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Geochemical differentiation of soils in the Amur Basin (Russian Part)

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ABSTRACT

The paper gives landscape-geochemical characteristics (processes of migration, dispersion and concentrations of elements in soils) of the Russian part of the Amur Basin. The impact of geographic factors on the formation of soil-geochemical systems is revealed and mechanisms of moisture interactions with the soil system are described. The spatial heterogeneity of chemical element concentrations in background soils is viewed as a function of the migration activity of elements. The role of iron in the regional geochemical background formation is revealed. Migration conditions of indicator elements and levels of their activity are discussed. The map Landscape-Geochemical Zoning of the Amur Basin, scale (1:2,500,000) was created based on ArcGis 10 (ArcMap). The map reflects soil-geochemical migration zones by indicator elements in soils.

1. Introduction

Intensive developments of natural resources in the Amur basin (reduction of forest area, mining operations, catastrophic fires, agricultural land use) impact the soil cover, disturb its biogenic processes and geochemical fluxes. Mining developments over many decades caused the appearance of numerous pits and tailings with enormous amounts of wastes, which are the sources of chemical pollution of soils (Makhinova et al., 2006). About 30% of the Amur basin soil cover suffers to this or that extent of direct or indirect pollution. Asia-Pacific countries express great interest in the diverse natural resource potential of this region of Russia. Considering this fact, environmental issues of the anthropogenic pressure on natural landscapes will always be of urgent importance (Ivashov and Sirotsky, 1996).

However, the modern level of knowledge on the geochemistry of natural and anthropogenic soils, i.e. soils whose natural properties are highly disturbed due to human activities, has been and remains insufficient. Many areas of the Amur basin are still weakly studied. Diverse natural conditions and a wide range of soil contaminants make the analysis of geochemical conditions of the soil cover rather difficult. Moreover, insufficient studies of the Amur basin hinder proper interpretation of the obtained results. Many theoretical and practical issues related to mechanisms of chemical pollution of soils and studies of their present degradation need further discussion (Makhinova and Makhinov, 2008). The problem of identifying mechanisms of the redistribution of soil pollutants and the formation of geochemical fluxes in space is one of the essential goals of soil ecology and landscape geochemistry related to the distribution of chemical elements in soils (Kasimov et al., 1989).

The objective of the presented research was to study dynamic indicators of element concentrations in background soils to assess: a) the geochemical activity of elements in different soil and environmental conditions, and b) the role of migration fluxes in the redistribution of elements of the soil-geochemical space and the creation of the classification of landscape-geochemical structures for zoning of a particular area.

2. Research methods

Various soil and soil-forming processes were analyzed in the main types of landscapes of the Russian part of the Amur basin (Fig. 1). Zones of mining activities are considered to be geochemically anomalous. The zones of mining impacts on the soil cover were defined. The content of total carbon in soils as a major factor of the formation of geochemical fluxes was estimated with the dichromate oxidation method using H_2SO_4–$K_2Cr_2O_7$, and TN was estimated with the semi-micro Kjeldahl digestion method using Se, $CuSO_4$ and K_2SO_4 as catalysts (Belchicova, 1975). The regional geochemical background of the area under study was estimated based on the results of the spectral analysis of major and trace elements in the upper horizons (0–25 cm) of the main soil types using the ICP OES (emission spectrometry with inductively coupled plasma on Spectroscan No 835 (Lif 200)). Only those microelements, whose concentrations exceeded the sensitivity of the spectral analysis, were used as indicator elements of the geochemical background. They were siderophile (Fe, Mn, Cd, Co, Ni) and chalcophile (Cu, Zn, Pb) elements. The statistical analysis was done using the SPSS software package for Windows

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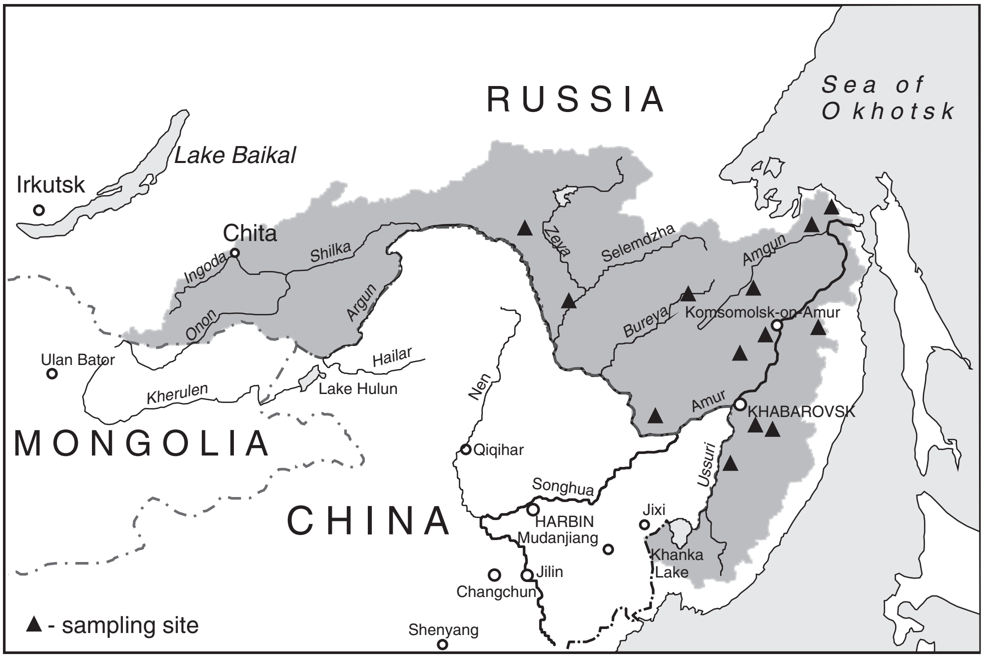

Fig. 1. Study area with location of the sampling site.

(SPSS 17). One-way ANOVA was used to test for significance. For all analyses, where $P < 0.05$, the tested factors and relations were considered to be statistically significant.

There were analyzed in background soils at different pH values:

a) The coefficient of water migration as the ratio of the concentration of element in the soil solution to their content in the soil-forming rock.
b) The coefficient of biogenic migration as the ratio of element concentration in the annual growth of biomass to their content in soil.

Main approaches of N.S. Kasimov et al. (2009), as well as the methodology of small-scale and review mapping of M.A. Glazovskaya (1989) were applied to complete the landscape-geochemical zoning of the studied region.

3. Results and discussions

The obtained research results were analyzed based on the soil-geochemical matrix as an integral model of chemical element distribution in soil space, where all processes are self-controlled (Kovda, 1973). Background soils of zonal landscapes and their formation factors were analyzed. Major and trace element content in the background soils was also analyzed. The soil-geochemical matrix (map-scheme in the form of contour lines) was designed to estimate the distribution of major and trace elements. It served as a support for determining specific geochemical fluxes. The results were analyzed in terms of soil-geochemical matrix as an integrated model of the distribution of chemical elements in the soil space where all processes are controlled by the laws of self-regulation (Kovda, 1973; Smagin, 2003).

The spatial variability of element concentrations as the state of the regional geochemical background of the area was estimated with the coefficients of element concentrations (Kj), defined as the ratio of the average element concentration in different soils to the geochemical background of an area, which characterizes the accumulation (or deficit) of elements compared to the geochemical background of an area. Three levels of element concentrations were identified in the soil-geochemical matrix such as:

- a — Levels of the element accumulation ($Kj > 1.1$);
- f — Levels of the compliance of element concentrations with their regional background ($0.7 < Kj < 1.1$);
- d — Levels of the element deficit ($Kj < 0.7$).

Levels of element concentrations in background soils (the state of scattering or concentration) functionally comply with soil-geochemical fluxes, which are determined by migration conditions and geochemical processes in soils.

Conditions of the migration of chemical element and their compounds in the Amur basin are determined by its climatic and biogeochemical potential. Relief specifics and the thickness of unconsolidated sediments also affect element migration conditions.

The climatic potential is characterized with the moistening coefficient (Q_m) defined as the ratio of annual precipitation to the annual evaporation in a particular landscape and also the length of a frost-free season. The biogeochemical potential is mainly characterized with indicators of concentrations of aggressive fractions of humic acids. Their role in geochemical processes of soil is shown in Fig. 2.

According to A.I. Perelman and Kasimov (1999), geochemical conditions of the element migration depend on the ratio of redox and acid-base parameters of the soil solution. Table 1 shows that the geochemical activity of major and trace elements depends not only on their belonging to certain geochemical groups, but also on the pH of the soil solution. In the Amur basin iron and manganese form the general regional background, and largely determine the behavior of microelements in soils, which is consistent with the widespread volcanic-sedimentary hematite–magnetite quartzites in the Amur basin (Kulakov et al., 2012; Vinogradov, 1962).

Geochemical processes and the migration of elements depend on the physical state of solid, liquid and biogenic phases of soils (Polynov, 1952). Processes of organic matter synthesis and decomposition play an important role at the biogenic phase due to the formation of fine and soluble fractions of humic acids.