

# Bioindication of environmental security in urban and rural territory according to *Betula pendula* Roth

Olesya Pishchimko<sup>1,2\*</sup>, Larisa Korobova<sup>1</sup>, and Vera Riksen<sup>3</sup>

<sup>1</sup>Federal State Budgetary Educational Institution of Higher Education Novosibirsk State Agrarian University, 160, Dobrolyubov str., Novosibirsk, 630039, Russia

<sup>2</sup>Federal State Budgetary Institution Siberian Regional Hydrometeorological Research Institute, 30, Sovetskaya str., Novosibirsk, 630099, Russia

<sup>3</sup>Siberian Federal Research Center of Agrobiotechnologies of the Russian Academy of Science, Krasnoobsk, Novosibirsk region, 630501, Russia

**Abstract.** In the modern era of urbanization, air pollution is becoming a significant cause of changes in the health of the population. The contribution of the complex of atmospheric pollutants to the state of the urban environment can be assessed by the bioindication method. In the article, this is done using the fluctuating asymmetry of the leaf blades of the silver birch on the example of the one and a half million city of Novosibirsk and a rural settlement located 50 km away. Novosibirsk is an industrial center and has a high transport and logistics significance. Bioindication data testify to the critical state of its environment in places of high transport load and industrial congestion and to a significant deviation from the norm when moving away from the park zone. This requires the development of additional measures aimed at minimizing the impact of environmental risks on the population.

## 1 Introduction

The urban environment is a combination of anthropogenic objects and components of the natural environment. The most important part of environmental protection activities in the urban environment is the environmental monitoring system, within which planned and systematic monitoring of the state of the environment, including the level of the most dangerous pollutants, is carried out. In Novosibirsk, observations are carried out at 10 stationary posts of the hydrometeorological service. This allows one to characterize the content of individual pollutants in the air of each of the 10 intra-city territorial districts, but does not make it possible to comprehensively assess the impact of pollutants on a particular biocenosis, especially if the effect of impurities is synergistic and enhanced by a combination of several pollutants. Therefore, it is advisable to supplement environmental monitoring data with bioindication characterizing the state of organisms. The assessment is

---

\* Corresponding author: [pishchimko@sibnigmi.ru](mailto:pishchimko@sibnigmi.ru)

carried out according to the taxonomic composition of cenoses, the presence of indicator organisms, disturbances in the functioning of the community, or deviations in the normal development of individuals [1-2].

Everyone in the city suffers from polluted air, but especially plants that have a very high intensity of gas exchange, many times higher than human gas exchange. For this reason, plants are most suitable for detecting the initial change in air composition [3-4].

Among trees and shrubs, silver birch (*Betula pendula* Roth) is often used as an indicator of the urban environment. It is attractive in ecological studies due to its wide distribution in the urban environment and responsiveness to anthropogenic impacts [5-9].

The purpose of this work is to assess the ecological state of the center and outskirts of the city of Novosibirsk in comparison with a nearby rural settlement using the method of fluctuating asymmetry (FA) of *B. pendula* leaves.

## 2 Materials and methods

To assess the FA indicator, we used a leaf of silver birch, which normally has bilateral symmetry. The study is based on the methodology for assessing the quality of the environment, developed under the guidance of V. M. Zakharov [10]. Since FA is highly sensitive to impurities in the air and well reflects the state of woody plant populations [11-13], the method for its determination was approved as a normative by the Order of Rosecology dated October 16.10.2003 No. 460-r.

The material was collected in August 2021 and 2022 near the stationary posts of the Environmental Monitoring Service in 3 administrative districts of Novosibirsk. Also, one sample was collected as a conditional control in the Moshkovsky district of the Novosibirsk region.

The impact on vegetation at these posts corresponds to the characteristic:

- Zone of transport pollution (formed by transport highways with heavy traffic: Krasny Prospekt St., Frunze St., Sovetskaya St., Dimitrova Ave., Vokzalnaya Mainline St., as well as the Main Station railway station). This is the city center.
- Zone of transport and industrial pollution (formed by the transport highway - Dusi Kovalchuk St., a local railway line; the terminal of the group of transport companies "ZhelDorExpedition", a meat processing plant, an instrument-making plant, a plant of semiconductor devices "Vostok" and earlier an oil plant). Located at a distance from the city center 4.3 km.
- Zone of the outskirts of the city with a weakened traffic flow - st. Lavrentiev, the border of the park. The distance from the center of Novosibirsk is 25 km.
- Forest belt near the village of Moshkovo in the Moshkovsky district - conditional control. The regional center Moshkovo is located in the north-east of the Novosibirsk region, 53 km from the regional center.

Leaves were collected from shortened shoots of the lower part of the crown. They were about the same size, solid, with a wedge-shaped base. The collection of leaves for one repetition was carried out from 5 birch trees of the same age (focusing on the diameter of the trunk) at 8 points near the post (total 8 repetitions). The number of leaves in the total sample for morphometric analysis at the sampling point is at least 100 pieces.

The ImageMeter Android software application was used to calculate the morphometric parameters of the collected material. The calculation of the integral indicator of fluctuating asymmetry was carried out on the basis of Microsoft Office Excel. Mathematical data processing (single-factor analysis of variance) was performed using the Snedekor program.

To assess the degree of detected deviations from the norm, a five-point rating scale was used, which characterizes the level of pollution of the territory by the values of the FA

indicator [9,10]. Scale points: 1 - conditional norm with FA less than 0.04; 2 - minor (initial) deviations from the norm (FA=0.04–0.044); 3 - the average level of deviations (FA = 0.045–0.049); 4 - significant deviations (FA = 0.05–0.054); 5 - critical condition (FA over 0.055).

### 3 Results

It has been established that the natural asymmetry of drooping birch leaves (the larger right side of the leaf) tends to increase in the urban environment. The trend of such changes in the leaves of birch growing in the surveyed part of Novosibirsk was clearly manifested in measurements of the distance between the bases of the first and second veins of the second order (measurement No. 3 out of five recommended ones) and the distance between the ends of these veins (measurement No. 4). Integral FA data for silver birch in the territories of Novosibirsk and a rural settlement, obtained on the basis of the recommended 5 measurements, are presented in table 1. A sample of birch plants with favorable growing conditions (1 point) was not found in the analyzed areas. In the rural settlement of Moshkovo (conditional control), the values of the FA indicator in 2021 corresponded to environmental conditions with a slight initial deviation from the norm (2 points), in 2022, an average deviation from the norm (3 points). In the urban environment of Novosibirsk, they were 1.7-2.6 times higher.

In terms of spatial dynamics, the indicator of fluctuating asymmetry in the surveyed areas of the city was non-uniform. In the zone of transport and industrial pollution, on Dusi Kovalchuk Street (Zaeltsovsky district of the city), the FA values in both years of research turned out to be maximum. On st. Sovetskaya (Central district of the city) - the zone of transport pollution - FA values were lower by 13-20%. But both here and there the state of the urban environment corresponded to critical and scored 5 points. And only in the territory of the Sovetsky district remote from the center, in the zone of the beginning of the park on Lavrentiev Avenue in 2021, the fluctuating asymmetry of birch leaves turned out to correspond to environmental conditions not with critical, but with significant deviation from the norm. The quality of the environment here was assessed with 4 points. In 2022, the situation with air pollution in the Sovetsky district worsened and the FA value reached 5 points, which corresponded to the critical state of the urban environment.

**Table 1.** Bioindication of the urban environment in terms of fluctuating leaf asymmetry of *B. pendula* in the territory of Novosibirsk and its suburb (2021-2022).

Researched indicators	Settlement Moshkovo (53 km from Novosibirsk) – conditional control	Sampling site		
		Novosibirsk city		
		Sovetskaya str. (center)	Dusi Kovalchuk str. (4.3 km from center)	Lavrentiev av- enue (25 km from center)
2021				
The value of the FA indicator	0.031 <sup>a</sup>	0.063 <sup>a</sup>	0.079 <sup>a</sup>	0.054 <sup>a</sup>
Points corresponding to FA	2	5	5	4
Quality of the environment (deviation from the norm)	minor initial deviations from the norm	critical condition	critical condition	significant deviation from the norm
2022				
The value of the FA indicator	0.049 <sup>a</sup>	0.062 <sup>a</sup>	0.071 <sup>a</sup>	0.061 <sup>a</sup>
Points corresponding to FA	3	5	5	5
Quality of the environment (deviation from the norm)	mean deviation from the norm	critical condition	critical condition	critical condition

<sup>a</sup>Note. Deviation from conditional control from  $P_{0.05}$ .

## 4 Discussion

The growing environmental problems of the urban environment of the one and a half million city of Novosibirsk are associated with the growth of urban development and with an increase in population density in areas that are attractive for living and close to the center. This regularly adds to the number of vehicles on central highways. Today, according to statistics, there are about 500,000 cars in the personal use of citizens alone. In total, more than 950 thousand vehicles are registered in the city.

The transport frame of the surveyed part of the city was formed in the 70s of the 20th century and did not provide for such a traffic load. Now this is extremely exacerbating the situation with traffic jams and leads to a significant increase in traffic pollution. The transport component of the city has a priority share of emissions polluting the atmosphere. This source regularly occupies the 1st place in terms of its contribution to the city's air pollution over the past 10 years.

In addition to it, the state of atmospheric air in Novosibirsk is affected by enterprises of the thermal power complex (2nd place), industrial enterprises, municipal boiler houses and emissions from the private sector [4]. All this undoubtedly affects the vegetation of city streets and squares. In the central districts of the city, the dominant species of the tree and shrub layer is silver birch; therefore, deviations in the morphology of the leaves of *B. pendula* can clearly characterize the total atmospheric pollution in the city.

According to the indicator of fluctuating asymmetry of leaves of *B. pendula*, the ecological state of the environment in Novosibirsk decreases when approaching transport load zones (which is still typical for the city center) and, especially, transport and industrial load zones. In both cases, it is rated as critical. And even on the outskirts of the city, near parks, the state of the habitat, according to bioindication, has signs of a significant deviation from the norm, reaching critical deviations in some years. In a rural settlement, the air condition is changing significantly for the better.

Air pollution is considered one of the first causes of diseases and mortality in the urban population [14], therefore, the current situation in Novosibirsk, identified by the interaction of the urban environment and the bioindication object *B. pendula*, requires closer attention to human health. Novosibirsk requires the development of additional preventive measures aimed at minimizing the impact of environmental risks on the population.

## 5 Conclusion

- The quality of the urban environment in the city of Novosibirsk, a large transport, logistics and industrial center with a population of 1.5 million, is assessed by the fluctuating asymmetry of the *B. pendula* leaf blade with the highest unfavorable points (4 and 5).
- In areas of transport and transport-industrial load, where the mean FA coefficient is in the range of 0.063-0.079, the quality of the environment is critical. On the outskirts of the city, near parks, the state of the environment, according to the values of FA= 0.054 - 0.061, significantly deviates from the norm or passes to a critical state of environmental quality. In contrast, in a small district center in a rural environment, there are only minor initial deviations from the norm, which in some years can increase to a mean deviation.
- The most informative in the bioindication of the urban environment of Novosibirsk are such elements of the asymmetry of silver birch leaves as "the distance between the bases of the first and second veins of the second order" and "the distance between the ends of these veins".

## References

1. Dunaev A, Rummyantsev I, Agapova I, Vergek K and Gundorina S 2018 Physical and chemical and biological monitoring in central Russia: Investigation of quality of atmospheric air and soil in territory of Rodniki town. *J. ChemChemTech* **61(8)** 96-104
2. Sidorenko M, Yunina V, Erofeeva E, Savinov A, Kuznetsov M and Novozhilov D 2020 Ecological state assessment of recreational areas in Nizhny Novgorod on heavy metal soil pollution and bioindication indicators of *Betula pendula* Roth leaves. *J. Samara J. of Sci.* **9(1)** 88-92
3. Opekunova M and Basharin R 2014 Application of fluctuating asymmetry of birch leaves (*Betula pubescens* Ehrh.) to assess the environmental pollution in the Kostomuksha area. *J. vest. of St. Petersburg. Univ. geol. and geogr. ser.* **3** 58-70
4. Plyatsuk D 2015 Integrated express-evaluation of air quality under changing industrial infrastructure of the region. *J. East.-Europ. J. of Enterp. Tech.* **3(6)** 58-63
5. Erofeeva E, Sukhov V and Naumova M 2011 Biphasic dependence of some ecomorphological and biochemical parameters of the birch leaf plate on the level of motor traffic pollution. *J. Biol. Bull.* **38(10)** 962-66
6. Erofeeva E 2015 Hormesis and paradoxical effects of drooping birch (*Betula pendula* roth) parameters under motor traffic pollution. *J. Dose-Resp.* **13(2)** 1559325815588508
7. Krupnova T, Mashkova I and Kostryukova A 2017 Using birch leaves to indicate air pollution. *J. Intern. J. of GEOMATE* **13(40)** 54-59
8. Shadrina, E, Turmukhametova N, Soldatova V, Vol'pert Y, Korotchenko I and Pervyshina G 2020 Fluctuating asymmetry in morphological characteristics of *betula pendula* roth leaf under conditions of urban ecosystems: Evaluation of the multi-factor negative impact. *J. Symmetry* **12(8)** 1317
9. Turmukhametova N and Shadrina E 2020 Changes in the fluctuating asymmetry of the leaf and reproductive capacity of *betula pendula* roth reflect pessimization of anthropogenically transformed environment. *J. Symmetry* **12(12)** 1970
10. Zakharov V, Shadrina E, Turmukhametova N, Ivantsova E, Shikalova E, Soldatova V, Sharova N and Trofimov I 2020 Assessment of Plant Status by the Stability of Development in Natural and Anthropogenic Conditions (Fluctuating Asymmetry of Leaf Features of the Silver Birch, *Betula pendula* Roth). *J. Biol. Bull.* **47(2)** 186-90
11. R Valeeva G 2019 Environmental bioindication using some morphometric and physiological parameters of plants. *J. Amer. J. of Biomed. Sci. & Res.* **4(1)** 15-16
12. Sandner T, Zverev V and Kozlov M 2019 Can the use of landmarks improve the suitability of fluctuating asymmetry in plant leaves as an indicator of stress? *J. Ecol. Indic.* **97** 457-65
13. Ulivanova G, Fedosova O and Antoshina O 2020 Complex evaluation of the modern atmospheric air of city ecosystems. *J. BIO Web of Confer.* **17** 00088
14. Lelieveld J, Evans J, Fnais M, Giannadaki D and Pozzer A 2015 The contribution of outdoor air pollution sources to premature mortality on a global scale. *J. Nature* **525** 367-71