the redistribution of chemical elements in the soil-plant system is played by the following parameters: humus, fine particles, carbonates, medium reaction and the value of the cation exchange capacity, the indicators of which are presented in Table 1.

TABLE 1: Physical and chemical properties of the soils of the lake Teletskoye.

Soil type	Horizon	Humus	Il	Physical clay	$CaCO_3$	pH_B	CEC, mEq. per 100 g of soil
		%					
Alpine belt							
Mountain tundra	A	79.2±9.8 [a]	Fine earth absent.	Fine earth absent.	Not updated	5.4±0.1	59.3±6.2
	T_1	61.3±7.1	-« »-	-« »-	-« »-	5.1±0.1	44.6±0.5
	T_2	33.6±2.9	-« »-	-« »-	-« »-	5.6±0.1	13.7±1.9
	C	1.8±0.2	-« »-	-« »-	-« »-	6.3±0.1	9.1±0.7
Mountain meadow-steppe	A	14.9±1.1	0.2±0.03	4.8±0.6	-« »-.	6.0±0.1	37.6±3.6
	AB	6.6±0.1	1.3±0.20	9.6±1.4	-« »-	6.1±0.1	21.8±2.4
	B	2.5±0.1	0.1±0.06	11.3±0.8	-« »-	6.1±0.1	21.3±2.0
	C	0.7±0.1	0.4±0.08	6.2±1.3	-« »-	6.2±0.3	17.7±2.3
Mid-mountain belt							
Mountain-steppe chestnut	A	1.7±0.2	2.2±0.08	10.4±3.4	1.7±0.4	7.2±0.1	14.6±1.7
	B	0.4±0.1	2.8±0.05	11.4±2.2	3.4±0.8	8.6±0.2	6.3±0.5
	C	0.1±0.03	2.8±0.01	6.9±0.54	3.6±0.4	9.3±0.1	4.2±0.5
Mountain-forest brown podzolized	A	10.1±1.6	5.5±0.8	8.6±0.2	2.8±0.3	6.4±0.6	66.1±0.8
	B	0.5±0.01	5.4±0.6	9.0±0.2	0.4±0.1	7.3±0.6	4.8±0.5
	C	0.2±0.01	5.0±0.9	9.0±0.2	1.5±0.1	8.5±1.0	4.1±0.5
River valley soils							
Alluvial	A	3.0±0.4	3.2±0.2	6.2±0.3	3.2±0.3	6.9±0.5	16.0±0.6
	A	2.2±0.2	3.2±0.1	5.6±0.5	1.1±0.1	7.9±0.5	9.0±1.0
	B	0.6±0.1	3.0±0.3	6.0±0.5	0.3±0.1	8.5±0.5	2.4±0.3
	C	0.5±0.1	3.2±0.1	6.0±0.5	0.3±0.1	8.8±0.5	6.5±0.5

[a] arithmetic mean ± error of arithmetic mean

In mountain-tundra soils, organic matter in the upper horizons is present in the form of coarse humus, its amount during calcination is on average 79.2 %. In the underlying horizons, where the processes of mineralization of plant residues are more pronounced, the amount of organic matter decreases, but also remains quite high. The granulometric composition could not be determined because there was no fine earth fraction. Carbonates are absent throughout the profile. For mountain-tundra soils characteristic of the acid reaction of the environment. In the upper part of the profile containing a large amount of humus, the exchange capacity is on average 59.3 mEq. per 100 g of soil. With a decrease in the content of organic matter and the absence of a clay fraction in the lower part of the profile, the number of absorbed cations decreases to 9.1 mEq. per 100 g of soil.

In mountain meadow-steppe soils, there is an accumulation of fine particles in the middle part of the profile. The humus content in the surface layer is high (14.9 %). The reaction medium is weakly acid. The maximum cation exchange capacity in the upper horizons. In the lower part of the profile, less humified, it decreases sharply.

In the mountain-steppe chestnut-shaped soils the humus content is 1.7 ± 0.2 %. In the lower horizon. In it falls to 0.4 ± 0.1 %. Boiling up of carbonates is observed from the surface, rapid -- from 24--30 cm. The content of carbonates increases with depth: from 1.7 ± 0.4 (in the humus horizon) to 3.7 ± 0.8 % (in horizon C). In some sections their content can reach 11.6 %. The reaction of the soil solution varies from close to neutral and weakly alkaline in horizon A to strongly alkaline in -- in horizon C. The cation exchange capacity is low, with depth its value drops sharply from 14.6 ± 1.7 in the humus horizon to 4.2 ± 0.5 mEq. per 100 g of soil in horizon C.

Brown mountain podzolized soils are distinguished by a light granometric composition, high humus content in the upper horizons, which drops sharply with depth. The distribution of fine particles along the profile is uniform. The reaction environment varies from close to neutral to alkaline. The cation exchange capacity decreases down the profile.

Alluvial soils are characterized by a light particle size distribution, low humus content and cation exchange capacity, alkaline reaction of the environment.

The above described soil properties influence the content and intra-profile distribution of elements.

The accumulation and migration of chemical elements along the profile of natural soils is determined by the type of soil formation, forming a large variety of types of profile distribution of elements.

In the mountain-tundra soils, the distribution of the total content of manganese and lead can be attributed to a uniform, copper -- progressively accumulative; mobile forms of copper and lead -- to progressively accumulative. Intensive biogenic accumulation is characteristic of mobile forms of manganese (Figure 1). In mountain meadow-steppe soils, the intra-profile distribution of the total content of all the elements studied, as well as mobile forms of copper and lead, approaches a regressive-eluvial type.

For mountainous chestnut-shaped soils, the distribution of the total content and mobile forms of all elements approaches a uniform or weakly expressed uniformly eluvial.

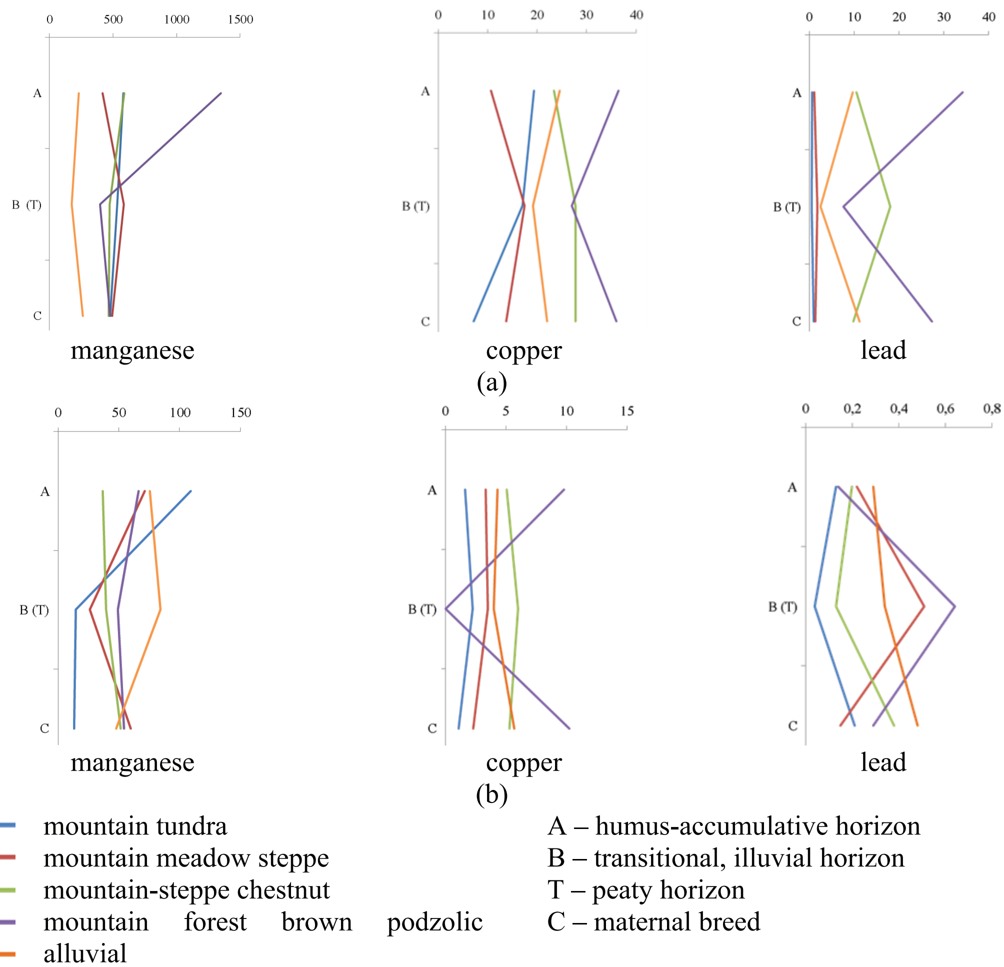

Figure 1: Gross content (a) and the content of mobile forms (b) of chemical elements in the soil profile, mg / kg.

The distribution of all elements in the profile of mountain forest brown podzolized soil is the same for both gross and mobile forms, and approaches the regressive-accumulative one, except for the distribution of mobile forms of lead with a pronounced eluvial-illuvial type of distribution.

The main processes that determine the distribution of elements in the profile of alluvial soils are high moisture content and light particle size distribution. The distribution in the profile for all elements can be attributed to the uniform-eluvial or uniform-soil-accumulative type.

Despite the obvious differences in the distribution of chemical elements in the soil profile of the studied soil types, it is necessary to note the general regularities caused by the composition and properties of the soil. The pronounced biogenic accumulation of all elements, but especially manganese and copper, is noted in mountain-forest brown soils that contain a lot of coarse humus in the upper horizon, which, when slightly acidic, can bind manganese in large quantities with annual forest litter and dying forest herbs. The increased lead content in the surface layer of mountain brown brown podzolized soils is not a consequence of pollution due to atmospheric precipitation or surface transfer. Profile distribution can be formed as a result of the redistribution of lead contained in the soil-forming rock, under the influence of its removal by plants with subsequent accumulation in the forest floor and humus horizon. In mountainous chestnut-shaped soils containing little organic matter, having an alkaline reaction of the medium, an adsorption carbonate barrier is created, on which the precipitation of elements occurs. Since the presence of carbonates is noted throughout the profile, from the surface itself, the chemical elements move slightly in the vertical direction.

According to the scale of ecological rationing for soils with a weakly acidic reaction of the medium according to A. I. Obukhov [8], the level of total lead content in the soils of the mountain forest belt is characterized as ``low'', and copper -- ``medium''. The established values of the content of mobile forms of copper and lead can be attributed to the "average" gradations. Concentrations of the studied elements in the soils do not exceed the values of the APC and MPC adopted in Russia and abroad. The above indicates the absence of contamination of the studied soil types with these metals. Many studies are devoted to the study of soil input into plants and the accumulation of biogenic and toxic elements, but most of them are devoted to the study of certain species, most often agricultural crops, and the distribution itself is examined by plant organs [9--11]. The study of the distribution of chemical elements in different parts of plant associations (aboveground, mass, roots, litter) is of scientific and practical interest.

The decrease in the content of elements in plants is evidence of their limited absorption by the latter due to the presence of physiological and biochemical absorption barriers and a rather low mobility of microelements.

The root system is more likely to prevent excess toxicants (lead) from entering the plants than biogenic elements (copper and manganese) (Figure 2). The ability of the plant root system to retain excess ions is due to the cumulative effect of morphological structures and chemical reactions of a nonspecific nature, which include the Caspari belt, the exchange capacity of the roots, and numerous organic compounds that form slow-moving compounds with elements. Root contribute to mechanical delay or adsorption on the cell walls, reducing their mobility or isolation [1]. The level of concentration of chemical elements in the aerial parts of plants is controlled by the processes of their transport from the root system. Limiting the processes of translocation to vegetative organs can be assessed by comparing the accumulating capacity of the root and aboveground parts of plants. It, as a rule, takes place in conditions of natural or technogenic pollution. In the absence of contamination, the root protection mechanisms do not enter action and a specific distribution of the element among plant organs and tissues is possible. Thus, in plant associations developed on the soils of the high-mountain belt, the content of nutrients (manganese and copper) in the root system is lower than in the above-ground mass.

In general, there is a tendency of the greatest accumulation of the studied elements in the underground mass in comparison with the above-ground mass. But the maximum of their content is noted in vegetable litter. This is especially true of forest flooring. Active biogeochemical processes occurring in the forest litter, due to the constantly flowing organic material, high deponent properties in relation to the chemical components falling out of the atmosphere -- all these qualities put the forest litters into a number of natural objects that play an exceptional role of the biogeochemical barrier to the migration of elements in forest landscapes [12].

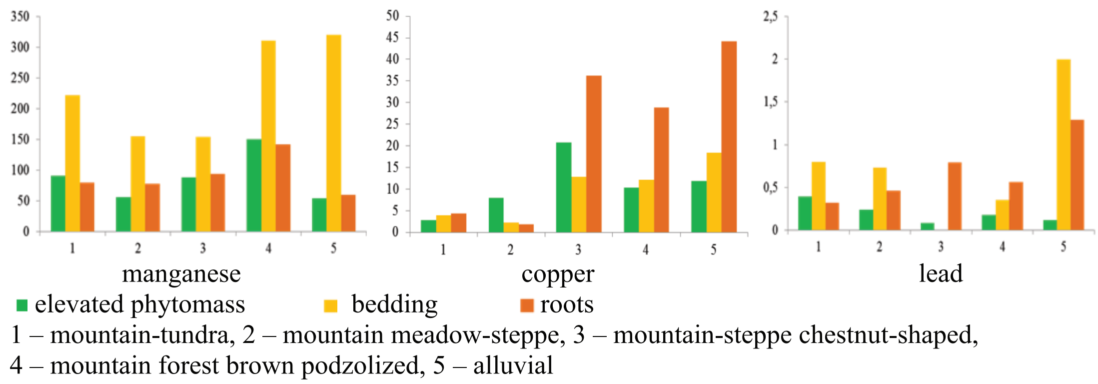

Figure 2: The content of chemical elements in different parts of plant associations.

4. Conclusion

The level of total lead content in the soils of the Chulyshman river is characterized as ``low'', copper -- ``medium''. The established values of the content of mobile forms of copper and lead are ``average''. which indicates the absence of contamination of the studied soils with heavy metals. Concentrations of the studied elements in the soils do not exceed the values of the APC and MPC adopted in Russia and abroad.

Despite the obvious differences in the distribution of chemical elements in the soil profile of the studied soil types, general patterns are also observed, due to the composition and properties of the soil. The pronounced biogenic accumulation of all elements, but especially of manganese and copper, is noted in mountainous brown podzolized soils. The increased lead content in the surface layer of mountain brown brown podzolized soils is not a consequence of pollution due to atmospheric precipitation or surface transfer. Profile distribution can be formed as a result of the redistribution of lead contained in the soil-forming rock, under the influence of its removal by plants with subsequent accumulation in the forest floor and humus horizon. In mountainous chestnut-shaped soils containing little organic matter, having an alkaline reaction of the medium, an adsorption carbonate barrier is created, on which the precipitation of elements occurs. Since the presence of carbonates is noted throughout the profile, from the surface itself, the chemical elements move slightly in the vertical direction.

The decrease in the content of elements in plants is evidence of their limited absorption by the latter due to the presence of physiological and biochemical absorption barriers and a rather low mobility of microelements. According to the content of chemical elements, separate parts of plant associations on the studied soil types, except for the soils of the high-mountain belt, can be arranged in the following descending series: litter> roots> above-ground mass. The obtained data can be considered as a reference point for possible anthropogenic pollution of the studied area.

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