The Problem of Monitoring the Atmospheric Air of Russian Metropolises on the Example of the Green Zones of St. Petersburg

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ABSTRACT

The article studies the problem of assessing the quality of atmospheric air in the green areas of the metropolis. The aim of the work is to compare the data obtained by the biomonitoring method with information from unified state environmental monitoring system (USEMS). The sample object of the study is a Udelny park located in the Primorsky district of the city of St. Petersburg. The objectives of the study include the analysis of atmospheric pollution of the Udelny Park by the method of bioindication, comparison of the data obtained with the general telephone indicators, as well as with information from the nearest USEMS posts. When studying the object, the method of V.M. Zakharov was used to study the fluctuating asymmetry of the leaf plates of the hanging birch (*Betula pendula Roth.*). The site between Udelny Ave., the Vyborg railway line, Testers Ave. and Kolomyazhsky Ave. with an approximate area of 18 hectares was chosen as a model site. The assessment was carried out on 12 pickets, at each 100 samples of leaf plates were taken in total. For comparison, data were obtained from a stationary observation post for the state of atmospheric air pollution, information on the content of pollutants in the air of the Primorsky district. The study found that the quality of atmospheric air in the territory is low. In part of the pickets, the value of the fluctuating asymmetry index was more than 0.054, which corresponds to the V score (critical pollution). These data are generally correlated with information about air pollution in St. Petersburg. Nevertheless, the state of the environment is assessed by the chosen method more critically. This is due to the fact that the biomonitoring method studies pollution from the point of view of direct impact on the ecosystem, taking into account, among other things, the cumulative effect. The result makes us to conclude that it is more correct to use an integrated approach, combining both methods, to assess the stability of urban ecosystems and the quality of the environment in them. It is important to separate information about the quality of the atmosphere in green areas from general data on residential areas.

Keywords: urban areas, urban ecosystem, biomonitoring, monitoring, atmospheric pollution, metropolitan area, fluctuating asymmetry, park

INTRODUCTION

An integral part of any metropolis is its green spaces. Megapolis is represented as a complex system consisting of the following elements [Smirnov and Ivanov 2018]: (a) urban ecosystem – an anthropogenically modified natural ecosystem of an urban area; (b) industrial zone – the technosphere of a modern metropolis; (c) the social system is the totality of the human capital of the city. The above confirms that the city can only be considered as a complex system. The interaction of all elements, including green spaces, ensures the stable existence of the metropolis [Klimanova et al. 2018]. Therefore, the condition of park areas is really an important part of maintaining the stability of this system.

In the Russian Federation, data on the state of atmospheric air in the city are provided to citizens from unified state environmental monitoring system (USEMS). The data is obtained by the instrument monitoring method. The use of the method of biotesting atmospheric air quality is not widely used in the monitoring system [Volkodaeva and Kiselev 2017]. It follows from this that the method is new for the domestic ecology, more focused

on working with instrumentation and regulatory frameworks. In St. Petersburg, state and territorial monitoring systems use automated and stationary posts. The subsequent assessment of the state of the air environment is carried out according to the data obtained by instruments [Characteristic of the level ...].

Biotesting is a method of non-destructive environmental monitoring, which is based on the study of the properties of biological objects called test organisms. At the same time, the goal is to study the effect of environmental factors on an organism, or a separate function, a system of organisms [Petrov 2015]. From the point of view of dendrology, the best vegetative organ for analysis is the leaf plate [Melikhova and Egorova 2007]. The work should assess how the data obtained by the instrument method and the biomonitoring method differ. The hypothesis of the study is that it is necessary to use both monitoring methods for a comprehensive assessment of the state of the megacity's air environment.

The following tasks were set: (1) Choose a representative model site for research; (2) Assess the state of the air environment of the selected green zone; (3) Compare the information received with the data from the USEMS; (4) Analyze the possibility of improvement of the USEMS.

The relevance of the work is due to the expansion and change of the unified state environmental monitoring system (USEMS). These works are carried out within the framework of the national project «Ecology».

Sample site

The following requirements were made to the sample site:
1. Location away from industrial areas. This is necessary to avoid distortion of background indicators.
2. The proximity of the monitoring post of the state of the atmosphere. This requirement will allow you to compare the data with the data of the state or territorial monitoring system.
3. Significant age of the urban ecosystem. A formed ecosystem is better suited for studying.
4. Isolation of the object from external factors. This, for example, includes a ban on the entry of vehicles. Thus, we will reduce the likelihood of external influences on the obtained indicators.

There were several other parks among the candidates:
a) Murinsky Park, next to post 4. The reason for the discrepancy is too high anthropogenic load, small area.
b) Primorsky Victory Park, near post 23. The reason for the discrepancy is a decrease in concentrations of pollutants due to winds from the Gulf of Finland.
c) Moscow Victory Park, near posts 8 and 19. The reason for the discrepancy is too high anthropogenic load, has already been investigated earlier.
d) The Park of the Forestry Academy. The reason for the discrepancy is too high anthropogenic load, has already been investigated earlier.

In view of this, a Udelny Park was chosen as a model site. The history of the Udelny Park dates back to the times of Imperial Russia. At the beginning of the XVIII century, this area was a forest. In 1832, the Udelninsky Forestry School was established. On its basis, a "forest dacha" was created, which served as the beginning of the park [Glezerov S.E. 2012]. Since 1922, the territory of the Udelny is located within the city of Engels [Udelny Park]. According to the documentation, the Udelny park is divided into two sections [The Law of St. Petersburg "On public green spaces"]: (a) Udelny park (section 1) between Udelny Ave., Vyborg railway line, Testers Ave., etc. Engels, registered № 3214, approximate area of 17.99 hectares; (b) Udelny park (section 2) between ave. Testers, Vyborg railway line and Fermskoye highway, registered № 15103, approximate area of 95.74 hectares.

The complexity of accounting for the lands of forest-park zones is a common problem of megacities of the Russian Federation [Norova et al. 2017]. This is largely due to the frequent changes in the status of land in the period from 1990 to 2000. The Udelny Park is included in the unified state register of cultural heritage objects (based on the order of the Committee for State Control, Use and Protection of Historical and Cultural Monuments № 10–53 dated 13.02.2013) [Act on the results of...].

Figure 1 shows a schematic map indicating the location of the Udelny park in St. Petersburg, including relative to industrial zones. Figure 2 shows the location of the park relative to the grid of atmospheric air monitoring posts.
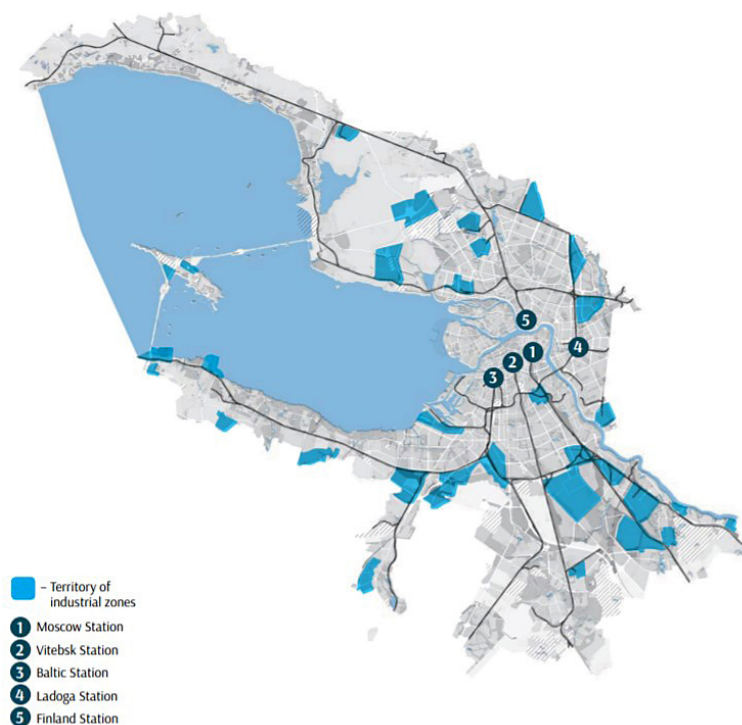
Figure 1. The location of the object relative to the industrial zones of St. Petersburg [Passport of industrial zones...]

The territory of the Udelny Park is located at the bottom of the ancient sea [Report on the results...]. There is a long hill in the middle of the park. Its height is about 6 m. The hill divides the Udelny Park into two parts. In addition, a third, well-maintained part can be singled out separately, where the natural forest area has been preserved the worst [from field observations].

The upper part is dry (due to altitude characteristics affecting hydrology). Phytocenosis is represented by hanging birch (*Betula pendula Roth.*) and Siberian larch (*Larix sibirica*) [from field observations]. The lower part is swampy. This is due to the fact that several unnamed streams flow here from the upper part of the park. Due to this, shrubs and moisture-loving grasses predominate here [from field observations]. More than 40 species of birds can be found in the park, including those rarely found in the city [Tsyplakov and Mikhailov 2019]. Transformation of spruce shoots was found in it, which indicates some isolation of this biogeocenosis from the urban ecosystem of St. Petersburg [Byalt and Orlova 2020].

Consider the background indicators of the state of the atmosphere. There are no sources of industry nearby, there is a boiler room located near the metro station "Chernaya Rechka".

MATERIAL AND METHODS

The study was conducted by collecting the leaves of the hanging birch (*Betula pendula Roth.*) and measuring their fluctuating asymmetry. The methodology was developed by Russian scientists Zakharov et al. [2000] to assess the damage caused to the environment. The leaves respond well to air pollution, as they are the key element of the photosynthesis process. Under favorable conditions, the body's reaction is controlled by a complex physiological system of buffer homeostatic mechanisms. However, with the negative influence of the environment, morphological changes occur. Their examples are the occurrence of asymmetry, a decrease in the area of the leaf plate [Petunkina 2007]. The leaves of the hanging birch (*Betula pendula Roth.*) were chosen as a test object as a tree with high absorption qualities [Andreeva 2017]. At the moment, according to researchers, fluctuating asymmetry can be considered as one of the morphological methods for assessing the state and dynamics of ecosystems. The calculated indicator is also proposed to be used as an index of the stability of the development of the organism [Sarkisyants 2017].
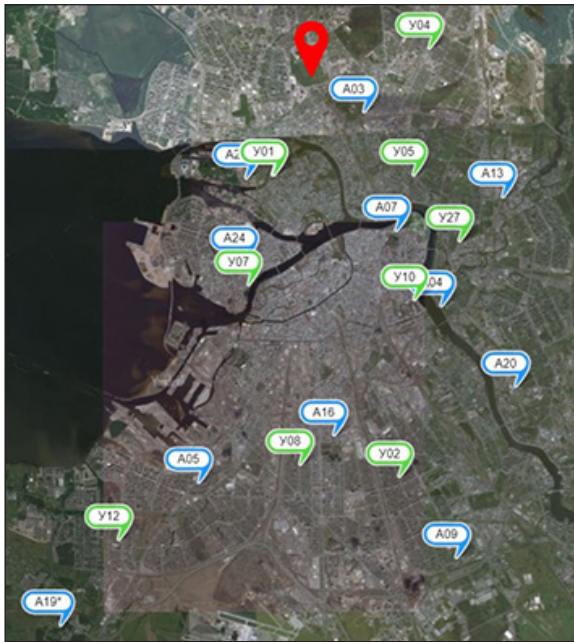
Figure 2. The location of the Udelny Park relative to the grid of posts of the state and territorial monitoring system of the state of the air environment of St. Petersburg (green mark «A» – automatic monitoring station for atmospheric air pollution of the Committee for Nature Management, Environmental Protection and Environmental Safety; blue mark «Y» – stationary monitoring post for the state of atmospheric air pollution (PNZ) of the Federal State Budgetary Institution "North-Western UGMS") [Certificate of the state of...]

Table 1. Criteria for assessing the state of the air environment [Strelcov et al. 2016]

Mark	FA_i, unit fraction	Meaning
I	< 0.040	Clean environment
II	0.040 – 0.044	Slightly polluted environment
III	0.045 – 0.049	Moderately polluted environment
IV	0.050 – 0.054	Highly polluted environment
V	> 0.054	Critical environmental pollution

The size of the leaves should be similar, average for this plant. When collecting the material, the age condition of the trees should be taken into account. In view of this, developed trees were selected as a sample of test organisms [Altabaev 2020]. The amount of asymmetry is calculated as follows: this is the ratio of the difference in the estimates on the left and right to the sum of these estimates according to the Eq. 1 [Zalesov et al. 2014].

$$FA_i = |R - L|/(R + L) \qquad (1)$$

To calculate the integral indicator of the stability of development, first calculate the average relative value of asymmetry for all signs for each leaf. It is obtained by adding the relative values of asymmetry for each feature, and then dividing
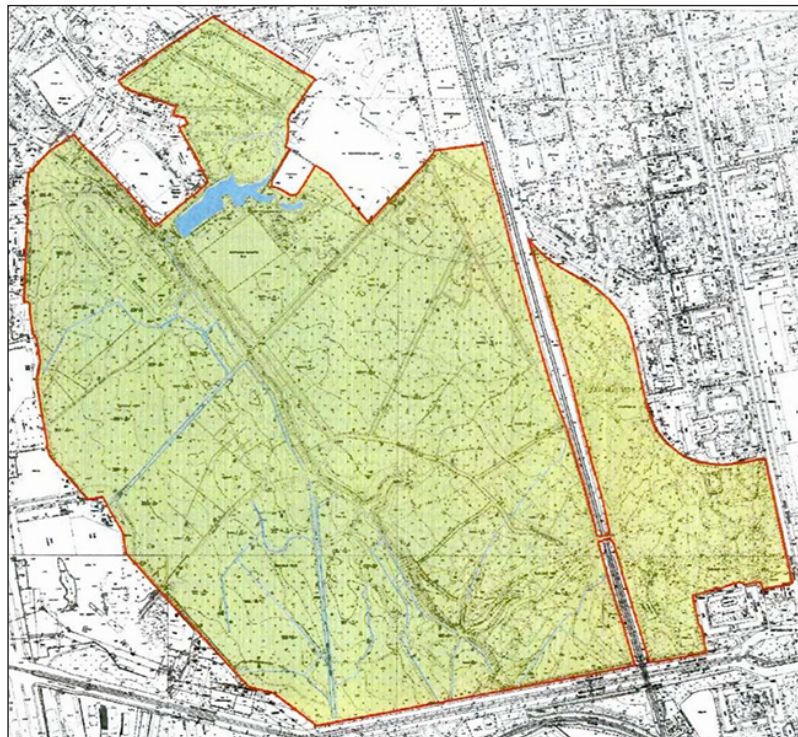

Figure 3. Map-plan of the boundaries of the Udelny Park [Act on the results of...]

the sum by the number of features. The next step is to calculate the arithmetic mean for this indicator for all samples from one picket [Kravchenko and Revinskaya 2011]. Table 1 shows the scale of assessment of the state of the air environment [Streltsov et al. 2016].

According to the rules of mathematical statistics, a representative sample is considered reliable if more than 30 measurements have been made [Kravchenko and Revinskaya 2011]. According to the method, it is necessary to collect 100 leaves from the picket (10 from 10 plants each), correlated with the requirement for the reliability of the study. From the model site, it is necessary to take samples of leaf plates from at least 20 individuals [Zakharov et al. 2000]. The location of the points was justified by the boundaries of the park according to cadastral data, the map is shown in Figure 3. Based on these requirements, the following testing methodology was compiled: (1) 12 model sites located taking into account the boundaries of the park; (2) There are 2 sampling pickets at each site; (3) At each picket, samples of leaf plates from 10 individuals are taken.

RESULTS AND DISCUSSION

Figure 4 shows a schematic map showing the leaf sampling pickets. The results of the measurements are presented in Table 2.

The best way to visualize atmospheric pollution is to build a thematic map in one of the
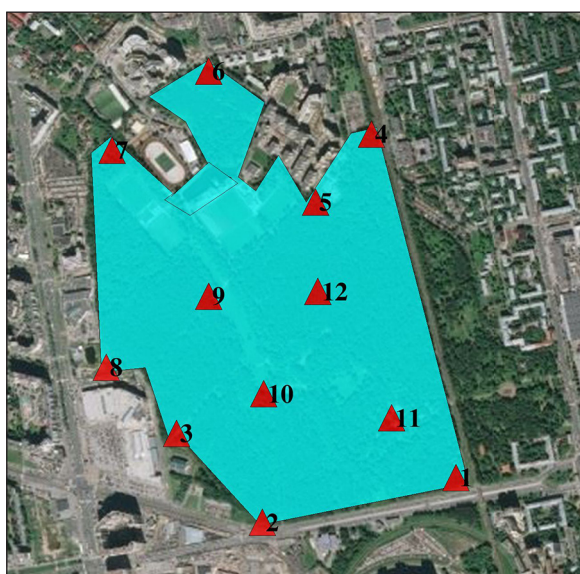
geoinformation systems [Pashkevich and Petrova 2017]. This allows you to visually visualize the information obtained during the study [Kartavtseva and Shumilina 2020]. Based on the area of the object under study, the Surfer Golden Software geoinformation system was selected. The kriging method was chosen for interpolation (Fig. 5).

Having constructed isolines for the distribution of values of fluctuating asymmetry in Surfer Golden Software, we see the following: the values change from those corresponding to critical pollution to those corresponding to weak pollution from the southwestern part of the park to the northeast. To the west is Kolomyazhsky Avenue with heavy traffic.

Let's turn to the data from the Committee on Nature Management, Environmental Protection and Environmental Safety. The closest monitoring post to the research object (see the map in Fig. 2) is post № 3 (automatic monitoring station of atmospheric air pollution of the Committee for Nature Management, Environmental Protection and Environmental Safety). Also we will use data from the post № 8, as it the official monitoring point for the state of atmospheric air for the Primorsky district. The merged data is presented in Table 3.

Cars emit sulfur and nitrogen oxides, which negatively affect urban vegetation [Eliseeva 2017]. Traffic flows are often the cause of the oppression of urban ecosystems [Ignatieva and Kroll 2013].

Most likely, the oppression of vegetation is caused by the negative impact of vehicles passing along the highways surrounding the park. This is

Figure 4. A schematic map showing pickets [compiled by the author with MapINFO software]

Table 2. Results of the study of fluctuating asymmetry of *Betula pendula Roth.*

| Picket	FA_i, unit fraction	Mark	Meaning
1	0.081	V	Critical environmental pollution
2	0.078	V	Critical environmental pollution
3	0.067	V	Critical environmental pollution
4	0.042	II	Slightly polluted environment
5	0.043	II	Slightly polluted environment
6	0.042	II	Slightly polluted environment
7	0.045	III	Moderately polluted environment
8	0.058	V	Critical environmental pollution
9	0.049	III	Moderately polluted environment
10	0.050	IV	Highly polluted environment
11	0.061	V	Critical environmental pollution
12	0.051	V	Critical environmental pollution
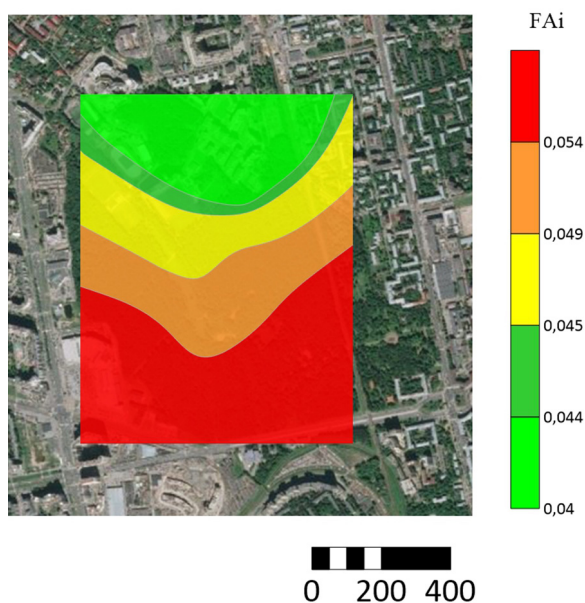
Figure 5. The map is a diagram of the distribution of the values of the fluctuating asymmetry of *Betula pendula Roth.* [compiled by the author in the Surfer Golden Software geoinformation system]

one of the key problems of preserving the forest park areas of St. Petersburg [Kudryavtseva and Melnichuk 2017].

Based on the study, the following recommendations can be put forward for an air monitoring system in a megalopolis: (1) The condition of green zones should be investigated separately, since plants accumulate pollutants in themselves (primarily due to the high contact zone due to leaf plates); (2) As methods for assessing the state of atmospheric air, it is necessary to use not only instrument analysis methods, but also the biomonitoring method.

CONCLUSION

In the course of the work, data on the state of the atmosphere in the urban environment obtained by the biomonitoring method and presented by the USEMS were compared. For the first time, an assessment of the state of the air environment of the Udelny Park in the Primorsky district of the city of St. Petersburg was carried out. The method of assessing the degree of favorability of the air environment by the method of biotesting was chosen. The hanging birch (*Betula pendula Roth.*) was chosen as a test organism. The measured parameter was the inflecting asymmetry of the leaf plates of trees. Measurements were carried out on 12 pickets, 100 samples were taken on each of them, which makes the reliability of the study high. As a result of the study, more than 20 trees were studied, which also meets the requirements of the methodology.

The data suggest that the Udelny Park is subject to significant environmental pollution. These sources of It are motor transport. Such an impact can lead to imbalance in this biogeocenosis. In this case, significant degradation of the stand will begin. The Park will not be able to perform a recreational function.

The data obtained are generally correlated with information about air pollution in St. Petersburg. Nevertheless, the state of the environment by the chosen method is assessed more critically. This is due to the fact that the biomonitoring method evaluates pollution from the point of view of direct impact on the ecosystem, taking into account, among other things, the cumulative effect. The obtained result allows us to conclude that it is more correct to use an integrated approach,

Table 3. Data on atmospheric air pollution from the posts № 3 and № 8 of the territorial monitoring of atmospheric air of St. Petersburg for 24.09.2021 – 01.10.2021 [Certificate of the state of...]

Contaminant	$MPCC_{ad}$[1]		$MPCC_{mo}$[2]	
	Post No. 3	Post No. 8	Post No. 3	Post No. 8
Carbon monoxide	0.1	0.1	0.3	0.2
Nitric oxide	*	*	0.3	**
Nitrogen dioxide	0.1	1.0	0.2	1.6
Sulfur dioxide	0.1	**	<0.1	**
Suspended particles PM10	0.4	**	0.7	**
Suspended particles PM2.5	0.3	**	0.3	**

*The hygienic standard of MPC for this substance (impurity) is not established (absent).

** Wasn't detected due to technical issues.

[1] $MPCC_{ad}$ – maximum permissible concentration (average daily).

[2] $MPCC_{mo}$ – maximum permissible concentration (maximum one-time).

combining both methods, to assess the stability of urban ecosystems and the quality of the environment in them. It is necessary to separate the quality of the atmosphere in green areas from general information about residential areas.

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