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Features of the elemental chemical composition of the magnetic phase of the urbic soil of the industrial city

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Abstract

A relevant environmental problem in cities is the increased concentration of some heavy metals in soils. Heavy metals come to the soil from natural and anthropogenic sources. Emissions from industry, transport, and fertilizers are anthropogenic sources. In the soil, heavy metals are bound by carrier phases: organic matter, clay minerals, sulfur compounds, oxides and hydroxides of iron and manganese. Highly magnetic iron-bearing minerals are concentrators of heavy metals in soils. The aim of the study is to characterize the features of the elemental chemical composition of the Urbic soils and its magnetic phase of the industrial city Gubakha, Perm region (Russia). We used the background soils, the clarke of the lithosphere, and the clarke of the soils of the world to assess the ecological-geochemical role of the magnetic phase in the accumulation of heavy metals. The magnetic phase is rich in Fe, Ni, Cu, Cr, and Zn. The Urbic Technosol Loamic, Skeletic of the city Gubakha is contaminated with Cu, Cr, Ni, and Zn. Ecological-geochemical monitoring of the soil cover by the method of ecological magnetism is relevant in the territory of the cities.

Keywords: URBIC TECHNOSOL, TECHNOGENIC MAGNETIC PARTICLES, IRON, HEAVY METALS, XRD, ECOLOGICAL-GEOCHEMICAL ASSESSMENT, GUBAKHA, PERM REGION, URAL, RUSSIA

Introduction

The top soil of industrial cities of the Cis-Urals and their environs is subject to anthropogenic pollution by heavy metals [1–3]. The main carriers of heavy metals in the soil are organic matter, clay minerals, magnetic oxides and hydroxides of iron, and manganese. Each heavy metal in the soil exhibits an affinity for certain carrier phases [4–8].

Analysis of the elemental chemical composition of magnetic particles is relevant in the study of environmental pollution and for understanding the mechanisms of modern soil formation processes in urban areas [9–16]. The mineralogy and chemical composition of the magnetic phase of the soils of cities on the western slope of the Ural Mountains have been insufficiently studied.

The aim of the study is to characterize the features of the elemental chemical composition of the Urbic soils and its magnetic phase of the industrial city Gubakha, Perm region (Russia).

Materials and methods

The object of the study was an Urbic Technosol Loamic, Skeletic of the industrial city Gubakha, Perm region (Russia) [17]. Soil sampling was conducted within the industrial zone in the existing production plants of JSC «Gubakha Coke» (fig. 1). Individual samples from the 0–10 cm layer have been selected by the «envelope» method. Each mixed sample included 10 single samples from an area of 10 m^2.

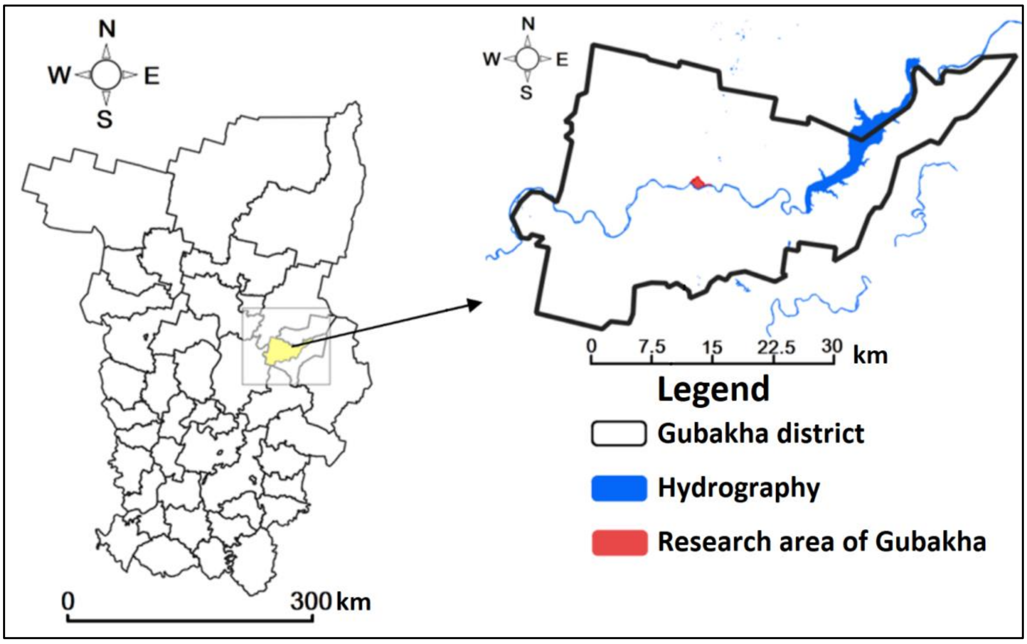

Fig. 1. Map of the location of the research object in the Perm region and Gubakha district

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Research methods:

1) dry fractionation of the magnetic phase of the soil with a permanent ferrite magnet;

2) the bulk elemental chemical composition of soil and magnetic phase was determined at the Vernadsky Institute of Geochemistry and Analytical Chemistry of the RAS by X-ray fluorescence with AXIOS Advanced PW 4400/04 spectrometer (PANalytical B.V., Holland);

3) ecological-geochemical assessment of the elemental composition of magnetic particles and soil was carried out using concentration factors (KK) according to the formulas (1–4):

$$KK_{soil} = \frac{C}{C_{soil}} \quad (1)$$

KK_{soil} – the coefficient of enrichment-impoverishment of the magnetic phase in heavy metals;

C – concentration of the i-th chemical element in the magnetic phase of the soil, ppm;

C_{soil} – concentration of the i-th chemical element in the soil before the extraction of magnetic particles, ppm.

If KK_{soil} is ≥1 then the magnetic phase is enriched with the i-th chemical element. When KK_{soil} is <1 then the magnetic phase is impoverishment with the i-th chemical element.

$$KK_{lithosphere} = \frac{C}{C_{lithosphere}} \quad (2)$$

$KK_{lithosphere}$ – concentration factor relative to the clarke of the lithosphere according to N.S. Kasimov;

$C_{lithosphere}$ – clarke of the i-th chemical element in the lithosphere according to N.S. Kasimov [18], ppm.

$$KK_{background} = \frac{C}{C_{background}} \quad (3)$$

$KK_{background}$ – concentration factor relative to regional background;

$C_{background}$ – concentration of the i-th chemical element of the regional geochemical background of the Perm region, ppm [19].

Note: The following values of $C_{background}$ were used to calculate the concentration factor $KK_{background}$: Fe 24522.6; Mn 760.9; Cr 127.0; Ni 40.9; Zn 59.0 ppm [19].

$$KK_{Vinogradov} = \frac{C}{C_{Vinogradov}} \quad (4)$$

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$KK_{Vinogradov}$ – concentration factor relative to clarke for soils of the world;

$C_{Vinogradov}$ – clarke of the i-th chemical element in the soils of the world according to A.P. Vinogradov [20], ppm.

When using $KK_{lithosphere}$, $KK_{background}$, and $KK_{Vinogradov}$ the pollution is classified as follows: ≤1 unpolluted soil, >1 polluted soil.

Results and discussion

The content of magnetic particles in the soils of Gubakha is 5–7%. Some of the magnetic particles in the soils of the city have a magnetite/maghemite composition and a spherical shape [21]. The elemental chemical composition of the soil before magnetic separation and its magnetic phase differ significantly (fig. 2A–2B). The concentration of iron is 4 times higher in the magnetic phase. The magnetic phase is also enriched with chemical elements from the iron group – Ni, Cu, Cr, and Zn. Concentration factors form a geochemical series of enrichment-impoverishment of an object in chemical elements (fig. 2A–2B). The following sequences were obtained KK for the magnetic phase, relatively:

1) soil before magnetic separation, KK_{soil}: Fe <Ni <Cu <Cr <Zn <Mn;
2) clarke of the lithosphere, $KK_{lithosphere}$: Cu <Fe <Ni <Cr <Zn <Mn;
3) regional geochemical background, $KK_{background}$: Fe <Ni <Cr <Zn <Mn;
4) clarke of the soils of the world, $KK_{Vinogradov}$: Cu <Ni <Fe <Zn <Cr <Mn.

Analysis of the concentration factors KK_{soil}, $KK_{lithosphere}$, $KK_{background}$, and $KK_{Vinogradov}$ made it possible to establish the pollution of the Urbic Technosol Loamic, Skeletic and its magnetic phase with heavy metals. The $KK_{Vinogradov}$ showed that heavy metals Cu, Zn, and Ni permeated the Urbic Technosol of Gubakha. The indicators KK_{soil}, $KK_{background}$, $KK_{lithosphere}$, and $KK_{Vinogradov}$ showed the enrichment of the magnetic phase in Ni, Cu, Cr, and Zn.

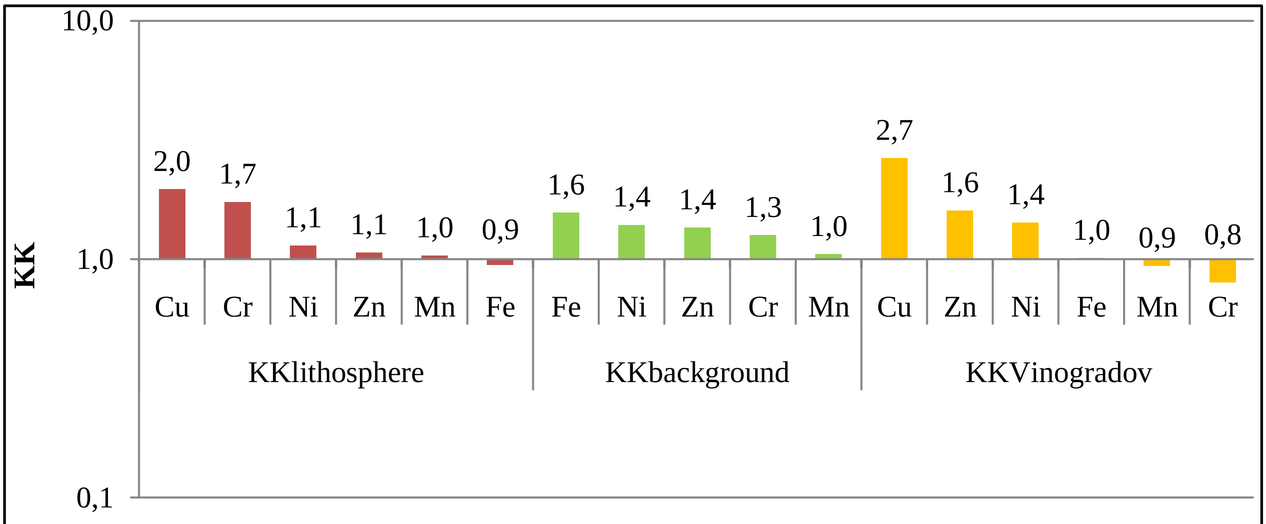

Fig. 2A

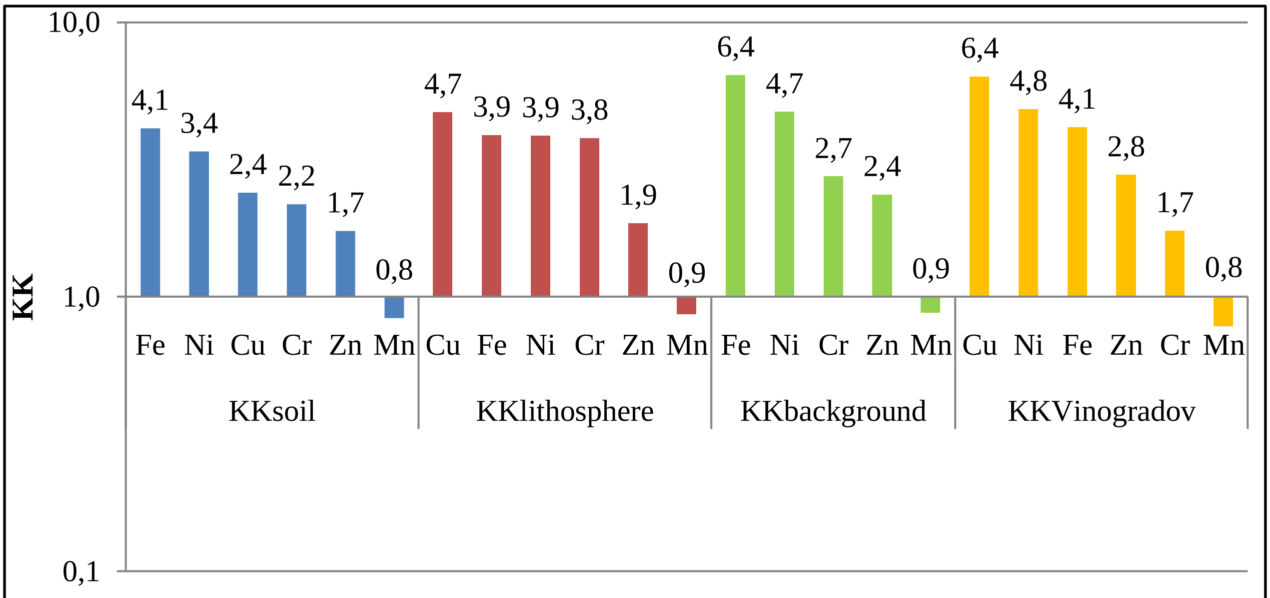

Fig. 2B

Fig. 2. Geochemical concentration factors for the Urbic Technosol Loamic, Skeletic (Gubakha, 0–10 cm layer): A – soil before magnetic separation; B – magnetic phase of soil

Note: The graph scales of concentration factors (KK) are log-transformed.

Conclusions

Thus, the chemical composition of the Urbic Technosol Loamic, Skeletic of the industrial city Gubakha and its magnetic phase differ much from each other. The magnetic phase is rich in Fe, Ni, Cu, Cr, and Zn. The spherical magnetic particles of the urban soils have a potential threat of heavy metal pollution. The use of concentration factors of regional geochemical background,

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clarke of the lithosphere, and clarke of the soils of the world made it possible to reveal geochemical series and pollution by chemical elements. The Urbic Technosol Loamic, Skeletic of the city Gubakha is contaminated with Cu, Cr, Ni, and Zn. Ecological-geochemical monitoring of the top soil by the method of ecological magnetism is relevant in the territory of the city Gubakha.

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