

Intradiurnal patterns of allergenic airborne pollen near a city motorway in Berlin, Germany

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Abstract In this study, the seasonally averaged intradiurnal patterns of four different pollen types (*Fraxinus*, *Betula*, Poaceae and *Artemisia*) and the role of traffic volume, air pollution and selected weather parameters were investigated. Measurements were carried out with a 7-day recording volumetric spore trap (Hirst type) near a congested city motorway (the A 100) in Berlin, Germany, in 2012, 2013 and partly 2011. Both Poaceae and *Artemisia* pollen showed distinct patterns which were similar across the years. The main period of grass pollen concentrations in the air was from 8 a.m. to 10 p.m. with peaks about

midday or in the afternoon. Mugwort pollen mainly occurred between 6 a.m. and 2 p.m. with a clear maximum from 8 to 10 a.m. With regard to *Fraxinus* and *Betula* pollen, the patterns were not as clear and showed differences throughout the years. The intradiurnal patterns of traffic volume and pollen load, mainly of Poaceae in the afternoon and *Artemisia* in the morning, were partly coincident. The combination of both a high pollen count and air pollution, due to exhaust emissions, represents a special health threat which could result in a double burden for allergy sufferers. In the case of the daily means of *Betula* and Poaceae, relative humidity had a significantly negative effect on pollen concentrations on the same and/or next day/s, sunshine duration (Poaceae) and air temperature (*Artemisia*) a positive one.

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1 Introduction

Allergic diseases are on the rise in industrialized countries. Nearly a fifth of the European population is affected by pollen allergy (Bergmann and Jäger 2010). In Germany, the lifetime prevalence is reported as 8.6 % for bronchial asthma and 14.8 % for allergic rhinoconjunctivitis based on patient history (Langen et al. 2013), but the real prevalence of airways

allergies is much higher especially in the younger generation reaching a point prevalence of more than 40 % in the age group 20–40 years (Blomme et al. 2013). The socioeconomic impact is enormous as allergies have an impact on cognitive functions, and the prevalence is the highest of all chronic diseases in the age group below 65 years who is mainly presenting the labor force (Zuberbier et al. 2014). A high social standing and living in large cities both increase risk of airways allergies (Langen et al. 2013).

Urban areas in Europe show a rising trend in yearly airborne pollen counts, which is less pronounced in semirural or rural areas (Ziello et al. 2012). In many cities, a great diversity of allergenic plants can be determined (Thompson and Thompson 2003). A lot of commonly planted trees in urban areas, e.g., hazel (*Corylus*), alder (*Alnus*) and birch (*Betula*), and other wild plants, e.g., grasses (Poaceae), mugwort (*Artemisia vulgaris*) and common ragweed (*Ambrosia artemisiifolia*), have a great allergological relevance. The planting of trees and other plants in public spaces should be carried out respecting the needs of pollen allergy sufferers, that is, less allergenic plant species should be preferred (Bergmann et al. 2012). For example, Turkish hazel (*Corylus colurna*) and European white birch (*Betula pendula*) belong to the most common allergenic trees in Berlin and should not be re-planted (Bergmann et al. 2012). Common ragweed findings in Berlin are systematically registered and eliminated to prevent a spreading of this plant (Bergmann et al. 2012).

Due to an increase in greenhouse gas emissions, especially anthropogenic carbon dioxide (CO₂), global warming has intensified over the past decades (D'Amato et al. 2014). Cities might be seen as “harbingers of climate change” because urban CO₂ and temperature levels are already higher than in rural areas (Ziska et al. 2003). In urban areas, common ragweed, for example, grows faster, flowers earlier and produces more pollen (Ziska et al. 2003). A prolonged and intensified pollen season caused by climate change affects allergy sufferers and might increase the probability of developing new allergies (D'Amato et al. 2014).

Air pollution caused by motor vehicles and industry is a rising problem, too. Nitrogen dioxide (NO₂), ozone (O₃) and particulate matter (PM) are the most common air pollutants in urban areas (D'Amato et al. 2014). The combination of high pollen counts and air

pollutant levels represents a special health threat. Pollen are considered to be more allergenic in a polluted atmosphere (Behrendt et al. 1992, 1997; Morgenstern et al. 2008), and PM by itself affects pulmonary function (D'Amato et al. 2010; Mazzearella et al. 2012). Vehicle exhaust particles belonging to urban PM are also able to act as carriers of allergens which can be deeply inhaled into the lungs (Namork et al. 2006). Several studies conducted in large cities revealed a positive correlation between high pollen counts, air pollution and asthma-related emergency department visits (Dales et al. 2008; Jariwala et al. 2011; Cakmak et al. 2012).

The aim of the study was to find out if there is a typical intradiurnal pattern of airborne pollen load of *Fraxinus*, *Betula*, Poaceae and *Artemisia*, near a congested city motorway in Berlin and to investigate the role of traffic volume, air pollution and selected weather parameters.

2 Materials and methods

2.1 Pollen measurements

2.1.1 Sampling

Pollen measurements were carried out with a 7-day recording volumetric spore trap (Hirst 1952). The use of this device is required for all European Aeroallergen Network (EAN) members (Jäger et al. 1995; Galán et al. 2014). Sampling was carried out at a monitoring site of the Federal Environment Agency (UBA), located near the city motorway A 100 in the German capital, Berlin, in the years 2011 (13 May to 22 June; 41 days), 2012 (6 March to 14 October; 223 days) and 2013 (13 February to 15 October; 237 days).

In 2011, a prior study investigated the distribution of pollen and particulate matter (PM₁₀, particles <10 µm) at three different sites in Berlin (Bergmann et al. 2013). One pollen trap was placed near to the city motorway A 100, two others in an inner-city park and in a suburban area.

The A 100, with three lanes running in both directions, is the busiest motorway in Germany. More than 150,000 vehicles per day pass the section (Lerschpfad 17, 14059 Berlin-Charlottenburg) where the pollen trap was located. The trap was fixated on a

table on a stage of the UBA directly adjacent to the motorway and had a measuring height of approximately 5 m above ground level. The stage with the trap was placed inside a fenced in area. In addition, the trap was secured by its own electric cable. The end of the cable that led to the power outlet was locked inside a junction box. Immediate surroundings were characterized by old five-story buildings in the North and a large cemetery with tall trees in the South–West. Additionally, from the North and the East, the trap was especially exposed to wind.

2.1.2 Analysis

Pollen analysis in 2012 and 2013 included *Fraxinus*, *Betula*, Poaceae and *Artemisia*. In 2011, only Poaceae pollen were considered due to the short monitoring period. Daily samples were analyzed regarding intradiurnal pollen load, using bi-hourly data, as recommended by Hecht (1994) and Jäger et al. (1995). In each sample, two horizontal central sweeps were analyzed light microscopically. Analyzing two sweeps, which had a total width of 970 μm altogether, with a magnification of 250 diameters led to the daily average of pollen grains per cubic meter of air (the daily mean). The length of 4 mm in a sweep is equivalent to 2 h. The pollen counts of both sweeps were related to the correspondent 2-hour intervals and correlate to approximately 83 l of air (2-hour mean).

Pollen season (PS) was defined to cover 90 % of the annual total, as suggested by Nilsson and Persson (1981), except in 2011, when 95 % were considered, because the grass pollen season was not yet over on the last monitoring day. The results were expressed in bar graphs: For each pollen type and year, the sum of the daily means was equated with 100 %. The sums of the correspondent 2-hour means were expressed to it as a percentage. Thus, seasonally averaged intradiurnal patterns were obtained.

A few monitoring days were missing due to technical or preparing problems: 24/5/2011, 10–11/4/2012, 21/4/2013.

2.2 Traffic volume and visible pollution on the slide

Intradiurnal data of the traffic volume of the city motorway A 100 in 2012 (5 March to 15 October) were provided by Traffic Management Centre Berlin

(VMZ), Germany. The data represent the number of vehicles that hourly passed the VMZ monitoring site located close to the pollen trap, averaged over the pollen sampling period and differentiated into 4 day types: “1” = Monday to Thursday, “2” = Friday, “3” = Saturday and “4” = Sunday/public holidays. The hourly data were converted into bi-hourly means and expressed in line diagrams.

Daily pollen samples in 2012 were examined with the naked eye regarding the intensity of visible pollution (dark dirt) on the slide. For each 2-hour interval, a grading between “0” and “3” was given, using the following classification devised by the author: “0” = (nearly) no, “1” = slight, “2” = medium and “3” = intense pollution. Reference samples (16/6/2012 = “0”; 15/6/2012 = “1”; 13/6/2012 = “2”; 27/7/2012 = “3”) were chosen for comparison. The given scores for each 2-hour interval were added to daily sums. For optional periods (day type 1, etc.), the daily sums were added and equated with 100 %. The sums of scores of the 2-hour intervals were expressed to it as a percentage. The results expressed in line diagrams were compared with the intradiurnal traffic volume and pollen load in 2012.

The grading was made again for 30 arbitrarily chosen samples by a second person. The results from both persons were compared with each other regarding concordance expressed as a percentage.

Daily means (daily averages of pollen grains per cubic meter of air) of *Betula*, Poaceae and *Artemisia* pollen in 2012 were correlated with the daily averaged pollution scores.

2.3 Meteorological variables

Daily means of *Betula*, Poaceae and *Artemisia* pollen in 2012 were correlated with daily meteorological data (air temperature, relative humidity, wind speed and sunshine duration) from the monitoring site Berlin-Tegel (measuring height: 36 m; distance: about 9 km to the north of the pollen trap) operated and provided by German Meteorological Service (DWD).

2.4 Statistical analysis

For correlation calculations (software: SPSS 20) between daily means of pollen (*Betula*, Poaceae and *Artemisia* [pollen/ m^3 air]), daily averaged pollution scores [no unit] and daily meteorological data (air

temperature (daily sum [°C]), relative humidity (daily mean [%]), wind speed (daily mean [km/h]) and sunshine duration (daily sum [min]), two analyses were used: (1) After preparing sequence diagrams with the charted mean value of all variables, autocorrelation function (ACF) and partial autocorrelation function (pACF) were calculated for each of the three pollen types and analyzed by inferential statistics (Box–Ljung statistics). Thus, the internal dependency structure of time series can be investigated. (2) Intercorrelation functions (CCF) were calculated between pollen time series and the respective variables, as well analyzed by inferential statistics. Thus, dependencies between values of two time series can be analyzed. In both analyses, 95 % confidence intervals (CI) were calculated.

3 Results

3.1 Intradiurnal pollen patterns

The main time of pollen load was defined as an intradiurnal period that exceeded the threshold of 8.33 % (cf. Jäger 1990). This threshold would be obtained for each 2-hour interval if the pollen load was uniformly distributed throughout the whole day. The most important pollen measuring details and results are summarized (Table 1). *Fraxinus* pollen (Fig. 1) did not show a clear intradiurnal pattern. The greater part (nearly 65 % in 2012, respectively, about 54 % in 2013) and the peaks occurred during the second half of the day. In 2013, the threshold of 8.33 % was also even exceeded in the early (from 2 to 4 a.m.) and late morning (from 10 to 12 a.m.), in contrast to the previous year. Lowest values were found in the morning between 6 and 8 a.m. *Betula* pollen (Fig. 2) showed different intradiurnal patterns in the two years. In 2012, most pollen (more than 70 %) were in the air between 10 a.m. and 12 p.m. with peak values about midday and in the early afternoon. In the following year, the midday peak was missing and no clear tendency of peak times concerning the pollen load was found. Lowest values occurred in the morning between 6 and 8 a.m. For both years, nightly pollen load is relatively high in the graph. This is mainly due to a few days with higher birch pollen concentrations, especially during the night (2012: 28/3/, 3/4/, 15/4/, 20/4/;

2013: 25/4/). These concentrations coincide with mainly two-digit temperatures, low relative humidities and long durations of sunshine. The previous days were more or less dry and warm, too, and with a lot of sunshine. Poaceae pollen (Fig. 3) showed good congruencies between the years. They mainly occurred from 8 respectively 10 a.m. to 8 respectively 10 p.m. with maxima about midday (2011) or in the afternoon (2012, 2013). This can be described as an “afternoon profile.” Lowest values were found around midnight (2011) or in the (early) morning (2012, 2013). *Artemisia* pollen (Fig. 4) had the most distinct intradiurnal pattern with a clear peak from 8 to 10 a.m. 30 % (2012) respectively 23 % (2013) of the total occurred between 8 and 10 a.m. More than 80 % (2012) and 75 % (2013) were found between 6 a.m. and 2 p.m. This can be described as a “morning profile.” Lowest values occurred around midnight and in the first hours of the day.

3.2 Traffic volume and visible pollution on the slide

The traffic curves of day type 1 and 2 (Fig. 5) start to rise steeply between 2 and 4 a.m. and reach their maxima from 6 to 8 a.m. Afterward, both curves remain at a slightly lower nearly constant level and decline from 6 p.m. until the end of the day. The correspondent pollution curves start to rise at the same time, but reach their peaks from 10 to 12 a.m. (day type 1) and 6 to 12 a.m. (day type 2); day type 2 shows a decrease between 2 and 4 p.m. The traffic and pollution curves of day type 3 and 4 (Fig. 6) are characterized by a slow increase. Peaks are reached about midday and/or in the afternoon. Traffic volume fluctuations in the course of a day can be explained by commuting and its decrease on Saturdays and on Sundays/public holidays.

The grading carried out by a second person for 30 samples led to the following results: (a) 166 (46 %) ratings of the total of 360 were identical to those of the first person; (b) 187 (52 %) differed in plus or minus 1 grade and (c) 7 (2 %) ratings in ± 2 ; (d) no rating differed in ± 3 grades.

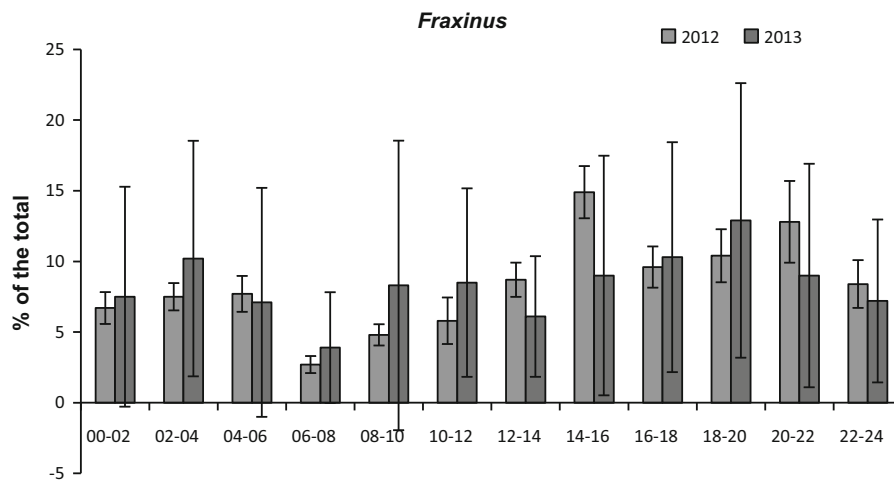
3.2.1 Airborne pollen, traffic and pollution

The “afternoon profile” of Poaceae pollen load matches intradiurnal traffic volume and pollution

Table 1 Summary of pollen measuring details and results

Taxon	Year	PS ^a	PS days	Count ^b	Main time ^c	Peak interval ^d		Pollen peak ^e
						Date	Interval	
<i>Fraxinus</i>	2012	28/3/–30/4/	32	415	12 a.m.–12 p.m.	3/4/	8–10 p.m.	12
<i>Fraxinus</i>	2013	18/4/–1/5/	13	915	2–4 a.m. 10–12 a.m. 2–10 p.m.	23/4/	8–10 a.m.	37
<i>Betula</i>	2012	28/3/–1/5/	33	16,060	10 a.m.–12 p.m.	3/4/	10–12 p.m.	388
<i>Betula</i>	2013	20/4/–5/5/	15	18,482	8–12 a.m. 4–12 p.m.	25/4/	10–12 p.m.	1364
Poaceae	2011	22/5/–22/6/	31	1405	8 a.m.–8 p.m.	31/5/	4–6 p.m.	22
Poaceae	2012	21/5/–26/7/	67	3096	8 a.m.–8 p.m.	29/5/	8–10 a.m.	44
Poaceae	2013	28/5/–27/7/	61	3224	10 a.m.–10 p.m.	1/7/	8–10 p.m.	29
<i>Artemisia</i>	2012	16/7/–14/8/	30	5055	6 a.m.–2 p.m.	7/8/	8–10 a.m.	245
<i>Artemisia</i>	2013	16/7/–24/8/	40	1116	6 a.m.–2 p.m.	26/7/	10–12 a.m.	25

^a Pollen season; ^b sum of daily averages of pollen grains per cubic meter of air during pollen season; ^c intradiurnal period that exceeded the threshold of 8.33 %; ^d date and 2-hour interval with highest amount of pollen; ^e amount of pollen per 83 l of air in the peak interval

**Fig. 1** Intradiurnal pattern of *Fraxinus* pollen load in the air at the A 100 in Berlin in 2012 and 2013

(Figs. 5, 6) to some degree, i.e., high grass pollen, traffic and pollution levels are partly coincident in the afternoon. Compared to the other three pollen types, Poaceae provided the largest number of days for the different day types due to the longest pollen season (day type 1 = 39 days; type 2 = 9 days; type 3 = 9 days; type 4 = 10 days). The “morning profile” of *Artemisia* (number of days: day type 1 = 18 days; type 2 = 4 days; type 3 = 4 days; type 4 = 4 days) passably matches the traffic and pollution peaks during the early morning hours for day type 1

and 2. The mugwort pollen load always peaks between 8 and 12 a.m., irrespective of the day type. Intradiurnal *Betula* pollen load (day type 1 = 16 days; type 2 = 4 days; type 3 = 5 days; type 4 = 8 days) shows similarities with traffic volume and pollution for day type 3 and 4. For day type 1 and 2, the concentrations converge about midday. Regarding *Fraxinus* (day type 1 = 16 days; type 2 = 4 days; type 3 = 5 days; type 4 = 7 days), a comparison is difficult and uncertain due to the small amounts of pollen for the different day types.

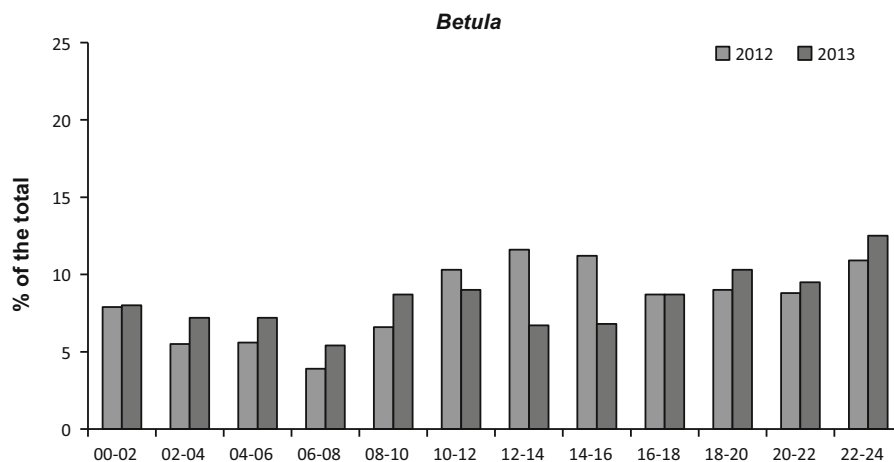


Fig. 2 Intradiurnal pattern of *Betula* pollen load in the air at the A 100 in Berlin in 2012 and 2013. Standard deviation is not charted because of very high values

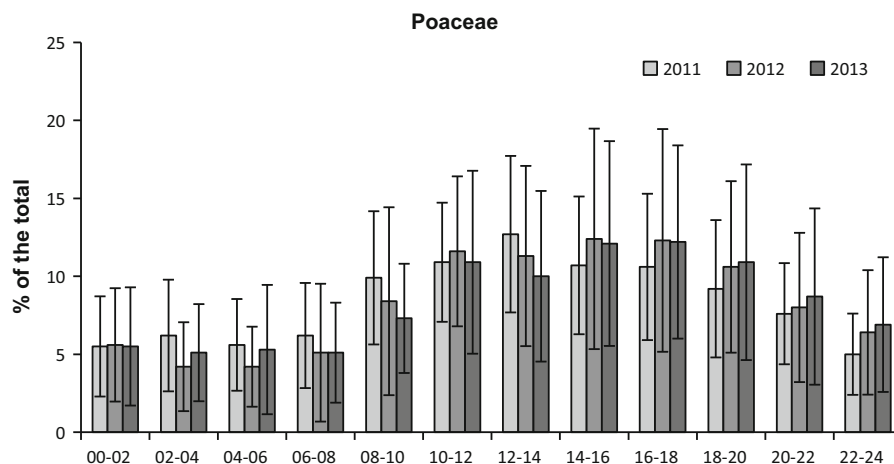


Fig. 3 Intradiurnal pattern of Poaceae pollen load in the air at the A 100 in Berlin in 2011, 2012 and 2013

3.2.2 Inferential statistical results

Poaceae pollen load might also be influenced by air pollution (Table 2). Intercorrelation between the daily means and the daily averaged pollution scores showed a significantly positive correlation for “lag -4”, i.e., the higher the pollution on day “x”, the higher the pollen concentration is on day “x + 4”, but this could also be a random result.

Partial autocorrelation function revealed that the pollen concentration of both Poaceae and *Artemisia* is at most dependent on the previous day (Table 2), but not on the days prior to that.

4 Airborne pollen and meteorological variables

4.1 Inferential statistical results

Significant correlations between the daily means of pollen and daily meteorological data in 2012 are summarized (Table 2). Relative humidity showed significantly negative correlations with both *Betula* and Poaceae pollen, i.e., the higher the relative humidity on day “x”, the lower the pollen concentrations are on day “x + 1” (*Betula*), respectively, “x”, “x + 1”, “x + 2”, ..., “x + 7” (Poaceae). Poaceae pollen load is also influenced by sunshine, i.e., the more sunshine hours on day “x”, the higher the pollen

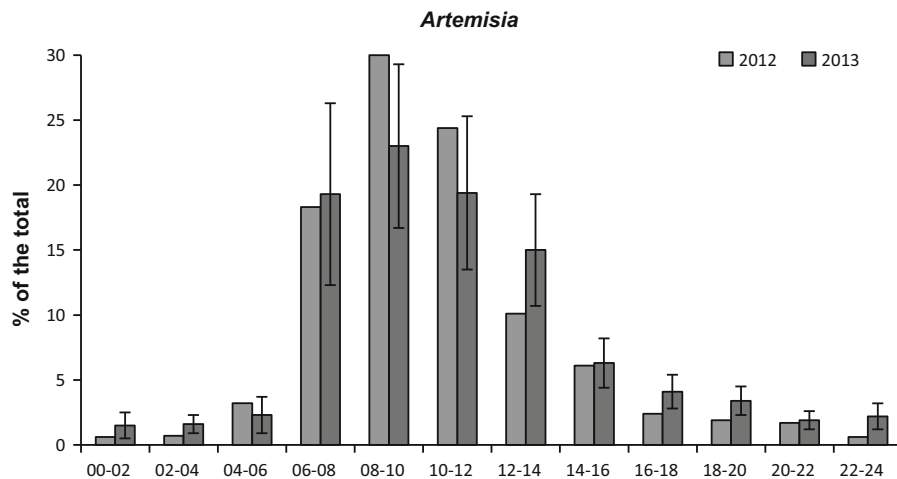


Fig. 4 Intradiurnal pattern of *Artemisia* pollen load in the air at the A 100 in Berlin in 2012 and 2013. Standard deviation for 2012 is not charted because of very high values

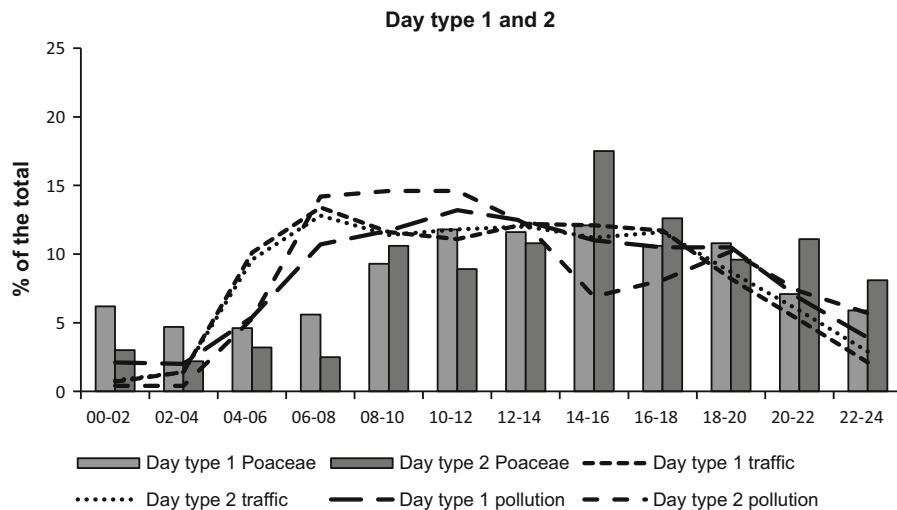


Fig. 5 Intradiurnal patterns of the traffic volume, visible pollution on the slide and Poaceae pollen load for day type 1 (=Monday–Thursday (122 days); Poaceae: 39 days) and day type 2 (=Friday (31 days); Poaceae: 9 days) at the A 100 in Berlin in 2012

concentrations are on day “ x ” and “ $x + 1$ ”. *Artemisia* pollen showed significantly positive correlations with temperature, i.e., the higher the temperature on day “ x ”, the higher the pollen concentrations are on day “ x ” and “ $x + 1$ ”.

5 Discussion

In this study, the seasonally averaged intradiurnal patterns of four different pollen types of allergenic importance (*Fraxinus*, *Betula*, Poaceae and *Artemisia*)

and the role of traffic volume, air pollution and selected weather parameters near a city motorway in 2012, 2013 and partly 2011 were investigated.

Both Poaceae and *Artemisia* pollen showed distinct intradiurnal patterns which were similar across the years. Although the plant family of Poaceae is composed of a lot of species with probably different flowering behaviors, as Käpylä (1981) described, in the present study the main time of pollen load was always observed between 8 a.m. and 10 p.m. with maxima around midday or in the afternoon, as also demonstrated by Jäger (1990) in Austria who found

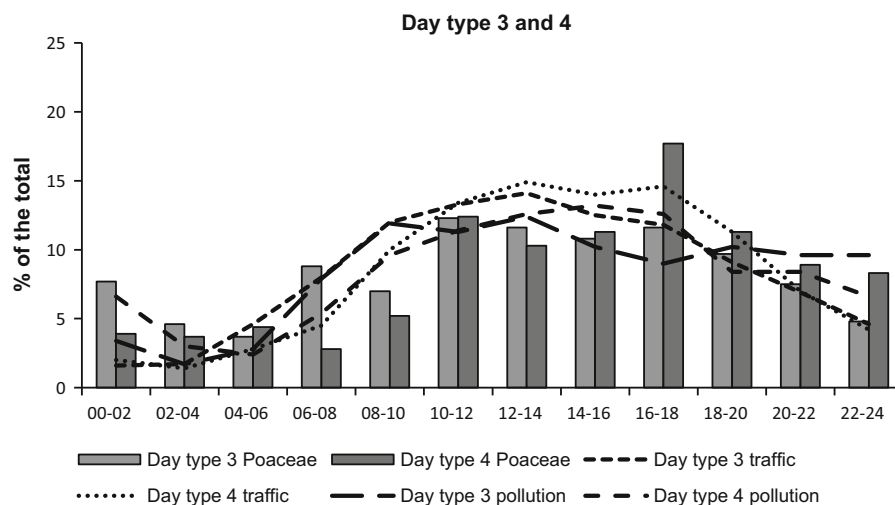


Fig. 6 Intradaily patterns of the traffic volume, visible pollution on the slide and Poaceae pollen load for day type 3 (=Saturday (32 days); Poaceae: 9 days) and day type 4 (=Sunday/public holidays (37 days); Poaceae: 10 days) at the A 100 in Berlin in 2012

Table 2 Significant correlations between daily means of pollen and some variables for the year 2012

Taxon	ACF ^a		pACF ^b		CCF ^c		T ^c		RH ^f		WS ^g		S ^h	
					P ^d									
	L	C	L	C	L	C	L	C	L	C	L	C	L	C
<i>Betula</i>	1	0.325	–	–	–	–	–	–	–1	–0.416	–	–	–	–
Poaceae	1	0.594	1	0.594	–6	0.262 ⁱ	4	–0.265 ⁱ	–7	–0.314	–	–	–5	0.304 ⁱ
	2	0.322	4	0.297 ⁱ	–4	0.291	5	–0.285 ⁱ	–6	–0.277			–4	0.272 ⁱ
	4	0.256					6	–0.285 ⁱ	–5	–0.356			–1	0.356
	5	0.237					7	–0.326 ⁱ	–4	–0.363			0	0.436
	10	0.239							–3	–0.409			7	–0.289 ⁱ
	11	0.322							–2	–0.380				
	15	0.217							–1	–0.451				
	16	0.222							0	–0.575				
									1	–0.459 ⁱ				
									2	–0.263 ⁱ				
<i>Artemisia</i>	1	0.554	1	0.554	–	–	–1	0.482	–6	–0.410 ⁱ	–3	–0.387 ⁱ	3	–0.493 ⁱ
	2	0.390	6	–0.376 ⁱ			0	0.439	3	0.389 ⁱ	–2	–0.391 ⁱ		
	15	–0.279 ⁱ					6	–0.419 ⁱ						
	16	–0.288 ⁱ												

^a Autocorrelation function; ^b partial autocorrelation function; ^c intercorrelation function; ^d visible pollution on the slide (daily mean); ^e air temperature (daily sum); ^f relative humidity (daily mean); ^g wind speed (daily mean); ^h sunshine duration (daily sum); L = “lag” (shifting of the time series); C = significant coefficient; ⁱ interpreted as random find

similar intradiurnal profiles across the years with no major differences between urban and rural areas. Since the sampling period in 2011 was shorter than in 2012 and 2013, the grass pollen season was not yet over on

the last monitoring day. Although the grass pollen count was less than half the counts of the other two years, the intradiurnal pattern was observed to be similar. Besides, the major part of grass pollen load in

Berlin in 2011 was measured in the investigated period (13 May–22 June). *Artemisia* pollen, which are mainly represented by only one species (*A. vulgaris*) (Käpylä 1981), showed the most distinctive intradiurnal periodicity. The main time was observed between 6 a.m. and 2 p.m. with a clear morning peak from 8 to 10 a.m., as also shown by Jäger (1990) in Austria and Käpylä (1981) in Finland. Allergic persons who suffer from pollinosis caused by grass and/or mugwort pollen allergens and live or work near the A 100 should avoid the aforementioned main times to air rooms or to be outside in order to reduce their risk of exposure. Airborne pollen load is strongly governed by meteorological conditions. For example, high relative humidity often results in low pollen concentrations on the same and/or next day/s (*Betula*, Poaceae), whereas long sunshine duration (Poaceae) and high air temperature (*Artemisia*) promote higher concentrations. On account of the weather and individual threshold values, allergic symptoms are generally possible at any time of the day. For *Fraxinus* and *Betula*, the intradiurnal patterns are not as clear, and forecasts about peak times of pollen load can hardly be made. *Fraxinus* pollen were mainly in the air during the second half of the day with maxima in the early afternoon (2012; a second high value (from 8 to 10 p.m.) should not be overestimated since it mainly traces back to only 2 days (28/3/2012, 3/4/2012)) or in the evening (2013), and lowest concentrations occurred in the morning, as also described by Jäger (1990) who observed a decrease around 8 a.m., with maxima mainly in the afternoon and time of most intense pollen occurrence until the evening hours. Low pollen counts caused that single days could notably affect the intradiurnal profile and contributed to a rather heterogeneous pattern. In 2012, most *Betula* pollen were counted between 10 a.m. and 12 p.m. with peak values about midday and in the early afternoon. In 2013, the midday peak was missing and no clear tendency of peak times concerning the pollen load could be observed. Peaks may occur at any time of the day and night (Käpylä 1984). High nightly pollen concentrations were also determined in the present study and could be explained by favorable meteorological conditions, such as increasing temperatures and decreasing relative humidities, as described by Käpylä (1984) and von Wahl et al. (1989), long-distance transport or the nightly sliding of pollen out of higher atmospheric layers.

The monitoring site “A 100” revealed the situation close to a congested city motorway where allergic persons do not only suffer from high pollen loads but also from high PM levels caused by traffic (Bergmann et al. 2013), such as diesel exhaust particles and other air pollutants. Grass pollen counts near the A 100, for example, were significantly higher than those at a park site (Bergmann et al. 2013) where grasses were close to the pollen trap. On the one hand, it might be possible that pollen and other particles settled on the road are resuspended by vehicles. On the other hand, it is probable that the lawn in the park is more often mowed so that a considerable fraction of grasses cannot reach flowering. The result that Poaceae pollen concentrations in 2012 were positively correlated with the air pollution 4 days ago seems to be a random find, because there are no significant correlations with the other days, and neither *Betula* nor *Artemisia* pollen loads show this correlation. The intradiurnal fluctuations of traffic volume, visible pollution on the slide and pollen load, mainly of Poaceae in the afternoon and *Artemisia* in the morning, were partly coincident. The combination represents a special health threat as pollen are considered to be more allergenic in a polluted atmosphere, and respirable dust affects pulmonary function. Due to the high prevalence of respiratory allergies in the age group below 65 years, the most common chronic disease for this fraction of the population, which mainly represents the labor force, and due to the impact of allergies on cognitive functions, the socioeconomic consequences are immense and include absence from work and reduced productivity (Zuberbier et al. 2014). That is why allergies must not be trivialized and need an early and adequate medical intervention.

The A 100 site was rather distant from local pollen sources. Therefore, the intradiurnal patterns do not only reflect the times of pollen release, but additionally all mechanisms involved in removing pollen from the anthers and carrying them to the trap (Käpylä 1981; Norris-Hill 1999). Sites that are close to the sources ideally composed of only one species will detect pollen earlier than remote ones and will reflect the times of pollen release more clearly.

For further studies, it would be interesting to correlate the 2-hour means of pollen load with bi-hourly meteorological, traffic volume and air pollution data in order to obtain more detailed relationships and

explanations for the intradiurnal patterns of airborne pollen.

6 Conclusions

The study revealed typical seasonally averaged intradiurnal patterns for both Poaceae and *Artemisia* pollen load. Allergic persons living or working near the A 100 should avoid the respective main times of pollen load to air rooms or to be outside in order to reduce their risk of exposure. The main time of grass pollen load in the air was from 8 a.m. to 10 p.m. with peaks about midday or in the afternoon. Mugwort pollen mainly occurred between 6 a.m. and 2 p.m. with a clear maximum from 8 to 10 a.m. Typical intradiurnal patterns for *Fraxinus* and *Betula* pollen load could not be determined. On average, maxima were observed in the second half of the day. However, meteorological conditions are always the decisive factor for pollen release and distribution. The intradiurnal fluctuations of traffic volume, visible pollution on the slide and pollen concentrations were partly coincident, mainly in the afternoon. This combination represents a special health threat for the urban population.

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Conflict of interest The authors declare that they have no conflict of interest.

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