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ORIGINAL RESEARCH PAPER

Changes in the concentration of pollen over an 11-year period in a Polish urban environment

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Abstract

Recent studies suggest that climate change can influence plant reproductive systems and have an impact on the increase in allergenic pollen in atmospheric air; highly allergenic pollen may intensify the allergic response in people. The aim of our study was to evaluate the seasonal dynamic concentration of the most allergenic pollen taxa, i.e., the following trees: *Alnus*, *Corylus*, *Betula*, and herbaceous plants: grasses (Poaceae), *Artemisia*, and *Ambrosia*, in the long-term period of 2003–2013 in the city of Lodz, Poland. Weekly airborne pollen concentrations were evaluated with a volumetric Lansoni pollen trap. The beginning and the end of the season were calculated by the 98% method. The birch (*Betula*) pollen was at the highest level and accounted for 79%, followed by alder (*Alnus*) – 19%, and hazel (*Corylus*) – 2%. Among the herbaceous taxa, grasses (Poaceae) pollen dominated – 79%, followed by mugwort (*Artemisia*) – 18%, and ragweed (*Ambrosia*) – 3%. Our findings indicate a lack of qualitative and quantitative change in the pollen produced over the 11-year period.

Keywords

allergenic pollen; pollen concentration; *Alnus*; *Corylus*; *Betula*; Poaceae; *Ambrosia*; *Artemisia*

Introduction

Pollen is a significant source of seasonal allergies, the symptoms of which complicate the lives of millions of people throughout the world [1–3]. Pollen allergy is a systemic illness, which is known to elicit particularly strong symptoms within the respiratory pathway, particularly the nose and conjunctiva. The development and course of pollen allergy occurs in response to many factors, among which are genetic predisposition, epigenetic factors and lifestyle as well as the degree of exposure to the allergen and adjuvant effects by environmental cofactors such as air pollution [4,5].

However, the mechanisms by which the allergens are released from the pollen grain and the initiation of type I hypersensitivity are only partially understood. Tests aimed at identifying the risk factors for pollen allergy have contributed to the discovery of multiple overlapping networks of interaction in human physiology and pathophysiology concerning changes in areas such as the environment, blooming biology and plant physiology, climatology and agriculture.

The collected data have also shown that pollen floating in the air of cities have a small electric charge (typically around 0.8 fC, but as high as 40 fC) and hence are able to absorb particulate matter (PM) particles contaminating the air. This charge physiologically affects the transport of pollen and enables capture by the floral stigma, but also promotes the deposition and accumulation of many PM particles and impurities, allowing them to interact with the substances released from the pollen grain [6].

Therefore, city pollen should be regarded as a significant source of bioparticles. Knowledge of daily, seasonal, and long-term trends in pollen concentration is vital for the effective diagnosis and treatment of pollen allergy as well as its prophylaxis [7–10].

Significant increases in the frequency of allergies and illnesses associated with exposure to pollen have been observed in many countries, including Poland, over the course of recent decades [11,12]. However, it remains unclear how these trends relate to climate change [13].

The objective of the research was to evaluate the long-term dynamics of the concentration of tree, grass, and weed pollen with the greatest allergenicity potential in Lodz over the period 2003–2013.

Material and methods

Identifying pollen taxa

The study incorporated data regarding the concentrations of the following types of pollen: *Alnus*, *Corylus* and *Betula* (Betulaceae) trees, grasses (Poaceae), and *Artemisia* and *Ambrosia* (Asteraceae) weeds.

Site of measurement

The tests were performed in the center of Lodz, 30 km from the geometric center of Poland.

Measurement point

From the beginning of the study in 2003 to 2013, the measurement point had been located in the center of Lodz (51°46′17.5″ N, 19°28′29″ E). The post consists of a Lanzoni camera (VPPS-2000) placed 15 m above sea level. Detailed topographical and botanical information is given in earlier publications [14,15]. The volume method was used, based on a steady suction rate of 10 liters of air per minute (using bioaerosols contained within the apparatus) continually over a period of 7 days. The Śródmieście (city center) district where the pollen monitoring took place is characterized by a high population density in a small area. Old brownstone apartments, which are not connected to the municipal heating network and so burn coal for heating, predominate. They have characteristic courtyards, where there is a tendency for airborne substances which are harmful to health to accumulate. As noted in the report on the state of the environment of the Lodz Voivodship, 2013 [16], the district is prone to the greatest emission of pollutants per unit area, of which PM particles adsorbed onto pollen constitute the highest mean annual concentration of metals.

The air of Lodz is known to be heavily polluted. For example, in 2013, a total of 163 751.40 Mg of pollutants was emitted (159 497.0 Mg of gases not including CO_2 and 4254.40 Mg of dust). About 40% of the abnormal concentrations of particulate matter and benzopyrene in Lodz and the local region was low emission, i.e., emission of PM10 particles, formed by combustion in municipal and domestic buildings. The highest concentrations of transport pollutants in Lodz were noted in the main roads crossing the city; as the city lacks adequate ring roads, the roads run through the center [16].

Laboratory procedures

The studies were conducted from February to September over a period of 11 years. The beginning and end of the season were calculated by the 98% method. Microscopic analysis was performed by the same worker throughout the study.

Statistical analysis

Excel 2013 and Statistica 10 were used for all analyses. Spearman's coefficient was used to analyze the direction of changes in concentration (r_S). A post hoc test was used to identify the diversification in pollen concentrations between different years.

Results

Corylus and *Alnus*

Trends in changes in annual totals. In all years, *Alnus* pollen dominated. *Alnus* represented 91% of total pollen and *Corylus* only 9% (Fig. 1a). During this period, the annual mean total for *Corylus* was 307.60 grains compared to 3197.80 for *Alnus*. A 2-year alternating cycle of pollen production was also noted for both taxa, as given in Fig. 1b. A significant relationship was found between the annual totals of *Corylus* and *Alnus* pollen in the years 2003–2013 (p = 0.00016) (Fig. 2). During the study period, an insignificant falling trend in annual pollen totals was observed for *Alnus* (r_S = −0.05; p = 0.89) (Fig. 3a), however, the *Corylus* pollen concentrations was constant (r_S = −0.01; p = 0.9) (Fig. 3c).

Length of pollen season. For both taxa, the values varied widely, however, the length of pollen seasons was found to be insignificantly longer for *Alnus* (r_S = 0.25; p = 0.45) (Fig. 3b), while a slight falling trend was observed for *Corylus* (r_S = −0.01; p = 0.9) (Fig. 3d). The start date of the pollen season was found to differ by more than 1.5 months for *Alnus* (50 days), with the start being placed between February 6 (2004) and March 27 (2006); however, the end of the season varied by nearly 2 months (58 days): from April 3 (2004) to May 30 (2010). In contrast, for *Corylus*, the beginning of the season ranged from February 5 (2004) to March 25 (2006) and the end from March 12 (2008) to May 14 (2003). The average length of the season for both taxa was similar: 44.5 days for *Alnus* and 45.7 days for *Corylus*.

Trends in daily totals. In subsequent years, a significant falling trend was observed in daily totals of *Alnus* pollen, with a Spearman's correlation coefficient of r_S = −0.72 (p = 0.01). The totals for *Corylus* pollen were also found to fall (r_S = −0.01), but this value was insignificant (p = 0.98).

Betula

Trends in changes in annual totals. For the years of study, the mean annual total of *Betula* pollen was 12 935.80. In addition, a 2-year cycle in pollen variation was observed (Fig. 3e). On average, *Betula* pollen was present for 28 days. The beginning of the season was observed between April 2 (2009) and April 21 (2006) (a 20-day difference), and ended between April 30 (2010) and May 27 (2012) (28 days). The correlation coefficient had a negative value (r_S = −0.27; p = 0.5), which indicates insignificant falling trend in annual concentration (Fig. 3e).

Length of pollen season. The length of the pollen season for *Betula* was found to have an insignificant rising trend: r_S = 0.20; no significance (p = 0.5) (Fig. 3f).

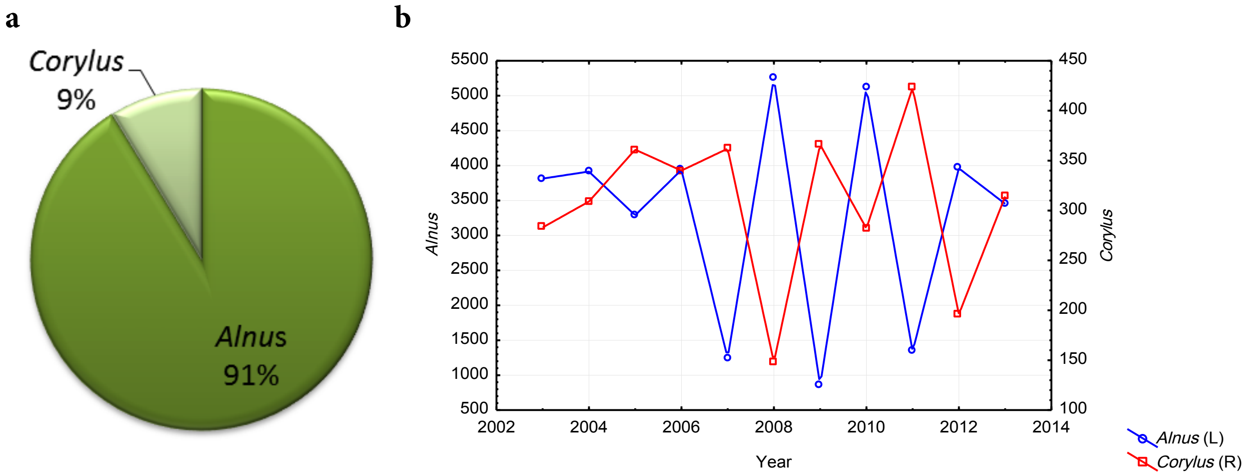


Fig. 1 **a** The pie chart shows the percentage distribution of *Corylus* and *Alnus* pollen for data obtained from 2003 to 2013 in Lodz, Poland. **b**. A 2-year alternating cycle of *Alnus* and *Corylus* pollen in the study period.

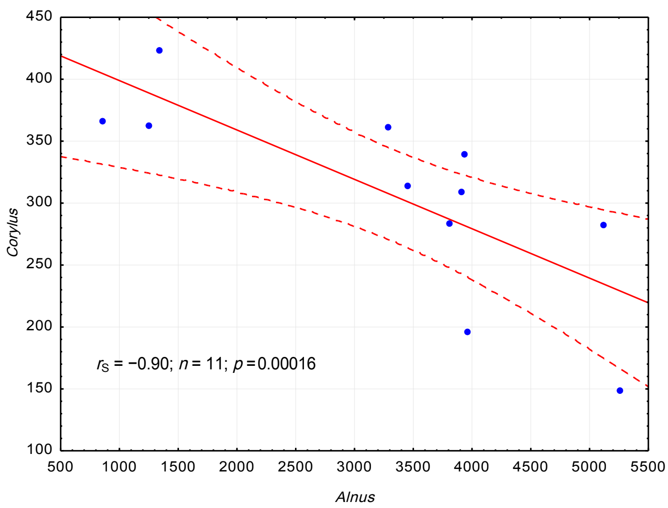


Fig. 2 The relationship between the annual totals of *Corylus* and *Alnus* pollen in the years 2003–2013 (Spearman correlation).

Trends in daily totals. An insignificant falling trend was found for daily concentration for *Betula* pollen (r_S = −20; p = 0.57).

Grass pollen (Poaceae)

Trends in changes in annual totals. The analysis of long-term trends for annual grass pollen concentrations revealed a falling tendency (r_S = −0.11; p = 0.75) (Fig. 3g). The mean annual total for grass pollen was 3795.70.

Length of pollen season. The length of the pollen season for grass was found to had shortened insignificantly (r_S = 0.14; p = 0.69) (Fig. 3h). The earliest beginning (May 3), and the latest ending (September 11), both occurred in 2009, indicating that the season was exceptionally long that year (131 days). Otherwise, the beginnings of the seasons occurred between May 3 (2009) and May 27 (2008) (25 days), and ended between August 7 (2012) and September 11 (2009) (54 days).

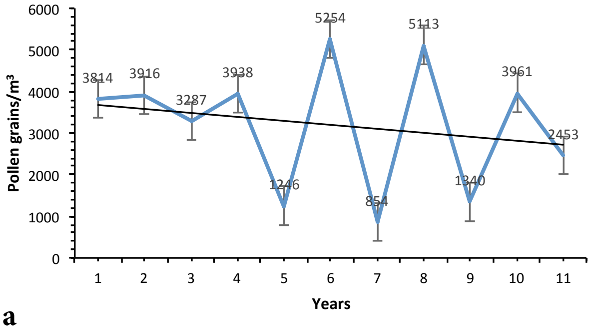
Trends in daily totals. A falling trend was noted in daily totals, with a correlation coefficient of r_S = −0.19 (p = 0.57).

Artemisia

Trends in changes in annual totals. For *Artemisia*, an insignificant reduction in annual concentrations was observed over time (r_S = −0.33; p = 0.33) (Fig. 3i).

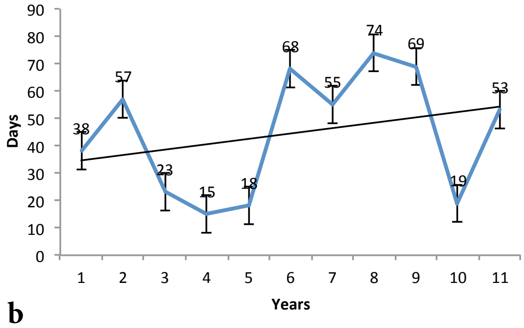
Length of pollen season. A comparison of the mean daily totals revealed a significant falling trend over time (r_S = −0.77; p = 0.01) (Fig. 3j). The beginning of the pollen season for *Artemisia* was found to range from June 1 (2012) to September 2 (2010) (94 days), with the end of the season occurring between August 10 (2012) and September 26 (2008) (48 days).

Trends in daily totals. The difference between study years with regard to *Artemisia* pollen concentration trends over subsequent days was insignificant (r_S = −0.17; p = 0.61).



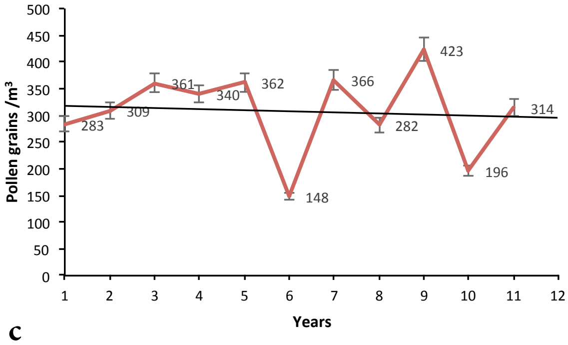
a

Trends in changes in annual totals for *Alnus*: an insignificant falling trend in annual pollen totals ($r_S = -0.05$; $p = 0.89$).



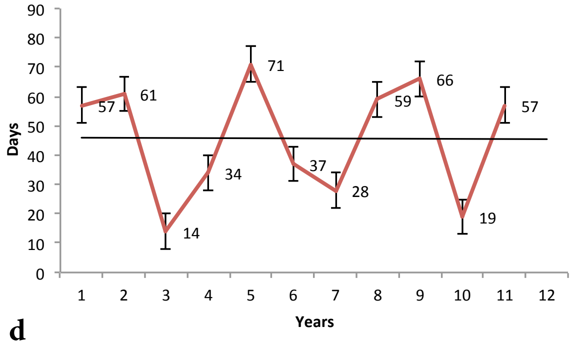
b

Seasons length of *Alnus* pollen: an undulating overall course with not significant increasing trends ($r_S = 0.25$; $p = 0.45$).



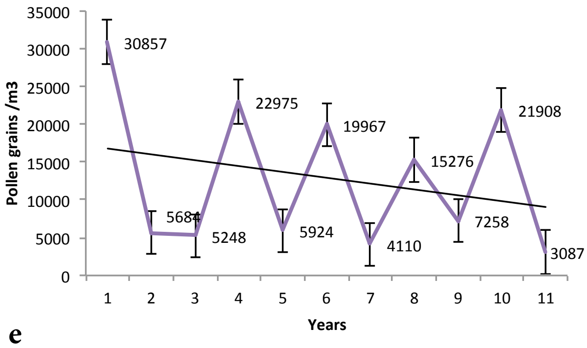
c

Trends in changes in annual totals for *Corylus*: not significant, falling trend ($r_S = -0.01$; $p = 0.90$).



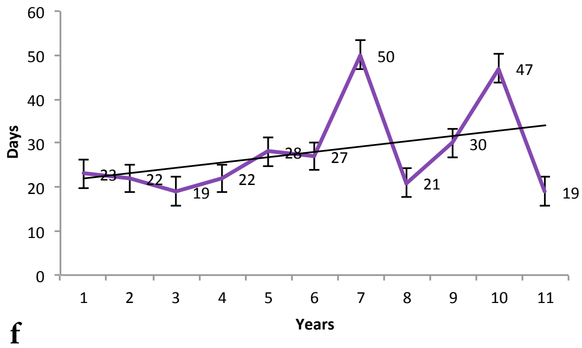
d

Seasons length of *Corylus* pollen: not significant, slight falling trend ($r_S = -0.01$; $p = 0.90$).



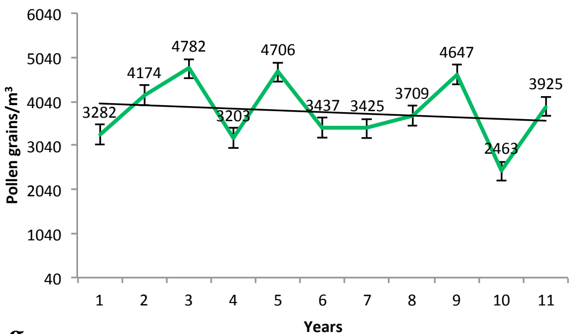
e

Trends in changes in annual totals for *Betula*: an insignificant falling trend ($r_S = -0.27$; $p = 0.50$).



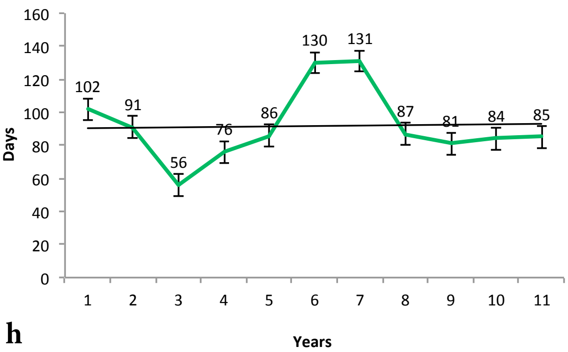
f

Seasons length of *Betula* pollen: an insignificant rising trend ($r_S = 0.20$; $p = 0.50$).



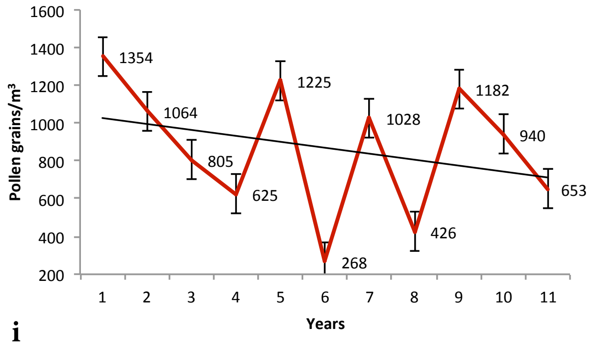
g

Trends in changes in annual totals for Poaceae: not significant falling, tendency ($r_S = -0.11$; $p = 0.75$).



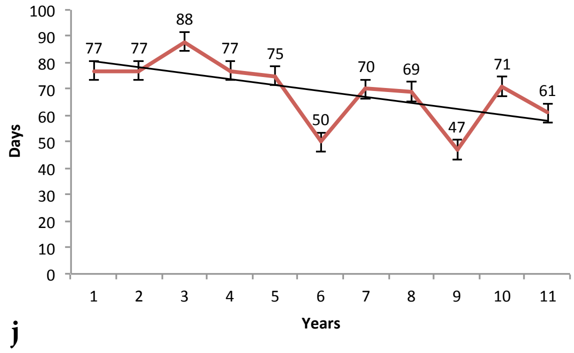
h

Seasons length of Poaceae pollen seasons: not significant falling level ($r_S = -0.14$; $p = 0.69$).



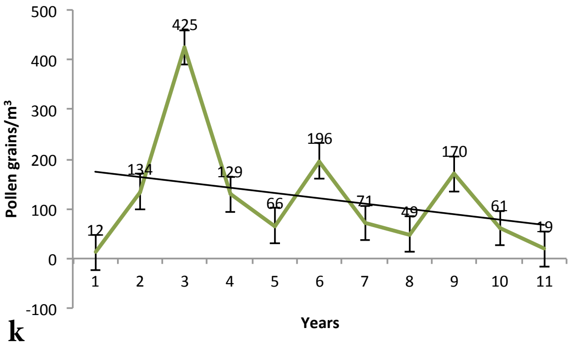
i

Trends in changes in annual totals for *Artemisia*: not significant decreasing trend ($r_S = -0.33$; $p = 0.30$).



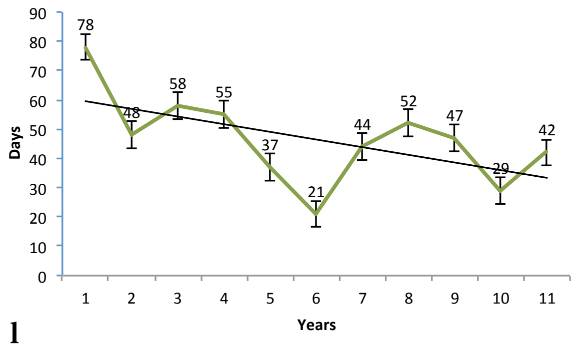
j

Seasons length of *Artemisia* pollen: year to year significant decreasing trend ($r_S = -0.77$; $p = 0.01$).



k

Trends in changes in annual totals for *Ambrosia*: not significant decreasing trend ($r_S = -0.22$; $p = 0.52$).



l

Seasons length of *Ambrosia*: year to year significant decreasing trend ($r_S = -0.61$; $p = 0.049$).

Fig. 3 The long-term quantitative trends in annual totals and lengths of pollen seasons of six airborn analyzed pollen types: *Alnus* (**a,b**), *Corylus* (**c,d**), *Betula* (**e,f**), Poaceae (**g,h**), *Artemisia* (**i,j**), and *Ambrosia* (**k,l**), in Lodz, Poland (over the period 2003–2013). Spearman's coefficient was used to analyze the direction of changes (r_S).

Ambrosia

Trends in changes in annual totals. An insignificant falling trend was observed with regard to annual total ($r_S = -22$, $p = 0.52$) (Fig. 3k). Significant differences were found in the number of *Ambrosia* pollen grains between years ($p = 0.006$), but it was not possible to indicate which year was significantly different from the rest (the results of the post hoc test were insignificant). The mean annual totals for *Ambrosia* pollen were generally low (121). In addition, a significant difference was found between the pollen seasons of *Artemisia* and *Ambrosia* ($p = 0.0002$).

Length of pollen season. The length of the pollen season shortened over subsequent years ($r_S = -0.61$; $p = 0.049$) (Fig. 3l). The beginning of the *Ambrosia* pollen seasons ranged from June 29 (2013) to August 12 (2008) (63 days) and the end from September 7 to September 29 (2007) (23 days) (Fig. 3l).

Trends in daily totals. An insignificant falling trend was observed in daily totals ($r_S = -0.16$; $p = 0.63$). The periods of *Artemisia* and *Ambrosia* did not overlap in any of the analyzed seasons (Fig. 4).

Discussion

The results of the presented analysis show that during the period 2003–2013, the mean annual and daily pollen concentrations in Lodz, Poland did not vary significantly; however, a falling tendency was observed during the period with regard to

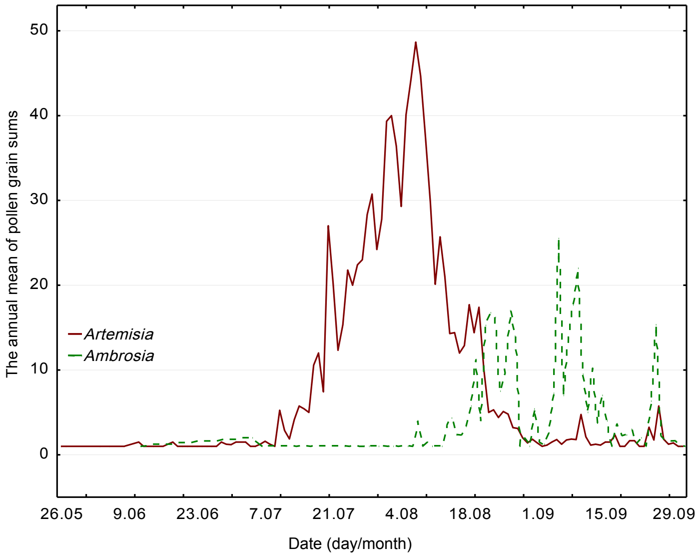


Fig. 4 Difference between the pollen seasons of *Artemisia* and *Ambrosia* pollen (Lodz, Poland, 2003–2013).

the concentration and length of pollen seasons. A significant falling trend was found only for the mean daily totals of *Alnus* pollen, which is found at the beginning of the vegetative season in Lodz, occurring with significant fluctuations in temperature, rainfall and snowfall.

Late ending of *Corylus* and *Alnus* pollen season raises some doubts, specially the end of the season, which varied by nearly 2 months. Perhaps, the other method should be used to define the start and end of the pollen season for these taxa. For example, the date when 2.5% of the total pollen census for the year has been trapped.

Comparison of obtained results with those obtained by other authors

Our findings contradict those of many other studies, typically those performed in coastal countries, which note that successive rises in air temperature significantly influence earlier flowering, increase annual totals and daily concentrations of pollen [17]. A study from Spain indicates an almost linear increase in grass pollen concentration over time and the authors foresee further rising tendencies and extreme scenarios. For example, on the basis of results extrapolated from grass pollen concentrations and existing trends, they predict that further increases in concentration as high as 28–30% may occur in Cordoba in the next 50 years. Significant rising trends are also predicted for other Spanish cities [18]. The other publications describe the earliest flowering times, longer pollen seasons, increased expansion of sensitizing plants, and more widespread allergy to pollen proteins [19–21].

Similar rising trends have been observed in the United States. Studies performed in the USA found significantly higher pollen concentrations in the period 2001–2010 compared to 1994–2000. Mean annual maximal values and totals were found to be 42% and 46% higher, respectively, during the 10-year period than the earlier 6-year period, and the pollen season began 3 days earlier, on average [22].

On the other hand, as observed in our study, a lack of upward trends, homology and synchronicity with *Betula* pollen concentrations was found during a 12-year study (1995–2007) in three stations in northwest Germany and two nearby stations in the Netherlands [23]. Similarly, in the years 2003–2011, decreasing trends were observed in the concentrations of 20 pollen taxa from Krakow and Sosnowiec compared to Lodz [24].

Similarly, international aerobiological research under the aegis of the European program EuroPrevall indicated no clear trends in pollen concentrations on the European scale [25]. It was noted that the only place in Europe where there had been an increase in the concentrations of *Betula* pollen in recent years was Zürich in Switzerland. Early beginnings of the Betulaceae pollen season were found in Derby (UK), Sofia (Bulgaria), and Reykjavik (Iceland), where the baseline levels were very low compared to other countries and trees of the Betulaceae are absent. In Reykjavik and Strasbourg on the Rhine, significantly earlier grass pollen seasons were recorded, while pollen seasons were shortened and less intense in Derby and concentrations were found to demonstrate an upward trend in Legnano, Italy [25].

Possible reasons for the observed trends

The reasons for the observed differences are certainly complex and not fully understood. It is important to mention that the pollen concentration were not monitored systematically throughout the year, so the beginnings of the *Alnus* and *Corylus* seasons may have been partly overlooked in some years.

A future analysis of meteorological data from the city center could shed further light on the results, however, this is not given in the present study. In this kind of study, knowledge of the weather factors would not only elucidate the most important parameters at a given place and time, but also construct effective models to enable the course of the pollen season to be predicted based on past and current aerobiological and meteorological data. Unfortunately, the instability of atmospheric phenomena observed in recent years may also complicate the accuracy of this type of forecast. In addition to the gradual rise in temperature, other studies frequently highlight other environmental parameters, particularly the availability of water (from precipitation or made available to the measurement point by its proximity to water sources such as the sea, rivers, or lakes), which is very important for plant development and intensity of pollen release [26].

In addition, the production of pollen may be influenced by recent phenomena such as the recently observed extended periods of winter without frost, changes in snow cover extend, the occurrence of heat waves and periods of severe drought, the variability of rainfall and storms, and increased air pollution. Similarly, an increase in the frequency of strong winds may contribute to the local precipitation of pollen transported from afar, which can cause increased levels of aeroplankton. This type of phenomenon was observed in 2005 in Lodz, when the station reported relatively high levels of ragweed pollen transported from Southern Europe [27].

In Poland, as in other countries, signs of global warming have been observed together with associated successive rises in temperature. While international studies note that both air and soil temperature have been growing at a relatively high rate over the past 50 years, on average about 0.13°C per decade, the average annual temperature in most parts of Poland have increased by approximately 0.2°C over 10 years [28]. Moreover, studies conducted since 1880 have indicated that the 20 warmest years since the beginning of the study were reported in the last two decades. The research of weather parameters for over 50 years in the area of Lodz (years 1951–2005) has also revealed a linear increase of temperature over time. During this period, average temperatures in Lodz had risen by around 0.3°C per decade [28]. Linear regression analysis revealed that the greatest rise in temperature in Lodz during 1990–2005 occurred mainly in the spring: in February ($r_S = 0.61$) and in March ($r_S = 0.47$) when *Corylus* and *Alnus* flower, then in May ($r_S = 0.42$), during the grass pollen season, and in August ($r_S = 0.38$), when weed pollen dominates. Although many studies indicate that this temperature change affects the stimulation of photosynthesis, increases pollen concentrations, and thereby increases exposure to allergens, our findings do not confirm this. However, a long-term study of precipitation in central Poland found that mean seasonal totals demonstrated a falling trend during spring, summer, and winter during the years 1951–2010, with the lowest level of precipitation in Poland, i.e., below 100 mm, which may indicate a slight tendency towards continentalism in this area [28]. Central Poland also received less snow during winter seasons compared to eastern regions, which also has an inhibitory effect on the processes of vegetation and pollen production [29].

Most importantly, the findings in Lodz reveal a gradual worsening of air quality, despite the promotion of a range of environmental protection policies. A steady rise in car use, a lack of ring roads, and the presence of a built-up area result in unacceptably high levels of gas and fumes, including NO_2. For example, point emission of NO_2 in Lodz was found to increase during the period 2006–2013 [annual NO_2 emission (Mg/a) was 5539.90 in 2006 and 8288.10 in 2013]. In turn, the emission of NO_2 by transport in Lodz rose from 8209 (Mg/a) in 2006 to 20 880 in 2012 [16]. NO_2 may lead to a range of pathological conditions in plant cells, for example damage to the chloroplast membranes and necrosis, which may limit the release of pollen in the tested plants [30].

Clinical and research implications

Pollen allergies are the most common form of the respiratory tract disorder, and the present findings may be valuable in determining the clinical significance of skin prick tests against pollen allergens and monitoring treatment and prophylaxis. Despite the overall falling trend regarding exposure to pollen observed in Lodz, the frequency of illness due to pollen allergy is high. As Lodz is a city with a high air pollution index, the allergenicity of the pollen can also increase [31]. For example, exposure to NO_2 increases the allergenicity potential of pollen at the level of human dendritic cells [32].

Among the analyzed taxa of trees, the highest share of pollen was for *Betula* (79%), followed by *Alnus* (19%) and *Corylus* (2%), which is reflected in the incidence of allergies in patients diagnosed and treated in our clinic, where the highest incidence of sensitization was found on extracts of *Betula* (81%). The incidence of positive skin prick tests was also very high for *Alnus* (72%) and *Corylus* (70%). Among the selected plant taxa, grass pollen dominated, accounting for up to 79% of pollen subjected to analysis, followed by *Artemisia* pollen (18%) and *Ambrosia* (3%). It is necessary to emphasize that 40% of patients who underwent the weed extract test panel demonstrated sensitivity to ragweed extract.

Our findings indicate relatively small exposure to *Ambrosia* pollen, and showed that the pollen seasons for *Artemisia* and *Ambrosia* are separated. *Ambrosia* pollen is known to be a major cause of allergies for the population of North America [33]. The presence of *Ambrosia* pollen in many European countries raises a lot of concern, especially as around 50 allergens and many isoforms exist. In addition, small pollen grains (18–22 μm) are emitted in large quantities and can be transported for great distances, posing a risk to people with allergies and asthma. Research conducted in Derby revealed the presence of ragweed pollen in only 7 of 44 years of research, but its clinical significance may be illustrated by the fact that approximately 25% of patients with allergy to ragweed developed asthma [34].

To summarize, our findings indicate a lack of qualitative and quantitative change in the pollen produced over an 11-year period. The stability of pollen production allows the search for the causes of the observed changes in morbidity caused by plant allergens to be moved on from simply addressing the question of pollen concentration. As pollen allergenicity is known to rise in contaminated environments, further aerobiological research in central Poland should take into account the degree of air pollution in the Lodz region. In addition, an updated analysis of thresholds of clinical symptoms used to scale concentrations of pollen in the air would be required, because the observed phenomena have the effect of reducing sensitivity thresholds and increasing the clinical significance of the low concentrations of pollen present in the air [35].

Acknowledgments

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References

1. Bunne J, Moberg H, Hedman L, Andersson M, Bjerg A, Lundbäck B, et al. Increase in allergic sensitization in schoolchildren: two cohorts compared 10 years apart. J Allergy Clin Immunol Pract. 2016 (in press). http://dx.doi.org/10.1016/j.jaip.2016.09.025
2. Majkowska-Wojciechowska B. Pyłek roślin i alergeny sezonowe w Polsce. Alergia Astma Immunologia. 2016;21:5–15.
3. Świebocka EM, Siergiejko P, Rapiejko P, Siergiejko Z. Long-term intense exposure to grass pollen can mask positive effects of allergenic immunotherapy on non-specific bronchial hyperresponsiveness. Arch Med Sci. 2014;29:10:711–716. http://dx.doi.org/10.5114/aoms.2014.44861
4. Majkowska-Wojciechowska B, Pełka J, Korzon L, Kozłowska A. Prevalence of allergy, patterns of allergic sensitization and allergy risk factors in rural and urban children. Allergy. 2007;62:1044–1050. http://dx.doi.org/10.1111/j.1398-9995.2007.01457.x
5. Krauss-Etschmann S, Meyer KF, Dehmel S, Hylkema MN. Inter- and transgenerational

epigenetic inheritance: evidence in asthma and COPD? Clin Epigenetics. 2015;7:53. http://dx.doi.org/10.1186/s13148-015-0085-1

6. Bowker GE, Crenshaw HC. Electrostatic forces in wind-pollination – part 1: measurement of the electrostatic charge on pollen. Atmos Environ. 2007;41:1587–1595. http://dx.doi.org/10.1016/j.atmosenv.2006.10.047
7. Grewling Ł, Kasprzyk, Borycka K, Chłopek K, Kostecki Ł, Majkowska-Wojciechowska B, et al. Searching for a trace of *Artemisia campestris* pollen in the air. Acta Agrobot. 2015;68:303–313. http://dx.doi.org/10.5586/aa.2015.040
8. Myszkowska D, Piotrowicz K, Ziemianin M, Chłopek K, Dąbrowska-Zapart K, Kasprzyk I, et al. Grass pollen seasons in Poland against a background of the meteorological conditions. Acta Agrobot. 2015;68:357–365. http://dx.doi.org/10.5586/aa.2015.038
9. Puc M, Wolski T, Câmara Camacho I, Myszkowska D, Kasprzyk I, Grewling Ł, et al. Fluctuation of birch (*Betula* L.) pollen seasons in Poland. Acta Agrobot. 2015;68:303–313. http://dx.doi.org/10.5586/aa.2015.041
10. Majkowska-Wojciechowska B, Wojciechowska A. Aerobiologia – kierunki badań i wyzwania XXI wieku. Alergia Astma Immunologia. 2008;13:142–146.
11. Bergmann KC, Heinrich J, Niemann H. Current status of allergy prevalence in Germany: position paper of the Environmental Medicine Commission of the Robert Koch Institute. Allergo J Int. 2016;25:6–10. http://dx.doi.org/10.1007/s40629-016-0092-6
12. Rapiejko P, Piekosz-Orzechowska B, Jurkiewicz D. Assessment of Polish physicians' therapy behaviour and patterns of prescribing antihistaminic medicines in day-to-day outpatient care. Otolaryngol Pol. 2009;63:509–512. http://dx.doi.org/10.1016/S0030-6657(09)70170-2
13. Höflich C, Balakirski G, Hajdu Z, Baron JM, Kaiser L, Czaja K, et al. Potential health risk of allergenic pollen with climate change associated spreading capacity: ragweed and olive sensitization in two German federal states. Int J Hyg Environ Health. 2016;219:252–260. http://dx.doi.org/10.1016/j.ijheh.2016.01.007
14. Majkowska-Wojciechowska B, Balwierz Z, Kowalski ML. Pyłek roślin i zarodniki grzybów mikroskopowych w powietrzu atmosferycznym Łodzi w roku 2013. Alergia Astma Immunologia. 2015;20:192–198.
15. Majkowska-Wojciechowska B, Balwierz Z, Kowalski ML. Pollen counts analysis in the atmosphere of Lodz (Poland) during vegetation in 2008. Alergia Astma Immunologia. 2008;13:250–263.
16. Raport o stanie środowiska w województwie łódzkim w 2013 r. 2016 [cited 2016 Dec 18]. Available from: http://www.wios.lodz.pl/Raport_o_stanie_srodowiska_w_wojewodztwie_lodzkim_w_2013_r,12,8
17. Emberlin J, Smith M, Close R, Adams-Groom B. Changes in the pollen seasons of the early flowering trees *Alnus* spp. and *Corylus* spp. in Worcester, United Kingdom, 1996–2005. Int J Biometeorol. 2007;51:181–191. http://dx.doi.org/10.1007/s00484-006-0059-2
18. García de León D, García-Mozo H, Galán C, Alcázar P, Lima M, González-Andújar JL. Disentangling the effects of feedback structure and climate on Poaceae annual airborne pollen fluctuations and the possible consequences of climate change. Sci Total Environ. 2015;530–531:103–109. http://dx.doi.org/10.1016/j.scitotenv.2015.05.104
19. Levetin E, van de Water P. Changing pollen types/concentrations/distribution in the United States: fact or fiction? Curr Allergy Asthma Rep. 2008;8:418–424. http://dx.doi.org/10.1007/s11882-008-0081-z
20. Ziska LH, Beggs PJ. Anthropogenic climate change and allergen exposure: the role of plant biology. J Allergy Clin Immunol. 2012;129:27–32. http://dx.doi.org/10.1016/j.jaci.2011.10.032
21. Ziello C, Sparks TH, Estrella N, Belmonte J, Bergmann KC, Bucher E, et al. Changes to airborne pollen counts across Europe. PLoS One. 2012;7:e34076. http://dx.doi.org/10.1371/journal.pone.0034076
22. Zhang Y, Bielory L, Mi Z, Cai T, Robock A, Georgopoulos P. Allergenic pollen season variations in the past two decades under changing climate in the United States. Glob Chang Biol. 2015;21:1581–1589. http://dx.doi.org/10.1111/gcb.12755
23. Wachter R, de Weger L, van der Smitte H. A comparison between airborne *Betula* pollen counts in the northwest of Germany and the Netherlands (1982–2011). Allergology and Immunology. 2012;9:188.

24. Majkowska-Wojciechowska B, Balwierz Z, Chłopek K, Myszkowska D, Wojciechowski Z, Kowalski ML. Pollen concentration of allergenic plant taxa at three different sampling sites of southern and central Poland – the evaluation of the 9-year period (2003–2011). Alergologia, Immunologia. 2012;9:186.
25. Smith M, Jäger S, Berger U, Šikoparija B, Hallsdottir M, Sauliene I, et al. Geographic and temporal variations in pollen exposure across Europe. Allergy. 2014;69:913–923. http://dx.doi.org/10.1111/all.12419
26. Clary J, Save R, Biel C, de Herralde F. Water relations in competitive interactions of Mediterranean grasses and shrubs. Ann Appl Biol. 2004;144:149–155. http://dx.doi.org/10.1111/j.1744-7348.2004.tb00328.x
27. Smith M, Skjøth CA, Myszkowska D, Uruska A, Puc M, Stach A, et al. Long-range transport of *Ambrosia* pollen to Poland. Agric For Meteorol. 2008;148(10):1402–1411. http://dx.doi.org/10.1016/j.agrformet.2008.04.005
28. Czarnecka M, Nidzgorska-Lencewicz J. Wieloletnia zmienność sezonowych opadów w Polsce. Woda – Środowisko – Obszary Wiejskie. 2012;12:45–60.
29. Czarnecka M. Zmienność terminów początku i końca pokrywy śnieżnej o różnym czasie zalegania i ich uwarunkowania cyrkulacyjne. Prac Studi Geograf. 2011;47:109–118.
30. Gheorghe IF, Ion B. The effects of air pollutants on vegetation and the role of vegetation in reducing atmospheric pollution. In: Khallaf M, editor. The impact of air pollution on health, economy, environment and agricultural sources. Rijeka: InTech; 2011. p. 241–280. http://dx.doi.org/10.5772/17660
31. Majkowska-Wojciechowska B, Kowalski ML. Allergens, air pollutants and immune system function in the era of global warming. In: Khare M, editor. Air pollution – monitoring, modelling, health and control. Rijeka: InTech; 2012. p. 221–254. http://dx.doi.org/10.5772/34804
32. Chassard G, Choël M, Gosselin S, Vorng H, Petitprez D, Shahali Y, et al. Kinetic of NO_2 uptake by *Phleum pratense* pollen: chemical and allergenic implications. Environ Pollut. 2015;196:107–113. http://dx.doi.org/10.1016/j.envpol.2014.10.004
33. Bordas-Le F, Groeme R, Chabre H, Baron-Bodo V, Nony E, Mascarell L, et al. New insights into ragweed pollen allergens. Curr Allergy Asthma Rep. 2015;11:63. http://dx.doi.org/10.1007/s11882-015-0565-6
34. Pashley CH, Satchwell J, Edwards RE. Ragweed pollen: is climate change creating a new aeroallergen problem in the UK? Clin Exp Allergy. 2015;45:1262–1265. http://dx.doi.org/10.1111/cea.12572
35. DellaValle CT, Triche EW, Leaderer BP, Bell ML. Effects of ambient pollen concentrations on frequency and severity of asthma symptoms among asthmatic children. Epidemiology. 2012;23:55–63. http://dx.doi.org/10.1097/EDE.0b013e31823b66b8

Zmiany koncentracji pyłku alergicznego w powietrzu miejskim w Polsce w okresie jedenastu lat (2003–2013)

Streszczenie

Najnowsze badania sugerują, że zmiany klimatyczne mogą wpłynąć na wzrost stężeń alergennego pyłku w powietrzu atmosferycznym i przez to wzmacniać reakcję alergiczną u ludzi. Celem badań była ocena dynamiki sezonów najsilniej uczulającego pyłku drzew z rodzajów: *Alnus*, *Corylus*, *Betula* i roślin zielnych: Poaceae, *Ambrosia*, *Artemisia* w okresie 2003–2013 w Łódzi, Polska. Tygodniowe stężenia pyłku w powietrzu oceniano za pomocą aparatu wolumetrycznego Lanzoni. Początek i koniec sezonu obliczono metodą 98%. Udział procentowy pyłku *Betula* wyniósł 79%, *Alnus* – 19%, a *Corylus* – 2%. W przypadku roślin zielnych dominował pyłek Poaceae (79%), znacznie mniej było pyłku *Artemisia* – 18% i *Ambrosia* 3%. Wyniki badań wskazują na brak jakościowej i ilościowej zmiany w produkcji pyłku badanych gatunków w okresie 2003–2013.