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The content of copper and zinc in the natural environment components of the park areas

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Abstract. The influence of man-made pollution on the accumulation of copper and zinc in the soil and plants of the forest park zones of Yelets was studied on the example of the woody–plant natural environment components prevailing in them hanging birch (Betula pendula Roth) and creeping wheatgrass *(Elytrigia repens)*. As a result of the conducted studies, the features of the deposition of copper and zinc in the plant organs were revealed, and the total accumulation of the studied elements in the soil under green plantations was estimated.

1 Introduction

Technogenic pollution of the environment by industrial and motor transport emissions negatively affects all the components of the biosphere without exception. Under the negative influence of industrial exhalates, human health deteriorates, natural ecosystems are destroyed and degraded, new anthropogenic landscapes are formed [1]. In the modern world, in conditions of high anthropogenic pollution, plants are still the most effective means to reduce pollution [2].

The study of the problem of pollution of forest ecosystems most often begins with the analysis of the deposition of copper and zinc in the plant organs, since these two elements are easily bioaccumulated and are part of most of the raw materials used by industry in technological processes in the world. Adverse effects on plants, with excessive content of available zinc and copper compounds in the atmosphere and soil, can be hidden for a number of years [3].

In the air, copper and zinc are mainly in suspended form as compounds of copper oxide and zinc oxide, in soils they accumulate in surface horizons. Copper and zinc are biogenic elements that are necessary for plant life, they are part of enzymes that activate the processes of respiration, protein and carbohydrate metabolism of plants [4, 5, 6]. However, due to the current state of the biosphere, the colossal intake of chemical elements into the atmosphere and soil from man-made sources, zinc and copper in certain situations are also considered as pollutants or heavy metals (TM) [7]. Excessive exposure to metals can cause insufficiency of vital nutrients (iron, calcium, selenium, phosphorus, copper, etc.), inhibit a large number of enzymes, disrupt several aspects of plant biochemistry, including photosynthesis, pigment synthesis and membrane integrity [8, 9, 10].

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The city park is considered to be the leading link in the greening system of the city. Woody plants growing in urban parks, under conditions of technogenesis, are able to act as a phytofilter, purifying the air from exhalates by mechanical precipitation of solid particles, partial absorption and detoxification of toxicants, but at the same time they themselves are often subjected to irreversible damage [1, 11, 12, 13, 14]. Therefore, in recent decades, works aimed at studying the concentration of chemical elements in the environment and their accumulation by plants have received significant development.

2 Materials and methods

The purpose of the work is to determine the content of copper and zinc in the natural environment components of the park areas of the city of Yelets, Lipetsk region.
Research objectives:

- To select the objects of research.
- To identify the degree of accumulation of copper and zinc in soil and plants in the park areas of the city of Yelets, Lipetsk region.

Research area. The Lipetsk region belongs to the large industrial centers of the Central Federal District (CFD), characterized by a mixed type of environmental pollution with a significant share of the industrial component. Yelets is the second largest industrial center of the Lipetsk region, with a population of 103.177 people. The main source of pollution in Yelets is Yeletskaya CHP, a branch of JSC TGC 4, Eastern Regional Generation, JSC Energia, JSC Gidroprivod, JSC Yelets Hydroelectric Unit, LLC J.T.I. Yelets. In 2020 the total emission of pollutants amounted to 4.000 tons.

The research was carried out in Yelets on two trial areas (PP): PP No. 1 is forest park area of 29 hectares and PP No. 2 is forest park area of 133ha. PP No. 1 is located within the city limits, from the north-eastern side, experiencing environmental pressure from industrial enterprises and the R-119 Orel –Tambov highway. Forest park zone No.2 is located on the opposite side of the city (in the southwest) in the area of the village of Olshanets, it is characterized by an ecologically clean territory.

The soil cover is the result of a long and complex development of natural conditions. The zonal type of soil is leached chernozems.

Object of research. The hanging birch (Betula pendula Roth.) belongs to the Birch family (Betulaceae), is the main forest-forming breed of central Russia. The average height of the tree is 25-30 m, the trunk diameter is up to 120 cm, the leaves are green, egg-shaped. The branches hang down and give the crown a weeping shape. This is the only tree that has a white bark color on most of the trunk. It requires well-lit areas for growth. Adult birch is resistant to both negative low temperatures (tolerates frosty winter (up to – 40 ° C) and high (up to + 40 ° C). The tree is widely used in landscape design in the decoration of city parks and squares. In conditions of man-made pollution the hanging birch (Betula pendula Roth.) is a fairly hardy species and is an effective means of cleaning the atmosphere from gas and dust pollution.

Creeping wheatgrass (Elytrigia repens) grows everywhere on the territory of the Russian Federation. The plant is naturalized on a global scale. Wheatgrass is a perennial herbaceous plant with a long branched creeping rhizome up to 3 m. The stem is smooth 54 – 135 cm, 50 – 70 cm high, the leaves are wide, linear 5 -13 mm, green in color. The inflorescence is an erect compound spike. The spikelets are multi-flowered (15 -27 mm), arranged in two rows on the notches of the axis of the ear. The flower and spikelet scales are spinous. The fruit is the grain.

Research methodology. Soil sampling for the determination of TM was carried out in accordance with the recommendations [15]. Soil samples were taken in each study area using a volumetric drill, in accordance with the methods adopted in geochemistry and soil science from May to August 2019 – 2021. Soil samples were taken from the topsoil of 0 – 30 cm. At the same time, needles were selected in the vegetation dynamics (monthly). The selected samples were brought to an air-dry state under laboratory conditions and subjected to grinding.

For the analysis of soil and plant samples, a weight of 5 grams was used. Soil samples were extracted in an acetate-ammonium buffer solution with a pH of 4.8. Plant samples were subjected to mineralization by dry salinization (according to GOST 26657-85). The resulting ozolate was extracted using 1M HNO3 acid. The quantitative content of copper and zinc was determined by atomic absorption method [16] on the spectrophotometer "Spectrum-5". The repetition of the experience is threefold.

3 Results and discussion

The accumulation of copper in the organs of the hanging birch (Betula pendula Roth) in all growing conditions on average during the growing season is within the normal range. But by the end of August, the accumulation of metal, compared with the beginning of the growing season, increases in birch leaves in Forest Park Zone No. 1 (Park of the 40th anniversary of October) by an average of 22%. On the territory of the Forest Park zone No. 2 of the village of Olshanets, an increase in metal was also detected, but by the end of August the increase was slightly less and amounted to 17% (Table 1).

Table 1. The content of copper in the organs of silver birch (*Betula pendula Roth*), wheatgrass (*Elytrigia repens*) and in the soil of the park areas of Yelets.

Content (Cu-Copper) mg/kg				
	May	June	July	August
Forest park zone No. 1 park of the 40th anniversary of October				
Betula pendula Roth				
Leaves	7.338	7.963	8.000	9.400
Roots	6.244	7.269	7.400	7.794
Elytrigia repens				
Leaves	8.503	9.022	9.780	10.023
Roots	9.425	10.694	10.338	11.482
Soil	2.662	2.825	2.888	3.106
Forest park zone No. 2 v. Olshanets				
Betula pendula Roth				
Leaves	6.513	6.663	6.956	7.413
Roots	6.114	6.121	6.854	6.955
Elytrigia repens				
Leaves	5.556	5.788	5.994	6.577
Roots	6.225	6.338	6.369	6.963
Soil	1 .413	1.481	1.600	1.956

The greatest accumulation of the element occurred in the period from July to August in Forest Park Zone No. 1 (+1.4 mg/kg). Accumulation of copper in birch leaves in Forest Park Zone No. 2 p. Olshanets during the growing season occurred more evenly and increased from month to month by an average of 0.200 mg / kg (May – 6.513; June – 6.694; July – 6.956; August – 7.413).

Comparative analysis of copper accumulation in the root system of silver birch (*Betula pendula Roth*) revealed some features. In forest park zone No. 1 with an increased technogenic load basipetal (metal content decreases from leaves to roots) accumulation of copper was noted. In the forest park zone No. 2, with a slight pollution, the differentiation between the accumulation of the element in the leaves and the root system is not so noticeable, which is associated with the biological importance of copper for plants and the ability to regulate its absorption.

The content of copper in the leaves of the wheatgrass (*Elytrigia repens*), in the territory of the park of the 40th anniversary of October, increased sharply in June and amounted to 9.022 mg / kg, in July – 9.780 mg / kg, and by the end of August reached 10.023 mg / kg of dry substances. In the root system of wheatgrass, the concentration of the element by the end of the growing season was 11.482 mg / kg, which is almost 2 times higher than the values in the forest park zone of Olshanets (Table 1). In the same plot (No. 2), the level of copper in the leaves practically did not change during the vegetative dynamics not only in the plant itself, but also relative to drooping birch (*Betula pendula Roth*) and remained within the biological characteristics of the plant [17].

The basis for assessing the danger of soil pollution is the translocation indicator of harmfulness which is the most important indicator in substantiating the MPC of chemicals in the soil. The maximum permissible concentration (MPC) of the mobile form of copper in the soil, according to the Hygienic Standard GN 2.1.7.2041-06, is 3.0 mg/kg. The data presented in Table 1 show that the content of copper in the soil of the analyzed territories is within the MPC. The maximum deposition of the element was noted in August in Forest Park Zone No. 1 with an indicator of 3.106 mg/kg. The concentration of zinc, for most plant species, ranges from 10 – 32 mg/kg of dry matter [7]. According to the results of the study, it was revealed that on the site of Forest Park Zone No. 1, in the samples of leaves of hanging birch (*Betula pendula Roth*) taken for analysis, the average zinc content for the growing season was 17.163 – 18.787 mg/kg of dry matter, accumulated in the root system from 13,000 to 13,438 mg/kg. In the forest park zone No. 2, the leaves contained 10.263 –12.513 mg/kg of dry matter, the root system 7.225 – 7.913 mg/kg (Table 2).

Table 2. Zinc content in the organs of hanging birch (*Betula pendula Roth*), creeping wheatgrass (*Elytrigia repens*) and in the soil of park areas of Yelets.

Content (Zn- zinc) mg/kg				
	May	June	July	August
Forest park zone No. 1 park of the 40th anniversary of October				
Betula pendula Roth				
Leaves	17.163	17.512	17.975	18.787
Roots	13.000	13.213	13.252	13.438
Elytrigia repens				
Leaves	18.410	19.683	20.242	21.496
Roots	12.106	12.125	13.125	13.350
Soil	3.512	4.063	4.800	5.275
Forest park zone No. 2 v. Olshanets				
Betula pendula Roth				
Leaves	10.263	11.950	12.400	12.513
Roots	7.225	7.313	7.813	7.913
Elytrigia repens				
Leaves	12.952	13.008	14.250	14.773
Roots	9.806	11.938	10.413	10.850
Soil	3.100	3.644	4.194	4.938

In the leaves of wheatgrass (Elytrigia repens), at plot No. 1, at the end of August, up to 21.496 mg/kg of zinc was detected which is approximately 1.2 times higher than in birch leaves and almost 1.5 times higher than the figure for plot No. 2 – 14.773 mg/kg. At the same time, the concentration of the element in the root system was practically at the same level and amounted to 9.806 – 10.850 mg/kg.

The background level of soil contamination with mobile zinc in the Lipetsk region for loamy soils is 1.39 mg / kg, in the studied areas the background level was exceeded and corresponded to the values from 3.512 – 5.257 mg / kg in the forest park area No. 1 and 3.100 – 4.938 mg / kg in the forest park zone No. 2.

Thus, the revealed difference shows a higher level of zinc contamination in the territory of the 40th Anniversary of October Park. The highest content of the metal is concentrated in the leaves. The accumulation of zinc in plants is affected, first of all, by the systematic affiliation of the plant.

4 Conclusion

The database for the ecological and geochemical assessment of the studied territories was formed based on the results of studies of the soil cover of parks and the prevailing tree and plant natural environment components such as the hanging birch (Betula pendula Roth) and the creeping wheatgrass (Elytrigia repens).

Comparative analysis of copper accumulation in the root system of hanging birch (Betula pendula Roth) revealed that with an increase in technogenic load basipetal (metal content decreases from leaves to roots) accumulation of copper is observed. With its decrease the differentiation between the accumulation of the element in the leaves and the root system is not so noticeable which is explained by the biological importance of copper for plants and the ability to regulate its absorption. The content of copper in the soil of the analyzed territories is within the MPC.

The territory of the park of the 40th anniversary of October is the most polluted with zinc. The highest content of the metal is concentrated in the leaves. The accumulation of zinc in plants is affected, first of all, by the systematic affiliation of the plant.

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