Peculiarities of profile distribution of metals in soils of geochemically conjugated landscapes of Chelyabinsk city

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Abstract. The article discusses the results of soil-geochemical studies carried out on the territory of the Chelyabinsk urban district. The features of the profile distribution of pollutants within the landscape catena are established. The maximum concentrations of heavy metals are confined to the upper soil horizons of the eluvial position under forest vegetation. The soils of the superaquatic position under moist meadow and swamp vegetation are less polluted. The most polluted soil layer is located at a depth of 4-10 cm from the surface. This may be due to a decrease in heterogeneous emissions from the city’s metallurgical enterprises over the past 30 years.

1 Introduction

The Urals is an old industrial and mining region with a large number of ferrous and non-ferrous metallurgy enterprises. The city of Chelyabinsk was formed as a major industrial center in the middle of the 20th century. At the same time, the Chelyabinsk Metallurgical Plant, the Chelyabinsk Electrometallurgical Plant, the Chelyabinsk Zinc Plant were built, that represent the economic basis of the city. Large metallurgical giants are a source of emissions of heavy metals and their compounds. The study of soils in the city makes it possible to obtain information on the intensity and dynamics of heterogeneous emissions from the start of industrial production to nowadays [5]. In addition, the study of the issues of migration and accumulation of pollutants is necessary to understand the rate of self-purification of soils in these natural and climatic conditions.

To identify the features of the distribution of pollutants in the soils of the city of Chelyabinsk, the principle of soil-geochemical conjugation of elementary landscapes from the local watershed to the depression, forming a landscape catena, was applied [1, 7]. According to this provision, geochemical landscapes are territorial units within which rows of soils, interconnected by lateral migration of substances, are formed. These paragenetic associations of soils can be called “soil-geochemical conjugations” or “soil-geochemical catenas” [2].

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The aim of the work is to establish the features of migration and accumulation of pollutants in the soils of the city of Chelyabinsk, based on the results of a study of the landscape catena in the settlement of Pershino. It is located in the Metallurgical District of Chelyabinsk.

2 Materials and methods

The settlement of Pershino was a village until the 50s of the XX century. After the inclusion of the settlement into the city limits, individual residential buildings and a forest area have been preserved on its territory to the present day. After the construction of metallurgical enterprises, the village is in the zone of direct influence of their emissions now (Figure 1).

![Fig. 1. Situational scheme of the research area: north-eastern part of Chelyabinsk.](https://doi.org/10.1051/bioconf/20237102001)
landscape, a soil section was laid according to the generally accepted methodology. The general description of the soil profile and soil diagnostics were carried out according to the Classification and Diagnostics of Soils in Russia [4]. Soil sampling was carried out from each genetic horizon; in the humus horizon sampling was carried out layer by layer.

The selected soil samples were delivered to the environmental monitoring laboratory of the Faculty of Ecology of the Chelyabinsk State University, were brought to an air-dry state, crushed and passed through a sieve with a cell diameter of 1 mm. The chemical decomposition of the samples was carried out according to the generally accepted method [6]. In the resulting solution, heavy metals were determined using an atomic absorption spectrometer with flame atomization "Kvant-2M". The reliability of the analyzed indicators was controlled using a standard soil sample of chernozem. The concentrations obtained from the analysis of the sample were within the acceptable range of values.

The hydrogen index was measured by the potentiometric method using the Ecotest-pH-meter-ionomer.

### 3 Results and Discussion

A description of the soil-vegetation complex of adjacent landscapes has been made.

Eluvial position. It is confined to the top and upper part of the gentle slope of the hill with an absolute height of 230 m. In some places there are outbursts of quartz bedrocks.

The vegetation is represented by birch forbs and cereals with an average stand height of about 18 m. The soil profile scheme is shown in Figure 2. According to the Russian Soil Classification, the soil can be diagnosed as a typical gray soil [4].

Transeluvial position. It is confined to the middle part of the slope, with a slope within 1.5°. The plant community is represented by a forb-grass meadow. According to the results of the morphological description, the soil was diagnosed as a dark clay-illuvial agrozem.

Superaqueous position. It is confined to an inclined terrace-like area near the bed of the Miass River. The established groundwater level is 160 cm. The plant community is represented by a wet-meadow community in elevated areas and a meadow-marsh community in depressions. According to the above data, the soil can be attributed to the humus-quasi-gley soil (in the "Classification of Soils of the USSR", the analogue is meadow soils).

Profile distribution of metals in geochemically conjugated landscapes.

The features of the distribution of the pH index and heavy metals along the soil profiles of the adjacent landscapes of the elementary landscape catena of the settlement of Pershino are shown in Figures 2-4. As can be seen from the figures, the pH of the studied soils is in the slightly or medium alkaline range. In the upper humus horizon of the soils of the eluvial and transeluvial positions, the acidity is 7.8–8.0; lower along the profile, it slightly decreases, reaching neutral and slightly alkaline values.

On the contrary, in the profile of the superaqueous position the maximum pH value is characteristic of the second buried humus layer. The upper humus horizon is characterized by a slightly alkaline reaction of the soil solution.

The distribution of Cr, Mn, Cu, Pb, Zn, Cd in the soil profile of the eluvial position has a pronounced accumulative character (Figure 2). The maximum concentrations of Mn are confined to the upper litter horizon (0-4 cm from the surface). For other metals, the maximum values were found in a layer of 4-10 cm with an excess of the standard of tentatively permissible concentrations / maximum permissible concentrations for Zn by 15.4; CD at 5.6; Cr at 3.8; Pb 2.9, Cu 1.1 times. At a depth of 20 cm from the surface, metal concentrations sharply decrease to background values. Ni and Co are evenly distributed along the profile.
The distribution of most metals in the soil profile of the transeluvial position also has an accumulative character with a maximum in the 5–10 cm layer. However, in numerical terms, $C_{\text{max}}$ is inferior to the concentrations of the same elements in the soils of the eluvial position: here, the Zn standards are exceeded by 13.9; Cd at 11.0; Pb by 1.3 times. For other elements, no excesses of standard indicators were revealed.

**Fig. 2.** Distribution of metals along the soil profile of the eluvial position.

**Fig. 3.** Distribution of metals along the soil profile of the transeluvial position.
As in the section of the transeluvial position, in the profile of the superaquatic position, the maximum concentrations are confined to the 5–10 cm layer. The difference is that in the soils of the superaquatic position, the concentrations of Cr, Cu, and Cd gradually decrease with depth. This may be due to a more intense leaching regime and the migration of metals with the clay fraction to the underlying soil horizons. In general, the excess of standard values was recorded only for Zn by 10.7 times and Cd by 11.5 times here. The concentrations of other considered elements do not exceed the norm.

4 Conclusion

On the landscape catena, the maximum concentrations of most metals were recorded in the upper part of the humus horizon of the soil of the eluvial position (layer 4–10 cm). This is due to a smaller amount of moisture entering the landscape. That is why, the radial transport of metal ions in the profile is weakened. Surface runoff is also weakened in forest communities due to more uniform snowmelt in spring.

In the soil of the transeluvial and superaquatic position, the layer of maximum concentrations is also at a depth of 5–10 cm. This circumstance may be associated with a decrease in aerotechnogenic metal inflows over the past 30 years, since the introduction of emission treatment systems at the city’s metallurgical plants.

Fig. 4. Distribution of metals along the soil profile of the superaquous position.

In the early 2000s, a sulfuric acid shop was launched at the zinc plant. It made it possible to reduce sulfur dioxide emissions into the atmosphere, and, thereby, change the conditions for the migration of pollutants. As is known, most metals are readily soluble in acidic media and form strong compounds in neutral and alkaline media [3].
To monitor the soils of the city of Chelyabinsk, it is advisable to carry out layer-by-layer sampling of 0-5 and 5-10 cm. This allows us to assess the change in the level of pollution of the territory over decades, and the effectiveness of the implementation of the environmental management system at the enterprises of the city.

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