RESEARCH PAPER

AEROPALYNOLOGICAL PROFILE OF CHEREPOVETS AND VOLOGDA, THE CITIES OF VOLOGDA REGION, NW RUSSIA

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ABSTRACT. The article presents data on the composition and seasonal dynamics of airborne pollen in Cherepovets and Vologda. The study was carried out from April 10 to September 30, 2014 and from April 16 to August 31, 2015 in Cherepovets, and from June 3 to September 30, 2019 in Vologda. Pollen data were obtained from the Durham gravimetric samplers. Samples were collected daily. Twenty-one types of pollen have been identified, ten of which are the most common allergenic types (*Alnus, Artemisia, Betula, Fraxinus, Salix, Plantago,* Poaceae, *Quercus, Rumex, Urtica*), which account for more than 50% of all pollen that has been registered. The article contains pollen calendars showing two peaks of pollen grain quantity: spring (from last decade of April to May), summer (from the end of June to the middle of July). *Betula* (30%) and Asteraceae (28%) pollen dominate in the pollen spectrum. *Pinus* (20%), *Plantago* (6%) and Poaceae (5%) also play an important role in the regional spectrum. The results show the presence of allergenic pollen from different taxa throughout the study. The proportion of damaged pollen grains is approximately 2%, which corresponds to the norm in natural population in normal condition. This data can become the basis for developing recommendations for reducing the level of pollinosis in the Vologda Region.

KEYWORDS: aerobiology, airborne pollen types, allergenic taxa, Vologda Region

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INTRODUCTION

More than half of the world's population lives in urban ecosystems. These ecosystems differ from natural ones and are often characterized by rapid changes in parameters caused by both intentional and unintentional actions of people as well as by the management of ecosystem components in the interest of creating a comfortable life (Gil and Brumm 2014). Maintaining high air quality is an immense problem as the atmosphere contains many particles of various origins. Among them, pollen grains and plant fragments play a significant role. Spores of various plants, fungi, bacteria, etc. are also important components of aerial plankton. Many of them, primarily pollen grains of plants, have long been known as an etiological factor of pollinosis — a classic allergic disease associated with human intolerance to plant pollen antigens that can significantly affect the quality of life (Malygina et al. 2010; Piotrowska-Weryszko and Weryszko-Chmielewska 2015; Posevina 2011).

In recent years, the necessity for aeropalynological research has been growing due to the widespread increase in the number of diseases caused by aeroallergens. Currently, "allergy" is one of the main public health problems in the Russian Federation. According to the results of the research conducted by the NRC Institute of Immunology FMBA of Russia, 17.5% to 30% of the population suffers from various forms of allergic diseases (Allergy. Statistics in Russia 2017; Federal Clinical Guidelines… 2015). A distinctive feature of allergic diseases caused by pollen is their seasonal nature. The severity of symptoms in patients with pollinosis is directly proportional to the concentration of allergens in the atmosphere (Kruczek et al. 2015).

The pollen of many plants is a strong allergen in itself, but in many large cities its effect can be enhanced by the influence of polluting gases (nitrogen oxide, sulfur oxide, ozone, and others) and solid particles. Pollen grains can deform and their allergenic properties may increase (Wang et al. 2009; Namork et al. 2006; Guedes et al. 2009; Bryce at al. 2010; Sénéchal et al. 2015). Seasonal airborne pollen content maxima often coincide with an increased presence of non-biological particles in the atmosphere (Barck et al. 2002, 2005; Dziuba 2006; Hajkova et al. 2015; Nenasheva 2013; Puc et al. 2015).

In a study conducted in Poland, Puc and co-authors (2015) established a correlation between weather and air pollutants (for example, nitrogen oxides), giving a new understanding of the mechanisms of respiratory allergic diseases. Air pollution increases symptoms in people with pollen allergies. Evidently, in this case there is a manifestation of the law of cumulative action of the factors of the Mitscherlich-Baule equation. Therefore, Puc and co-authors (2015) suggests simultaneous monitoring of the amount of pollen and air pollutants.

In general, the amount of pollen in the atmosphere, the dynamics, and the duration of pollen seasons are determined by many factors; therefore, long-term observations are required to obtain the information necessary for management, and data analysis should include various aspects. Long-term observations are also important for detecting phenological shifts in pollen seasons due to global climatic changes (Haselhorst et al. 2017; Van Vliet et al. 2002; Zhang et al. 2022).

In terms of the prevention and treatment of allergic diseases, pollen calendars prepared in a certain region are a valuable source of information for predicting the concentration and dynamics of pollen rain. Since effective advice for the prevention and treatment of pollinosis can only be based on local data, such calendars are particularly significant for a given area due to the variability of vegetation cover and weather conditions of the regions.

Currently, the monitoring of the aeropalynological situation is carried out on the territory of all continents. The key monitoring points with the highest concentration of volumetric traps include the majority of European countries, the United States of America, several South American countries, the southeastern territory of Australia, and the Japanese Islands (Worldwide Map of Pollen Monitoring Stations 2022). On the territory of Russia, similar observations are conducted in Moscow, Ryazan, Stavropol, Tyumen, St. Petersburg, Krasnodar, Yekaterinburg, and some other cities (ZAUM… 2022).

The purpose of the study was to obtain an aeropalynological calendar for the major cities of the Vologda Oblast — Cherepovets and Vologda — for the purpose of developing recommendations for reducing the level of pollinosis in the region.

MATERIALS AND METHODS

Study area

The research was carried out in the Vologda Region of the North-Western Federal District of European Russia (Fig. 1). The region is located in the boreal climate zone of the Eastern European taiga. Spruce and pine forests dominate the vegetation cover; in the southern part of the region, the share of broad-leaved trees is noticeable. The main tree species are spruce (41%), pine (24%), birch (28%), and aspen (6%) (Antipov et al. 1957; Vorobyov 2007). There are also larch, elm, alder, and arborescent willows. The duration of the growing season is 150 days (Report on the State… 2019; Skupinova 2007).

Vologda (59°13′26″ N, 39°53′02″ E, 120-130 m a.m.s.l.) is the administrative, transportation, industrial, and cultural center of the Vologda Region. Cherepovets (59°07′59″ N, 37°53′59″ E, 130-140 m a.m.s.l.) is the transportation, scientific, and industrial center of the region, in which the enterprises of ferrous metallurgy and chemical industry are the largest. The area of Cherepovets is 122 km² (Official website of the city of Cherepovets. Architecture 2022), the population is 309445 (Official website of the city of Cherepovets. Population of Cherepovets 2022). As of 2012, there were 500 hectares of green space in the city's residential area (Shvetsov 2012). The area of Vologda is 116 km², the population is 320566 (Official website of the Administration of the city of Vologda 2022). Green spaces cover an area of 413 hectares as of 2019 (Official website of the Administration of the city of Vologda. Decision of the Vologda City… 2022).

The level of atmospheric air pollution in Cherepovets during the study period was categorized as elevated, and in Vologda as low (Report on the State… 2016; Report on the State… 2019). The atmospheric pollution index is expressed in units (standard index — the average annual concentration of various pollutants divided by the maximum permissible concentration and reduced to the

Fig. 1. Study area (http://yandex.ru/maps/)

harmfulness of sulfur dioxide), which correspond to the level of atmospheric air contamination (Documents on the state… 2006).

The atmospheric pollution index was estimated at 9.9-3.9 units in 2014 and 4 units in 2015 in Cherepovets. In Vologda the atmospheric pollution index was estimated at 2.5 units in 2018. The index was determined by the concentrations of benzo[a]pyrene, formaldehyde, nitrogen dioxide, suspended solids, and ammonia. The volume of emissions of pollutants into the atmosphere from stationary sources in 2015 in Cherepovets reached 316.797 tones (Report on the State… 2016).

Meteorological data

The region is located in a zone of excessive humidification, where the annual amount of precipitation exceeds the evaporation rate. The average amount of precipitation is 588 mm per year, of which 171 mm falls during the cold period of the year (November-March), 417 mm falls during the warm period (April-October) (Vorobyov 2007). Western and southern winds at a speed of 3–5 m/s prevail (Report on the State… 2019; Skupinova 2007), characterized by a long cold, snowy winter, a short spring, a relatively short moderately warm humid summer, and a long and wet autumn (Skupinova 2007). The average temperature in January is -12.6 °C, the average temperature in July is 16.8 °C, the frost-free period is 116 days (Vorobyov 2007).

The aerobiological method

The study was conducted from April 10 to September 30, 2014 and from April 16 to August 31, 2015 in Cherepovets, and from June 3 to September 30, 2019 in Vologda.

To establish the taxonomic composition of pollen spectrum and its daily quantity, Durham gravimetric pollen samplers were used (Durham 1946), which were installed in the open roof space in the central districts of Cherepovets and Vologda at an altitude of about 15 m. Samples were collected daily. The collection of samples had started after the beginning of the growing season due to legal difficulties in accessing the roof.

The trapping surface in the pollen trap is a glass slide coated with a glycerin–gelatin mixture. The composition of the mixture and the method of preparation are based on standard methodological guidelines described in the work of N.R. Meyer-Melikyan and co-authors (1999). Determination and counting of pollen grains were carried out using a light microscope with a magnification of ×640 on the total area of the cover glass (3.24cm^2).

Fifteen pollen types dominating in pollen spectra and possessing strong allergenic properties were selected for the pollen calendar according to the list of the most important (allergenic or abundant) types (Meyer-Melikyan et al. 1999; Nilsson and Spieksma 1994). According to the recommendations (Nilsson and Spieksma 1994), the list was supplemented with other species whose pollen causes outbreaks of pollinosis in the study area. Taxa not found in the airborne spectrum of the locality were excluded. The current list for the region is presented in the Table 1.

Pollen calendars were created using 'AeRobiology' R package.

RESULTS

Results of aeropalynological monitoring of Cherepovets

As a result of the study conducted in 2014 and 2015, 21 pollen types were identified in the aeropalynological spectrum (*Acer, Alnus, Betula, Fraxinus, Picea, Pinus, Populus,* Rosaceae, *Quercus, Salix, Tilia, Ulmus, Artemisia,* Asteraceae, Chenopodiaceae, *Plantago,* Poaceae, *Rumex, Taraxacum* and Apiaceae, *Urtica* (Fig. 2).

Pollen of seven taxa of arboreal plants accounted for 75% of the total number of pollen grains found, and pollen of six

Table 1. Significant allergenic taxa for the Vologda Region (according to the recommendations (Nilsson and Spieksma 1994))

№	Recommended	Excluded	Relevant	Additional
1.	Alnus	—	—	Asteraceae
2.	Ambrosia	Ambrosia	—	Populus
3.	Artemisia	—	—	Rosaceae
4.	Betula	—	—	Salix
5.	Castanea	Castanea	—	Tilia
6.	Chenopodiaceae	—	—	Apiaceae
7.	Corylaceae	Corylaceae	—	—
8.	Cupressaceae	Cupressaceae	—	—
9.	Oleaceae	—	Fraxinus	—
10.	Pinaceae	—	Picea, Pinus	—
11.	Plantago	—	—	—
12.	Poaceae	—	—	—
13.	Quercus	—	—	—
14.	Rumex	—	—	—
15.	Urticaceae	—	—	—

taxa of herbaceous plants accounted for 25%. These taxa were the most dominant in the pollen rain.

In 2015, four more taxa appeared in the aeropalynological calendar: *Populus, Rumex, Quercus, Tilia* (Fig. 3).

Two peaks in quantity were determined in the calendars for both years. First peak occurred in spring (from the last ten days of April to May) due to the flowering of anemophilic arboreal and shrubby plants, and the second peak occurred in summer (from late June to early and mid-July) due to the flowering of herbaceous plants.

Alnus (~7%) and *Betula* (~41%) were the absolute dominants in the spring spectrum. The summer and autumn dominants were *Pinus* (~21%) among the trees and *Plantago* (~4%) among the herbaceous plants. Chenopodiaceae (~3%) and Poaceae (~3%) were also very significant in the summer-autumn spectrum.

The share of damaged grains (characterized by traces of physical destruction: in the form of ruptures and cracks on the shell, torn off wings of gymnosperm pollen, deformation of the body of pollen grains, etc.) in the aeropalynological spectrum was approximately 2%. The occurrence of such grains is approximately the same during the observation period.

Results of aeropalynological monitoring of Vologda

The study of the pollen rain in the atmosphere of Vologda conducted in 2019 showed that 21 types of pollen are found in the aeropalynological spectrum (*Acer, Alnus, Betula, Fraxinus, Picea, Pinus, Populus, Quercus, Salix, Tilia, Ulmus,* Rosaceae, *Artemisia, Plantago, Rumex, Typha, Urtica,* Asteraceae, Chenopodiaceae, Poaceae, Apiaceae). Single spores of *Lycopodium* were also found. However, the most significant taxa determined in the summer and autumn period were six taxa of arboreal plants (*Acer, Betula, Picea, Pinus, Populus, Tilia*), the pollen of which constitutes to approximately 30% of the total number of pollen grains recorded and eight taxa of herbaceous plants (*Artemisia*, Asteraceae, Chenopodiaceae, *Plantago*, Poaceae, *Rumex*, Apiaceae, *Urtica*), the pollen of which constitutes to approximately 70%. These taxa were included in the pollen calendar (Fig. 4).

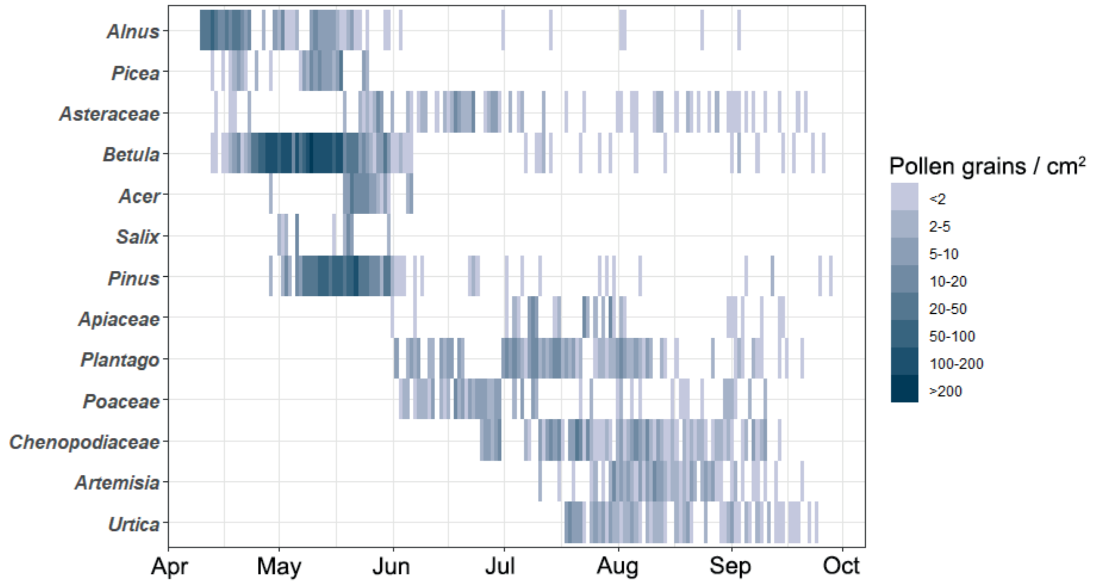

Fig. 2. Pollen calendar of Cherepovets's aeropalynological spectrum in 2014

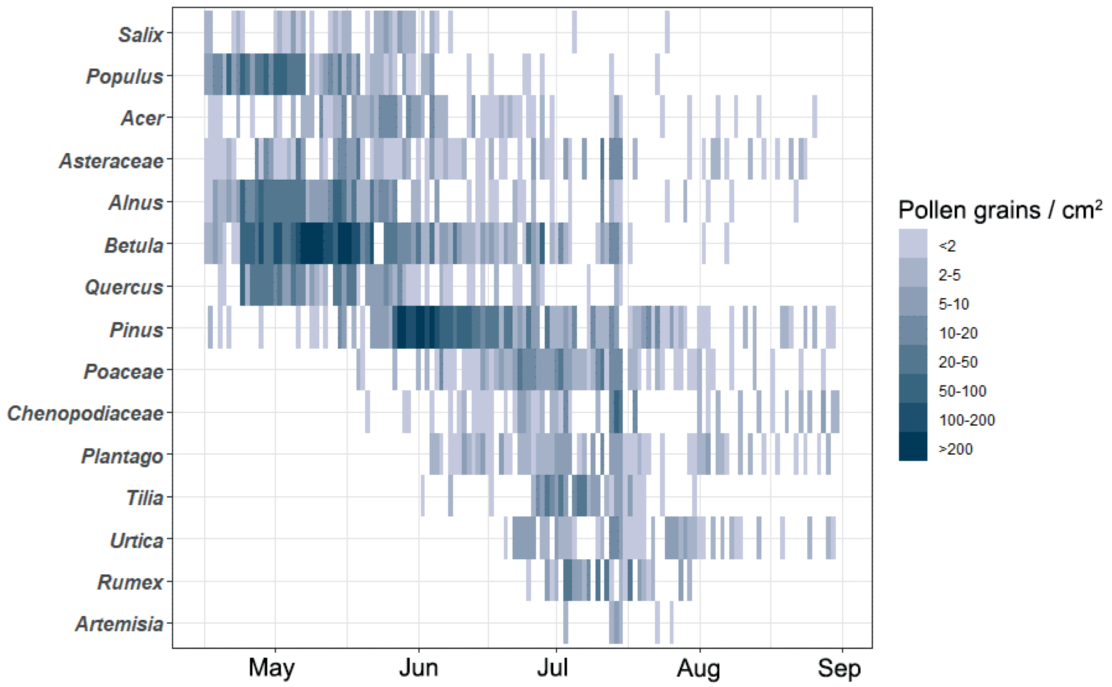

Fig. 3. Pollen calendar of Cherepovets's aeropalynological spectrum in 2015

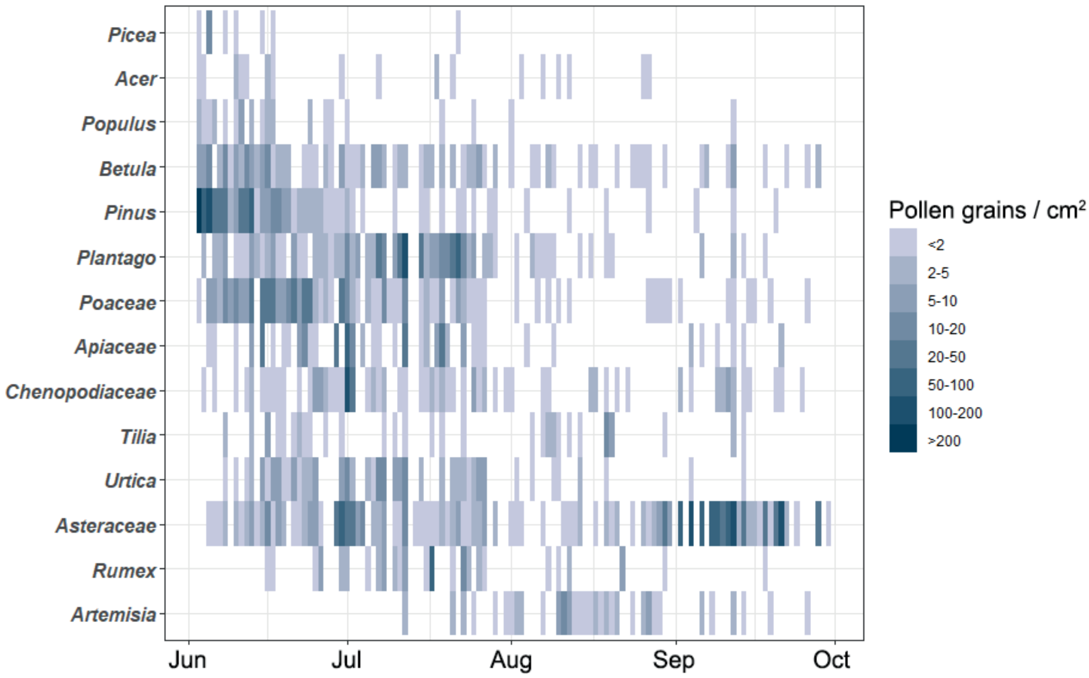

Fig. 4. Pollen calendar of Vologda's aeropalynological spectrum in the summer-autumn of 2019

Since spring samples were not collected in 2019, we can clearly trace only the early-summer peak of pollination on the calendar: from late June to early July.

The calendar shows that in the first ten days of June, the influence of the spring peak of pollination periods of arboreal plants is still very noticeable. In general, in the summer and autumn period, there is a gradual decrease in the amount of arboreal plants' pollen in the air.

In the second decade of June, number of pollen grains of herbaceous plants increases until the first decade of July and then pollination decreases by the end of the month. The autumn maximum, due to late flowering Asteraceae species, was at the same level during the whole September. The predominance of pollen grains of herbaceous taxa indicates that herbaceous plants are the basis for the formation of summer and autumn pollen rains. Asteraceae pollen dominates the aeropalynological spectrum among herbaceous plants. These pollen grains account for about 28% and play a significant role in the summer and autumn peaks. In summer *Pinus* pollen was most common among arboreal plants (~18%).

The proportion of damaged grains in the pollen spectrum was approximately 1%.

Thus, observations in the two cities showed a fundamentally similar pattern of pollination, a small feature was the presence of an autumn maximum in pollination of herbaceous plants in Vologda.

DISCUSSION

The study showed that *Acer, Alnus, Betula, Fraxinus, Picea, Pinus, Populus, Quercus, Salix, Tilia, Artemisia,* Asteraceae, Chenopodiaceae, *Plantago*, Poaceae, *Rumex*, Apiaceae, and *Urtica* are the main airborne pollen types in large cities of the Vologda Region. These taxa are also typical of the boreal zone of Europe (Sofiev and Bergmann 2013).

Earlier, similar studies were also conducted in the north-west of European Russia in Petrozavodsk and showed that the dominant taxa in this region are *Betula, Pinus*, Poaceae, *Urtica, Artemisia* (Elkina 2007). In other Russian cities, such as Moscow, Ryazan, Smolensk, aeropalynological studies have revealed the same dominant taxa (Posevina et al. 2010, 2011; Posevina and Severova 2017; Slabkaya et al. 2012).

The differences in pollen rain are related to the regional peculiarities of flora and landscaping in different countries. For instance, in Ukraine, in addition to *Betula* and *Urtica*, one of the most important dominants is *Ambrosia*, a dangerous allergenic plant (Rodinkova 2015). In Denmark, *Corylus*, Cupressaceae/Taxaceae, *Fagus, Sambucus,* and Cruciferae also play a significant role in pollen spectra (Goldberg et al. 1988), and in Switzerland *Carpinus, Platanus,* and *Castanea* (Clot 2003). Poland is characterized by a significant presence of *Betula, Alnus, Corylus, Fraxinus, Populus, Carpinus,* and Cupresaceae/Taxaceae in aerospectrums (Malkiewicz et al. 2017). On the East of European Russia, in the Perm region, the most important pollens for monitoring are of *Betula*, Poaceae, and *Artemisia* (Novoselova and Minaeva 2015). According to the results of the study, the most significant taxa for the Vologda Region are *Betula, Alnus* and *Pinus* among the trees, as well as Asteraceae, *Plantago* and Poaceae among the herbaceous plants.

Two pollination periods were distinguished: spring (from the last decade of April to May) coincides with the flowering of generally anemophilous trees with *Betula* as the dominant pollen type and summer (from late June to early and mid-July) due to the flowering of herbaceous plants (pollen shed of Poaceae, Asteraceae, *Artemisia* and other weeds). The results of many Russian and European studies turn out to be similar, but the pollination periods differ in duration for several weeks. In Croatia, pollen concentrations also showed two peaks, one in April and one in August (Peternel et al. 2005). Similar results have also been reported from central Italy and south France (Clot 2001; Emberlin et al. 1993; Jäger et al. 1991; Spieksma and Frenguelli 1991). There were two principal periods of the increase in the pollen concentration in Vinnitsa (central Ukraine) in late April and from mid-June until the end of August (Rodinkova 2015). In contrast to the Vologda Region, researches in the Perm Region (Russia) and Ryazan have shown three pollen shed periods in mid-spring, early summer, and late summer, which might be explained by regional peculiarities of vegetation and climate (Posevina et al. 2010; Novoselova and Minaeva 2015).

The most allergenic, according to (Sofiev and Bergmann 2013), is pollen of 18 taxa, of which ten (*Alnus, Artemisia, Betula, Fraxinus, Salix, Plantago*, Poaceae, *Quercus, Rumex, Urtica*) account for about 50% of all pollen grains detected in the atmosphere of Cherepovets and Vologda.

Birch pollen dominates (30%) in the pollen spectrum of arboreal taxa in the Vologda Region, which coincides with the results of other researchers in Russia (Posevina et al. 2010, 2011; Posevina and Severova 2017; Elkina 2007; Slabkaya et al. 2012), and also in the Northern and Central Europe (Adams-Groom et al. 2002; Sofiev and Bergmann 2013; Spieksma et al. 1995). We have detected the presence of birch and pine pollen in the spectrum of the second half of the growing season, which does not coincide with the period of its flowering. This phenomenon was noted earlier in the Czech Republic, Poland, and Germany (Estrella et al. 2006; Hajkova et al. 2015; Szczepanek 1994). It can be caused by the secondary lifting of pollen grains from the ground by the wind, or the transfer of pollen grains over long distances from other territories. (Skjøth et al. 2009), comparing data from Poland and the UK, showed that long-distance transport is an important source of *Betula* pollen grains in both countries, indicating that sensitization and symptoms of pollinosis may occur in areas remote from the pollen source.

Among herbaceous plants, attention should be paid to the species of the Poaceae and Asteraceae families, especially *Artemisia* (Posevina et al. 2010; Novoselova and Minaeva 2015). Studies by Grewling and co-authors (2015) in Poland, Câmara Camacho and co-authors (2015) in Portugal, and Ianovici (2015) in Romania showed trends toward a significant increase in the pollination period of Poaceae although with a relatively low concentration compared to arboreal plants. Poaceae pollen is among the main causes of pollen allergy in Europe, a long pollination period can be harmful for patients with allergies (Ianovici 2015; D'Amato et al. 2007; Sanchez-Mesa et al. 2003). In Russia grass pollen is also considered as one of the most important allergen (Posevina et al. 2010; Posevina and Severova 2017; Elkina 2007; Slabkaya et al. 2012).

Despite the fact that many plant species of the Asteraceae family are pollinated by insects and do not have a high potential for spreading pollen grains by wind, pollen allergens of plants of the genus *Artemisia* are an important cause of pollinosis in Europe and Russia (Kazlauskas et al. 2006; Shamgunova and Zaklyakova 2010). In this context, it is worth noting that although *Artemisia* species belong to anemophilic plants, their pollen grains are not as well adapted for wind transport as other lighter and smaller ones (Grewling et al. 2015); however, they cause on average a stronger allergic reaction in patients at a lower concentration compared, for example, with birch (Sofiev and Bergmann 2013).

In recent years, an increased prevalence of allergy to ragweed pollen from the Asteraceae family has been estimated in Europe, especially in Hungary, Austria, France, Italy, and several other countries (Asero 2002, 2007; Bottero et al. 1990; Corsico et al. 2000; Déchamp et al. 1995; Dervaderics et al. 2002; Járai-Komlódi and Juhász 1993; Rybnicek and Jäger 2001; Thibaudon et al. 2003). In North America, ragweed is one of the strongest sensitizing pollen types causing the main symptoms of pollinosis during its pollination in late summer and autumn (White and Bernstein 2003). In Austria, it has been demonstrated that there is a high correlation between an increase in the amount of ragweed pollen and sensitization rates (Jäger 2000). Pollen grains of ragweed have not been detected in the Vologda Region; however, because this plant continues to spread throughout Europe moving northward, it is necessary to closely monitor the presence of its pollen in the spectra, especially in connection with the trend of increasing temperatures (Gleisner et al. 2022).

In a few studies, opinions are expressed that the proportion of damaged pollen grains increases with environmental pollution (Dziuba 2007); however, researchers do not usually record the presence of damaged pollen and its quantity (Bicakci et al. 2003; Erkara et al. 2009). We were able to show that in the aeropalynological spectra of Cherepovets and Vologda the amount of damaged pollen reached 2%. But in general, according to numerous works of Dziuba (Dziuba 1993, 2006, 2007; Dziuba et al. 1996, 1999, 2001, 2005), in natural population in normal condition without any pollutions the percentage of damaged pollen can reach up to 7-10% because of mistakes in microsporogenesis. Thus, according to the results of our study, we have not identified a clear effect of air pollution on pollen in the Vologda Region.

CONCLUSIONS

Thus, as a result of the conducted studies, the data of monitoring the airborne pollen diversity and its seasonal dynamics in Cherepovets and Vologda were obtained, as well as the pollen grains with allergenic potential were detected and a pollen calendar was compiled.

Twenty-one types of pollen have been identified, ten of which are the most common allergenic types (*Alnus, Artemisia, Betula, Fraxinus, Salix, Plantago,* Poaceae, *Quercus, Rumex, Urtica*), which in total amount to more than 50% of all registered pollen. The results show the presence of allergenic pollen from different taxa throughout the study. Pollen calendars show two peaks of pollen grain quantity: spring (from last decade of April to May) and summer (from the end of June to the middle of July). *Betula* (~30%) and Asteraceae (~28%) pollen dominate in the pollen spectrum in the Vologda Region. *Pinus* (~20%), *Plantago* (~6%) and Poaceae (~5%) also play an important role in the regional spectrum, that generally correlates with the data of neighboring regions.

Despite the mostly elevated level of atmospheric air pollution during the study period, the proportion of damaged pollen grains was approximately 2%, which corresponds to the norm in natural population in normal condition without any pollutions.

This new data can become the basis for developing recommendations for reducing the level of pollinosis in the Vologda Region.

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