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Summary

The co-occurrence of airborne allergenic pollen grains and fungal spores was estimated in Rzeszów in the years 2000-2002. The volumetric method was used in this aerobiological study. Six taxa of pollen grains and five types of fungal spores characterized by strong allergenicity and/or high concentrations in the air were analyzed. The time series of pollen grains and fungal spores were compared using PCA analysis. The periods of the greatest concentrations of tree pollen did not coincide with similar periods for herbaceous plants and fungal spores. From February to mid-March, Alnus pollen dominated in the air. The second period was characterized by Betula pollen. It occurred in April. Herbaceous pollen and fungal spores occurred in the air simultaneously (from mid May to the end of August), creating a risky situation for sensitized people. The periods of the highest concentrations of Epicoccum and Ganoderma fungal spores did not coincide with the same period for the examined plant taxa. In Rzeszów the probability of becoming exposed to very high concentrations of allergenic pollen and fungal spores at the same time was high, especially in July, when the highest concentrations of Poaceae, Alternaria and Cladosporium were noted. The hypersensitivity to only one plant or fungal allergen is rarely encountered. Under the present scenarios of global warming, pollen seasons of many taxa will be longer and sufferers will have year-long symptoms.

Key words: aeroallergens, fungal spore, pollen, pollen season, threshold value

INTRODUCTION

Viruses, bacteria, yeasts, fungal spores, pollen belong to particles naturally occurring in air, but from the point of view of medicine they can be regarded as bioaerosol (Adams, 1964; Corden et al. 2003; Weryszko-Chmielewska and Piotrowska, 2004; Bugajny et al. 2005; Myszkowska, 2006; Kasprzyk, 2006; Smith et al. 2007). These particles occur in the atmosphere during almost all year and affect human health (Emeryk et al. 2004; Atkinson et al. 2006). Numerous authors found close associations between the occurrence of airborne pollen grains and fungal spores and the increasing incidence of allergy or even a death (Targonski et al. 1995; Frei and Leushner, 2000; Kurup et al. 2002; Myszkowska, et al 2002; D’Amato et al 2007; Smith et al. 2007). The knowledge of the periods of occurrence and of concentrations of all aeroallergens is highly important in determining the etiology of inhalation allergies and their future treatment. In aerobiological papers pollen grains and fungal spores are usually approached separately. In standard aerobiological investigations several allergenic pollen taxa are taken into consideration (Arobba et al. 2000; Clot, 2003; Weryszko-Chmielewska and Piotrowska, 2004; Myszkowska, 2006; Stach, 2006). With respect to fungal spores, Cladosporium and Alternaria are the most frequently identified in continuous monitoring (Stępalska et al. 1999; Corden et al. 2003; Hollins et al. 2004; Grinn-Gofron, 2007; Grinn-Gofron and Mika, 2008), however, the list of fungal spores causing inhalation allergies is long. Here belong conidial spores (like Epicoccum), basidiospores (like Ganoderma) and also ascospores (Didymella). Currently, about 70 fungal allergens have been approved (Kurup et al. 2002; Bush and Portnoy, 2001).

The occurrence of airborne sporomorphs is characterized by seasonal and temporal variability affected by weather and type of climate, thermal turbulence and stability, geobotanical characteristics (Stępalska et al. 1999; Arobba et al. 2000; Frei and Leushner, 2000; Corden et al. 2003; Hollins et al. 2004; Stępalska and Wołek, 2005; Kasprzyk, 2006; Myszkowska, 2006; Weryszko-Chmielewska et al. 2006; Smith et al. 2007; Grinn-Gofron and Mika, 2008). These factors interact synergistically or infinitively.
The co-occurrence of many allergenic pollen grains in the air might have a cumulative effect on allergy sufferers (Hjelmroos-Koekkoek et al. 2006; Ranta and Satri, 2007). The aim of the present work was to determine if and to what extent the seasons of maximum concentrations of airborne allergenic airborne pollen and fungal spores overlap.

MATERIALS AND METHODS

Aerobiological investigations were carried out in Rzeszów in the years 2000-2002 using the volumetric method. Sporomorphs are identified on the basis of their morphology; it is not possible to estimate their viability. The monitoring was continuously conducted using a Hirst type volumetric spore trap (Lanzoni VPPS 2000) situated about 12 m above the ground level. For each day of the year, a microscopic slide was made and subjected to qualitative and quantitative analysis. Samples were examined at x 400 magnification for pollen grains and at x 600 magnification for fungal spores using light microscopy. Pollen grains were counted along 12 latitudinal transects on each microscope slide, fungal spores samples from one horizontal sweep. The results were expressed as daily average pollen grains/fungal spores in cubic metre.

Six taxa of pollen grains and five types of fungal spores characterized by strong allergenicity and/or high concentrations in the air were analyzed. The start and the end of pollen/fungal seasons were determined when the cumulative sum of sporomorphs reached 5% and 95% of the total sum, respectively. The number of days above the threshold value in the season was selected on the basis of literature data (Rapiejko, 1995; Jäger, 1998; Rapiejko et al. 2004).

The times series of pollen grains and fungal spores were compared using PCA analysis (Principal Component Analysis). Each of three components carried independent information. In the results, several groups of the examined factors were created, ranked according to their numerical importance. Taxa (factors) can be grouped in many respects: frequency, time of pollen seasons. The first component gives the highest percentage of explained variance, but the others can highlight additional, important information. The number of factors was chosen according to Kaiser’s criterion. The obtained results were compared with these from the CONSLINK method (dendrogram). Numerical analyses were done with Polpal (Nalepka and Wala, 2003). Days of year (365) were grouped into pentads (73).

RESULTS

Of the investigated taxa, alder (Alnus) pollen showed the greatest variability in the dates and length of atmospheric seasons and the number of days above the threshold value. In 2002 the pollen season started at the beginning of February but in 2001 about one month later (Tab. 1). The length of pollen seasons ranked between 15 and 62 days. The number of days above the threshold value ranged between 6 and 13 and was not connected with the pollen season length. In 2000 and 2001 the airborne Betula pollen seasons occurred by the end of April, but in 2002 in April. The period of the highest pollen concentrations was very short. The numbers of days dangerous for sensitive people were almost the same in all the years, e.g. 12-13 days. In the second half of May, the start of the Poaceae pollen seasons was noted, then, of the Urtica pollen seasons in the middle of June. In all the years, the pollen seasons of Poaceae and Urtica were very long, e.g. above two months. Among the plant taxa, the number of days above the threshold value for Poaceae and Urtica was the highest – about fifty. The maximum concentrations of mugwort (Artemisia) pollen grains occurred in August. Single grains were noted in September and even to October. For about 10 days, sensitive people were exposed to a dangerous Artemisia pollen concentration. The atmospheric Ambrosia pollen seasons were characterized by high variability. Ragweed pollen release started in August and maximum pollen concentrations were usually noted at the end of August and at the beginning of September. In 2000 single pollen grains of Artemisia and Ambrosia remained in air even until October (Tab. 1, Fig. 1).

Generally, Alternaria fungal spores occurred in air from mid-May to mid-October. For above 30 days people were exposed to dangerous concentrations of fungal spores. The period of the occurrence of Cladosporium spores in air began already at the end of May and usually lasted to mid-October. Mean daily concentrations were the highest among the investigated taxa and the number of days dangerous for allergic people was very high, too. The remaining fungal spores appeared in air from July to October. The periods of maximum counts of all fungal spores were very long in comparison with the plant pollen seasons (Tab. 1, Fig. 1).

Based on the prepared dendrogram, several periods can be distinguished. From the February to the middle of March, Alnus pollen dominated in the air. The second period was characterized by Betula pollen. It occurred in April. In Rzeszów the pollen seasons of Alnus and Betula did not overlap with the same periods of other strongly allergenic pollen grains and fungal spores.

Herbaceous pollen and fungal spores occurred in the air simultaneously (from mid-May to the end of August). Airborne Urtica, Poaceae pollen grains and Cladosporium spores dominated in this period.
Table 1
(threshold values for *Botrytis*, *Epicoccum* and *Ganoderma* are not known).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dates of seasons</td>
<td>maximum</td>
<td>days above the thresholds value</td>
</tr>
<tr>
<td><em>Alnus</em></td>
<td>19.02 04.04</td>
<td>78/25.03</td>
<td>0</td>
</tr>
<tr>
<td><em>Betula</em></td>
<td>16.04 29.04</td>
<td>2186/24.04</td>
<td>22</td>
</tr>
<tr>
<td><em>Poaceae</em></td>
<td>16.05 31.07</td>
<td>238/22.06</td>
<td>45</td>
</tr>
<tr>
<td><em>Urtica</em></td>
<td>13.06 22.08</td>
<td>479/06.08</td>
<td>51</td>
</tr>
<tr>
<td><em>Artemisia</em></td>
<td>28.07 08.10</td>
<td>59/13.08</td>
<td>11</td>
</tr>
<tr>
<td><em>Ambrosia</em></td>
<td>19.08 19.10</td>
<td>86/21.08</td>
<td>6</td>
</tr>
<tr>
<td><em>Alternaria</em></td>
<td>25.05 12.10</td>
<td>299/10.08</td>
<td>30</td>
</tr>
<tr>
<td><em>Botrytis</em></td>
<td>27.06 28.10</td>
<td>106/16.08</td>
<td>–</td>
</tr>
<tr>
<td><em>Cladosporium</em></td>
<td>24.05 24.10</td>
<td>11906/18.07</td>
<td>58</td>
</tr>
<tr>
<td><em>Epicoccum</em></td>
<td>20.06 24.10</td>
<td>299/28.08</td>
<td>–</td>
</tr>
<tr>
<td><em>Ganoderma</em></td>
<td>28.06 27.10</td>
<td>191/16.08</td>
<td>20.06 19.10</td>
</tr>
</tbody>
</table>
In September high concentrations of all the examined fungal taxa were noted. The next period was characterized by high concentrations of airborne Epicoccum, Ganoderma and Cladosporium fungal spores, which occurred in October and November. From December to January, Cladosporium spores predominated in the air (Fig. 1). These results were confirmed by PCA analysis (Tab. 2). On the basis of Kaiser’s criterion, three factors were chosen. They explained 64%, 12%, 8% of the total variance, respectively. The taxa could be grouped into four groups on the basis of high similarity of the pollen season dates. Alnus and Betula formed two independent groups (the second factor), all herbaceous pollen taxa, Alternaria, Botrytis and Cladosporium belonged to the third one (the first factor), Epicoccum and Ganoderma were characterized by high similarity (the third factor; Tab. 2). From June to August, the concentrations of pollen grains and fungal spores of several investigated taxa exceeded the threshold values. Pollen concentrations which simultaneously exceeded the threshold values were most frequently observed between Poaceae and Cladosporium (18-35 days), Alternaria and Cladosporium (24-28 days) (Tab. 3).
Figure 1. Pollen and fungal spore calendar for Rzeszów (2000-2002);
Ranges 1-8 correspond to average pollen grains/fungal spores concentrations (s×m$^{-3}$): 1-10; 11-30; 31-90; 91-270; 271-810; 811-2430; 2431-7290; >7291; dendrogram of pentads (CONSLINK method) based on the occurrence of 11 taxa.
DISCUSSION

Pollen grains and fungal spores induce allergy if they occur at a sufficiently high concentration, i.e. a concentration exceeding a threshold value. In the respective literature concerning pollen, varied data are given depending on the geographical region and the phase of the pollen season; some authors claim that this value is associated with individual traits of the patient (Targonski et al. 1995; Waisel, 2003; Rapiejko et al. 2004; Myszkowska et al. 2002; D’Amato et al. 2007; Smith et al. 2007). Major pollen allergens are structurally and immunochemically similar. We can observe cross-reactions between tree, herbal allergens within one genus, family (Gadermaier et al. 2004; Mothes and Valenta, 2004; D’Amato et al. 2007). A paper by Puc (2003) contains a review of the literature.

In the years of the investigation, the pheno- nology of the occurrence of pollen from selected taxa was consistent with the tendencies presented by authors for different regions of Poland (Weryszko-Chmielewska and Piotrowska, 2004; Myszkowska, 2006; Stach, 2006). Pollen of trees appeared first, followed by pollen of grasses and, subsequently, of other herbaceous plants. In the second half of the year, the highest concentrations of fungal spores were noted. Aeroallergens usually occur in air throughout a greater part of the vegetation season, which poses a serious problem to allergic people. This phenological cycle is reflected in the specific rhythm of incidence of diseases, i.e. in spring pollen of trees causes the so-called spring pollinosis, of grasses and cereals – the summer incidence, and pollen of other herbaceous plants, the late-summer form of this disease (Frei and Leuschner, 2000).

Hjelmoos-Koski et al. (2006) suggest that, instead of that, individual taxa pollen and fungal spores should be grouped and then used to describe daily exposures for sufferers. Allergic pollen grains and fungal spores occurred in air during almost the whole year, from early spring to late autumn. *Alnus* sp. starts pollen shedding in very unstable weather conditions before leaf development (Weryszko-Chmielewska and Piotrowska 2004; Kasprzyk, 2006; Emberlin et al. 2007b; Smith et al. 2007). In favorable temperature, first airborne pollen grains can occur in January, when temperature is low for a long time, and the start of the pollen season is noted at the end of March. *Betula* sp. requires higher temperature to start flowering and leafing (Weryszko-Chmielewska et al. 2006; Emberlin et al. 2007a; Ranta and Satri, 2007).

The pollen seasons of these taxa did not overlap and they created two independent time series, but in 2000 the *Betula* pollen season started only 12 days after the end of the *Alnus* pollen season. Because of cross-reactivity, *Alnus* pollen has a priming effect on allergic people before the start of the *Betula* season. Under the present scenarios of global warming, the tree pollen seasons will start earlier and be longer, and sufferers will be exposed to allergenic tree pollen throughout all spring (Emberlin et al. 2007a; Ranta and Satri, 2007). Frei and Leuschner (2000) report that in Switzerland the sensitivity to tree pollen is observed to increase together with the tendency to its increased concentrations in air. As far as the Polish population is concerned, the first symptoms from the nose in 25% of examined people were noted when *Betula* and *Alnus* pollen concentrations were relatively low, at 20 and 45 grains/m³, respectively (Rapiejko et al. 2004). A constant increase in total airborne pollen counts of early-flowering trees has been found in many European cities (Clot, 2003; Phenology and human health... 2003). In Poznań, Poland, and Worcester, UK, a trend toward longer *Alnus* pollen season was found (Smith et al. 2007), and in the future periods with *Betula* and *Alnus* pollen concentrations above threshold values might overlap. It can have a strong effect on sufferers.

Herbaceous pollen grains contain similar allergenic proteins, which are responsible for extensive cross-reactivity among pollen-sensitized patients (Gadermaier et al. 2004). Grass pollen grains are the main cause of allergy in Europe and in Poland, too. According to Rapiejko et al. (2004), in Poland the first symptoms of allergy are noted when a grass pollen concentration exceeds 20 g·m⁻³. *Urtica* pollen is considered to be weakly allergenic. In the air of Rzeszów, they occurred at very high concentrations together with Poaceae pollen; above the threshold values (50 g·m⁻³; Rapiejko, 1995) for 28–13 days. Could it increase allergy symptoms? This problem should be considered with respect to the regions where *Urtica* pollen concentrations are very high, i.e. in Lublin (Weryszko-Chmielewska and Piotrowska, 2004).

*Ambrosia* pollen is considered to be highly allergenic even in low concentrations. In Rzeszów and other Polish cities, the number of days exceeding the threshold value (20 g·m⁻³; Jäger, 1998) is low (Weryszko-Chmielewska and Piotrowska, 2004; Myszkowska, 2006; Stach, 2006), but episodes of high or very high concentrations were noted in several cities in Poland (Smith et al. 2008). It should be stressed that many Polish patients had a positive skin prick test to ragweed pollen (Stepalska et al. 2002). Global warming may augment *Ambrosia* pollen production and intensify cross-reactive allergies with other pollens (Wan et al. 2002).

The results concerning the seasonal occurrence of airborne fungal spores do not differ from Polish literature data (Stepalska et al. 1999; Bugajny et
Climate change has an impact on the start and length of the pollen season, pollen production and phenological phenomena. In Europe the length of the growing season has increased by 10-11 days over 30 years. Also, changes in the pollen season have been observed. An earlier start, peak and end of the pollen seasons has tended to occur later (Wan et al. 2002; Phenology and human health... 2003). It will be possible that the pollen seasons of many taxa will overlap. In some areas, non-monosensitized patients will have year-long symptoms (D’Amato et al. 2007).

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REFERENCES


Współwystępowanie alergennych ziaren pyłku i zarodników grzybów w powietrzu Rzeszowa, Polska (2000-2002).

S t r e s z c z e n i e