Assessment of the state of the urboecosystem by integral indicators of pine and soil cover

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Abstract. Soil contamination due to the accumulation of heavy metals directly affects the biogeochemical composition, development stability (fluctuating asymmetry) of urban vegetation. To assess the condition of urbanized territories, monitoring is required, especially biological. This work shows an assessment of the stability of the development of populations of Scots pine growing in the urban environment, depending on the content of heavy metals in the soil cover, needles. The representativeness of the data obtained is confirmed by appropriate statistical processing. Higher values of integral indicators were found for all the territories examined, especially for the Central Park, which is characterized by maximum traffic load. The values of the fluctuating asymmetry index of pine needles reflect the elemental composition of the soil cover (Pb, Cd, Zn, Cu, Ni, Co Cr, Mn).

1. Introduction

Among the anthropogenic factors affecting the functioning of ecosystems in a city, chemical pollution plays an important role. Compounds of heavy metals are indispensable components of the soil and water environment, which significantly affect their quality [1]. Soil contamination due to the accumulation of mobile forms of heavy metals has an impact on the biogeochemical composition of urban green spaces.

The main sources of pollution of the urban ecosystem are industrial enterprises, motor vehicles, and emissions, which determine the distribution and accumulation of toxic elements in environmental components [2].

2. Problem statement

The urgency of the problem is due to the increasing technogenic impact on the natural environment, especially in the industrial cities of Siberia. Technogenic pollution affects soil characteristics, the functioning of the soil – plant system, and the state of vegetation, including wood [3].

Green spaces of cities carry out environment-forming, recreational, economic, social functions, as well as an important function as the basis of biological monitoring, which is the main component of environmental monitoring [4].

The ordinary pine is of great interest among ecologists as a bioindicator, which can be explained by its features: long life span, area of contact with the environment, high sensitivity to toxic elements [5]. At the same time, various indicators of common pine are investigated: the content of trace elements

[6], the accumulation of heavy metals [7], the vital state and productivity of plantations, the concentration of photosynthetic pine needles, fluctuating asymmetry of the needles [8, 9].

Under the influence of the anthropogenic factor, developmental stability is violated, which manifests itself in the fluctuating asymmetry of pine needles [10]. It should be noted that a number of Russian and foreign researchers demonstrate quite successful application of the fluctuation asymmetry index of pine needles in assessing the stability of plant development under the influence of anthropogenic factor [11, 12, 13].

Thus, the aim of our study is to assess the accumulation of heavy metals in the urban ecosystem (soil-plant link) based on the calculation of integral indicators, as well as the effect of heavy metals on the stability of development of Scots pine.

3. Materials and methods

An ordinary pine growing in the city of Krasnoyarsk was chosen as the object of study, since it is highly sensitive to pollutants and widely distributed in most cities of the Russian Federation [14].

In different areas of the city of Krasnoyarsk, trial plots with plantations of common pine were identified (figure 1), the average age of the trees was 18 years, the average height was 4.9 m, the average diameter was 12 cm, the needles of the second year of life were selected for research, from one and the same part of the crown, from different sides of the tree.

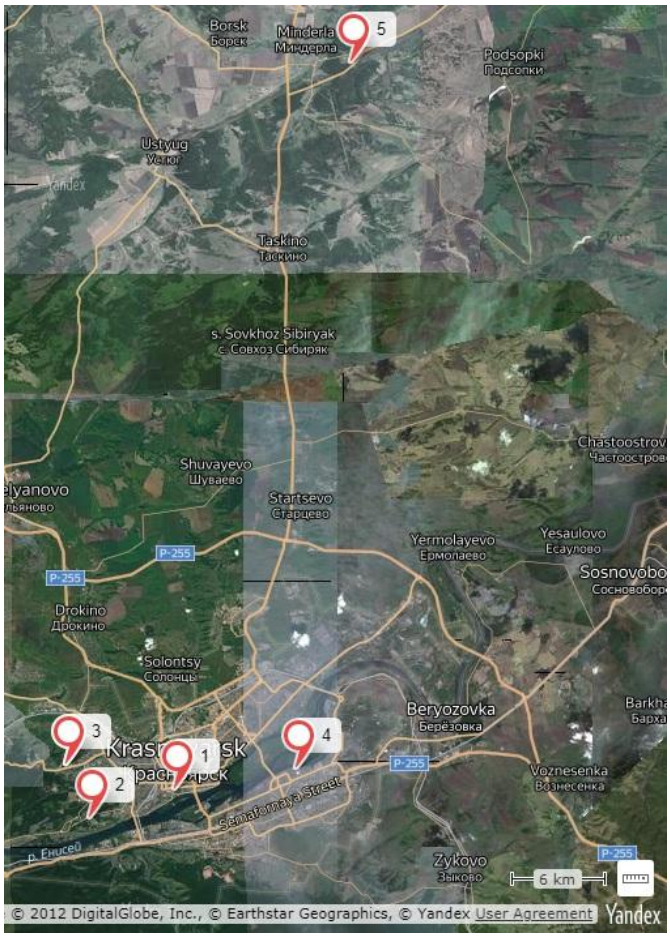


Figure 1. Map of soil and plant sampling sites in the city of Krasnoyarsk: 1 - Central Park, Central District, the left bank of the city (56 ° 00'32.4 "N 92 ° 51'02.5" E), 2 - Akademgorodok microdistrict, Oktyabrsky district , the left bank of the city (55 ° 59'31.6 "N 92 ° 45'37.4" E), 3 - the microdistrict of Vetluzhanka, Oktyabrsky district, the left bank of the city (56 ° 01'24.3 "N 92 ° 44'10.7" E), 4 - Park named after May 1, Leninsky district, the right bank of the city (56 ° 01'14.3 "N 92 ° 58'40.3" E), 5 - Background - 46 km from Krasnoyarsk, Sukhobuzim district (56 ° 26'06.0 "N 93 ° 02'08.6" E).

The selection of plant and soil samples was carried out according to standard methods in 2018, the sample is representative. Each sample included 100 paired needles (10 pairs from 10 trees). The material was processed immediately after collection. Paired needles from one sample were placed on a

sheet of A4 white paper with a ruler and scanned. ImageM was used to measure the morphometric parameters of needles.

The content of heavy metals (Pb, Cd, Zn, Cu, Ni, Co Cr, Mn) in soil and plant samples was determined by atomic absorption method on a PinAAcle 900T analyzer. In the analyzed samples, mobile forms of heavy metals, accessible to plants, were extracted with an acetate-ammonium buffer solution with a pH of 4.8.

The index of fluctuating asymmetry (IFA) of the length of the needles was calculated as the ratio of the difference between the length of one needles in a pair and the length of another needles in a pair multiplied by 2 [15].

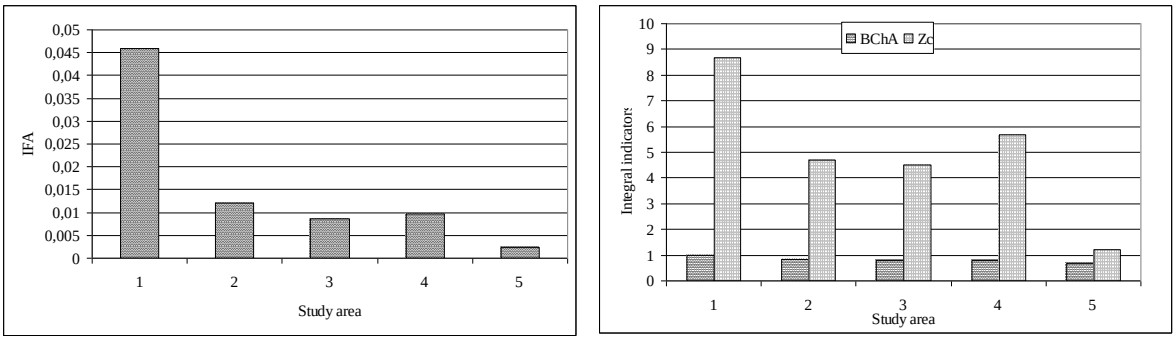
An environmental assessment of the degree of chemical pollution of the soil cover was carried out according to the total pollution index [16].

To assess the effect of heavy metals on plants, the biogeochemical activity of the species (BAS) was calculated as the sum of the biological absorption coefficients of individual heavy metals [17].

Statistical processing was performed using the programs Microsoft Excel, Statistica.

4. Results and discussion

The calculation of the integral indicators of the concentration of heavy metals in the studied samples indicates the processes of their accumulation in the soil cover and needles of ordinary pine (figure 2).



a) Index of fluctuating asymmetry

b) Biogeochemical activity of plants, total indicator of soil pollution

Figure 2. Values of integral indicators: total indicator of soil cover pollution (Zc), biogeochemical activity of plants (BAS) and fluctuation asymmetry index (IFA).

For all the studied areas of the city, the integrated indicators exceed the background values. So, the total indicator of soil pollution (Zc) for the studied sites of the city exceeds 3.7-7.2 times the background indicators.

The index of fluctuating asymmetry turned out to be the most sensitive, since it was very different from the background: in Central Park it was 19 times more, in the Vetrushanka microdistrict and Akademgorodok microdistrict 3 and 5 times, respectively, in the Park named after May 1 - 4 times.

Differences in the degree of excess within urban sites indicates the greatest pollution of the soil cover in Central Park, which indicates different volumes of heavy metals entering the atmospheric air of the city. The studied sites are located in residential areas of the city and differ in different levels of traffic load. So Central Park is characterized by the greatest load and, accordingly, pine populations are most affected by pollutants.

The trend of increasing integral indicators is marked by the following series: Vetrushanka microdistrict Акад Akademgorodok microdistrict < Park named after May 1 < Central Park.

As the correlation analysis revealed, the elemental composition of the soil cover and pine needles create conditions for deviation from the normal development of pine (figure 3).

Correlation analysis of the studied parameters revealed a strong relationship between BAS and IFA (R^2=0.93), Zc and BAS (R^2=0.93) and the average - Zc and IFA (R^2=0.77).

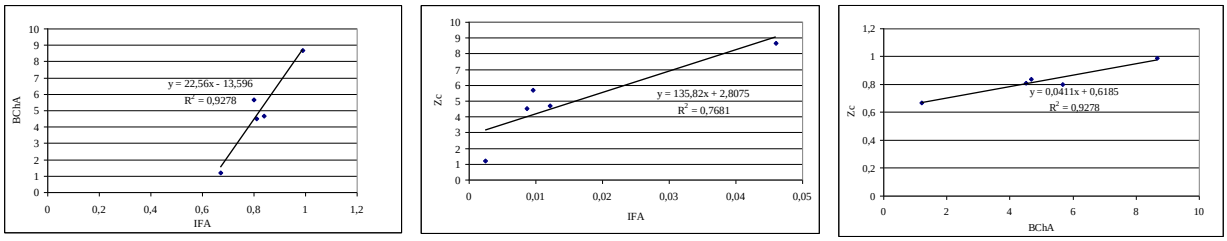


Figure 3. Correlation analysis of indicators: total indicator of soil cover pollution (Zc), biogeochemical activity of plants (BAS) and fluctuation asymmetry index (IFA).

It is necessary to note the different reaction of conifers to the degree of chemical pollution. As it can be seen from the data presented, the greatest response is characteristic of the index of fluctuating asymmetry of the needles on the state of the environment.

In order to identify the main sources of anthropogenic pollution, the integral indicators characterizing soil and plant pollution at various points in the urban zone were analyzed. The results were processed by factor analysis.

As it can be seen from the treatment results, the observed levels of soil and vegetation pollution by 93.93% are explained by the action of one factor (figure 4).

Figure 5 shows the location of sampling points in the space of identified factors.

As it can be seen from the figure, point number 5 is characterized by a low level of action of polluting factors. For points No. 2, 3, 4, a strong impact of vehicles is noted. Point number 1 is characterized by an increased level of anthropogenic factor. With a high degree of probability, this indicates that a change in the stability of the development of Scots pine is associated with emissions from vehicles. It is known that such elements as: Cr, Mn, Ni, Cu, Zn, Cd, Pb in the form of solid particles with exhaust gases of vehicles enter the atmosphere of cities [18].

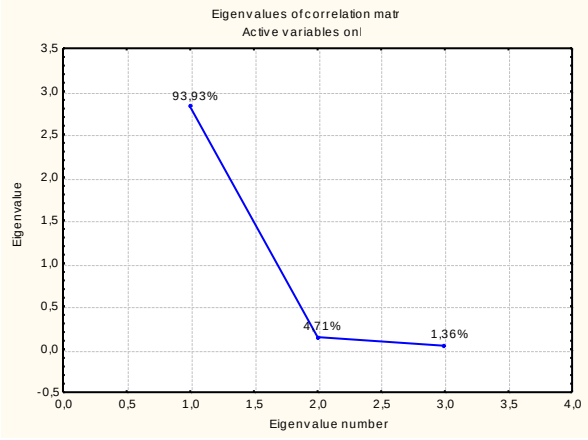


Figure 4. The location of the sampling points in the space of the identified factor.

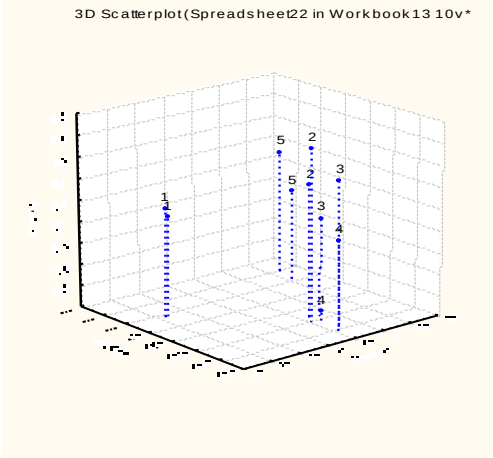


Figure 5. Factor load.

5. Conclusion

Thus, we can note that, in view of the accumulation of heavy metals in the soil cover and plant tissues, the morphometric characteristics of needles in populations of common pine change.

According to the BAS values, ordinary pine quite actively accumulates heavy metals in needles; perhaps, ordinary pine is a potential object for phytoremediation of urban soils as we noted earlier [1]. And so, for example, Agnieszka B, Kazimierz W and Barbara A [19] indicate the use of pine for phytoremediation and in case of soil contamination with oil products.

References

[1] Korotchenko I S and Muchkina E Ya 2017 Heavy metals in the soil cover and woody plants of the urbanized territory of the city of Krasnoyarsk *Ecology of urbanized territories* **2** 6-11
[2] Korotchenko I S and Muchkina E Ya 2016 Heavy metals in technogenic surface formations of the Krasnoyarsk agglomeration *Modern problems of science and education* **4** 224
[3] Korotchenko I S, Pervyshina G G, Romanova O V, Alekseeva A N and Medvedeva V A 2019 Features of the development stability of tree plantations of large city industrial zones *IOP Conf. Ser.: Earth Envir. Sci*. **315(2)** 022012
[4] Avdeeva E V, Poletaykin V F and Avdeeva E A 2008 Assessment of the quality level of urban landscaping objects by applied qualimetry methods *Conifers of the boreal zone* **25(1-2)** 93-8
[5] Soboleva O M 2009 Phytoindication using Scots pine in the Kemerovo region *Mountain Information and Analytical Bulletin* **18** 56-61
[6] Shcherbenko T A, Koptsik G N, Gronenberg B Ya, Lukin N V and Livantsova S Yu 2008 Absorption of pine cells and heavy metals under atmospheric pollution *Moscow University Herald: Soil Science* **17(2)** 9-16
[7] Borodina N A 2012 Accumulation of heavy metals of pine needles in the urban ecosystem of Blagoveshchensk *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences* vol 14 **1(8)** 1958-62
[8] Ovechkina E S and Shayakhmetova R I 2015 The influence of anthropogenic factors on the pigment content of common pine in the summer-winter period in the Nizhnevartovsk region *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences* **17(6)** 236-41
[9] Skripalschikova L N, Stasova V V and Plyashechnik M A 2013 Assessment of the ecological state of Scots pine in the urbanized territories of the Krasnoyarsk forest-steppe *Bulletin of the Krasnoyarsk State Agrarian University* **11** 176-81
[10] Osipenko R A and Osipenko A E 2018 The fluctuating asymmetry of pine needles as an indicator of environmental pollution by a mining enterprise *Forests of Russia and the economy in them* **4** 30-7
[11] Kozlov M V and Niemela P 1999 Difference in needle length – a new and objective indicator of pollution impact on Scots pine (Pinus sylvestris) *Water, Air and Soil Pollution* **116** 365-70
[12] Chudzinska E, Pawlaczyk E M, Celinski K and Diatta J 2014 Response of Scots pine (Pinus sylvestris L.) to stress induced by different types of pollutants – testing the fluctuating asymmetry *Water and Environment Journal* **28** 533-9
[13] Makarenko E S, Udalova A A and Geraskin S A 2016 Morphometric indicators of pine needles under chronic radiation exposure *Forestry* **5** 355-64
[14] Korotchenko I S 2018 Assessment of the accumulation of heavy metals in the urban system based on integral indicators *Man-Nature-Society: Theory and Practice of Life Safety, Ecology and Valeology* **4(11)** 62-3
[15] Palmer A R and Strobeck C 1986 Fluctuating asymmetry: measurement, analysis, patterns *Ann. Rev. Ecol. Syst.* **17** 391-421
[16] Hygienic standards 2.1.7.2041-06 *Maximum allowable concentration (MPC) of chemicals in the soil* (Moscow: Publishing house of standards)
[17] Dobrovolsky V V 2003 *Fundamentals of biogeochemistry* (Moscow: Academy)
[18] Golokhvast K S, Chernyshev V V and Ugay S M 2016 Automobile emissions and human ecology (literature review) *Human Ecology* **1** 9-14
[19] Agnieszka B, Kazimierz W and Barbara A 2019 Long-term responses of Scots pine (Pinus sylvestris L.) and European beech (Fagus sylvatica L.) to the contamination of light soils with diesel oil *Environmental Science and Pollution Research* **26(11)** 10587–608