

Research of the *Pinus sylvestris* pollen as a method of assessing the degree of air pollution

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As a result of exposure to plants of various factors associated with anthropogenesis, a huge amount of pollen grains with altered morphological structures and biochemical properties is produced, which affects its fertility and the normal functioning of phytocoenoses. In the present work, using the example of *Pinus sylvestris* L. growing on the territory of the city of Barnaul as a model object, the possibility of using the quantitative and qualitative characteristics of pollen of plants depending on the state of the bioindication of the state of the environment (primarily atmospheric air) is substantiated. The data used for the analysis were obtained during the six seasons of flowering of *Pinus sylvestris* (May–June 2010–2015) in six permanent and nine additional observation points in the city of Barnaul located in the territory with a tense and critical ecological state of the landscapes. An analysis of the quality of the pollen was carried out by selecting it directly from the anthers during the active dusting period. As a control, pollen samples collected in the countryside of the Barnaul pine forest belt, which is an isolated and remote vegetation site relative to the industrial zone of Barnaul and large motor roads, were used. As a result of the research, it was found that the points with the highest pollen sterility and teratomorphic grain areas in the zone of very unfavorable ecological situation, which correspond to the areas of the greatest air pollution. More negative impact is shown in the territories located in an accessible proximity to motorways and parking lots. The proportion of sterile and teratomorphic pollen grains at such points is much higher than the reference values, which indicates a large share of the negative impact of emissions of mobile sources of atmospheric air pollution (vehicles) on the change in the morphological, biological and physical characteristics of Scotch pine pollen. Thus, palynoindication analysis can be one of the methods of bioindication of the state of the environment (primarily atmospheric air), as the most accessible and effective method of research and monitoring.

Key words: palynology; bioindication; pollen; monitoring; *Pinus sylvestris*

Introduction

At the present stage of the development of society, its active impact on the environment increasingly leads to negative back reactions.

Under the influence of various factors associated with anthropogenesis, the processes of vital activity of plants, primarily determining the development of pollen, are violated. As a result, a huge amount of pollen grains with altered morphological structures and biochemical properties is produced, which affects its fertility and normal functioning of phytocenoses (Kochubei, 2012; Dzyuba, Kochubey, 2014; Morozova, Vasilevskaya, 2015).

Thus, the assessment of qualitative (fertility and sterility) and quantitative (percentage of fertile and sterile pollen grains) characteristics of plant pollen in the system of palynomorphological studies can be used as one of the methods of bioindicating the state of the environment, primarily atmospheric air (Elkina, Markovskaya, 2007; Seroglazova, Baktasheva, 2012; Vasilevskaya, 2014).

In connection with the foregoing, the purpose of this work is to substantiate the possibility of using the quantitative and qualitative characteristics of pollen of plants to determine the ecological state of atmospheric air. As an object of research, we took *Pinus sylvestris* L., which grows on the territory of the city of Barnaul.

Material and methods

The studies were carried out at the federal seven-zone flowering of *Pinus sylvestris* (May–June 2010–2015) in the city of Barnaul in six permanent and nine additional observation points.

An analysis of the quality of the pollen of *Pinus sylvestris* was carried out by selecting it directly from the anthers during the active dusting period.

Constant observation points from 2010 were Zmeinogorsky Tract, near the ski base "Dynamo"; square behind the Administration of the Altai Territory; section of Molodezhnaya Street, square behind the Altai Regional Universal Library; intersection of Malakhova and Georgia Isakova streets; section of 80th Guards Division Street, near the Herman Titov public garden (Nenasheva et al., 2012). All objects are located in territories with a strained and critical ecological state of landscapes. In order to identify background (control) indicators, *Pinus sylvestris* pollen was collected and analyzed in the countryside of the Barnaul pine forest belt, which is an isolated and remote vegetation site relative to the industrial zone of Barnaul and major highways (Fig. 1).

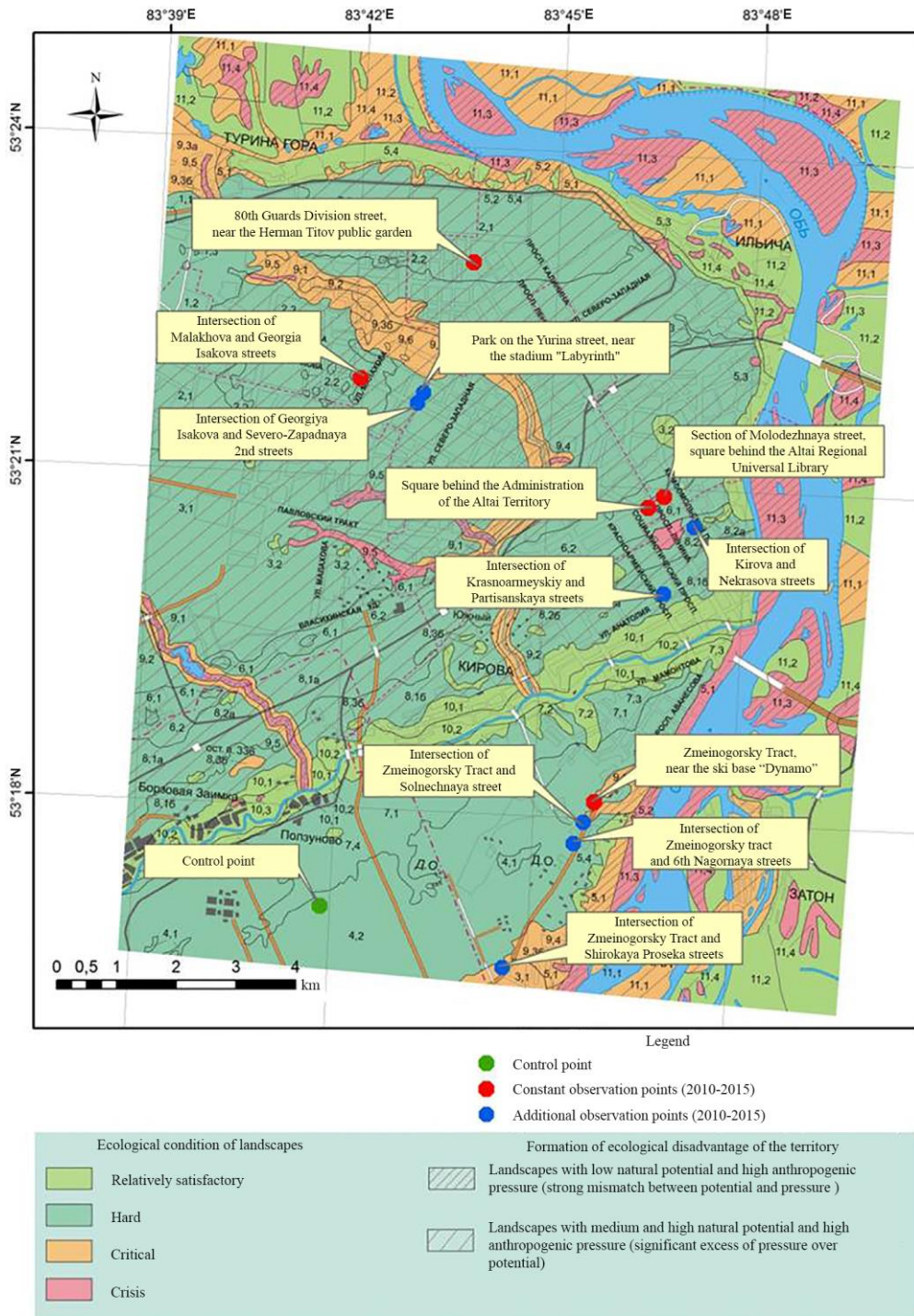


Fig. 1. Arrangement of pollen collection points for *Pinus sylvestris* in Barnaul for the period 2010–2015.

Additional points for collecting pollen of Scotch pine were taken from different objects in different years of observation, in different parts of the city. These include intersection of Kirova and Nekrasova streets; park on the Yurina Street, near the stadium "Labyrinth"; intersection of Krasnoarmeyskiy and Partisanskaya streets; alley at the intersection of Georgiya Isakova and Severo-Zapadnaya 2nd streets; intersections of Zmeinogorsky tract and 6th Nagornaya streets, Zmeinogorsky Tract and Solnechnaya Street, Zmeinogorsky Tract and Shirokaya Proseka streets – two collection points; square behind the Administration of the Altai Territory.

The results of the studies are processed by methods of mathematical statistics.

Results

As a result of the research, it was found that the points with the highest pollen sterility and teratomorphic grains are located in the zone of very unfavorable ecological situation, which correspond to the territories of the greatest air pollution (Atlas..., 2006). Thus, the collection point of pollen which is located on the section of 80th Guards Division Street, near the Herman Titov public garden is in the zone with the maximum pollution of the atmosphere by industrial enterprises and motor vehicles emissions. Here in 2015, the highest indicator of pollen sterility – 97.5% – was recorded, and the highest indicator of grains with unsatisfactory morphological characteristics was about 95%.

The point on the intersection of Malakhova and Georgia Isakova streets with a sterility rate of 78.3% is in the zone of severe pollution of the atmosphere, industrial and motor transport outlets. In the zone of unfavorable ecological conditions, or more precisely in the zone with medium pollution of the atmosphere by industrial enterprises and vehicles, the following points are placed: square behind the Administration of the Altai Territory; section of Molodezhnaya Street; square behind the Altai Regional Universal Library; Zmeinogorsky Tract, near the ski base "Dynamo". All additional pollen collection points are also located in the zone of unfavorable ecological situation.

The proportion of sterile and teratomorphic pollen grains at these collection points is significantly higher than the reference values (Fig. 2).

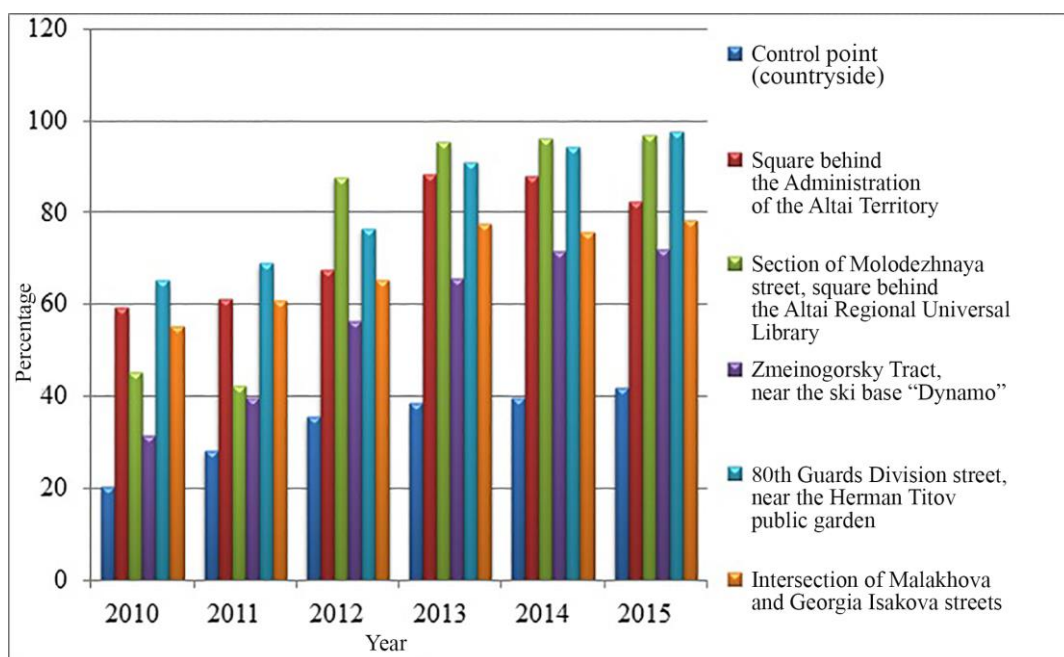


Fig. 2. Change in the percentage of sterile pollen grains in the collected samples for the period 2010–2015.

According to the report on the state and protection of the environment of Barnaul in 2013, substances that determine the high level of atmospheric air pollution in Barnaul over the last years are suspended substances (dust), nitrogen dioxide, soot, formaldehyde and benzo(a)pyrene. The main pollutant of atmospheric air in Barnaul is suspended matter. Its concentration increases sharply in the spring, after snow melting (in winter, suspended substances are retained by snow).

In May, after germination of grass and the formation of crowns, the concentration of suspended particles decreases. The pollution of the atmospheric air consists of the receipt of harmful substances from stationary and mobile sources. Their total contribution to air pollution in 2014 was 89.54 thousand tons.

The share of stationary sources of pollution from the total number of emissions is 49.52%, mobile sources – 50.48% (according to the Report on the State and Protection of the Environment of Barnaul in 2014). The main sources of pollution of the city's atmospheric air from stationary sources are enterprises of heat power engineering, machine building, petrochemical, and food industries. Mobile sources are mostly the motor vehicles.

Analysis of the dynamics of emissions from stationary sources and the amount of fertile pollen does not record their apparent relationship (Fig. 3).

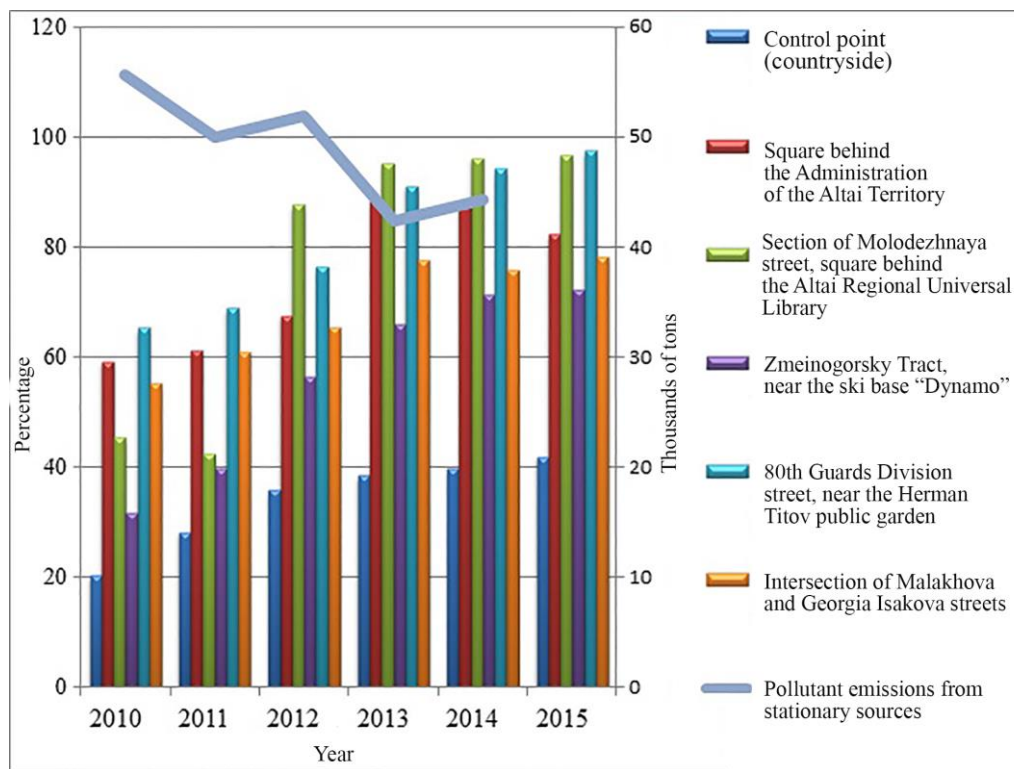


Fig. 3. Change in the percentage of sterile pollen grains in the collected samples for the period 2010–2015 and the change in the volume of pollutant emissions from stationary sources

However, one can speak of a pronounced share of the negative impact of emissions of mobile sources of atmospheric air pollution (vehicles) on the morphological, biological and physical characteristics of *Pinus sylvestris* (Fig. 4). The increasing number of vehicles every year and, accordingly, the share of their emissions has a progressive influence on the growth of sterile pollen grains and grains with poor morphological characteristics. More negative impact is evident in the territories located in close proximity to motorways and parking lots.

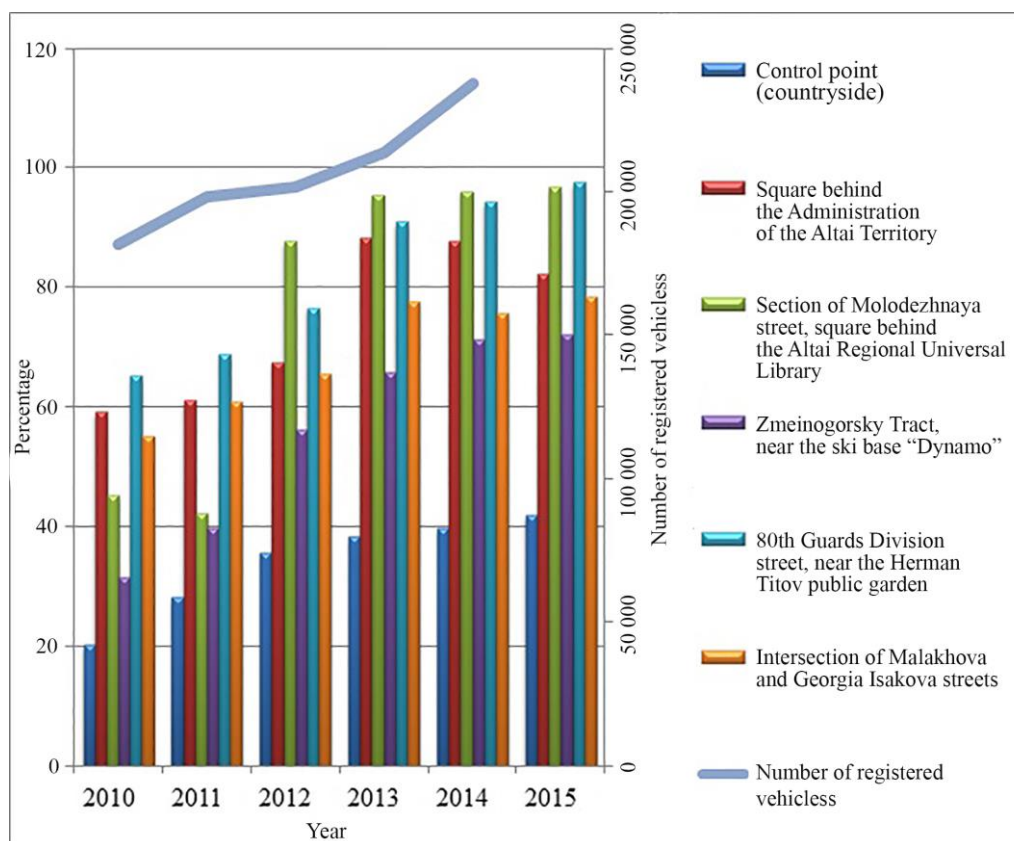


Fig. 4. Change in the percentage of sterile pollen grains in the collected samples for the period 2010–2015 and change in the number of registered vehicles

Conclusion

In general, it can be concluded that the pollen characteristics considered (indicators of teratomorphicity and sterility of grains) of *Pinus sylvestris* reflect the dynamics of pollution of the territory of the city of Barnaul by motor vehicle emissions. Thus, palynological analysis can be used for practical purposes as one of the methods of bioindication of the state of the environment (primarily atmospheric air), as the most accessible and effective method of research and monitoring.

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