Environmental Safety of Arctic Cities and New Methods of Research

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Keywords: Sustainable Development, Environmental Safety, Arctic Cities.

Abstract: The article presents the results of studying the impact of industrial emissions of enterprises of the city of Murmansk on the fertility of pollen of Sorbus gorodkovii Pojark (Gorodkov's rowan). In the vicinity of the local heating plants operating on fuel oil, a low level of pollen fertility and high sterility is revealed. In the course of the research, the size groups of pollen are identified. It is shown that emissions from Murmansk thermal power plants are toxic, have a gametocidal effect, resulting in the formation of a large amount of sterile nano-pollen. The rejection of the use of fuel oil and the transition of thermal power plants to the use of natural gas is a promising direction for the sustainable development of the city of Murmansk.

1 INTRODUCTION

Ensuring the environmental safety is one of the prerequisites for sustainable development of the Arctic territories. The main features of the Arctic zone of the Russian Federation are: extreme natural and climatic conditions, vulnerability of ecosystems, cluster nature of the development of territories, low population density, high resource intensity, dependence on other regions of Russia (Yakovlev, 2014). Murmansk is one of the largest cities in the Russian Arctic with developed infrastructure and industrial facilities. The main pollutants of the area are toxic heavy metals, oil, polycyclic aromatic hydrocarbons and volatile substances (SO2 and NO2) (Guzeva, Slukovskii, Myazin, 2020). The main sources of pollution are emissions from thermal power plants and dust pollution of the city by the Murmansk Commercial Sea Port, which is result of loading and unloading of coal, apatite concentrate and other raw materials. The soils of Murmansk are heavily contaminated by heavy metals (Cu, Zn, Ni, V) (Vasilevskaya, Struzko, 2020), similar data are obtained in research of bottom sediments of small lakes in the city (Guzeva, Slukovskii, Myazin, 2020; Slukovskii, Guzeva, Dauvalter, 2020).

In recent years the new methods of palynoindication of the environment have been used to assess environmental quality (Dzyuba, 2006). In the Murmansk region, such studies were carried out on woody species of plants in the cities of Murmansk, Severomorsk, Monchegorsk, Zapolyarny, Apatity (Vasilevskaya, Domakhina, 2018; Vasilevskaya, Sikalyuk, 2021; Vasilevskaya, Osechinskaya, 2021). Unlike laboratory test objects, plants of natural habitats respond to the entire spectrum of chemical, physical and climatic factors, which are typical of the ecosystem under consideration (Avere, 2004). Reproductive organs of plants can be used in environmental studies as biomonitors showing the gametocidal effect of various pollutants (Ibragimova, 2006). Impact of pollutants leads to the formation of sterile pollen, disruption of its size and shape. The suitability of pollen for detecting of the phytotoxic and mutagenic effects of pollutants is due to its sensitivity to exposure to pollutants and it is just in the haploid state that lethal mutations appear (Bessonova, Fendyur, Peresypkina, 1997).

The aim of the study is to assess the quality of the environment of the city of Murmansk using pollen of Sorbus gorodkovii.

2 MATERIALS AND METHODS

Gorodkov's rowan (Sorbus gorodkovii Pojark) is used as an object of research, it is a European hypoarctomontane species, one of the few

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Vasilevskaya, N. and Sikalyuk, A.
Environmental Safety of Arctic Cities and New Methods of Research.
DOI: 10.5220/0010663900003223
In *Proceedings of the 1st International Scientific Forum on Sustainable Development of Socio-economic Systems (WFSDS 2021)*, pages 64-67
ISBN: 978-989-758-597-5

representatives of the genus Sorbus L., which grows in the polar latitudes. An endemic of Eastern Fennoscandia, widely spread in green plantings of urbanized territories of the Murmansk region. In natural conditions, it is found in the tundra and forest zones, mountain-forest and mountain-tundra of Fennoscandia. Winter-hardy and fast-growing species, ubiquitous in urban green plantings of the Murmansk region as the most resistant to the Arctic climate.

At the end of May 2020, in the city of Murmansk, in the zone of impact of environmentally hazardous facilities, five experimental sites were laid: P1 – Molodezhnaya Str., 170 m from the «Roslyakovo Yuzhnoye» boiler house; P2 – Domostroitelnaya Str., 482 m from the plant for thermal treatment of municipal solid waste; P3 – Portovy proezd Str., 950 m from the industrial site of the Murmansk Commercial Sea Port; P4 – Tralovaya Str., 353 m from the Central Heating Plant; P5 – Baumana Str., 930 m from the South Heating Plant. The control site is located in the Verkhnetulomsky settlement, at a 70 km distance from the city of Murmansk.

At the end of June 2020, during the period of massive bloom of rowan, ten inflorescences were collected from each of the 10 marked trees on each of the experimental sites, from which five flowers were randomly selected (N = 500). The samples were fixed in 40° ethyl alcohol. The studies were carried out by the acetocarmine method. Fertile pollen contains starch and turns crimson, as opposed to sterile pollen, which remains colorless. Cytological analysis was performed on temporary preparations using light microscopy (magnification 400 times). In each field of view of the microscope, number of fertile and sterile pollen was counted (N=500). An eyepiece micrometer was used to measure the size of the polar axis of pollen grains. Three size groups of pollen have been identified: dwarf, normal (medium), and hypertrophied. According to the generally accepted classification (Erdtman, 1952), dwarf pollen grains include grains with a polar axis length of up to 25 µm. Pollen grains with a polar diameter of 25–27.5 µm are attributed to normal (medium) sizes, and more than 27.5 µm to hypertrophied ones.

3 RESULTS AND DISCUSSION

The studies have shown that the ratio of fertile pollen of S. gorodkovii in the control sample (settlement Verkhnetulomsky) is 72%. In the city of Murmansk, in the vicinity of the environmentally hazardous industrial facilities, the content of such pollen is much lower and varies from 35 to 52%. The minimum content of fertile pollen grains was found in the samples from the vicinity of the South and Central Heating Plants, and the «Roslyakovo Yuzhnoye» boiler house (figure 1).

In the control sample the proportion of sterile pollen of S. gorodkovii is 28%. This hypoarctic species is characteristic of a fairly high spontaneous sterility of the male gametophyte under natural conditions, which is primarily determined by its origin (Yandovka, 2010). Indicators of induced sterility of rowan pollen are increasing in the vicinity of industrial facilities of the city of Murmansk. The highest content of abortive pollen of S. gorodkovii is found in the vicinity of the South Heating Plant and the Central Heating Plant, operating on fuel oil, as well as the «Roslyakovo Yuzhnoye» coal-fired boiler house (figure 1). This sterility of pollen grains is induced by technogenic pollution of the environment and indicates the toxicity of emissions from the Murmansk city boiler houses.

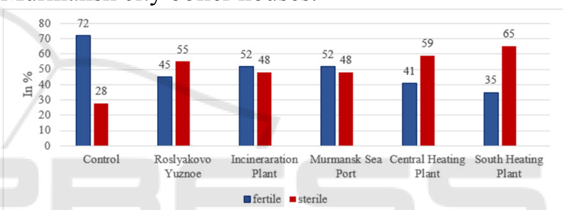

Figure 1: The ratio of fertile and sterile pollen of Sorbus gorodkovii in the vicinity of industrial facilities of the city of Murmansk (in %).

Cytological studies have shown that pollen of S. gorodkovii is three-lobed from the pole and elliptical at the equator. As a result of measuring the polar diameter of pollen grains, it is found that fertile and sterile pollen of S. gorodkovii under industrial pollution significantly vary in size. Three size groups of pollen have been identified: dwarf, medium (normal), and hypertrophied. The average size of the polar axis of medium fertile pollen in the control is 25.8 µm. In the samples from the test sites of the city of Murmansk, it varies from 25.7 to 25.9 µm (table 1). The highest content of medium-sized S. gorodkovii pollen is found in the control samples, from the vicinity of the incineration plant and the Murmansk Commercial Sea Port (figure 2). The proportion of such pollen decreases markedly in the vicinity of the Murmansk boiler houses (61.8–69%).

Table 1: Length of the polar diameter of the fertile pollen of Sorbus gorodkovii in the zone of industrial impact of the city of Murmansk (in µm).

Experimental sites pollen	Dwarf pollen M ± m	Medium pollen M ± m	Hypertrophied M ± m
P1	21.9 ± 1.3	25.7 ± 1.1	30.3 ± 2.0
P2	22.5 ± 1.1	25.9 ± 1.2	31.1 ± 2.5
P3	22.5 ± 0.9	25.9 ± 1.2	30.7 ± 1.7
P4	22.2 ± 0.8	25.8 ± 1.2	30.6 ± 1.5
P5	22.1 ± 1.9	25.7 ± 1.1	30.6 ± 1.7
Control	22.3 ± 0.8	25.8 ± 1.2	30.5 ± 1.3

In the tested samples, a lot of dwarf and hypertrophied pollen are revealed. The length of the polar axis of dwarf fertile pollen in control is 22.3 µm, in Murmansk 21.9 – 22.5 µm (table 1). An increased content of nano-pollen of S. gorodkovii is found in the vicinity of the Murmansk boiler houses (12.9 – 17.9%), while in the settlement Verkhnetulomsky – 5.5% (figure 2). Many authors point to the formation of small pollen grains due to dry air under industrial pollution (Dzyuba, 2006). At the same time, V. N. Bessonova (Bessonova, 1992) showed that the appearance of dwarf pollen is associated with disturbances in meiosis in which part of the genetic material is lost, as a result of fission spindle damage or chromosomal mutations.

The size of the polar axis of the hypertrophied fertile pollen in the city of Murmansk is 30.3 – 31.1 µm, in control – 30.5 µm (table 1), its share significantly increasing in the vicinity of the Murmansk heating plants (17.4 – 22.7%), being 6% in the control (figure 2). This is a presumably diploid pollen, 1.2 times the normal diameter. The appearance of hypertrophied pollen is associated with disturbances in meiosis, as a result of the exposure to mutagens of various nature. Their appearance can be caused by a violation of the divergence of microspore tetrads during microsporogenesis (Emirova, Ibragimova, 2010).

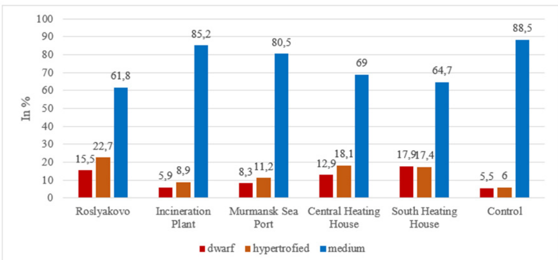

Figure 2: Ratio of normal, dwarf and hypertrophied fertile pollen grains of Sorbus gorodkovii in the city of Murmansk (in %).

As a result of the study of the size of the sterile pollen of S. gorodkovii, all samples showed a significant increase of the proportion of dwarf pollen. Its content is very high in all samples from the vicinity of industrial enterprises of the city of Murmansk (59 –70%) and in the control (53%) (figure 3). Moreover, dwarf sterile pollen is significantly smaller (19.7 – 20.8 µm) than fertile one (21.9 – 22.8 µm) (table 1,2). The maximum amount of abortive nano-pollen is found in the vicinity of the Murmansk boiler houses (figure 3).

Table 2: Length of the polar diameter of Sorbus gorodkovii sterile pollen in the industrial impact zone of the city of Murmansk (in µm).

Experimental sites	Dwarf pollen M ± m	Medium pollen M ± m
P1	19.7 ± 2.5	25.2 ± 0.9
P2	20.8 ± 1.9	25.5 ± 1.1
P3	20.3 ± 2.1	25.6 ± 1.1
P4	20.1 ± 2.3	25.3 ± 0.8
P5	20.4 ± 2.2	25.2 ± 0.7
Control	20.5 ± 2.1	25.3 ± 0.8

The length of the polar axis of medium-sized sterile pollen grains in Murmansk is 25.2 – 25.5 µm, in the Verkhnetulomsky settlement – 25.3 µm (table 2). A significant decrease of its share is noted in the zone of industrial impact of all enterprises of the city of Murmansk, especially in the vicinity of the South and Central Heating Plants (29 – 33.4%) (figure 3). The average size of the polar axis of hypertrophied sterile pollen grains in the samples from the experimental sites varies from 30 to 35 µm (in control–30 µm), it is found in all samples quite occasionally (0.6–1.2%). A sterile microgametophyte is characterized by deformation and degeneration of nuclei, cytoplasm, or a cell as a whole. The formation of such pollen in plants is associated with disturbances in meiosis and microsporogenesis (Yandovka, 2010). The highest values of abortive pollen are associated with the highest frequencies of meiotic disorders (Saylor, Smith, 1966).

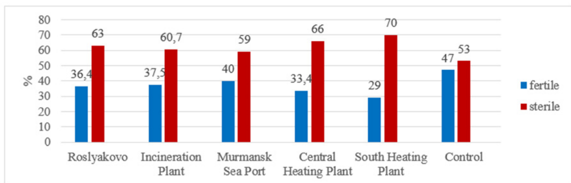

Figure 3: Ratio of size groups of sterile Sorbus gorodkovii pollen in the vicinity of industrial enterprises in Murmansk (in %).

Usually, the size of pollen grains is a stable feature of species of plants (more often – of genera) and is characterized by very low individual, intrapopulation, and intraspecific geographic variability (Kozubov, 1974). A change in the size of pollen is associated with a disturbance in the process of growth and division of cells during the formation of primary cells of archesporium and tetrads of microspores, which leads to genetic variability of pollen (Bessonova, 1992). Under conditions of environmental pollution, pollen grains of plants vary in size more than that of plants in the clean environment.

4 CONCLUSION

The Murmansk region is one of the last regions of the North-West of the Russian Federation where fuel oil is used for heating in boiler houses. In Petrozavodsk, Arkhangelsk and Vologda, heating plants have been re-equipped and use natural gas. Studies have shown that emissions from Murmansk thermal power plants are toxic, have a gametocidal effect, resulting in the formation of a large amount of sterile nano-pollen of native tree species.

It is known that thermal stations operating on fuel oil or coal are the most dangerous for living organisms, including humans (Mejia, Rodriguez, Armienta, 2007). The South and Central Heating Plants in the city of Murmansk belong to the 2nd class of environmental hazard, the coal-fired boiler house - to the 3rd. The emissions from the Murmansk thermal power plants contains pollutants with a high degree of mutagenicity and related to hazard classes I and II (benz (a) pyrene, manganese and its compounds (in terms of manganese (IV) oxide), dihydrosulfide (hydrogen sulfide) and others). Emissions from any fuel oil-fired heating plants have elevated levels of Fe, V, Ni, Cr and other elements (Teng, Ni, Zhang, Wang, Lin, 2006). The fly ash generated during the combustion of fuel oil from heating plants contains 3 – 4% of nickel (Ni) and 6 – 12% of vanadium (V) (Slukovskii, Guzeva, Dauvalter, 2020). Vanadium and nickel are impurities in fuel oil, which is currently used at the Murmansk Heating Plants (Guzeva, Slukovskii, Myazin, 2020). Vanadium (V) oxide is a toxic and hazardous substance for the environment, has mutagenic properties. The rejection of the use of fuel oil and the transition of thermal power plants to the use of natural gas is a promising direction for the sustainable development of the city of Murmansk.

REFERENCES

Yakovlev, S. Yu., 2014. *Herald of the Kola Science Center RAS*, 3: 84.

Guzeva, A. V., Slukovskii, Z. I., Myazin, V. A., 2020. *Limnology and Freshwater Biology*, 4: 511

Vasilevskaya N. V., Struzko,V., 2020. *IOP Conf. Series: Earth and Environmental Science*, 421: 52031

Slukovskii, Z. I., Guzeva, A.V., Dauvalter, V. A., 2020. *Limnology and Freshwater Biology*, 4: 513

Dzyuba, O. F. 2006. *Palynoindication of Environmental Quality*, p. 197, St. Petersburg: Nedra.

Vasilevskaya, N. V., Domakhina, A. D., 2018. *Czech Polar Reports*, 8: 24.

Vasilevskaya, N. V., Sikalyuk, A. I., 2021. *IOP Conf. Series: Earth and Environmental Science*, 677: 052067.

Vasilevskaya, N. V., Osechinskaya, P. V., 2021. *IOP Conf. Series: Earth and Environmental Science*, 723: 032010.

Avere, D. 2004. Assessment of the State of the Urban Environment by Bioindication Methods (on the Example of St. Petersburg). Thesis, St. Petersburg, p 156.

Ibragimova, E. E. 2006. *Scientific Notes of V I Vernadsky Crimean Federal University Series Biology and Chemistry*, 19: 92.

Bessonova, V., Fendyur, L., and Peresypkina, T., 1997. Botanicheskii Zhurnal, 82: 38.

Erdtman, G., 1952. *Pollen Morphology and Taxonomy. Angiosperms.* Stockholm, 539 p.

Yandovka, L. 2010. *Agrarian Bulletin of the Urals*, 6: 58.

Bessonova, V. N., 1992. Russian Journal of Ecology, 4: 45.

Emirova, D. E., Ibragimova, E. E., 2010. *Scientific Notes of V I Vernadsky Crimean Federal University Series Biology and Chemistry*, 23: 186.

Saylor, L. C., Smith, B. W., 1966. *American Journal of Botany*, 53: 453.

Kozubov, G. M., 1974. *Biology of Fruiting of Conifers in the North*, p. 138, Leningrad: Nauka.

Mejia, J. A., Rodriguez, R., Armienta, A., 2007. *Water, Air, and Soil Pollution*, 185: 95.

Teng, Y., Ni S., Zhang, C., Wang, J., Lin, X., 2006. *Chinese Journal of Geochemistry*, 25: 379.