Rapid assessment of the state of atmospheric air by bioindication of dendroforms

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Abstract. In the urban environment, the main sources of pollutants entering the atmosphere are industrial enterprises and vehicles, which leads to a significant change in the composition of the air. Various monitoring methods are used to analyze the state of the atmospheric air. On their basis, methods have been developed to monitor the state of the natural environment of the technosphere. Most often, gas analyzers and various chemical methods for determining aerosol pollution are used. The creation of a methodology that makes it possible to quickly and efficiently assess the state of the environment is urgent. The described method of rapid assessment of the state of atmospheric air by bioindication and biotesting of dendroforms makes it possible not only to quickly and qualitatively assess the quality of atmospheric air, but also to take appropriate environmental measures in a timely manner. The developed rapid assessment includes several stages of the assessment of the objects under study, carried out depending on the goals of the study. To test the methodology, the objects of the study were the most anthropogenically loaded public green spaces (PGS) - public gardens of Sevastopol, located in different administrative districts of the city. The obtained results showed the possibility of using the developed methodology both in stages and in a complex manner.

1 Introduction

In the urban environment, the main sources of pollutants entering the atmosphere are industrial enterprises and vehicles, which leads to a significant change in the composition of the air. Carbon oxides, sulfur dioxide, nitrogen oxides, hydrocarbons, as well as industrial dust make up the bulk of the emitted compounds. The whole complex of negative effects of gaseous emissions leads to a negative effect on human health, his vital activity, as well as to biological changes and a 2-3-fold reduction in the life expectancy of plants [1]. Thus, the state of the surrounding air environment is relevant, and its control is vital.

Various monitoring methods are used to analyze the state of the atmospheric air. On their basis, methods for monitoring the state of the natural environment of the technosphere have been developed. Most often, gas analyzers and various chemical methods for determining aerosol pollution are used for this. Sampling is carried out both at stationary and mobile stations [2]. Such methods are expensive and time consuming to use and

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maintain. In addition, the methods used cannot always take into account both the scattering power of the atmosphere and, in general, the resource potential of the atmosphere.

The analysis of signs of changes and resistance of plants in the urban environment is used as indicators of the state of atmospheric air. Based on this, it becomes possible to develop new approaches to solving the problems of minimizing the spread of aerosol pollution. One of them is air monitoring based on bioindication and biotesting of plant forms [3].

The existing methods of bioindication and biotesting significantly reduce the cost and speed up the control process. However, the currently used methods are not sufficiently reliable due to the large number of ecological and biological factors that affect the state of test objects [4]. Besides, the plants of urban environments proposed as bioindicators are not always applicable as universal for all biocosnoses. Dendroforms - endemic trees and shrubs - are the closest to solving the problem.

Thus, the creation of a methodology that makes it possible to quickly and efficiently assess the state of the environment is urgent.

2 Materials and methods

The purpose of the study is to create a rapid assessment of the state of atmospheric air by bioindication and biotesting of dendroforms, which allows us not only to quickly and qualitatively assess the quality of atmospheric air, but also to take appropriate environmental measures in a timely manner.

Various field and paper research methods were used in the work:

1. Basic method - bioindication and biotesting of plant forms:

- morphophysiological method (analysis of the vital state of tree plantations);
- physical methods (analysis of the degree of damage to the leaf plate, fluctuation asymmetry of the analyzed objects);
- chemical methods (analysis of chlorophyll, determination of sulfur, dust in the leaves of trees);
- biochemical methods (determination of the enzyme peroxidase (I.II.I.7), catalase CF (EC 1.11.1.6).

3 Results and discussion

The developed methodology for express assessment of the state of atmospheric air includes several stages of assessing the objects under study, carried out depending on the goals of the study. [5] At the first stage, the vital state of the selected tree forms was assessed. Assessment is visual - according to the degree of damage to the assimilation apparatus and plant crowns, biomorphological signs are taken into account, a connection is made with the geoecological assessment of plant biodiversity. In this analysis, the marker of pollution is the morphophysiological state of tree plantations. A system of points has been proposed: 5 points (the highest) are assigned to the healthiest tree, 1 point - to a tree with a high degree of damage. [6,7] The assessment of the biodiversity of the study area is carried out according to the Shannon method, using this parameter as a marker and correction factors that take into account the degree of anthropogenic loading of the area. At the second stage, a quantitative assessment of changes in the state of dendroforms was carried out. Markers - the degree of damage to the leaf plate and the fluctuating asymmetry of test objects, which makes it possible to apply methods of accumulating bioindication in assessing the state of the environment. The third stage includes biochemical analysis of dendroforms. The indicators of the activity of such antioxidant enzymes as catalase, peroxidase [5,8] and

polyphenol oxidase are used as criteria-markers. The content of ascorbic acid is also analyzed, the content of peroxide groups is determined. The fourth stage is the analysis of the content of various chemical substances in the leaf plate of test objects, including the assessment of the content of chlorophyll, sulfur and dust, which makes it possible to more fully assess the content of exhalates in the atmospheric air of the regions under study. At each of the four stages, points are awarded based on the results of dendroform studies. The excess/decrease of the total score is normalized on the basis of many years of research and complex indicators of complete measurements and calculations. The scoring scheme, excluding the "weight" factors, is shown in Table 1.

To test the methodology, the objects of the study were the most anthropogenically loaded public green spaces (PGS) - public gardens of Sevastopol, located in different administrative districts of the city. The studies were carried out during 2017-2020. Sampling was carried out depending on the stage of assessment and the vegetative period of the used test object.

As of June 2020, the green area of garden squares, parks, boulevards in Sevastopol is 1,466,150 m2 (of which 689.966 m2 are garden squares). Accounting for green spaces is based on inventory data, which is carried out in accordance with the Methodology for Inventory of Urban Green Spaces. However, a full-fledged inventory of PGSs in the city was not carried out.

Table 1. Step-by-step assessment of the degree of pollution of the study area, in points.

Degree of environmental pollution	1st stage Assessment of the morphophysiological state	2nd stage Assessment of the degree of damage to the leaf plate and fluctuating asymmetry	3rd stage Biochemical analysis of dendroforms	4th stage Assessment of the chemical component
Permissible degree of pollution **(0- 6 points)**	0-2 points	1-3 points	- Catalase CF (EC 1.11.1.6) -high - Peroxidase (I.II.I.7) - low **(total – 1 point)**	MPC and less **(0 points)**
Moderate degree of pollution **(7- 11 points)**	3 points	4-6 points		1-3MPC **(1 point)**
High degree of pollution **(12-17 points)**	4 points	7-9 points	- Catalase CF (EC 1.11.1.6) - low - Peroxidase (I.II.I.7) **-** high **(total – 2 points)**	3-5MPC **(2 points)**
Extremely high degree of pollution **(18 – 20 points)**	5 points	10 points		More than 5MPC **(3 points)**

The main type of garden and park plantations (TGPP) of all studied PGSs of the city are rows of trees and shrubs (hedges), groups, single plantations of trees and shrubs, lawn, herbaceous flower plants in vases and containers, lianas in the form of vertical gardening on special structures. In the garden squares of Sevastopol, alleys and hedges are most often used. PGSs were studied for amenities according to the developed point system [6]. Figure 1 presents a summary of the research results.

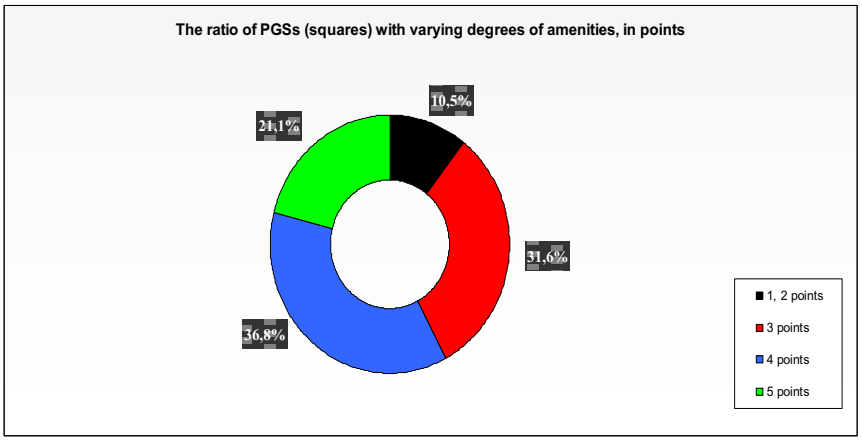

Fig. 1. The ratio of PGSs (squares) with varying degrees of amenities in Sevastopol, in points.

According to the results of the research, 12 garden squares were selected: 3 "very good amenities", 3 "good amenities", 3 "poor amenities" and 3 "not good amenities" in each of the municipal districts (MD) of Sevastopol. The selection criterion was the maximum points in each category. In the Leninsky MD, the following objects were chosen - object No. 1 - the square with the best amenities - the square named after Leninsky Komsomol (11 points), object No. 2 – "good amenities" - the square near the Peter and Paul cathedral (5 points), object No. 3 – "not good amenities" - the garden square on General Ostryakov avenue from the General Lebed street up to the 5th km (pine planting adjacent to the avenue) - 0 points. In the Nakhimov MD of Sevastopol: object No. 4 - a square near the Monument to the Deported peoples of Crimea (10 points), object No. 5 - a square "Heroes of the Soviet Union" (6 points), object No. 6 - a square near the monument "2nd Bastion" (1 point). The objects of research in the Gagarinsky MD were the following squares: object No. 7 – a square along Oktyabrskaya Revolution Avenue from 59 to 43 (1 point), object No. 8 – a square near the shopping center "NOVUS" (5 points), object No. 9 – a square "Sevastopol cadets" (8 points). As a result of the analysis of the Balaklava MD: object No. 10 – a square "U Rybachka" (11 points), object No. 11 – a square on the Krestovsky street (4 points), object No. 12 - a square near the Gorky BRU (7 points).

On the basis of information data obtained during the study of 110 squares in all administrative districts of the city, the occurrence of trees and their share of participation in plantings were determined. The following families were identified in the following percentages: *Hippocastanaceae* (2.95%), *Fabaceae* (31.51%), *Aceraceae* (1.08%), *Oleaceae* (5.42%), *Juglandaceae* (1.78%), *Platanaceae* (6.73%), *Salicaceae* (4.1%), *Cupressaceae* (10.15%), *Pinaceae* (24.7%), *Sapindaceae* (1.92%), *Bignoniaceae* (1.57%), *Rosaceae* (4.44%), *Simaroubaceae* (2.47%), *Elaeagnaceae* (0.2%), *Betulaceae* (0.13%), *Moraceae* (0.47%), and *Ulmaceae* (0.2%). According to the degree of occurrence, all species were divided into the following categories: I - very rare species, II - rare species, III - moderately occurring species, IV - common species, V - frequently occurring species. The most common in garden squares are *Robinia pseudoacacia* - 21.97%, *Pinus pallasiana* - 15.31% and *Cupressus sempervirens* - 9.54%. The highest frequency of occurrence is inherent in the following species: *Robinia pseudoacacia* and *Cupressus sempervirens*.

Thus, trees that are both sensitive to the main pollutants and gas-resistant trees grow in all selected objects. Dendroforms growing in all studied squares were selected as test objects. The studied dendroforms were: Japanese pagoda tree (*Styphnolobium japonicum*), Norway maple (*Ácer platanoídes*), black poplar (*Pópulus nígra*). In addition, the small-

leaved linden (*Tilia cordata*) was studied in the places of growth as the most gas-sensitive test object.

Desktop studies were also carried out with the most widespread tree plantations in the city of Sevastopol: black locust (*Robínia pseudoacácia*), honey locust (*Gleditsia triacanthos)*, Norway maple (*Acer platanoides*), walnut (*Juglans regia*). However, the data obtained did not allow making reliable conclusions, which requires additional research.

The proposed rapid analysis is complex and step-by-step. At the first stage, the vital state of the selected tree forms was assessed. The assessment is visual - according to the degree of damage to the assimilation apparatus and plant crowns, biomorphological signs were taken into account, a connection was made with the geoecological assessment of plant biodiversity. In this analysis, the morphophysiological state of tree plantations is taken as a marker of pollution. [7] The assessment of the biodiversity of the study area was made according to the Shannon method.

As a result of the conducted field studies, data on the direct dependence of the number of ill and damaged dendroforms on the degree of anthropogenic load were obtained. Air pollution has a depressing effect on plants. There is a depression in the growth of functionally important parts of plants (a decrease in the size of leaves, wood yield, etc.) due to a decrease in assimilation, loss of green mass due to necrosis or premature fall of foliage, as well as due to impaired growth of the root system as a result of the influence of toxic substances [9,10]. Figure 2 shows a summary diagram for all research objects.

However, it should be borne in mind that a high anthropogenic load can serve not only as the cause of the development of an oppressed, stressful state, but also the activation of biological pollution by various pathogens, fungi, etc.

Thus, taking into account the weight coefficients allowing to compare test objects of different types, ages and conditions [12] and Table 1, objects No. 1,9,10 are classified as objects of the “permissible degree of pollution”, objects No. 2, 5, 6, 8, 11, 12 – “moderate degree of pollution”, objects No. 3, 7 – “high degree of pollution”.

At the second stage, a quantitative assessment of changes in the state of dendroforms was carried out. Markers are the degree of damage to the leaf plate (DDLP) and the fluctuating asymmetry (FA) of test objects, which makes it possible to apply the methods of accumulating bioindication in assessing the state of the environment [4, 8, 9, 10].

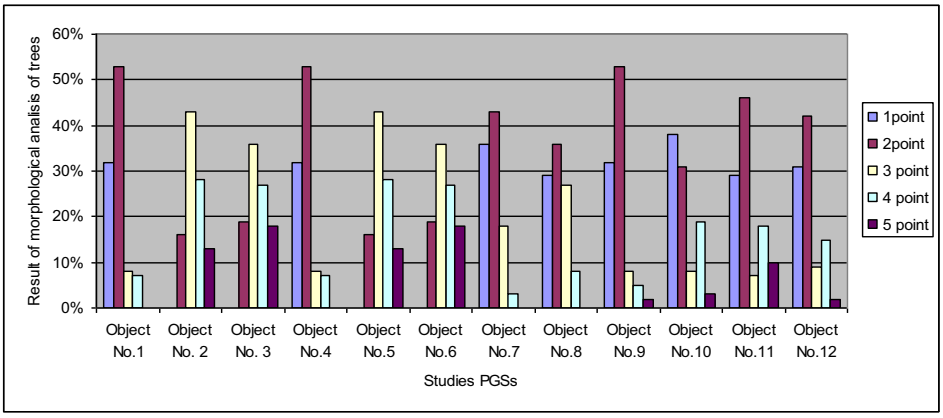

Fig. 2. Summary results of the first stage of research.

Based on the results, histograms were constructed (Figure 3 shows a summary histogram).

The results of the study of the second stage showed that object No. 1 can be attributed to "permissible degree of pollution", objects No. 2, 3, 4, 10,11,12 – "moderate degree of pollution", and objects No. 5, 6, 7, 8 and No. 9 - "high degree of pollution". The results obtained differ from the previous stage, however, the developed weight coefficients allow taking into account the age of dendroforms, the amenities of the PGS, the ability of plants to bilateral symmetry, and allow obtaining more reliable results when using this marker.

The third stage includes biochemical analysis of dendroforms. The indicators of the activity of antioxidant enzymes such as peroxidase (I.II.I.7), catalase CF (EC 1.11.1.6) were used as criteria-markers. [5,10,12,13-15] These enzymes were selected for the analysis due to the simplicity of the research methodology. Figure 4 shows a summary histogram based on the results of this stage of research.

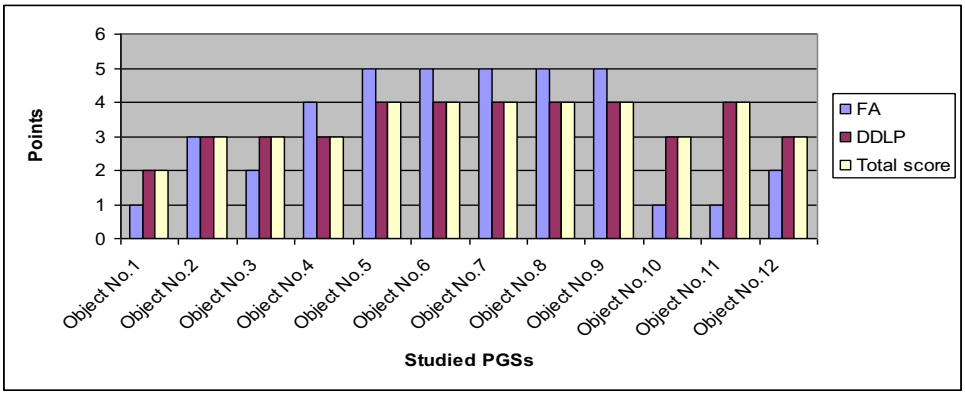

Fig. 3. Summary histogram based on the results of the second stage of the PGS studies.

The results of the study of the third stage showed that objects No. 1,4,9,10 can be attributed to "permissible degree of pollution", objects No. 2, 3, 5, 6,7,8, 11,12 – "high degree of pollution".

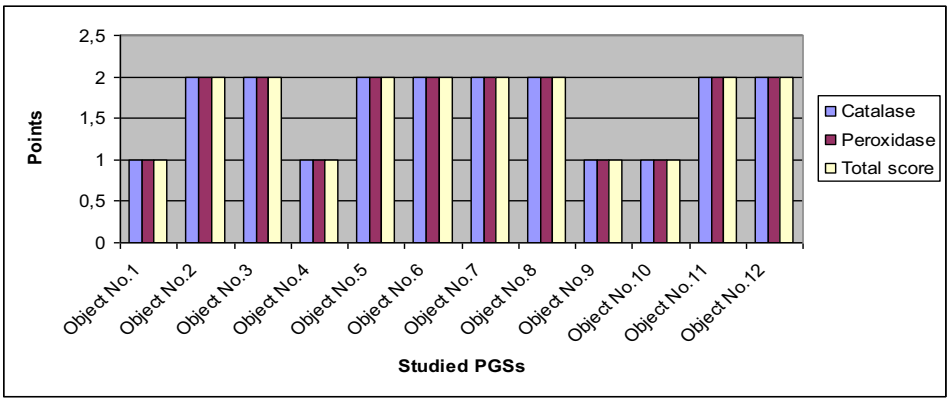

Fig. 4. Summary histogram based on the results of the third stage of the PGS studies.

The weight coefficients for this analysis are the presence of factors influencing the change in the enzyme activity in the leaf plates. A change in the activity of antioxidant enzymes was shown under conditions of xerophytism (K=2), salinity (K=2), high (K=3) and low temperatures (K=3), UV irradiation (K=3), treatment with elicitors of microorganisms (K=4) and other stress factors (K=5), including changes in the activity of

antioxidant enzymes under the toxic effects of heavy metals and a number of pollutants (K=5).

The fourth stage - the assessment of the content of chlorophyll, sulfur and dust in the leaf plate of the test objects made it possible to more fully assess the content of exhalates in the atmospheric air of the regions under study [5,6]. The results of the research showed that the maximum permissible concentration for suspended solids was exceeded for all the objects under study, except for object No. 1. However, the detected concentrations did not exceed 2MPC. For the rest of the substances, the excess of the normative parameters was not revealed. Thus, all studied subjects should be attributed to PGSs with a "moderate degree of pollution". Object No. 1 - PGS with "permissible degree of pollution" for this marker. The results obtained insignificantly differ from the data of the first, second and third stages.

Histogram 5 shows the result of all performed analyzes. Objects No. 1-12 are taken as point 1-12, respectively.

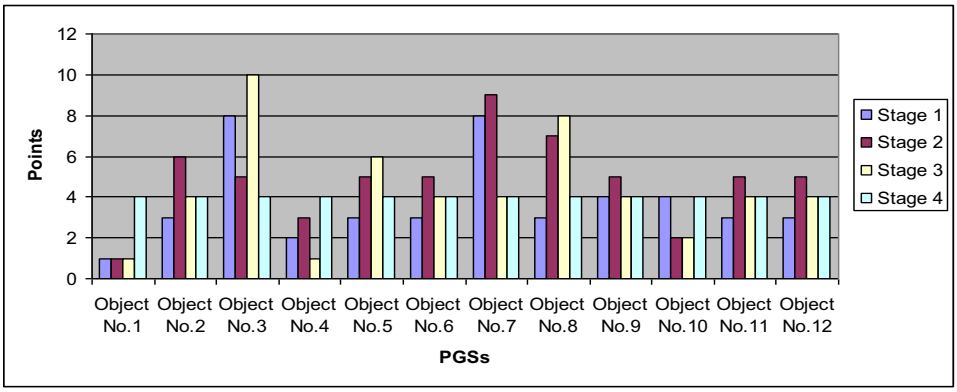

Fig. 5. Final control of selected PGSs by the used markers.

Thus, the results obtained show the possibility of using the developed method for rapid assessment both in stages and in a comprehensive manner.

4 Conclusions

The developed method for rapid assessment of the state of atmospheric air using dendroforms of varying degrees of resistance to the main pollutants and exhalates of urbanized areas allows:

1. Controlling the level of contamination without the use of expensive and time-consuming laboratory tests by several levels of assessment, depending on the set goals: statistical assessment (single-level), differentiated assessment, and full assessment.

Studies have shown that a combined stratification technique for assessing the relationship between levels of pollution by dendroforms is the most effective.

2. The created universal system of atmospheric air pollution markers can be used both for registering and for accumulating bioindication.

3. The proposed universal method for assessing the state of the environment makes it possible to analyze not only the state of PGSs, but also any natural territory of urban development, including protected areas.

4. The proposed method makes it possible to identify areas with a high level of pollution and dendroforms that can be used for phytoindication.

Indirectly, the system of markers makes it possible to identify the most gas-resistant forms of tree plantations that perform all the functions of green areas of urbanized areas in general and green areas of public use in particular.

5. The identified test objects in the study area make it possible to create a system of continuous monitoring using bioindication and biotesting methods. Such a system will allow timely recording of changes in the state of the environment in the event of emergency releases.

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