ORIGINAL ARTICLE

Prevalence of *Artemisia* Species Pollinosis in Western Poland: Impact of Climate Change on Aerobiological Trends, 1995–2004

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Abstract

Background: *Artemisia* species pollen represents a major cause of allergy in Central Europe. Variations in the pollen season, the influence of climate variables and the prevalence of pollinosis to it were analyzed in Poznan, in western Poland between 1995 and 2004.

Methods: A Hirst volumetric spore trap was used for atmospheric sampling. Pollination date trend analysis and Spearman correlation tests were performed. Skin prick tests (SPT) and allergen specific immunoglobulin (Ig)E antibody measurements were performed in 676 and 524 patients, respectively.

Results: The *Artemisia* species pollen season grew longer due to a clear advance in the starting day and only a slightly earlier end point; the peak day also came slightly earlier. Rainfall in the first fortnight of July highly influenced pollen season severity. Temperature was directly correlated with daily *Artemisia* species pollen levels; relative humidity was inversely correlated. Twelve percent of patients had a positive SPT reaction to *Artemisia* species. Their symptoms were rhinitis and conjunctivitis (15%), atopic dermatitis (15%), chronic urticaria (14.3%), bronchial asthma (2.4%), and facial and disseminated dermatitis (1.3%). Elevated specific IgE concentrations were detected in the sera of 10.1% of patients.

Conclusions: *Artemisia* species pollen is an important cause of pollinosis in western Poland. Pollen season intensity is highly influenced by rainfall in the previous weeks. Trends towards earlier season starts and longer duration, possibly caused by climate change, may have an impact on the allergic population.

Key Words: Aerobiology, *Artemisia* species pollen. Climate change impact. Meteorological influence. Pollen allergy.

Resumen

Antecedentes: El polen de *Artemisia* es una importante causa de alergia en Europa Central. En el presente trabajo se analizan las variaciones en su estación polínica, la influencia de la meteorología y la incidencia de polinosis en la ciudad de Poznan (Oeste de Polonia) durante 1995-2004.

Métodos: Se utilizó un captador volumétrico tipo Hirst para el muestreo atmosférico. Para el análisis estadístico se aplicaron análisis de tendencia y test de correlación de Spearman. Se realizó un SPT y un control de anticuerpos AsIgE en 676 y 524 pacientes.

Resultados: Se detectó un aumento en la duración de la estación polínica de *Artemisia* debido al fuerte avance de la fecha de inicio y a un menor avance de la fecha de final de estación. También se observó un ligero avance de las fechas de máxima concentración. La lluvia de la primera quincena de Julio es el parámetro meteorológico más influyente en la severidad de la estación. La temperatura ejerce una influencia positiva en los niveles polínicos diarios, un efecto contrario ejerce la humedad relativa. Respecto a los datos clínicos, 12% de los pacientes mostraron una reacción positiva del SPT de *Artemisia*. Sus síntomas fueron: 15% rinitis y conjuntivitis; 15% dermatitis atópica; 14.3% urticaria crónica; 2.4% asma bronquial; 1.3% dermatitis facial y diseminada. Niveles elevadas de AsIgE fueron detectados en suero del 10.1% de pacientes.

Conclusiones: El polen de *Artemisia* es una causa importante de polinosis en el Oeste de Polonia. La intensidad de la estación polínica está influenciada por la lluvia de las semanas previas. La tendencia hacia un avance de la fecha de inicio y hacia una mayor duración de la estación polínica, probablemente causas del Cambio Climático, puede tener un impacto importante en la población alérgica.

Palabras claves: Aerobiología. Polen de *Artemisia.* Cambio Climático. Meteorología. Polinosis.

Introduction

Artemisia species, or mugwort, is an anemophilous genus included in the Compositae family. Mugwort plants produce high quantities of pollen grains [1,2]. Pollen from the various *Artemisia* species is an important cause of allergy in Central and Eastern Europe, where the frequency of sensitization ranges between 3% and 15% [3,4]. In Poland, *Artemisia* species pollen is one of the main causes of pollinosis in summer and is responsible for most seasonal rhinitis symptoms during August [5,6].

The genus *Artemisia* includes 57 species in Europe [7]. In the city of Poznan 5 of them are present, although only *Artemisia vulgaris* L, *Artemisia campestre* L, and *Artemisia absinthium* L are significantly represented [8] (Figure 1). *A vulgaris* is by far the most common species in the city. Poznan is located in western Poland and has a population of 600 000 inhabitants. It is estimated that about 15% of the population have symptoms related to pollen allergy [9].

Previous studies revealed that this pollen type was one of the most frequent in the Poznan atmosphere during summer [10]. Allergy symptoms against mugwort pollen usually appear in the Poznan population at a concentration higher than 5 gr/m^3/d [9]. Nevertheless, little is known about the real impact of this pollen type on the allergy sufferers of the area or about its aerobiological behavior and trends. The present study aimed to shed light on these questions by means of the analysis of 4 main objectives: 1) to determine the number of allergic patients in Poznan sensitized to mugwort pollen allergens and their levels of specific immunoglobulin (Ig) E in serum; 2) to examine the variations in the length of the *Artemisia* species pollen season and therefore its start, peak, and end dates over time; 3) to determine the relationship between the annual pollen index and late spring meteorological conditions; and 4) to determine the influence of daily meteorological conditions on daily *Artemisia* species pollen variations.

Material and Methods

Study Area

Poznan is located in Western Poland (52° 25’ north, 16° 53’ east). It is situated 80 m above sea level. The mean annual precipitation is below 500 mm and the average yearly temperature is 8.5ºC. Average January and July temperatures are –1.4ºC and 19.2ºC, respectively. Prevailing wind directions are from the west and southwest. The Institute of Meteorology and Water Management supplied Poznan meteorological data from a station located 1.5 km west of the aerobiological station (Figure 1).

Aerobiological Monitoring

A Burkard (Rickmansworth, UK) 7-day Hirst-type volumetric spore trap was used. In 1995, it was placed 36 m above the ground level on a building located in the city center. From 1996 until the present, it has been located on the medical sciences building of the university, 1.5 km from the city center (Figure 1).

The sampling management procedure was proposed by the International Association for Aerobiology. The samples from 1995 to 1999 were counted following the rules proposed by the British Aerobiology Federation, a transverse traverse method. From 2000 until now, the Spanish Aerobiology Network (REA) rules have been used. This is a longitudinal traverse method and was adopted following the recommendations of Cariñanos et al [11]. These authors did not discover statistically significant differences in daily concentrations of samples counted by the 2 methods but they demonstrated that the REA method was more reliable for the hourly analysis of concentrations during 24-hour sampling periods.

The start of the pollen season was defined according to Garcia-Mozo et al [12] as the day on which 1 pollen gr/m^3 had been reached for 5 days and when subsequent days contained 1 or more pollen gr/m^3. The end of season was the last day on which 1 pollen gr/m^3 was recorded and when subsequent days presented concentrations below this level. The pollen index is the average daily number of pollen grains per cubic meter recorded during the pollen season.

Statistical Analysis

For identifying patterns in the time series, data trend analysis was used. The Spearman nonparametric correlation test was used to detect the possible relationship between the *Artemisia* species pollen index and fortnightly meteorological parameters (average mean and maximum temperature and cumulated rainfall). We also sought to detect the influence of daily meteorological parameters (maximum, minimum, and mean temperature, rainfall, humidity, sunshine hours, cloudy hours and wind velocity) on daily pollen concentrations, examining each year separately and for all 10 years together.

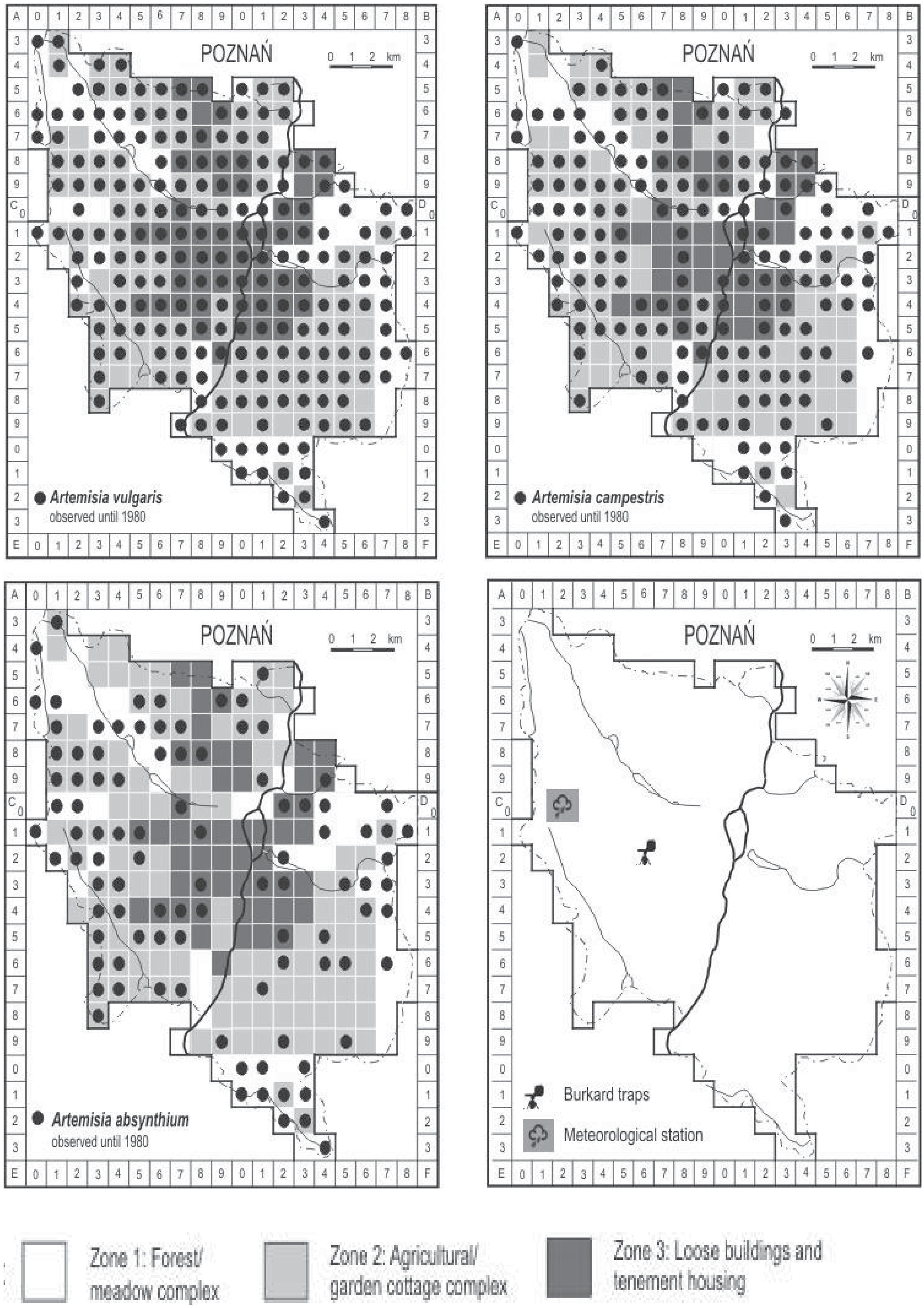

Figure 1. Distribution maps for the 3 most frequent *Artemisia* species in Poznan, Poland. Adapted from Jackowiak [8].

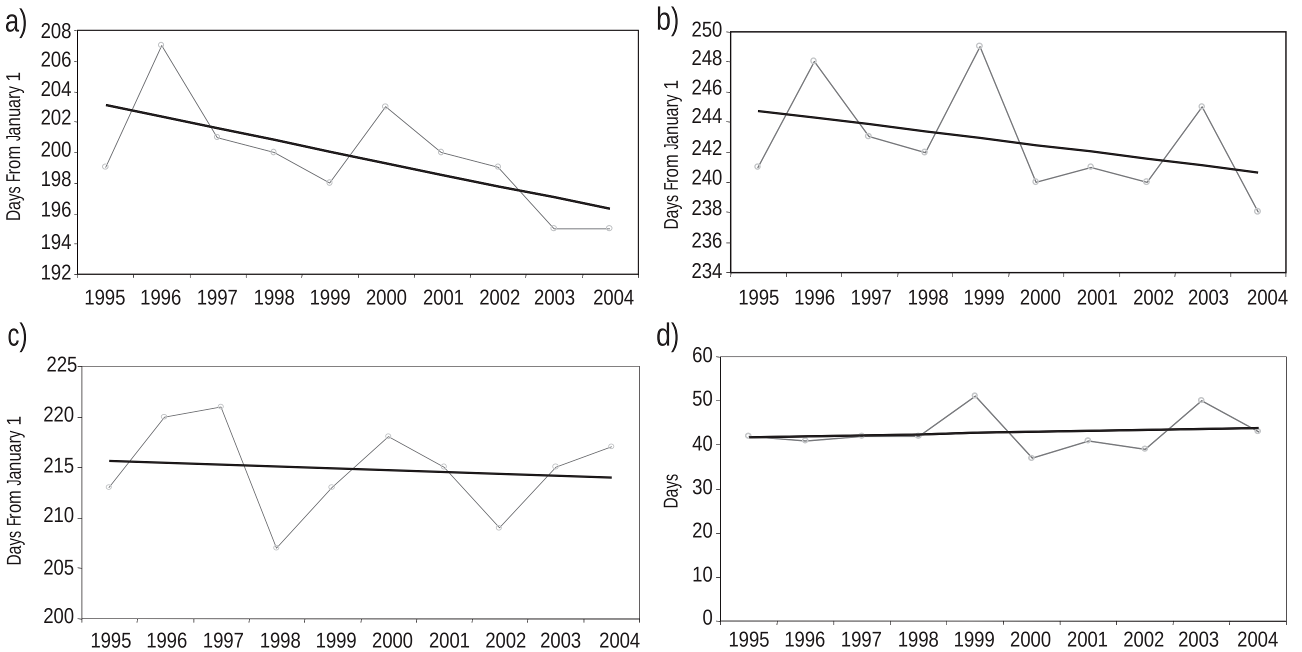

Figure 2. *Artemisia* species pollen season dates during the study period (1995-2004) in the city of Poznan, Poland: a) season start date; b) season end date; c) peak day; d) season length. Trend equations are plotted by the linear equation shown in each graph.

Statistical analyses were performed by using the STATISTICA 6.0 software (Tulsa, Oklahoma, USA).

Clinical Study

Clinical studies were performed at the Allergic Diseases Diagnostic Center of the University of Medical Sciences in Poznan during 2002, 2003, and 2004. The allergy diagnostic procedures consisted of 2 different analyses. Firstly, skin prick tests (SPT) were performed on a total of 676 patients showing symptoms of airborne allergen sensitivity. Patients were residents in the city of Poznan and the surrounding area. *A vulgaris* allergen extract (Nexter Allergopharma, Berlin, Germany) was used for the SPTs. Secondly, serum for the measurement of *Artemisia* species specific IgE antibodies were collected from 524 patients. Specific IgE level was measured using 2 methods: fluorescent enzyme immunoassay (FEIA) (CAP System FEIA Pharmacia, Uppsala, Sweden) and enzyme-linked immunoassay (ELISA) (Nexter Allergopharma).

Results and Discussion

Pollen Season

The main *Artemisia* species pollen season usually started in the second 10 days of July and lasted to the end of August. The peak day usually took place at the beginning of August, coinciding with other observations in northwest Europe [3] and in many other parts of Poland [13]. Nevertheless, trend analysis showed a strong advance in the pollen season start dates (Figure 2a). This advance was also detected, to a lesser extent, for the end dates of the season (Figure 2b) and for the peak day (Figure 2c). An increase in the *Artemisia* species season length was therefore being recorded in the area of Poznan (Figure 2d). Annual tendencies in meteorological factors recorded during late spring and summer (May to August) showed a gradual increase in temperature, except for the years 2003 and 2004, and a decrease in rainfall (Figure 3). Those climate trends reflect the general climate change trend in Europe during recent decades [14]. This change in climate could be affecting the *Artemisia* species pollen season dates in the city of Poznan. The consequences of these changes in pollinosis sufferers can be important, due to the longer period of risk. Many authors have produced evidence to suggest that climate change has already had an impact on aeroallergens [15-18], including studies suggesting longer pollen seasons in spring flowering herbaceous species [19-22]. Our results agree with these studies on herbaceous plants and also with the second main conclusion presented by the World Health Organization related to climate change impact on the phenology of allergenic plants: 1) “an earlier start and peak of the pollen season is more pronounced in species that start flowering earlier in the year,” and 2) “the duration of the season is extended in some summer and late summer flowering species” [23].

Pollen Index

Figure 4 shows pollen index variations that range from 3454 in 1996 to 353 in 2002. After *Urtica* and *Poaceae* species,

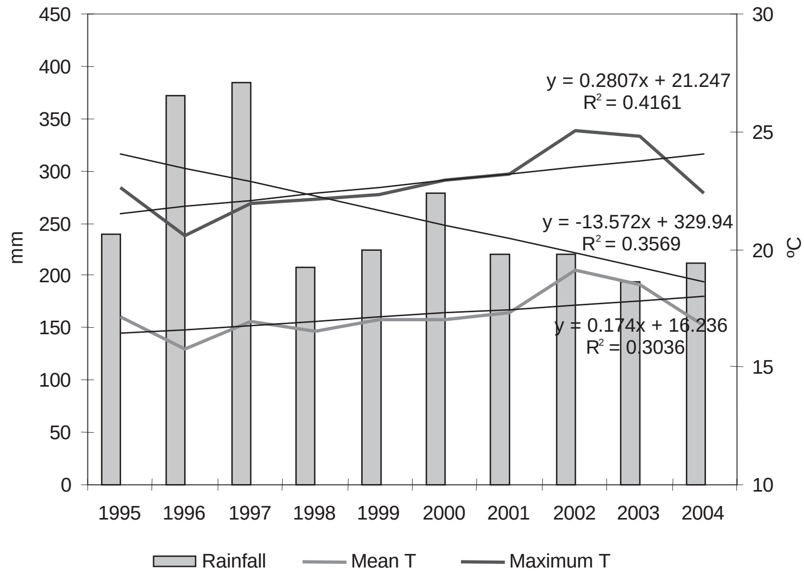

Figure 3. Four-month (May to August) meteorological data. Average mean and maximum temperatures, and total rainfall. Trend equations are plotted by the linear equation shown in each graph. T indicates temperature in degrees Celsius.

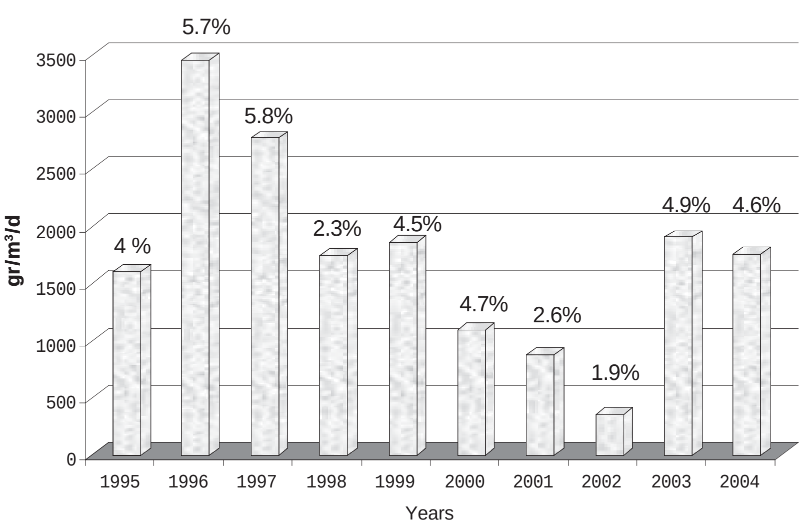

Figure 4. *Artemisia* species pollen index variation during the study period (1995-2004). Annual percentage of *Artemisia* species pollen over the total pollen spectrum of Poznan, Poland, is also indicated on the histogram.

Artemisia species was the third most frequent herbaceous pollen type in the air, representing an average of 4% of the total pollen spectrum. *Artemisia* species pollen concentrations were higher in Poznan than in other investigated areas of Poland, such as Krakow [24], Lublin [25], Szczecin [26], or Ostrowiec [13]. During the present study, the maximum percentage was recorded in 1997 (5.8%) and the minimum one in 2002 (1.9%). From the start of the study to the year 2002 the *Artemisia* species pollen index tended to decrease. However, between 2002 and 2004, pollen concentrations seem to be recovering.

Higher pollen indexes were detected in years when the maximum temperature was between 22°C and 25°C during this 4 month period. Note that the 2 years with the highest pollen counts (1996 and 1997) also recorded the highest amount of rainfall (about 380 mm) during the preceding 4 months. In years with low rainfall, 220 mm in 2002, and high maximum temperature, 27 °C, the pollen index was extremely low. Spearman nonparametric correlations did not reveal many significant results (Table 1), nevertheless it is possible to observe that temperatures usually had a negative influence (inverse correlation) on the annual pollen index, whilst rainfall recorded in the months prior to flowering exerted a positive influence (direct correlation) on the index. The meteorological factor with the most positive effect on pollen season severity was rainfall recorded in the first fortnight of July. Lower rainfall recorded during the years studied could explain the decrease in the detected *Artemisia* species pollen concentrations. The influence of rainfall in preceding months has been shown to be important on the pollen emission of other herbaceous species such as *Poaceae* species [27]. On the other hand, new buildings in semi-rural areas near the trap from the year 2000 onward could have resulted in a decrease in the number of *Artemisia* species plants and therefore in a consequent pollen concentration decrease.

Table 1. Spearman Correlation Coefficient Between Fortnight Meteorological Parameters and Annual *Artemisia* species Pollen Index

	Mean Temperature		Max Temperature		Rainfall	
Month	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight	First Fortnight	Second Fortnight
May	–0.527	–0.334	–0.600	–0.369	0.260	0.042
June	0.430	–0.454	0.430	–0.534	0.587	0.212
July	–0.224	–0.369	–0.478	–0.115	0.769*	0.212*
August	0.006	–0.248	–0.054	–0.321	–0.284	–0.127

*$P < .05$

Daily Pollen Concentrations

The *Artemisia* species pollen season showed a short and homogeneous curve over the years (Figure 5). The period just before the peak is usually short and the curve rises very quickly whereas the period after the peak is longer and has small fluctuations probably due to the resuspension of pollen grains. The homogeneous shape of the average curve suggests that a single species could be responsible for the emission of most of the airborne *Artemisia* species pollen in the area. In other areas where several *Artemisia* species contribute in a similar proportion to the airborne pollen spectrum several peaks are usually found [28,29]. In-situ phenological surveys around the city indicated *A vulgaris* to be the most abundant species in the area, and its flowering period coincided with the *Artemisia* species pollen season recorded by the aerobiological trap.

Temperature was positively correlated with daily atmospheric pollen concentrations of *Artemisia* species (Table 2). Conversely, rainfall and relative humidity usually were usually inversely correlated with concentrations, especially in years when high precipitation was recorded. Similar results were observed in Szczecin, Poland, and Murcia, Spain [26,28]. In some years, our analyses showed a direct correlation between the number of sunshine hours and concentrations and a negative correlation between the number of cloudy hours and concentrations; nevertheless both correlation coefficients were low. In days when a high wind speed was recorded, the pollen concentration was lower (Table 2). Table 3 shows the dominant wind directions recorded in Poznan during the peak pollen day and the preceding and following 5 days. Winds coming from the east and northeast were dominant on the peak pollen days. In that direction it is possible to find old and abandoned factories and also a wide area of railway embankments where *A vulgaris* is abundant. Other authors in Europe have also indicated the high influence of wind on the aerobiological behavior of *Artemisia* species pollen [30,31].

Clinical Study

A total of 721 individuals were studied; 676 of them had symptoms of airborne allergy. Table 4 shows the SPT results during different years. The percentage of patients sensitized to *A vulgaris* pollen allergens in the city of Poznan was very similar during the 3 years of study at approximately 12%. The 676 patients with airborne allergy symptoms was comprised of 306 patients suffering from rhinitis and conjunctivitis, 187 from atopic dermatitis, 85 from asthma, 77 from disseminated eczema, and 21 from chronic urticaria. The results of SPTs on these patients revealed that a considerable percentage of them were sensitized to *A vulgaris* pollen allergens (Table 5); the sensitized patients were mainly those suffering chronic urticaria, rhinitis and conjunctivitis and atopic dermatitis.

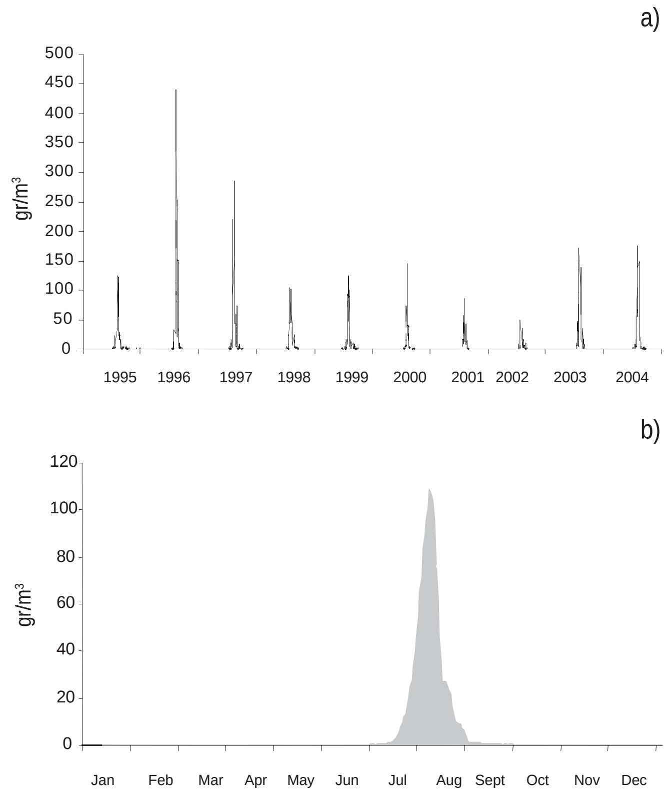

Figure 5. a) Daily variation of *Artemisia* species pollen in Poznan, Poland, during the study years (1995-2004); b) 10-year average pollen season curve.

The results of allergen specific IgE serum level measurements performed on 524 patients showed that 53 out of 524 patients (10.1%) were sensitized to *Artemisia* species pollen allergens. Fluorescent enzyme immunoassay and ELISA revealed the presence of specific IgE against mugwort pollen allergens in 24 out of the 181 studied patients (13.2%) in 2002, in 12 of 96 patients (12.5%) in 2003, and 17 of 247 (6.8%) in 2004.

Table 2. Spearman Correlation Coefficients Between Daily Meteorological Parameters and Daily Pollen Concentrations for the Main *Artemisia* Species Pollen Season

Year	Mean Temperature	Maximum Temperature	Minimum Temperature	Rainfall	Relative Humidity	Sunshine Hours	Cloudy Hours	Wind Velocity
1995	0.518*	0.504*	0.503*	–0.052*	–0.272*	0.283*	–0.184*	–0.149*
1996	0.114	0.160	–0.108	–0.499*	–0.617*	0.367*	–0.236	–0.039
1997	0.308*	0.284	0.112	–0.361*	–0.454*	0.092	–0.098	0.139
1998	0.253	0.275	0.020	–0.314*	–0.196	0.298	–0.323*	–0.361*
1999	–0.067	–0.228	–0.064	0.193	0.113	–0.208	0.135	0.216
2000	0.605*	0.564*	0.373*	–0.204	–0.549*	0.348	–0.255	–0.048
2001	0.330*	0.396*	–0.050	0.044	–0.339*	0.125	–0.181	–0.342*
2002	0.303*	0.329*	0.235	0.134	–0.218	0.049	–0.018	–0.088
2003	0.344*	0.285	0.337*	0.167	0.147	–0.022	0.079	0.127
2004	0.524*	0.415*	0.391*	0.066	0.029	0.247	–0.141	–0.509*
1995-2004	0.518*	0.504*	0.503*	–0.0518*	–0.271*	0.283*	–0.184*	–0.149*

*$P < .05$

Table 3. Wind Directions on the *Artemisia* Species Pollen Peak Day and the Preceding and Next 5 Days

Year	Preceding 5 Days	Peak Day	Next 5 Days
1995	E, E, E, E, NE	NE	N, C, W, N, E
1996	NW, C, NE, NE, E	E	E, E, E, E, E
1997	C, N,N, NE, E	E	E,E,NE, NW, W
1998	SE, W, SE, W, N	E	E, NW, W,SW, SW
1999	N, NE, NE, NE, E	NE	NE, E, E, SW,W
2000	W, S, W, E, N	NE	W, W, W, S, W
2001	E, W, W, NW, E	S	SW, W, W, SW, S
2002	W, SW, W, SW, S	E	E, NE, E, E, W
2003	NW, N, N, N, NW	E	N, N, N, C, NW
2004	C, NW, NW, W, NE	E	E, E, E, NE, NE

*E indicates east; N, north; W, west, C, calm

Table 4. Patients With Positive Skin Prick Tests (SPT) to *Artemisia vulgaris* Pollen in 2002, 2003 and 2004 in Poznan, Poland

Year	Patients	Patients With Positive SPT for *Artemisia vulgaris*	Patients With Negative SPT for *A vulgaris*	Percentage
2002	179	19	160	11%
2003	122	15	107	12%
2004	420	45	375	12%
Total	721	79	588	11.6%

Table 5. Patients With Positive Skin Prick Tests (SPT) to *Artemisia vulgaris* Pollen, by Allergy Symptoms, in the Studied Population of Poznan, Poland

Allergy Symptoms	Patients	Patients With Positive SPT	Percentage
Rhinitis and conjunctivitis	306	45	15.0%
Atopic dermatitis	187	28	15.0%
Bronchial asthma	85	2	2.4%
Dermatitis, facial or disseminated	77	1	1.3%
Chronic urticaria	21	3	14.3%

The results of serum allergen specific IgE measurements in relation to *Artemisia* species pollen allergens were expressed as antibodies class ranging from 0 to 6. In an overall analysis for 2002–2004, 3% of patients sensitive to *Artemisia* species had specific IgE measurements in class 1 (≥0.35 and <0.7 kU/L), 45% of patients were in class 2 (≥0.7 and <3.5 kU/L), 28% were in class 3 (≥3.5 and <17.5 kU/L), 13% were in class 4 (≥17.5 and <50 kU/L), and 11% were in class 5 (≥50 and <100 kU/L).

Results obtained in our study agree with other authors' research in Europe. In Poland, it was found that 15% of 1107 Polish soldiers analyzed in 1988–1990 had positive SPTs to *Artemisia* species pollen allergens [32]. Moreover, intradermal tests with *Artemisia* species pollen allergens were positive in 30 out of 50 examined patients suffering from seasonal asthma, and positive in 37% of patients hospitalized in an ear–nose–throat clinic in Warsaw [32]. Sensitization to mugwort pollen allergens was confirmed in 198 of 1311 investigated atopic patients (15.1%) evaluated over 15 years at Aristotle University in Thessaloniki, Greece, [33]. This frequency is similar to the prevalence observed in Belgium, where it has remained almost unchanged for the last 15 years [34].

Despite unquestionable progress in allergology and immunology in recent years, the etiopathogenesis of atopic diseases remains partially unclear, especially with regard to atopic dermatitis and asthma. There has been an alarming increase in the prevalence of atopic diseases in the past 2 decades and they are becoming a serious social problem in European countries, including Poland. Airborne pollen allergens are responsible for more than half of allergic diseases in Poland; pollinosis affects between a 10% and 30% of the Polish population, depending on region [35].

There is therefore a strong need for further investigation on the mechanisms and causes of atopic diseases in this country. Among many causative factors, pollen allergens are considered particularly important. In our study, mugwort pollen allergens sensitized 15% of patients suffering from atopic dermatitis and 15% of patients diagnosed with rhinitis and conjunctivitis. As a consequence these allergens should be considered in the diagnostic procedures of allergic diseases in the city of Poznan. Furthermore, *Artemisia* species pollen should be considered in pollen allergy studies throughout Poland. As found by other authors [5], aerobiological analysis is useful in guiding the management of pollen allergy.

Conclusions

Artemisia species pollen allergy is an important cause of pollinosis in the city of Poznan. The results indicate that the pollen season intensity is influenced by rainfall in the previous weeks. Changes on the amount of allergenic pollen, pollen allergenicity, plant distribution and pollen seasons are considered one of the more important ways that climate change has an impact on human health. Our study suggests that trends towards an earlier *Artemisia* species season start and a longer duration, possibly caused by climate change, may have an impact on the allergic population in the future.

Acknowledgments

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