Concentration of heavy metals in the soil cover of industrial zones of Krasnoyarsk

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Abstract. The article is devoted to the assessment of soil pollution in industrial zones of the city of Krasnoyarsk. The comparison of the regions of Krasnoyarsk CHPP-1, Krasnoyarsk CHPP-2 and Krasnoyarsk CHPP-3 is performed by the total index of soil pollution with heavy metals. The representativeness of the obtained data was confirmed by the corresponding statistical processing. In the studied areas, an increased content of mobile forms of lead, cadmium, copper, nickel, zinc, manganese, cobalt, chromium was recorded, which, in contrast to the control, is higher on average by 2.7; 2.6; 5.1; 6.1; 6.7; 4.4; 2.1; 1.7 times, respectively. An excess of the MPC (APC) for the elements under study was recorded, and only the content of mobile forms of cadmium in all 3 industrial zones does not exceed the MPC (APC). In the areas of TPP-1, TPP-2 and TPP-3 of the city of Krasnoyarsk, the content of Co, Cd, Ni and Mn has an indicator value. Indicators of the level of accumulation of heavy metals can be used in monitoring urban areas.

1. Introduction

To assess the environmental consequences of anthropogenic impact, to ensure the required level of environmental quality and environmental safety of the urban environment, it is necessary to monitor the content of pollutants in the components of the urban environment. In the atmospheric air of industrial cities, such as Krasnoyarsk, there are suspended compounds that determine a high degree of risk to public health. The emitted substances settle on the earth's surface, vegetation, accumulate in the soil cover and accumulate in the tissues of organisms [1].

As a result of long-term industrial activity around the enterprises, man-made geochemical anomalies with an increased content of pollutant elements in the environment arise [2, 3, 4].

Among the components of urban systems in studies on the accumulation and distribution of pollutants, the soil cover is of great importance.

2. Statement of the problem

The soil cover is one of the most important components of terrestrial ecosystems, including in the conditions of industrial agglomeration. Soil is a depositing component of the environment that reflects air pollution in the territory over a long period. Under the conditions of urbanization, including industrial development, the depositing properties of soils are especially pronounced. Heavy metals (HM) accumulate in the soil cover.
It is important to have information on the migration, accumulation, and transformation of HMs in the soil cover.

It has been proved that the mobile forms of a number of HMs in excess quantities have a negative effect on the functioning of the soil-plant system [5].

Heavy metals are hazardous pollutants of priority interest for environmental monitoring, since most metals are biologically active, and in relatively low concentrations can have a toxic effect on the body. Metals do not undergo biodegradation, and once they enter the biochemical cycle, they leave it extremely slowly, accumulating in the components of the environment. The majority of heavy metals accumulate in various links of the trophic chains, which leads to disruption of the biotic cycle and destabilization of ecosystems [6].

Of practical importance is information on local concentrations of HM in specific components - areas with industrial specificity. It is important to assess the level of the content of mobile forms of HM, since it is the mobility of HM that determines their danger to other components of the biosphere.

The aim of our study is to identify the technogenic specificity in the accumulation of HMs in the soil cover of the industrial territory of Krasnoyarsk.

Subject of research: mobile forms of HM in the soil cover.

3. Materials and methods

On the territory of Krasnoyarsk, within the framework of this study, 3 trial plots were laid in industrial zones at a distance of about 500 m from pollution sources (CHP-1, CHP-2, CHP-3) in the direction of the prevalence of the wind rose and 1 trial plot - background (village. Successful city of Krasnoyarsk). The sampling sites of the soil cover are shown in figure 1:

- CHPP-1;
- CHPP-2;
- CHP-3;
- control site (settlement Udachny).

The collection of material was carried out in 2017. The determination of the content of mobile forms of HM in soils was carried out using standard methods. At the Research Center of the Krasnoyarsk State Agrarian University, the concentration (mg/kg) of mobile forms of the following heavy metals was determined by the atomic absorption method on a PinAAcle 900T analyzer:

- Pb,
- Cd,
- Zn,
- Cu,
- Ni,
- Co,
- Cr,
- Mn.

The multicomponent impact of HM on the state of the soil cover was assessed by the indicator of total pollution [7]. This indicator is calculated using the formula:

$$Zc = \frac{1}{n} \sum_{i=1}^{n} \left( \frac{C_i}{C_{fp}} \right)^{(n-1)}$$

where $n$ is the number of considered metals; $C_i$ - concentration of an element in the sample, $C_{fp}$ - background concentration of an element. The critical values that allow to characterize the total pollution $Zc$ according to the degree of hazard are as follows: at $Zc < 16$, the pollution is considered acceptable; at $16 < Zc < 32$ - moderately dangerous; at $32 < Zc < 128$ - highly dangerous.
The results of the analysis of the HM content in the soil cover of all points of the study were brought together for static processing using the Statistica 6.0 program.

4. Discussion of results

In the conditions of the city of Krasnoyarsk, the sources of HMs entering with emissions are combined heat and power plants that burn brown coal. With ash at a CHPP during coal combustion, there is a significant emission of heavy metals [8], the specific emission of which (mg/kg of fuel) increases in the series Cd$_{30}$ $<$ Co$_{40}$ $<$ Cu$_{300}$ $<$ Pb$_{2100}$ $<$ Zn$_{2800}$ [4].

According to various studies [3, 9] in the Krasnoyarsk agglomeration, there are localized pollution by heavy metals: Zn, W, Cd, Mo, Cu, Sn, Co, Pb, As, Ni, Be, Cr.

The studied HMs (lead, cadmium, cobalt, nickel, zinc, chromium, copper, manganese) were found in all the studied soil samples. Comparison of the average HM content with the MPC level revealed an excess of MPC for seven elements: Pb (2.3-3 times), Cu (4.7-5.2 times), Ni (2.8-4.3 times), Zn (up to 1.6 times), Mn (1.7-5.2 times), Co (1.6-1.8 times), Cr (up to 1.2 times) (table 1).

| Sample areas | Element | Pb  | Cd  | Cu  | Ni  | Zn  | Mn  | Co   | Cr  |
|--------------|---------|-----|-----|-----|-----|-----|-----|------|-----|
| CHPP -1      |         | 13.79 | 0.36 | 15.07 | 17.42 | 17.49 | 726.16 | 9.43 | 7.79 |
| CHPP -2      |         | 18.21 | 0.68 | 15.16 | 15.89 | 25.34 | 504.32 | 8.23 | 6.85 |
| CHPP -3      |         | 14.56 | 0.27 | 14.28 | 11.47 | 38.51 | 245.70 | 4.98 | 3.84 |
| Control (Сф) |         | 5.66  | 0.17 | 2.92  | 2.43  | 4.01  | 112.56 | 3.52 | 3.49 |
| MPC (APC), mg/kg[7] |   | 6   | 1   | 3   | 4   | 23   | 140  | 5    | 6   |

When analyzing the results of studies on the HM content in the soil cover of the industrial zones of the city of Krasnoyarsk, the presence of polymetallic pollution was revealed, the level of which reflects the total index Zc (figure 2).

It was found that the total indicator of soil pollution at CHPP-2 is 23% higher than at CHPP-3. The level of accumulation of heavy metals occurs to the greatest extent in the Sverdlovsk region of the city of Krasnoyarsk, where there is a more intense industrial impact, and as a result of inversion pollutants emitted by CHPP-2, a cement plant and small industrial enterprises accumulate.
Factor analysis showed that the variation in heavy metals by 69-73% is due to two main factors (figure 3). The Value axis corresponds to the informational contribution of the factor in terms of variance. Factors with an information contribution of less than 1 are considered to be “noise”. Factor load analysis shows that the Cd-Cu-Mn-Co-Cr group apparently has one common main source (factor 1). Zinc definitely has a separate main source (factor 2), and lead is partly related to this source.

**Figure 2.** Total pollution index (Zc) of the soil cover in the study area.

**Figure 3.** Results of factor analysis of the concentration of mobile forms of heavy metals in the soil cover.

Statistical analysis of factor loadings revealed a close relationship between the concentrations of Mn and Co, with which Cd and Ni are always associated. With a high degree of probability, this indicates that the supply of Mn, Co, Cd, Ni to the environment is associated with one source - the products of coal combustion. The obtained data are comparable with the data of scientists from Serbia [10].

**5. Conclusion**

Based on the above, it should be noted: due to the accumulation of a number of toxic elements, polyelemental pollution of the soil cover of industrial zones of the city of Krasnoyarsk was observed, a high degree of pollution was recorded in the area of CHPP-2 with a decrease in the area of CHPP-1 and CHPP-3. The total pollution of the soil cover can be characterized as moderately hazardous (Zc varied from 21.058 to 27.320).

Based on this study, we believe that it is necessary to develop a system for assessing the pollution of the soil cover under the influence of CHP, taking into account the mobile forms of HM.
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