Ecological monitoring of soils in urban and rural areas

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Abstract. The burden on the environment is increasing in direct proportion to the development of the scientific and technological revolution of mankind. Large industrial centers are characterized by the release of a diverse complex of pollutants into the environment, including HMs, which are deposited on the earth's surface, polluting plants and soil. The article presents the results of determining the level of heavy metals in the soils of urban and rural areas. According to the data obtained, in the soils of household plots in the territories of rural settlements, a significant decrease in heavy metals to the MPC level was revealed in comparison with the same pollutants in urban household plots. When conducting a correlation analysis, a relationship was established between the value of the mobile form of the element in the soil and the gross forms of the studied HMs, however, the mobility of the elements in the soil is more variable in comparison with the indicators of urban areas.

1. Introduction
The soil occupies a central position in the interactions of natural cycles, being the habitat, physical and biological support for a huge number of organisms [2;7]. The soil arranges all the flows of substances in the biosphere, regulates the composition of the atmosphere and hydrosphere, so it constantly experiences the consequences of impacts from human activities. In this regard, the study of the state of soils used for personal plots is relevant [9;11].

2. Materials and methods
The studies were carried out in 2017-2020. The object of study is soils of varying degrees of urbanized areas.

The top fertile soil layer was sampled to a depth of 20-30 cm using the envelope method in accordance with GOST 17.4.3.01-2017 Nature Protection. Soils. General requirements for sampling.

In the process of work, methods of system analysis, instrumental methods for assessing chemical pollution, and statistical analysis were applied. All studies were carried out in accordance with the established state standards and methods.

3. Results and Discussion
Urban areas are the most loaded with cars and their number is constantly growing. They are a source of environmental pollution with Pb, Ni, Cr and Cu. Accumulating in the air, heavy metals are deposited on the earth's surface, polluting plants and soil. Along with this, a large number of industrial enterprises operate in the city, that is, the formation of soil in the city is under constant and destructive anthropogenic pressure [3].
The emerging interest in the accumulation of heavy metals in the environment (including soil, air, water and living organisms) is confirmed by many authors whose work is aimed at studying the anthropogenic load and monitoring external factors that have harmful toxic, mutagenic and carcinogenic effects [1; 6].

Numerous studies have shown that the content of heavy metals in soils varies significantly, depending on the type of soil. This is facilitated both by the composition of the original rocks and directly by human anthropogenic activity. Soils with a heavy granulometric composition, acidity close to neutral and, as a rule, more fertile lands are susceptible to the accumulation of heavy metals [4-5].

World and domestic experience shows that high and sustainable agricultural productivity is possible only with a comprehensive account of all agrochemical and environmental factors necessary for the normal growth and development of plants, the formation of crops and their quality, and the prevention of land degradation (acidification, salinization, overconsolidation, erosion, deflation), , depletion of organic matter reserves and nutrient elements available to plants, pollution with harmful substances, etc.) [2;10].

In this regard, the main task of monitoring soil fertility of agricultural land is to monitor the chemical, physico-chemical, biological, physical and water-physical properties of soils, their pollution with production and consumption waste, chemical and radioactive substances, as well as the phytosanitary condition of soils and crops., meteorological conditions and productivity of plants on each land plot [8].

We have carried out studies to determine the level of accumulation of heavy metals in the soils of urban household plots. As a result of the studies, it was found that the gross forms of heavy metals in soils in most of the studied areas are contained in acceptable concentrations. However, the concentration of Zn and Pb in the soil selected in the study areas is 2-5 times higher than the accepted MPC. This may be due to the high load of these places by road transport, tk. Zn and Pb are products of fuel combustion. I would like to note that a wide range of variation of most heavy metals within the study areas is most likely associated with local contamination of individual samples in the selected areas, and leads to an excess of the MPC in the whole sampling area.

A similar situation develops according to the data on the number of mobile forms of Zn, where in most cases the content of the element exceeds the MPC in the sampling areas by 1.87-3.45 times, and in some cases even the MPC by 32.4%. On the basis of statistical analysis, a positive correlation was found between the content of mobile Zn and the amount of gross forms of the element in the soil (r=0.88). The value of mobile Pb in these soils approaches the MPC value and the maximum concentration is 0.94 MPC (5.69 mg/kg), and the maximum Cu concentration is 3.88 mg/kg, which is almost 1.3 times higher than the MPC. The remaining concentrations of mobile forms fluctuate: Mn - 0.08-0.21 MPC; Ni - 0.10-0.18 MPC; Pb - 0.24-0.95 MPC; Cu - 0.06-0.73 MPC; Cd - 0.09-0.18 APC, Co and Cr less than 0.1 MPC.

When analyzing the correlations of the heavy metals we studied, a high and medium direct dependence of the content of mobile forms of Zn (r=0.88), Ni (r=0.99), Cd (r=0.63), Mn (r= 0.48), Co (r=0.41) Cr (r=0.45) on the value of gross forms of these elements in soils. However, the concentrations of mobile forms of Cu, Fe and Pb are inversely related to the content of gross forms of these HMs (r=−0.99, r=−0.79, r=−0.49, respectively).

The predominant elements among the studied gross forms of HMs are Fe and Mn. The least in the studied soils is Cd 0.1 mg/kg.

Analyzing the obtained results, the sequence Fe > Mn > Zn, Co > Cd is typical for all sampling sites. The highest content of Fe, Mn and Zn may indicate the predominance of these elements throughout the city.

An important indicator characterizing the availability of an element to plants is its mobility, represented by the ratio of the content of mobile forms of the element to the total content, expressed as a percentage. The results of calculations of the mobility of chemical elements in the soils of the studied territories are presented in table 1.
Table 1. Mobility coefficient of elements in soils.

| Element name | No. of sampling area | Average for chem. element | Mobility of elements, % |
|--------------|----------------------|--------------------------|------------------------|
|              | 1        | 2        | 3       |                |
| Fe           | 0.07     | 0.03     | 0.08    | 0.06          |
| Mn           | 21.76    | 27.08    | 30.01   | 26.30         |
| Zn           | 12.25    | 24.81    | 31.22   | 22.80         |
| Ni           | 2.96     | 2.55     | 3.23    | 2.90          |
| Pb           | 1.79     | 6.28     | 33.32   | 13.80         |
| Cu           | 16.69    | 5.12     | 24.49   | 15.43         |
| Cd           | 57.55    | 28.64    | 41.15   | 42.50         |
| Co           | 4.37     | 2.75     | 2.25    | 3.10          |
| Cr           | 0.38     | 0.84     | 0.46    | 0.70          |

As a result of the studies, it was found that the degree of mobility of elements in the studied areas varies significantly. The maximum indicators of the mobility of elements on average are: for Cd - 42.5%; Mn - 26.3%; Zn - 22.8%; Pb - 13.8%. With lower mobility, among these HMs are Ni - 2.9%; Cr and Fe - less than 1%.

On the basis of average data, a series of degrees of mobility of chemical elements was built: Cd>Mn>Zn>Pb>Cu>Co>Ni>Cr>Fe, and as a result, the content of such heavy metals as Cd and Zn, which are predominantly of anthropogenic origin, are easily accessible to plants. This is especially important, given that anthropogenic factors are the main sources of these elements entering the soil: Cd as an admixture with phosphate fertilizers and precipitation from the atmosphere, and Zn as fertilizers, air dust of industrial origin.

Thus, our studies on the content of pollutants in urban soils indicate the excess of the MPC of the gross and mobile forms of the chemical element for Zn - from 2 MPC to 5.4 MPC; Pb - up to 1.5 MPC (gross forms); Cu - 1.3 MPC (mobile forms). For other elements, the concentration range is up to 0.7 MPC. The maximum correlations between mobile forms and bulk forms of the element are observed for Zn and Ni. Different degrees of influence of heavy metals on each other were also revealed.

For a qualitative and comparative analysis of the main indicators of soil fertility and the content of heavy metals in the soils of the city, samples were taken in the territories of districts located at a distance from the city.

Important indicators for the distribution and accumulation of HMs are agrochemical criteria of soil fertility. The results of these studies in the territories of rural settlements are presented in table 2.

Table 2. The value of humus and the pH of the salt extract of the soil.

| No. of sampling area | Mass fraction of organic matter, % | salt extract pH, units |
|----------------------|-----------------------------------|-----------------------|
| District No.1        | 1.7                               | 6.52                  |
| District No.2        | 2.2                               | 6.98                  |
| District No.3        | 2.4                               | 5.94                  |

It should be noted the low (2-4%) and very low humus content (<2%) in these areas, which requires additional costs for improving soil fertility. The pH value indicates a neutral and slightly acidic soil reaction (table 2), however, these soils are suitable for growing all garden crops.

Analyzing the results of the main agrochemical indicators, it should be concluded that the studied soils have a fairly high level of nitrate nitrogen. These soils are sufficiently enriched and do not experience a deficiency of mobile phosphorus.

The next stage of research is to determine the level of accumulation of heavy metals in the soil of household plots on the territory of rural settlements. As a result of the studies, it was revealed that the gross and mobile forms of heavy metals in soils are contained in acceptable concentrations.
When analyzing the data obtained, it was found that the predominant elements among the studied gross forms of HMs are also Fe and Mn. The concentrations of these heavy metals vary: Fe from 231.3 to 16273.87 mg/kg; Mn from 93.24 to 928.41 mg/kg. The least in the studied soils is Cd from 0.001 to 0.111 mg/kg.

In contrast to the studied soils of urban areas, rural areas are characterized by a smaller range of concentrations of some elements (Zn, Ni, Pb, Cu) and the average content of heavy metals in the soil, which may be associated with lower anthropogenic loads, as well as a uniform distribution of pollutants on territories of private household plots in rural settlements.

The number of mobile forms of heavy metals is not large, most of all in the soils of Mn (32-76 mg/kg) and Fe (2.4-11.6 mg/kg), since these elements are the main components of the parent rock and the most common elements of the earth's crust. At the same time, their number is 0.1-0.3 MPC. The remaining values of the concentrations of mobile forms fluctuate within small limits and are: Zn - 0.04-0.91 MPC; Ni - 0.03-0.26 MPC; Cu - 0.02-0.63 MPC; Pb, Co and Cr - less than 0.1 MPC. When analyzing the correlations, it was revealed that for these territories the concentrations of mobile forms of elements are in the medium degree dependent on the value of the gross forms of heavy metals. For example, for mobile forms Ni - r=0.47, Zn and Cr - r=0.56, Cu - r=0.60. It should be noted that there is a direct correlation between the content of mobile Mn and the value of mobile Cd, Cu, Zn Co (r=0.95, r=0.84, r=0.86, r=0.92, respectively), gross forms Zn (r=0.82), as well as mobile Ni with total Pb (r=0.66), mobile Cu with total concentrations of Mn and Zn (r=0.83, r=0.84, respectively).

In addition, in all the studied areas, there is a tendency for Cu to occupy one position, while the Cu>Ni ratio is preserved for all areas. Relationships of HM concentrations in the orders Mn>Fe and Mn>Fe>Zn are of the same type, most likely associated with zinc contamination of certain sampling areas.

These dependences of the series of concentrations of mobile HM forms differ from the series of the amounts of these elements in gross forms. This is due to the possibility of antagonistic or synergistic action, soil pH, humus content in the fertile layer, as well as varying degrees of element mobility.

The mobility of HMs in soils selected in the territories of rural settlements is similar to the mobility of HMs in soils studied from the territory of the city, but for most elements this indicator is much lower. The maximum values of the mobility of elements on average are: for Cu - 29.49%; Cd - 20.17%; Mn - 18.48%; Zn - 16.08%. The remaining chemical elements are the least mobile: Ni - 2.71%; Pb - 4.43%; Co - 3.98%; Cr and Fe - less than 1%.

It should be noted that, according to the degree of mobility, the studied chemical elements in soil samples taken in the conditions of household plots in rural areas can be placed in the following order: Cu> Cd> Mn> Zn> Pb> Co> Ni> Cr> Fe and it differs from similar series for urban areas where the mobility of Mn, Zn, Ni, Cd and Pb is higher.

4. Conclusion

Thus, our studies of the content of pollutants in the soils of household plots in the territories of rural settlements showed a significant decrease in HM to the MPC level in comparison with similar urban soils. Correlation analysis revealed the relationship between the value of the mobile form of the element in the soil and the gross forms of the studied pollutants. The degree of mobility of elements in the soil is more unstable in comparison with these indicators for urban areas. However, the average mobility of a chemical element in soil is lower than in urban areas for Mn, Zn, Ni, Pb, and Cd.

References
[1] Aubakirov M Z, Domatsky V N, Mustafin M K, Selunskaya L S, Khassanova M A, Murzakayeva G and Khaivor G K 2019 The technology of preventing ecological and economic damage caused by echinococcosis. International Journal of Engineering and Advanced Technology 8(6) 2933-2936
[2] Iglovikov A, Kulyasova O and Sannikova N 2022 Reclamation of mechanically disturbed soils using forest plantations. Lecture Notes in Networks and Systems 246 395-403
[3] Iglovikov A and Motorin A 2019 Composition of organic matter in peat soils of the northern trans-urals depending on groundwater level. E3S Web of Conferences. Innovative Technologies in Environmental Science and Education, ITESE 2019 01004

[4] Chernykh E G, Bogdanova O V, Sizov A P and Simakova T V 2020 Assessment of media-forming potential of the territory in the implementation of the lands. Advances in Intelligent Systems and Computing 1116 577-588

[5] Kovaleva O, Sannikova N and Ilyasov O 2021 Content of heavy metals in the bottom sediments of the wastewater of the processing enterprise. E3S Web of Conferences. 22. Цеп. "22nd International Scientific Conference on Energy Management of Municipal Facilities and Sustainable Energy Technologies, EMMFT 2020" 01009

[6] Motorin A S, Iglovikov A V and Bukin A V 2018 Changing in water-physical properties of drained peat soils during extraction and exploration of minerals in the conditions of the Northern Urals. IOP Conference Series: Earth and Environmental Science 8 082026

[7] Pashayan S A, Sindireva A.V and Boev V A 2020 Features of accumulation of trace elements in the soil-honey plants system in the tyumen region. IOP Conference Series: Earth and Environmental Science. III International Scientific Conference: AGRITECH-III-2020: Agribusiness, Environmental Engineering and Biotechnologies. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations 62044

[8] Pashayan S A 2019 Ecological state of honey plants in apiaries of the tyumen region. IOP Conference Series: Earth and Environmental Science. Krasnoyarsk Science and Technology City Hall of the Russian Union of Scientific and Engineering Associations 72001

[9] Sidorova K, Dragich O, Shvets N, Bukin A, Ryabova N, Klyushnikova E and Kochetova O 2020 Ecological and physiological feature of some microelements and their concentration in vegetable products. IOP Conference Series: Materials Science and Engineering. Цеп. "International Scientific and Practical Conference "Modern Problems of Ecology, Transport and Agricultural Technologies" 012013

[10] Simakova T V, Skipin L N, Evtushkova E P, Simakov A V, Pashnina E A, Matveeva A A and Yurlova A A 2018 Monitoring of reclaimed land in Tyumen. Region 39(14) 22

[11] Skipin L, Gaevaya E, Zaharova E, Petukhova V and Sidorova K 2016 Biogeochemistry of heavy metals in trophic chain in terms of the south of tumen region. 15th International scientific conference 'underground urbanisation as a prerequisite for sustainable development. Procedia Engineering 860-868