Monitoring of urban pollution as an indicator of environmental engineering

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Abstract. The comfort of the urban population living in a particular territory is characterized by a combination of factors on it. The analysis of natural, socio-economic, architectural and environmental indicators is a comprehensive system for establishing the quality of life and safety in the conditions of technogenesis. The paper presents the results of the study the trees vital state in the urban agglomeration. It is recommended to include the obtained data in the graphoanalytic structure of environmental quality laboratory studies in the framework of the priority direction of sustainable development. Based on the principles of improving and maintaining the environment with the help of bioindication methods, it becomes possible to propose preventive measures of urbanized territories degradation. The paper takes into account the response of plants and justifies the changes that occur within them under the influence of anthropogenic factors. It is established that the results of bioindication studies allow us to assess the real ecological situation of the territory and can be included in the concept of environmental engineering.

The main development strategy of Russia is the implementation of sustainable development model for each industrial enterprise and the country as a whole. Achieving a specific goal - reducing the negative impact on the environment - is possible by increasing the efficiency of the technological process and introducing the best available technologies into the modern industry. An essential role at this stage of the industrial development is assigned to the systematic control of the quality of atmosphere, soil and water.

Living in an ecologically clean area is a natural desire of the citizens. Official information on the environmental situation is provided only for the prevailing pollutants. Information about pollutants does not take into account retrospective data and the cumulative effect of pollutants in environmental objects. Based on only a limited number of indicators, the end of 2020 was characterized by a high level of atmospheric pollution, with an excess of the maximum permissible concentration of formaldehyde was 32.6 % [1]. Obtaining accurate and objective information about the current situation is possible with the help of bioindication methods.

Currently, a significant complex of measures has been developed to assess the aerogenic situation of specific areas in large industrial cities [2,3]. Various organisms can serve as indicators, but it is more expedient to use coniferous tree plantings, first of all, their assimilation apparatus. Changes in the structure of plantings, morphometric, biochemical and other indicators of trees correlate with the intensity of pollution in their growth place.
The aim of the study was to assess the ecological state of the air in the urbanized territory of the Krasnoyarsk and to characterize the priority of areas for comfortable living.

The advantages of bioindication methods are an accessible of objects and rapid assessment of the impact of the entire combination of air contaminant. The use of these methods allows for successful monitoring of industrial sites, recreational areas, and background woodlands. The obtained information is used for ecological zoning of cities and surrounding territories. At the same time, visual, morphometric and gravimetric methods of analysis provide qualitative and semi-quantitative results, so for obtaining representative quantitative results of the study it should be carried out biochemical experiments. The main substances analyzed into a plant organism from the primary metabolites are the pigment system, the secondary - essential oils and their components. The α-pinene content in the essential oil of coniferous trees can show the intensity of atmospheric pollution, and the ratio of four main monoterpenic hydrocarbons in oil allows to set the chemotypes of the emerging plantings [4]. The precise correlation between the intensity of the anthropogenic stress and the content of the monoterpenic hydrocarbons amount in the essential oil is more clearly expressed by conducting gas-liquid chromatography of the oil in the SE-30 phase [5]. The retention time of this group hydrocarbons is significantly shorter compared to other components under the influence of pollutants, which makes it possible to identify the level of contamination.

The ecological state of the atmosphere in the region center was established using Siberian spruce as an indicator, which is very sensitive to changes in the environment. In each of the seven districts of Krasnoyarsk, spruce stands were evaluated visually on a point scale and morphometric measurements of needles were carried out. The results of the visual assessment and characteristics of spruce stands are presented in table 1.

**Table 1. Characteristics of the Siberian spruce categories.**

| Tree category                      | Main features                                                                 | Visual representation |
|------------------------------------|-------------------------------------------------------------------------------|-----------------------|
| 1 – no signs of weakening           | The needles are green and shiny, the crown is thick, the growth of the current year is normal |                       |
| 2 - weakened                       | The needles are lighter than usual, the crown is slightly azure, the growth is reduced by no more than half |                       |
| 3 - severely weakened              | The needles are gray, the crown is openwork, the growth is reduced by more than half |                       |
4 - shrinkable  
The needles are yellowish, the crown is noticeably sparse, the growth of the current year is still visible.

5 - dead wood of the current year (fresh)  
The needles of the current year are brown, the crown is very sparse.

6 - dead wood of previous years (old)  
Needles crumbled or partially preserved.

Biometric measurements included determining the length, width, and thickness of the hundred second-year needles from each site under the MSP-1 series microscope. The volume of needles was determined volumetrically [6]. Visual observations showed changes in the skeletal part of trees, crown structure, life expectancy, color and diseases of needles. The obtained data were averaged around the city districts and are presented in the table 2.

**Table 2.** Results of biometric measurements of Siberian spruce needles and visual assessment of plantings.

| City district | Length of needles, mm | Volume of needles, mm³ | Visual assessment Index | Category of plantings |
|---------------|------------------------|-------------------------|-------------------------|-----------------------|
| Leninsky      | 14.79 ± 0.21           | 10.97 ± 0.43            | 3.51                    | seriously weakened    |
| Kirovsky      | 16.52 ± 0.36           | 17.62 ± 0.60            | 3.27                    | moderately weakened   |
| Sverdlovsky   | 16.95 ± 0.28           | 15.39 ± 0.51            | 3.15                    | moderately weakened   |
| Sovietsky     | 15.34 ± 0.33           | 11.18 ± 0.16            | 3.77                    | seriously weakened    |
| Central       | 15.09 ± 0.13           | 9.74 ± 0.11             | 3.98                    | seriously weakened    |
| Railway       | 17.16 ± 0.22           | 18.19 ± 0.52            | 3.01                    | moderately weakened   |
| Oktyabrsky    | 18.47 ± 0.38           | 23.63 ± 0.41            | 2.12                    | faintly weakened      |

The obtained measurements indicate a high level of air pollution in the city, especially in its Central, Sovietsky and Leninsky districts. According to the state report [1], the elevation of the hygienic standard for benz(a)pyrene was recorded by 2.8 times in 2019 on these areas. In the third quarter of 2020, the maximum single concentration of formaldehyde in the Leninsky District was exceeded by 7.44 times, and as a whole in the city, the frequency of maximum permissible concentration exceedances was 14%. Cases of exceeding hygiene standards at the end of 2020 were recorded for suspended substances, carbon monoxide, nitrogen dioxide, hydrochloride and formaldehyde. The highest frequency of maximum permissible concentration exceedances was observed in the Central District. It is also necessary to take into account the wind rose which is changed throughout the year in Krasnoyarsk and the frequency of unfavorable meteorological conditions, which make their own adjustments to the
natural dispersion of pollutants in the air (figure 1). So, the direction of the winds changed during only 2020: in January, south winds prevailed (44 %), in July - west winds (26 %), and in December, southwest winds prevailed (60 %). Warnings about the occurrence of adverse weather conditions for the dispersion of pollutants for 2020 were announced 10 times, and in 80 % of cases during the period of negative temperatures. And since the beginning of 2021, only in the first two months, unfavorable conditions have already been announced 5 times. In addition, a special negative contribution to the ecological situation of the city is made by the height of residential blocks under construction, which contribute to the stagnation of air flows.

![Figure 1. Location of Krasnoyarsk districts and the wind rose.](image-url)

Recreation areas were studied in more detail in the ecologically unfavorable districts identified in table 1. «Guards park» is situated in the Sovietsky district, park «Chemist» - in Leninsky district, «Central park» - in Central district and in the favorable Oktyabrsky district, a park «Greymyachaya griva» was chosen for comparison.

Tree plantings significantly improve the ecological situation in the city, so the greening of residential areas is an important task of urban management. In the surface layer of the atmosphere, which is important for comfortable living, tree stands adsorb and absorb pollutants. In a certain sense, this allows us to consider the ecological situation within the recreation zone as an average for the area of its location.

A visual assessment of the condition and structure of such stands in the most polluted areas of the city and the calculation of indicators of the vital tree state (L), carried out by the ratio of healthy \( n_1 \), weakened \( n_2 \), severely weakened \( n_3 \) and dying \( n_4 \) trees [7] are presented in the table 3.

| Recreation area         | Visual assessment Index | \( n_1 \) | \( n_2 \) | \( n_3 \) | \( n_4 \) | L        | Category of plantings |
|-------------------------|-------------------------|-------|-------|-------|-------|--------|-----------------------|
| Leninsky park «Chemist» | 3.04                    | 45    | 32    | 13    | 10    | 7440   | weakened              |
| Sovietsky «Guards park» | 3.17                    | 52    | 22    | 20    | 6     | 7670   | weakened              |

**Table 3.** Indicator of the vital state of tree stands in recreational areas.
Compared to the average urban district pollution levels, the ecological situation changes for the better in the recreational area. However, it is impossible to consider favorable conditions in urban parks. So, in the Leninsky district, recreation is located near a thermal power plant, the emissions of which are carried in its direction by the prevailing winds. In addition, the "retrospective" impact of currently inactive chemical industry should be taken into account. Even after their elimination, the ecological situation throughout the district keeps dangerous.

The main causes of atmospheric pollution of the Sovietsky district are aluminum, metallurgical industry, emissions of power plants containing nitrogen oxides, formaldehyde and benz(a)pyrene - the main components of the calculated index of atmospheric pollution. Of course, the introduction of improved technologies in the production process, the increase in the height of pipes and the arrangement of the sanitary protection zone play an important environmental protection function, reducing the concentration of dangerous, including carcinogenic, pollutants in the surface layer. But their release is still produced, which means that the cumulative effect of their harmful influence remains.

The environmental situation in the Central District is slightly better, although recently the grow flow of vehicles leads to increased impact in the form of suspended substances and products of incomplete fuel combustion. At the same time, with constant monitoring of the recreational area, there was discovered a migration to the park raven for the night from the landfill of solid municipal waste. Violation of the cuticle of needles and the presence of chlorosis and necrosis, dryness and premature fall of needles show a multifactorial influence of biotic and anthropogenic factors on tree stands.

Thus, the results of bioindication studies evidence a significant air pollution of the regional center and allows to conduct a comprehensive assessment of the well-being of the population within the framework of environmental engineering. Visual and morphometric data indicate that the most unfavorable situation is in the Leninsky, Sovietsky and Central districts. On a narrow territorial scale, a particularly dangerous situation is observed in the Central district, where the recreational area is experiencing a serious depressing effect. On a citywide scale, the Soviet district is not a recommended place of residence for citizens.

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