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Original Research

Effects of Meteorological Factors and Air Pollution on Urban Pollen Concentrations

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Abstract

The presence of biological particles and non-biological pollutants in the atmosphere is closely related to the incidence of adverse reactions affecting human health. The present study demonstrates different effects of ambient air pollution and meteorological factors on pollen concentration of selected taxa in the atmosphere. The investigation was carried out in Szczecin, Poland, between 2006 and 2008 using the volumetric method (Lanzoni VPPS, Italy) and an automatic weather station (Vaisala, Finland). Statistically significant correlations between pollen counts and air pollution, as well as weather parameters, were noted; the strongest correlation is with the mean air temperature. Statistical correlation between pollen concentration and air pollution factors was found to be a consequence of the relation between the latter and meteorological conditions.

Keywords: pollen, allergens, meteorological parameters, air pollution, canonical correspondence analysis (CCA), Szczecin, Poland

Introduction

Numerous experimental and epidemiological studies have shown that air pollutants may evoke airway sensitization by modulating the allergenicity of airborne allergens. Furthermore, an individual's response to pollution exposure depends on the source and contamination components as well as meteorological factors [1-8]. Traffic-related pollutants such as ozone and nitrogen dioxide and particulate matter with size less than 10 µm have been linked to allergic responses and asthma exacerbation [9-12]. Some air pollution-related incidents with inhaled allergy aggravation are conditioned not only by the increased concentration of air pollution, but by weather parameters that favour the accumulation of air pollution at ground level. In addition, pollen grains react with air pollution and environmental conditions and influence plant allergenicity. Evidence suggests that microorganisms occurring on the pollen grains play a relevant role in the etiopathogenesis of pollinosis. On the allergenic pollen of anemophilous plants a mixed bacterial flora, bacterial endotoxin and a mixed fungal flora are present. Fungi and their products, similar to bacteria, can cause allergic and immunotoxic reactions [9, 13].

The pollen seasons of the taxa-producing pollen at the turn of winter and spring and in early spring show the greatest variability because of the much pronounced changes in the meteorological factors in that time. The pollen seasons of the taxa flowering and pollinating in late spring and summer are much less variable as the weather conditions are stabilized, and because of their dependence on the photoperiod [14, 15].

The aim of this study is to analyze the relationship between meteorological factors, air pollution, and the concentrations of selected taxa pollen in the atmosphere of Szczecin and identification of groups of taxa characterized by a similar course of phenologic phenomena.

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Materials and Methods

Data and Study Site

The city of Szczecin is located in northwestern Poland, on the Odra River, south of Szczecin Lagoon and the Bay of Pomerania. The city is situated along the south-western shore of Dąbie Lake, on both sides of the Odra and on several large islands between the western and eastern banks of the river. It has a mild climate: average annual temperature is 8.4ºC, annual mean relative humidity ranges between 70% and 77%, and rainfall is mainly concentrated in summer. The average annual sum of precipitation in the period 1956-90 amounted to 528 mm. The average velocity of the wind in the years 1956-99 in Szczecin was 3.9 $m \cdot s^{-1}$. The municipal agglomeration causes a decrease in the speed of the winds as compared to areas outside the town [16].

Analyses of the pollen count distribution were performed on the basis of the data collected in Szczecin in the seasons of 2006-08. The measuring site was located in the city centre (53º26'26" N, 14º32'50' E), at an elevation of 21 m above ground level.

The pollen count was measured by the Hirst-type volumetric trap (model VPPS-2000 Lanzoni, Italy) [17]. The pollen concentration was expressed as the number of pollen $grains \cdot m^{-3}$ per 24 h.

The meteorological and air pollution data for the 3 years were provided by an automatic weather station (Vaisala, Finland), located in direct neighbourhood of the spore trap. The meteorological parameters taken into account in assessing the effect of meteorological conditions were: daily level of precipitation, wind speed, relative humidity, air temperature, and air pollution (ozone, sulphur dioxide, carbon dioxide, particulate matter PM_{10}, nitrogen dioxide).

Statistical Data Analysis

Relationships between airborne pollen taxa and environmental factors were analyzed with the CANOCO package v. 4.5 [18]. The pattern of pollen taxa composition was analyzed by canonical correspondence analysis (CCA), after detrended correspondence analysis (DCA) results detected a strong unimodal structure of the pollen data [19].

The selected meteorological and air pollution variables were included in the CCA. The environmental data were not required to be transformed but the pollen taxa date were transformed into the ordinal scale values in the following way: 1-2 pollen $grains \cdot m^{-3} \rightarrow 1$, 3-6 → 2, 7-11 → 3, 12-24 → 4, 25-49 → 5, 50-99 → 6, 100-199 → 7, 200-399 → 8, 400-799 → 9, and ≥800 → 10; the values were assigned according to the scale for pollen calendars [20]. Canonical ordination techniques are designed to detect the patterns of variation in the pollen taxa data that can be explained by the observed environmental variables. The resulting ordination diagram expresses also the main relations between the species and each of the environmental variables. The pollen taxa are positioned as points in the CCA diagram. The environmental variables are represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of changes and can be interpreted in conjunction with the pollen taxa point as follows. Each arrow determines an axis in the diagram and the pollen taxa points must be projected onto this axis. These projection points estimate the position of the optimum for the distribution of each pollen taxon along each environmental variable. The pollen-environment correlation coefficients with the ordination axes, as well as the correlation between the environmental variables and the ordination axes were used to interpret the CCA results. The relative importance of each environmental variable for the prediction of pollen taxa composition along the CCA axes can be inferred from the signs and relative magnitude of the correlation coefficients; this magnitude is related to the rate of changes in pollen taxa composition [19]. The relative importance of each environmental variable in pollen composition was assessed by the forward selection of explanatory variables. A Monte Carlo permutation test was used to select the most important variables that explain variations in the data set ($p \leq 0.05$). Tests of significance of the first and all canonical axes were evaluated for the statistical assessment of the relation between pollen taxa and environmental variables [18].

The degrees of correlation between particular meteorological and air pollution parameters were described by the Spearman's rank correlation coefficient due to the presence of non-normality and non-linearity in the data set. Furthermore, pollen counts were log(x+1) transformed in order to normalize their distribution and linearize their dependences on meteorological parameters and pollution. Then the analysis was applied using Statistica software version 9.0 [21]. Statistical error risk was estimated at the significance level of 95%, $\alpha \leq 0.05$.

Results

Variation in the onset and duration of the pollen seasons is greater the earlier a given plant produces flowers. In spring the course of the pollen season is most dependent on weather, in particular on air temperature. The composition of the groups of taxa (clusters) of similar or the same course of phenological phenomena is the least stable for the plants flowering from January to March/April. For these taxa the greatest deviations from the group composition were noted, especially in relation to high gradients of weather factors (Figs. 1, 2).

The Spearman's rank correlation analysis between meteorological factors and pollutants showed some correlations of rather low strength (Table 9). Statistical correlation between pollen concentration and air pollution factors was found to be a consequence of the relation between the latter and meteorological conditions.

Pollen Taxa vs. Meteorological Parameters

Linear combinations of the environmental variables used in the ordination (assignment) of these variables are represented by the canonical axes. The eigenvalue of the first ordination axis was high in all years studied, relative to the same parameters for the other axes. This finding justifies the presence of a single main gradient determining the differentiation in the composition of the plant taxa groups. Variation in the pollen taxa composition, explained by all canonical axes (sum of all canonical eigenvalues: 0.8-1.0), represented 27.5-29.7% of the total variance in the pollen data set (sum of all eigenvalues: 3.0-3.6) (Table 1).

In the pollen taxa-environment relations, four meteorological variables (DP, TME, RH, WINDME) were identified as significant ($p \leq 0.05$) after CCA and Monte Carlo permutation test. The forward selection of explanatory meteorological variables demonstrated that the temperature had the largest contribution to the total variation of the pollen taxa composition: in 2006 and 2007 – DP (explained 18.8-21.7% of total variation), in 2008 – TME (explained 17% of total variation). The other determinants of the pollen taxa distribution were: relative humidity (explained 0.1-7.2% of total variation) and the weakest – daily mean wind speed (explained 0.1-3.2% of total variation) (Tables 2, 3).

According to intra-set correlations (r) of meteorological standardized variables with the first two axes of CCA, the first axis was defined by temperature (for DP – r reaching absolute values 0.81-0.87, for TME – 0.79-0.85) and the second axis by the relatively humidity (r=0.44-0.58) (Table 4). First axis and all canonical axes were significant in all three years as tested by the unrestricted Monte Carlo permutation test (in all cases p=0.002).

The dispersion of the pollen taxa in the CCA ordination diagram indicated some clusters (Fig. 1). Following the gradient of increasing temperature represented by the DP and TME arrows, the first cluster contained the pollen taxa: Chenopodiaceae, *Artemisia*, and *Urtica* related to high or moderate temperature. The second cluster contained the pollen taxa *Plantago*, *Tilia*, Poaceae, *Rumex*, *Secale*, and *Pinus* found at moderate temperature in all three years. The third cluster contained the pollen taxa *Aesculus*, *Platanus*, *Quercus*, *Rosa*, and *Morus,* which reached their optima with low or moderate temperature. The fifth cluster contained the pollen taxa *Alnus*, *Corylus*, *Ulmus*, *Salix*,

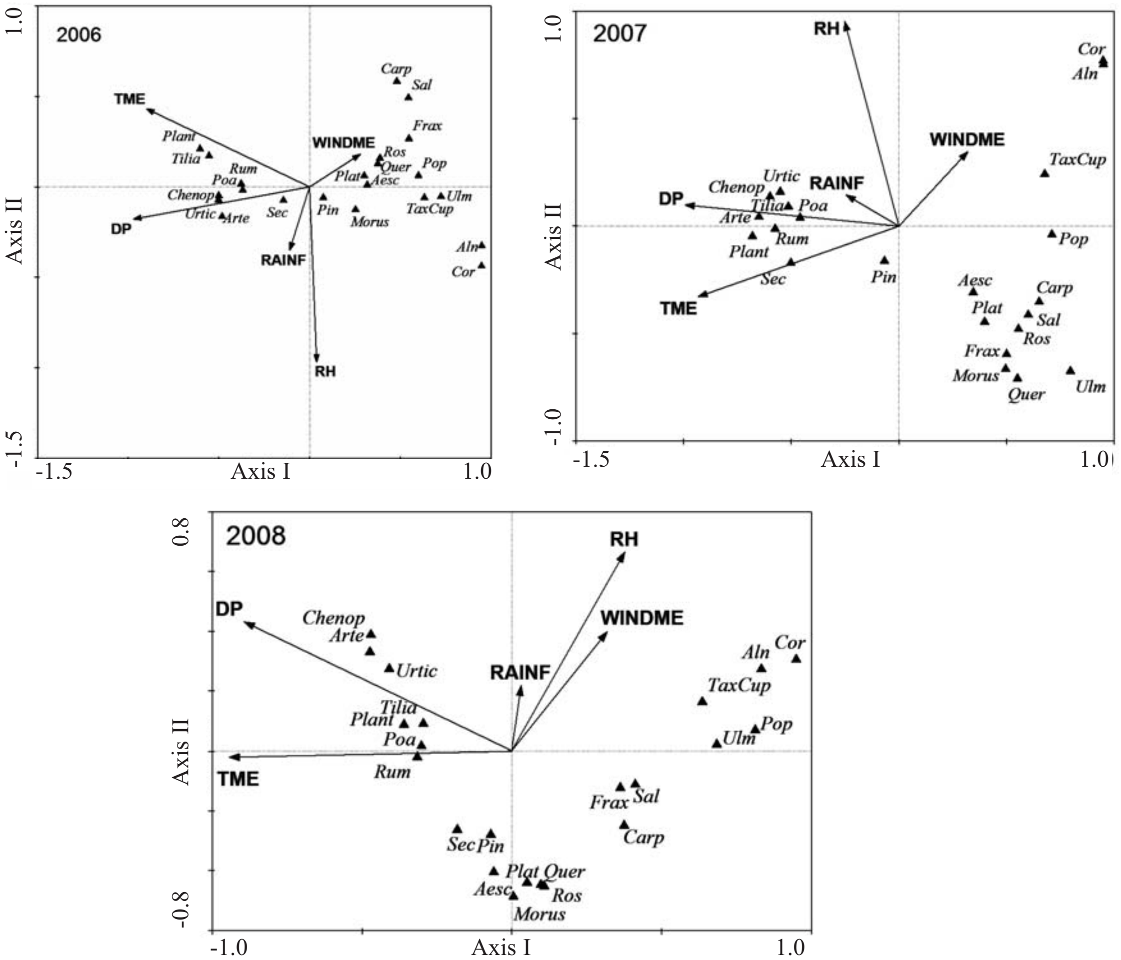

Fig. 1. Diagrams of pollen taxa and meteorological variable ordination on the first two CCA axes for the samples collected in 2006-08 in Szczecin (NW Poland).

Abbreviations used are as follows: meteorological factors: DP – dew point temperature, RAINF – rainfall, RH – relative humidity, TME – average air temperature, WINDME – average wind speed; Aesc – *Aesculus*, Aln – *Alnus*, Arte – *Artemisia*, Bet – *Betula*, Carp – *Carpinus*, Cor – *Corylus*, Chenop – Chenopodiaceae, Frax – *Fraxinus*, Morus – *Morus*, Pin – *Pinus*, Plant – *Plantago*, Plat – *Platanus*, Poa – Poaceae, Pop – *Populus*, Quer – *Quercus*, Ros – Rosaceae, Rum – *Rumex*, Sal – *Salix*, Sec – *Secale*, TaxCup – Taxaceae/Cupressaceae, Ulm – *Ulmus*, Urtic – *Urtica*.

Taxaceae/ Cupressaceae, *Populus*, *Carpinus* and *Fraxinus,* connected with the lowest values of DP and TME in all three years.

Following the gradient of increasing relative humidity, represented by RH arrow, the first cluster contained the pollen taxa *Alnus*, *Corylus*, Taxaceae/Cupressaceae, and *Populus,* which were connected with high or moderate relative humidity. The second cluster contained the pollen taxa Chenopodiaceae, *Artemisia*, *Urtica*, Poaceae, and *Rumex,* which reached their optima with moderate relative humidity in all three years. The third cluster contained the pollen taxa *Fraxinus*, *Carpinus*, *Salix*, *Morus*, *Rosa*, *Quercus*, *Platanus*, *Aesculus*, *Pinus*, *Secale*, *Tilia*, and *Plantago*, which occurred at low or moderate relative humidity. The remaining pollen taxon, *Ulmus,* occurred at moderate relative humidity in 2006, at low value of RH in 2007, and at high value of RH in 2008. The influence of the daily mean wind speed on the composition diversity of pollen taxa was similar to that of relative humidity, particularly in 2008.

Pollen Taxa vs. Air Pollution

Analysis of the influence of air pollutants on certain taxa has revealed two main gradients determining the variation in taxa group compositions in particular years. Variations in the pollen taxa composition, explained by all

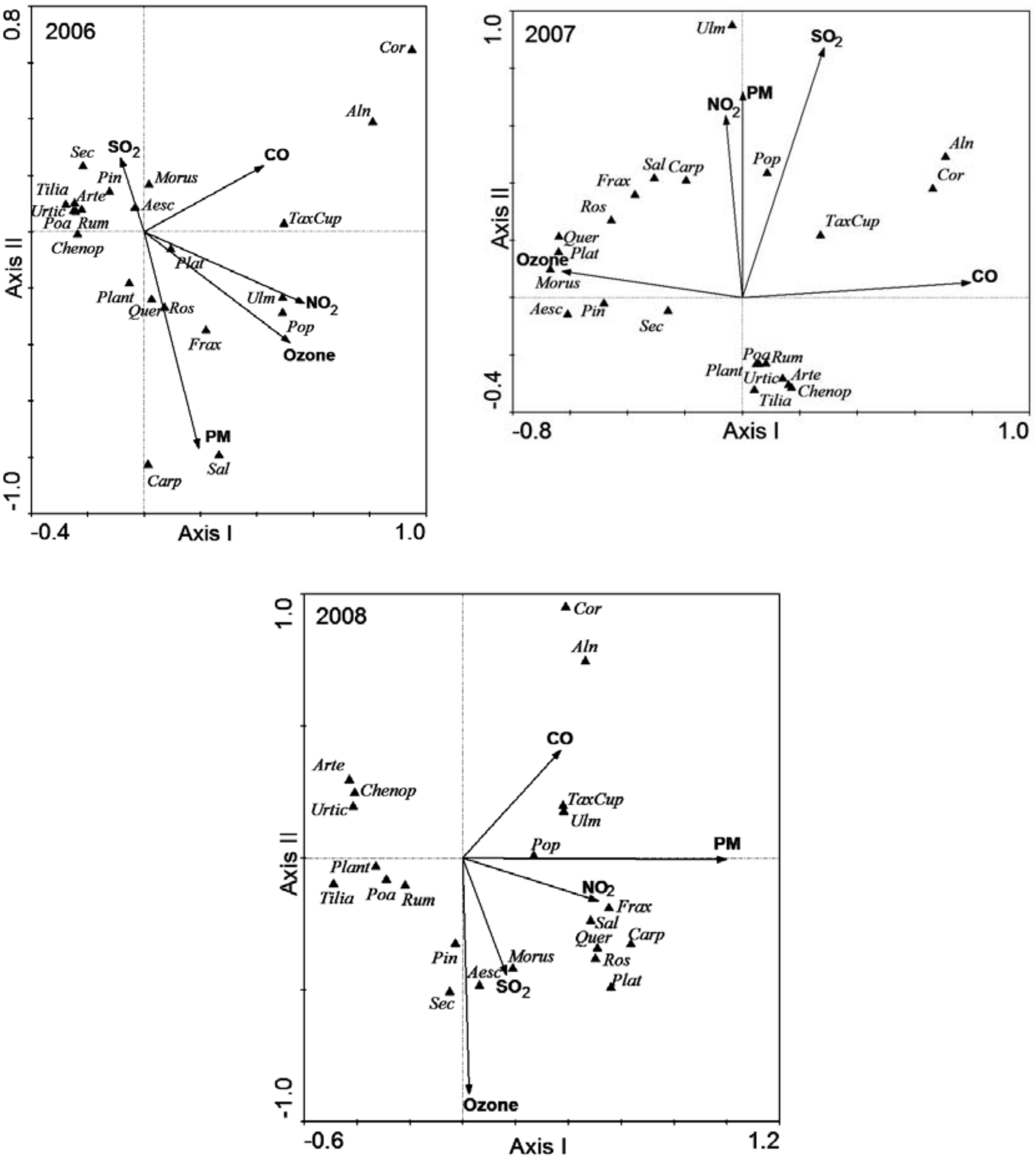

Fig. 2. Diagrams of pollen taxa and air pollution variables ordination on the first two CCA axes for samples collected in 2006-08 in Szczecin (NW Poland).

Abbreviations used are as follows: air pollution factors: CO – carbon oxide, NO_2 – nitrogen dioxide, Ozone – O_3, PM – particulate matter PM_{10}, SO_2 – sulphur dioxide, Aesc – *Aesculus*, Aln – *Alnus*, Arte – *Artemisia*, Bet – *Betula*, Carp – *Carpinus*, Cor – *Corylus*, Chenop – Chenopodiaceae, Frax – *Fraxinus*, Morus – *Morus*, Pin – *Pinus*, Plant – *Plantago*, Plat – *Platanus*, Poa – Poaceae, Pop – *Populus*, Quer – *Quercus*, Ros – Rosaceae, Rum – *Rumex*, Sal – *Salix*, Sec – *Secale*, TaxCup – Taxaceae/Cupressaceae, Ulm – *Ulmus*, Urtic – *Urtica*

Table 1. Pollen taxa vs. meteorological factors: summary of CCA for the samples collected in Szczecin (NW Poland).

	Axes	2006	2007	2008
Eigenvalues:	1	0.696	0.715	0.694
	2	0.087	0.268	0.241
	3	0.034	0.031	0.062
	4	0.010	0.017	0.025
Pollen taxa-environment correlations:	1	0.887	0.878	0.906
	2	0.451	0.607	0.644
	3	0.326	0.330	0.524
	4	0.209	0.337	0.338
Cumulative percentage variance of pollen taxa data:	1	23.0	20.0	20.0
	2	25.9	27.4	26.9
	3	27.0	28.3	28.7
	4	27.3	28.8	29.4
Cumulative percentage variance of pollen taxa-environment relation:	1	83.4	68.9	67.4
	2	93.9	94.7	90.8
	3	98.0	97.7	96.8
	4	99.2	99.3	99.2
Sum of all eigenvalues:		3.029	3.583	3.469
Sum of all canonical eigenvalues:		0.834	1.038	1.030

canonical axes (sum of all canonical eigenvalues: 0.5-0.8) constituted 16.7-23.7% of the total variance in the pollen data set (sum of all eigenvalues: 3.0-3.6) (Table 5). Statistical correlation between pollen concentration and air pollution factors was found to be a consequence of the relation between the latter and the meteorological conditions.

In pollen taxa-environment relations, five air pollutants (PM, NO_2, Ozone, CO, SO_2) were identified as significant ($p \leq 0.05$) after CCA and the Monte Carlo permutation test. The forward selection of explanatory meteorological variables demonstrated that ozone and PM had the largest contribution to the total variation of the pollen taxa composition in 2006 and 2008 (explained 5.3-6.6% and 3.9-8.9% of total variation, respectively), and in 2007 – CO and SO_2 (explained as 8.3% and 7.3% of total variation, respectively). The fifth determinant of pollen taxa distribution was NO_2 (explained 1.7-4.5% of total variation) (Table 6, 7).

The part of variation in the pollen data explained by the gradients of pollutant concentrations coincides with the part explained by climatic factors. Over the period of the three years of observation the strongest negative correlation concerned relative humidity and ozone concentration. Ozone concentration was also weakly positively correlated with temperature. The concentration of particulate matter was not particularly strongly negatively correlated with humidity and air temperature. The concentration of SO_2 was weakly negatively correlated with air temperature.

According to intra-set correlations (r) of air pollution, standardized variables with the first two axes of CCA, the first axis was defined in 2006 by ozone (r=0.31), and the second axis by the PM (r=-0.44), in 2007 – the first axis by CO (r=0.62), and the second axis by the SO_2 (r=0.50), in 2008 – the first axis by PM (r=0.62) and the second axis by ozone (r=-0.58) (Table 8). First axis and all canonical axes were significant in all three years as tested by the unrestricted Monte Carlo permutation test (in all cases p=0.002).

In the composition of pollen taxa in the CCA ordination diagram, there were groups whose composition changed dynamically over the three years of observation (Fig. 2). The most stable clusters were found in the ordination with respect to the concentration of PM and NO_2 in the air. The correlation between the concentrations of these pollutants was the strongest in all three years (0.49-0.59). At the highest PM in two years the most abundant was the pollen *Carpinus*, while low PM values were accompanied by the highest concentrations of *Secale* and Chenopodiaceae, *Urtica*, *Artemisia*, *Tilia*, *Rumex*, Poaceae, *Plantago*, and *Pinus*.

High concentrations of NO_2 occurred together with high pollen counts of *Salix* and *Populus*, *Ulmus*, *Corylus*, *Alnus*, Taxaceae/Cupressaceae, *Fraxinus*, *Rosa*, *Platanus*, and *Quercus*. High concentrations of ozone were related to the abundant presence of pollen from *Salix*, *Morus*, *Platanus*, *Quercus*, *Aesculus*, *Rosa*, *Carpinus*, *Pinus*, and *Secale*. High concentrations of CO were accompanied by the abundant presence of pollen from *Corylus* and *Alnus*, while moderate

Table 2. Pollen taxa vs. meteorological factors: forward selection results with the test of variables significance (*p≤0.05).

Variable	Var. N	Lambda A			p			F		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
DP	2	0.66	0.71	0.07	0.002*	0.002*	0.002*	46.58	56.23	6.62
TME	1	0.11	0.03	0.62	0.002*	0.004*	0.002*	8.07	2.89	49.53
RH	3	0.03	0.26	0.21	0.048*	0.002*	0.002*	2.16	22.84	17.33
WINDME	4	0.03	0.02	0.11	0.036*	0.050*	0.002*	2.05	1.86	10.01
RAINF	5	0.00	0.02	0.02	0.826	0.214	0.128	0.53	1.36	1.51

Table 3. Pollen taxa vs. meteorological factors: percentage of significantly explained pollen data variation ($p \leq 0.05$).

Variable	Significantly explained pollen data variation [%]		
	2006	2007	2008
DP	21.7	18.8	2.0
TME	3.6	0.8	17.0
RH	0.1	7.2	6.0
WINDME	0.1	0.5	3.2
Σ	25.5	27.3	29.1

concentrations of CO – by the abundant presence of pollen from Taxaceae/Cupressaceae, *Ulmus*, and *Populus*. At the highest SO_2 concentrations, the maximum abundance of pollen from *Corylus* and *Secale* was observed, while at the lowest SO_2 concentrations the abundant presence of pollen from Chenopodiaceae, *Artemisia,* and *Urtica* was noted.

The strongest correlated variables excluded from CCA were: daily average temperature, daily maximum and minimum wind speed, NO, NO_2. The correlations between the pollen counts of the taxa analyzed and the air pollutants are a consequence of the effects of weather factors on these two groups of variables. Therefore, the exacerbation of allergic symptoms in pollinosis sufferers should be considered from the aspect of synergic effects of pollen allergens and the presence of air pollutants.

Table 5. Pollen taxa vs. air pollution: summary of CCA for the samples collected in Szczecin (NW Poland).

	Axes	2006	2007	2008
Eigenvalues:	1	0.259	0.448	0.310
	2	0.158	0.300	0.271
	3	0.058	0.069	0.095
	4	0.022	0.022	0.020
Pollen taxa-environment correlations:	1	0.552	0.776	0.619
	2	0.573	0.577	0.649
	3	0.457	0.469	0.476
	4	0.307	0.317	0.309
Cumulative percentage variance of pollen taxa data:	1	8.6	12.5	8.9
	2	13.8	20.9	16.7
	3	15.7	22.8	19.5
	4	16.4	23.4	20.1
Cumulative percentage variance of pollen taxa - environment relation:	1	51.4	52.9	44.0
	2	82.7	88.4	82.5
	3	94.2	96.5	95.9
	4	98.6	99.1	98.8
Sum of all eigenvalues:		3.029	3.583	3.469
Sum of all canonical eigenvalues:		0.505	0.849	0.704

Discussion

The beginning of pollen season with trees flowering in early spring depends mainly on the nonlinear equilibrium between winter cold and the warmer spring temperatures needed for breaking the winter rest/dormancy [22]. Dynamics of composition changes in individual groups of taxa observed in the CCA ordination diagram in this study concerned mainly the tree flowering and producing pollen in early spring. The main meteorological factor significantly and positively correlated with the appearance of pollen in early spring was air temperature. The significant effect of the mean air temperature on pollination was noted also in subsequent months, until early summer. In light of the results of the current analysis it will be necessary to assess the implication of earlier seasons for allergy suffersers, also in relation to increasing the presence of air pollutants in industrial areas and in large cities.

The effect of meteorological factors varied among seasons. Similar results emerged from a canonical correspondence analysis (CCA) conducted in the Kitchener-Waterloo area [23]. The average values of the meteorological parameters were generally more important than maximum and

Table 4. Canonical coefficients and intra-set correlations of meteorological standardized variables with the first two axes of CCA.

Variable	Regression coefficients						Correlations					
	2006		2007		2008		2006		2007		2008	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
TME	0.06	0.60	0.91	3.24	1.22	2.21	-0.79	0.19	-0.82	-0.19	-0.85	-0.02
DP	-1.04	-0.51	-1.96	-3.59	-2.29	-1.50	-0.86	-0.08	-0.87	0.06	-0.81	0.28
RH	0.25	-0.60	0.52	2.48	1.39	1.74	0.03	-0.44	-0.22	0.58	0.34	0.42
WINDME	0.12	0.25	0.03	0.16	0.28	0.29	0.24	-0.08	0.28	0.21	0.29	0.26
RAINF	-0.03	-0.05	-0.09	-0.07	-0.12	-0.08	-0.09	-0.15	-0.21	0.09	0.03	0.14

Table 6. Pollen taxa vs. air pollution: forward selection results with the test of variables significance (*$p \leq 0.05$).

Variable	Var. N	Lambda A			p			F		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
PM	4	0.12	0.05	0.31	0.002*	0.004*	0.002*	6.83	3.57	22.06
NO_2	2	0.10	0.16	0.06	0.002*	0.002*	0.002*	5.72	13.02	4.21
Ozone	3	0.16	0.08	0.23	0.002*	0.002*	0.002*	10.19	6.51	17.51
CO	5	0.07	0.30	0.04	0.002*	0.002*	0.002*	4.42	21.27	3.77
SO_2	1	0.05	0.26	0.06	0.006*	0.006*	0.002*	3.61	19.13	5.30

Table 7. Pollen taxa vs. air pollution: percentage of significantly explained pollen data variation ($p \leq 0.05$).

Variable	Significantly explained pollen data variation [%]		
	2006	2007	2008
PM	3.9	1.3	8.9
NO_2	3.3	4.5	1.7
Ozone	5.3	2.2	6.6
CO	2.3	8.3	1.1
SO_2	1.6	7.3	1.7
Σ	16.4	23.8	20.0

minimum values [3, 24]. In the study reported in this paper, the meteorological parameters analyzed were also significantly correlated with the concentration of pollen in the air; strongest correlation was noted with mean air temperature.

Laaidi [25], with the help of multiple component analysis (MCA), studied the influence of different weather types on the concentration of *Betula* pollen and exacerbation of allergy symptoms and showed that pollination depends on many factors, including anticyclonic and windy weather, and low relative humidity. Additionally, there are some exceptional effects, some weather types being able to increase the number of clinical manifestations: an anticyclonic situation with fog in temperature inversion, not favourable to pollination, corresponded to the highest per-

Table 8. Canonical coefficients and intra-set correlations of air-pollution standardized variables with the first two axes of CCA.

Variable	Regression coefficients						Correlations					
	2006		2007		2008		2006		2007		2008	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
SO_2	-0.12	0.31	0.35	0.68	-0.07	0.20	-0.04	0.15	0.22	0.50	0.10	-0.29
NO_2	0.90	-0.14	-0.49	0.29	-0.01	-0.52	0.28	-0.14	-0.04	0.36	0.32	-0.11
Ozone	0.96	0.03	-0.37	-0.02	0.05	-0.95	0.31	-0.22	-0.49	0.05	0.01	-0.58
PM_{10}	-0.74	-0.96	-0.01	0.32	1.00	0.12	0.11	-0.44	0.00	0.41	0.62	-0.00
CO	0.289	0.66	0.80	-0.24	0.04	0.37	0.23	0.13	0.62	0.03	0.23	0.26

Table 9. Spearman's rank correlation analysis between meteorological factors and air pollutant concentrations in Szczecin (2006-08).

Faktors ($\mu g \cdot m^{-3}$)	SO_2	NO_2	O_3	PM_{10}	CO
Windmean ($m \cdot s^{-1}$)	0.05	-0.02	0.33*	-0.18*	-0.26*
Rain (mm)	-0.26*	-0.25*	-0.13	-0.24*	0.04
Humidity (%)	-0.39*	-0.31*	-0.32*	-0.13	0.19*
Tmean (ºC)	0.18*	0.13	0.20*	0.54*	0.08
Dew point (ºC)	-0.18*	-0.12	-0.12	0.50*	0.26*

*significant coefficients, $p < 0.05$.

centage of asthma, and strong winds corresponded to a high prevalence of conjunctivitis and asthma as a result of their irritant effect. Our study conducted in Szczecin has shown that a similar effect can be produced by air pollutants, although by themselves they do not cause an increase in the pollen concentration in the air, but their presence can lead to enhanced immunological response to the allergens present in the air.

A strong correlation between pollen concentration and the presence of air pollutants in the atmosphere is related to a significant effect of weather parameters on the content of ozone, sulphur oxides, nitrogen oxides, and particulate matter in the air. Investigation and recognition of the interrelationships between all the factors is hoped to permit avoidance of their accumulated allergy symptoms producing effect.

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