



Birch, grass, and mugwort pollen concentrations and intradiurnal patterns at two different urban sites in Berlin, Germany

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Abstract

Purpose The study investigated the seasonal courses and intradiurnal patterns of birch (*Betula*), grass (*Poaceae*), and mugwort (*Artemisia*) pollen at two sites in the city of Berlin in 2014 and 2015.

Methods The “Motorway Site” was situated at a busy city motorway and the “City Center Site” on the roof of a large hospital. Sampling was undertaken with 7-day recording volumetric spore traps. Light microscopic analysis led to daily means (pollen/m³ air) and 2-h means (daily %). Correlation coefficients were calculated to compare pollen season between the sites. Rainless days were examined for their intradiurnal maximum of pollen concentration and corresponding wind direction in order to identify the impact of local pollen sources. Birch trees, grassed areas, and

mugwort/field sagewort stems were mapped at both sites.

Results The seasonal courses of *Betula*, *Poaceae*, and *Artemisia* pollen each showed significantly positive correlations between the sites, but absolute counts were higher at the motorway. *Artemisia* pollen showed a distinct morning profile at both sites. *Poaceae* pollen concentrated on the second half of the day peaking in the evening or at night. *Betula* pollen offered no clear trend, but the main period mostly started at 8 am and lasted until the end of day.

Conclusions Higher pollen counts at the motorway seem to be associated with the local vegetation that was much more abundant than at the city center. Local sources of weeds (*Artemisia*) and grasses (*Poaceae*) releasing pollen at low heights appear to be more contributing for local pollen load than trees (*Betula*) at these sites.

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Introduction

Birch (*Betula*), grass (*Poaceae*), and mugwort (*Artemisia*) pollen belong to the most important aeroallergens. In Germany, *Betula* and *Poaceae* pollen each induce clinically relevant sensitizations in more than a third of the total population [1]. *Artemisia* pollen affects nearly 20% of the German population [1]. Although seasonal allergic rhinitis clearly impairs health-related quality of life and, e.g., performance on the job, insufficient treatment of the symptoms, underdiagnoses, or self-diagnoses by patients not turning to a doctor are prevalent socioeconomic problems [2, 3]. Birch trees and grass are widely spread in urban areas [4]. Birch trees are favored ornamental trees in cities, but should not be

further planted in public spaces in order to reduce urban pollen load [5]. Local sources in cities, such as ornamental trees, may play a prominent role in the development of sensitizations to their particular pollen [6]. In many cases, graminaceous vegetation frequently occurs on the outskirts due to adjacent fields and meadows [7, 8], but there can be relevant sources within the city as well [4]. Mugwort can be found as pioneer plant on disturbed soils due to building activities, for example [9].

There is an upward trend of the annual pollen sums of many taxa in Europe, even if not all species show this tendency. The uptrend is more distinct in urban than in rural or semirural areas [10]. The increase in carbon dioxide (CO₂) and air temperature as a result of the ongoing climate change, especially observable in urban areas, might be crucial factors [10, 11]. Urban air pollution, such as nitrogen dioxide (NO₂), ozone (O₃), and particulate matter (PM), e. g., diesel exhaust particulates (DEPs), also poses a health threat to allergic subjects because it might aggravate their symptoms [12–15]. The inner-city spatial distribution of airborne pollen concentrations, already worked on by some researchers [4, 7, 16], as well as their seasonal and intradiurnal occurrence are valuable information for allergy sufferers. In this study, the seasonal courses and intradiurnal patterns of *Betula*, *Poaceae*, and *Artemisia* pollen were investigated at two different urban sites in order to determine if and why there are differences in the particular pollen load.

Materials and methods

Study area and pollen sampling

Berlin, the German capital, is located in the east of Germany (52°31'N, 13°24'E). The city has a population of approximately 3.5 million [17]. Berlin is situated in the temperate zone. The mean annual temperature is 9.5 °C and the average annual rain amounts to 591 mm (German Weather Service [DWD]).

Sampling was carried out using 7-day recording volumetric spore traps [18] at two sites, nearly 7 km apart from each other, in the urban area of Berlin in 2014 (12 Feb–27 Oct) and 2015 (28 Jan–5 Oct) (Fig. 1). One site (52°30'59.9"N, 13°17'01.9"E; sampling height: 5 m above ground level) was located next to the city motorway "A 100", which is the busiest motorway in Germany. An average of 177,700 vehicles/24 h passed the section where the "Motorway Site" was set up [19]. The pollen trap was installed on a stage of the German Environment Agency (UBA). The three-lane motorway ran to the east of the stage from north to south and vice versa. Five-story buildings in the north-west and a large cemetery in the south-west adjoined the site. The trap was especially exposed to wind from northern and eastern directions. The Motorway Site was first installed in 2011 and kept due to the allergologically relevant combination of high pollen counts

and road traffic [16, 20]. A second pollen trap, the "City Center Site", (52°31'38.5"N, 13°22'40.6"E; sampling height: 20 m above ground level) was set up on the roof of the Allergy-Centre-Charité hospital. The surroundings were characterized by streets and large buildings. The section on the main road near the City Center Site had an average of 21,800 vehicles/24 h. The trap was especially exposed to wind from southern and western directions.

Analysis

Pollen

Daily samples were analyzed by light microscopy with regard to *Betula*, *Poaceae* (wild and cultivated species), and *Artemisia* pollen [21]. Pollen grains were counted (magnification 250-times), in two horizontal central transects (length: 48 mm, width: 485 µm), i. e., in approx. 7% of the whole sample area. The analysis led to daily means (pollen grains/cubic meter air [p/m³]) and 2-h means. Pollen season (PS) was defined to cover 90% of the annual pollen index (PI) [22]. Correlation coefficients according to Pearson were calculated in order to compare PS between both sampling sites. Bi-hourly means obtained on rainless days (daily rainfall: 0.0–0.1 mm) were used for bar graphs showing mean intradiurnal patterns of pollen load. For this, the daily means of each pollen type and sampling site were added and set to be 100%. The pollen sums of each 2-h period were expressed as a percentage of this total (daily %). The intradiurnal main period of pollen load was defined to be the period in which a threshold value of 8.3% is exceeded (cf. [23]). Times of day are indicated in Central European Summer Time (CEST). All rainless days were further examined for their respective intradiurnal maximum of pollen concentration and the corresponding wind direction at these peak times of the day.

Hourly rainfall and wind direction data, measured at the meteorological station "Berlin-Tegel" (52°33'36.0"N, 13°18'36.0"E; measuring height: 10 m above ground level), were provided by the DWD (Fig. 1).

Vegetation

Birch trees (*Betula*), grassed areas (*Poaceae*) including dominant grass species, and mugwort (*Artemisia vulgaris*; bloom: Jul–Sep) and field sagewort (*Artemisia campestris*; bloom: Aug–Oct) stems were mapped at both sites within a radius of 100 m. *Artemisia* pollen do not only come from mugwort plants, but also from other *Artemisia* species. However, *A. vulgaris* is the most common species in Europe [24]. That is why "mugwort pollen" is used synonymously for "Artemisia pollen" in this paper. Maps were created using Microsoft Paint.

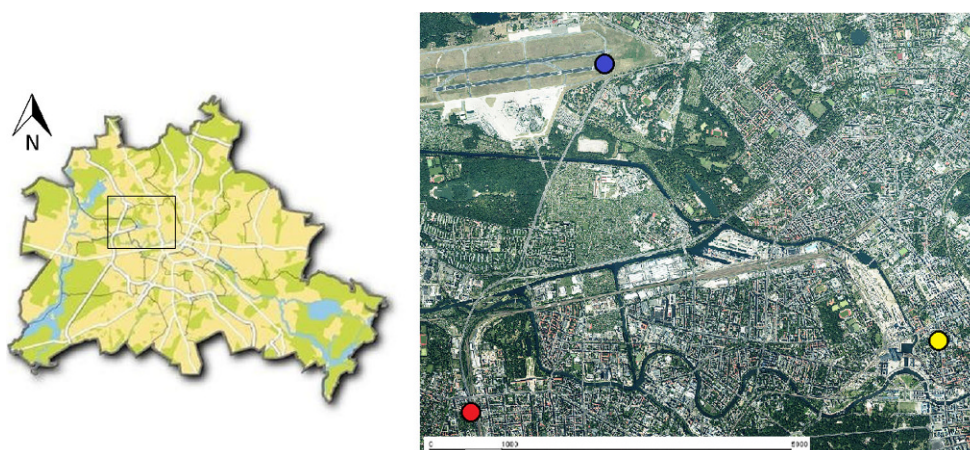


Fig. 1 Locations of the monitoring sites in the city of Berlin. Red circle Motorway Site, yellow circle City Center Site, blue circle meteorological station (DWD). Map derived from http://www.in-berlin-brandenburg.com/Berliner_Bezirke/Bilder/berliner-stadtplan.jpg; © Increa; Transformation by the author: Adding rectangle and north arrow. Aerial photo derived from Geo-

portal Berlin/Digitale farbige Orthophotos 2015 (DOP20RGB), http://fbinter.stadt-berlin.de/fb/index.jsp?Szenario=fbinter_jsc. Transformation by the author: Adding colored circles. Not protected by copyright: <http://www.stadtentwicklung.berlin.de/geoinformation/download/nutzIII.pdf>

Results

Pollen

Seasonal courses

The total sum of the daily means of *Betula*, *Poaceae*, and *Artemisia* pollen was higher at the Motorway Site (2014: 37,529; 2015: 17,488) compared to the City Center Site (2014: 22,969 [61% of the Motorway Site count]; 2015: 9025 [52%]) during PS in both years. The separate pollen sums of *Betula*, *Poaceae*, and *Artemisia* were each higher at the Motorway Site as well (Table 1, see *Seasonal pollen sum*).

Throughout both years, the daily means of *Betula* pollen at the Motorway Site were consistently higher than at the City Center Site (Fig. 2a). The daily means of *Poaceae* pollen were mostly (in approximately 80% of the days) higher at the Motorway Site (Fig. 2b). Finally, almost all daily means of *Artemisia* pollen were higher at the Motorway Site as well (Fig. 2c).

The particular seasonal courses of *Betula*, *Poaceae*, and *Artemisia* pollen each showed significantly positive correlations between both sites (Fig. 2a–c, see *correlation coefficients*). *Betula* PS occurred in the same (2014) and nearly the same period (2015) respectively at both sites (Table 1). Peak days were found on dates differing in five days (2014) and on the same date (2015), respectively. *Poaceae* PS started on similar dates at both locations, but ended earlier at the City Center Site. Days with maximum pollen level occurred on similar dates. Start and end dates of *Artemisia* PS differed more clearly between the sites. At the City Center Site, PS lasted longer, and peak days occurred earlier.

Intradiurnal patterns

At the Motorway Site, the average intradiurnal main period of *Betula* pollen was between 8 am and 12 pm (Fig. 3a). The peak occurred in the afternoon (2014) and at night (2015), respectively. At the City Center Site, the main period lasted from 8 am until 2 am in 2014, with interruptions in the evening and at night. In 2015, the main period at the City Center Site was between 10 am and 2 pm and between 8 pm and 2 am. The peak was reached from 10 to 12 am (2014) and from 10 to 12 pm (2015), respectively. The latter mainly traces back to a single high bi-hourly mean on a certain date (15 Apr).

Poaceae pollen at the Motorway Site mainly occurred between 10 am and 12 pm (2014) and between 2 and 12 pm (2015), respectively (Fig. 3b). In both years, the peak was reached in the evening. The main period at the City Center Site in both years was the second half of the day peaking at night (2014) and in the evening (2015).

Artemisia pollen showed the most peaked intradiurnal pattern at both sites. At the Motorway Site, the main period was between 4 and 12 am (2014) and between 6 am and 4 pm (2015), respectively (Fig. 3c). The peak occurred in the morning (2014) and in the late morning (2015), respectively. At the City Center Site, the main period lasted from 6 am until 6 pm in 2014. In 2015, *Artemisia* pollen mainly occurred between 8 am and 2 pm and between 6 and 8 pm. The peak was reached in the morning (2014) and in the late morning (2015), respectively.

Vegetation

Vegetation at the Motorway Site was much more abundant than at the City Center Site (Figs. 4 and 5). Twelve fertile birch trees were found to the south of

Fig. 2 Daily means of *Betula* (a), *Poaceae* (b), and *Artemisia* pollen (c) during pollen season at the Motorway Site (MS) and the City Center Site (CS) in Berlin in 2014 and 2015. Correlation coefficients according to Pearson, $p < 0.001$, regarding the respective pollen type between both sites

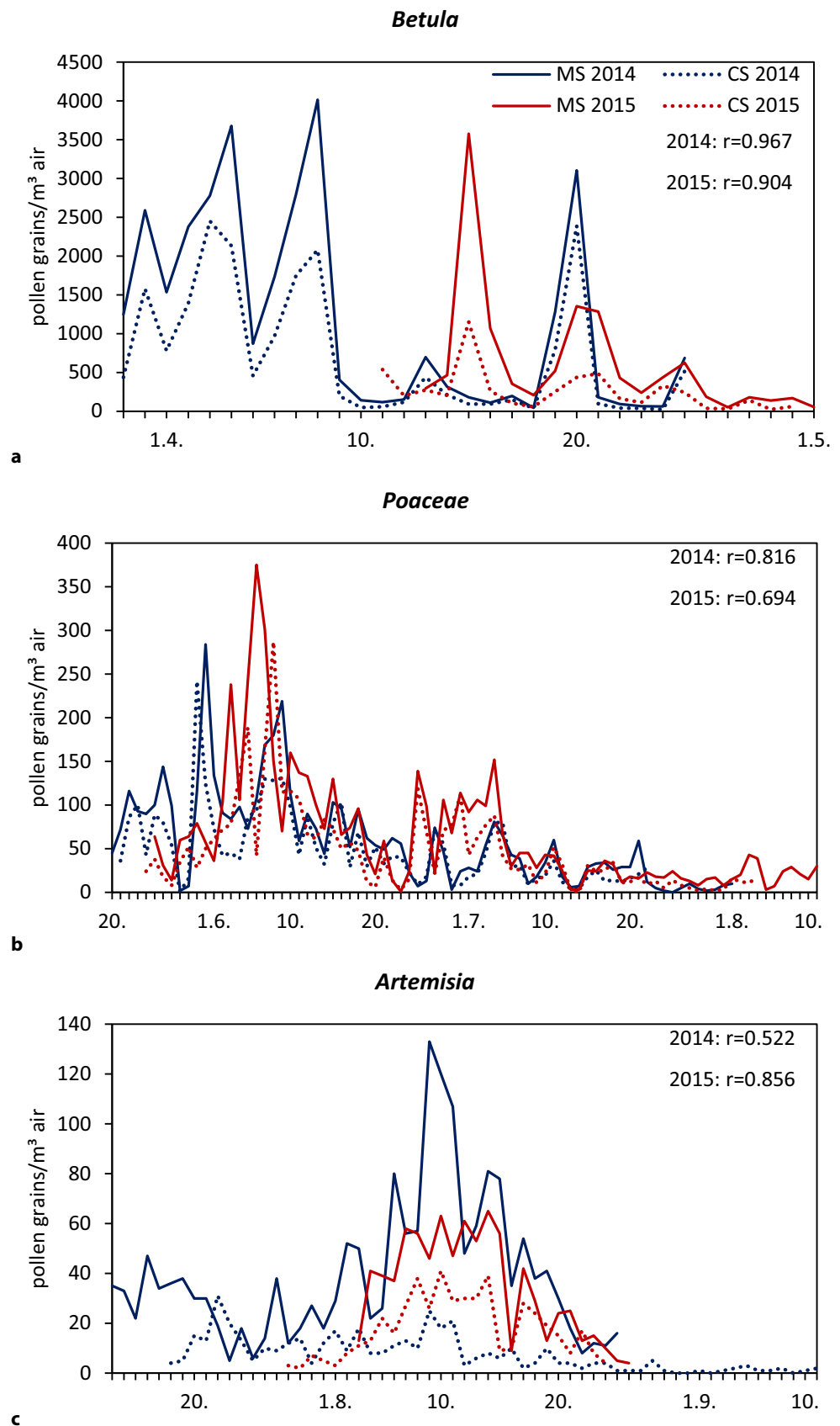


Fig. 3 Bi-hourly means of *Betula* (a), *Poaceae* (b), and *Artemisia* pollen (c) on rainless days (daily rainfall: 0.0–0.1 mm) during pollen season at the Motorway Site (MS) and the City Center Site (CS) in Berlin in 2014 and 2015. The intradiurnal main period of pollen load was defined to be the period in which a threshold value of 8.3% is exceeded (cf. [23]). Times of day are indicated in Central European Summer Time (CEST)

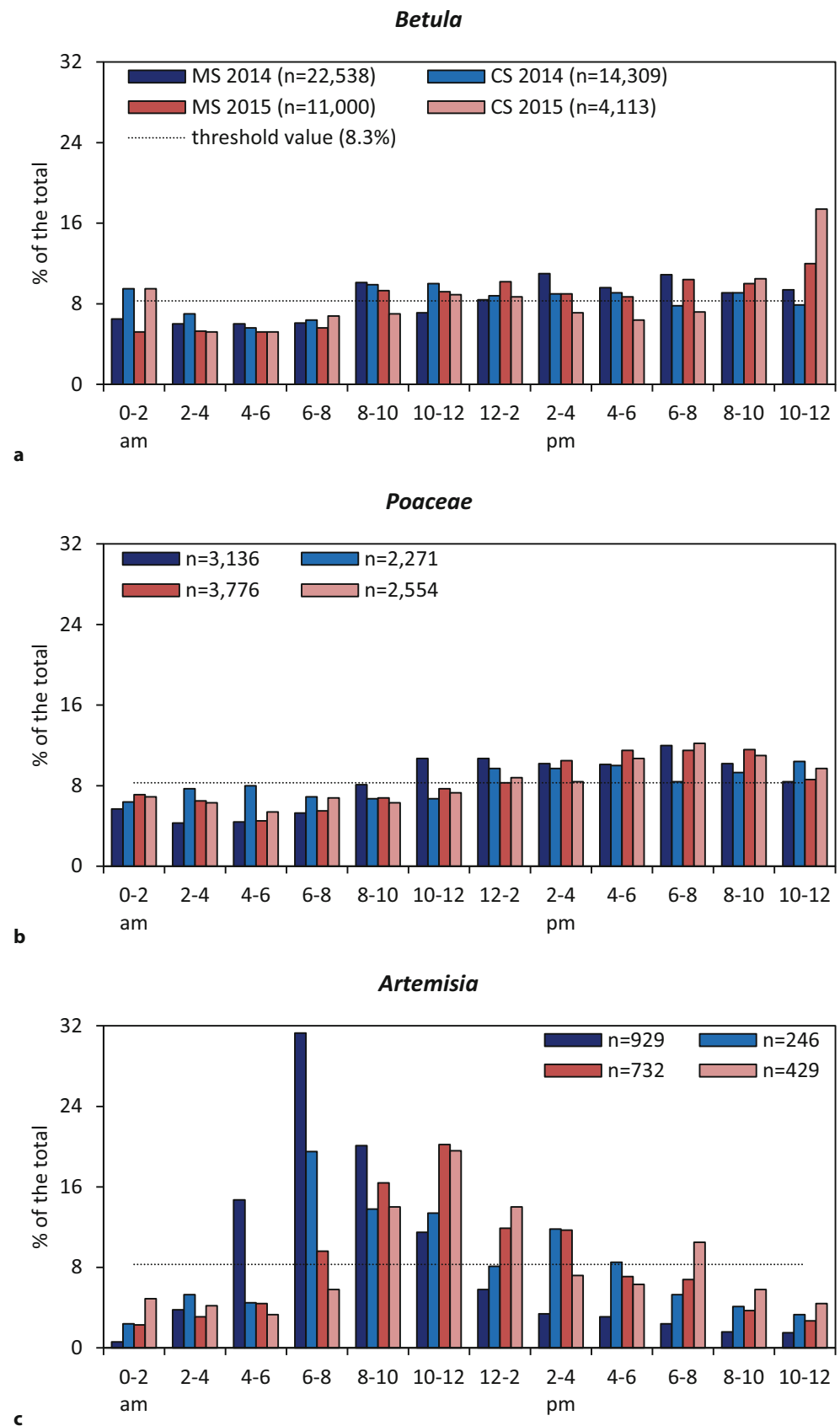


Table 1 Pollen season of *Betula*, *Poaceae*, and *Artemisia* at the Motorway Site and the City Center Site in Berlin in 2014 and 2015

	<i>Betula</i>		<i>Poaceae</i>		<i>Artemisia</i>	
	Motorway	City Center	Motorway	City Center	Motorway	City Center
Start date						
2014	30 Mar	30 Mar	20 May	21 May	13 Jul	18 Jul
2015	13 Apr	11 Apr	25 May	24 May	03 Aug	28 Jul
End date						
2014	25 Apr	25 Apr	01 Aug	22 Jul	25 Aug	11 Sep
2015	1 May	30 Apr	11 Aug	04 Aug	26 Aug	24 Aug
Length [days]						
2014	27	27	74	63	44	56
2015	19	20	79	73	24	28
Seasonal pollen sum^a						
2014	31,480	19,385 (62%)	4,308	3,169 (74%)	1,741	415 (24%)
2015	11,646	5,126 (44%)	5,018	3,407 (68%)	824	492 (60%)
Arithmetic mean						
2014	1,165.9	718.0	58.2	50.3	39.6	7.4
2015	612.9	256.3	63.5	46.7	34.3	17.6
Peak^b [p/m³]						
2014	4,014	2,451	284	242	133	31
2015	3,576	1,153	375	287	65	41
Peak date						
2014	08 Apr	03 Apr	31 May	30 May	09 Aug	22 Jul
2015	15 Apr	15 Apr	06 Jun	08 Jun	14 Aug	10 Aug

^aSum of daily means (pollen grains/cubic meter air [p/m³]) during pollen season (PS), the percentage in the “City Center” columns indicates the proportion of the corresponding Motorway Site count; ^bhighest daily mean during PS

Table 2 Wind directions at the intradiurnal peak times of pollen concentration at the Motorway Site and the City Center Site in Berlin in 2014 and 2015

	<i>Betula</i>		<i>Poaceae</i>		<i>Artemisia</i>	
	Motorway (%)	City Center (%)	Motorway (%)	City Center (%)	Motorway (%)	City Center (%)
N-NE	6.7	20.0	11.8	9.8	9.1	10.7
NE-E	20.0	10.0	19.4	18.3	20.5	21.4
E-SE	20.0	10.0	7.5	6.1	25.0	12.5
SE-S	3.3	3.3	7.5	4.9	4.5	7.1
S-SW	3.3	3.3	6.5	7.3	9.1	10.7
SW-W	13.3	13.3	10.8	12.2	15.9	19.6
W-NW	20.0	23.3	30.1	30.5	11.4	14.3
NW-N	13.3	16.7	6.5	11.0	4.5	3.6
No. of days	30	30	93	82	44	56

N north, S south, W west, E east

the Motorway Site trap, whereas, at the City Center Site, there were no birch trees within the 100 m radius. Various types of grassed areas (cemetery, roadside greenery, lawn, and ruderal vegetation) and seven dominant grass species were found at the motorway. In addition, there were a lot of uncut grassed areas that can bloom. In the city center, grassed areas (roadside greenery, lawn, park, and ruderal vegetation) were regularly or irregularly cut, and six dominant grass species were found. At the Motorway Site, a total of 557 *Artemisia vulgaris* stems and

783 *A. campestris* stems were counted, whereas there were only 156 *A. vulgaris* stems at the City Center Site.

Intradiurnal peaks and wind direction

At the Motorway Site, the intradiurnal peaks of *Betula* pollen mainly coincided with wind from eastern and western directions (Table 2). At the City Center Site, westerly to north-westerly winds dominated at peak time. At both sampling sites, the intradiurnal peaks of *Poaceae* pollen were mainly associated with wind from western to north-western directions. Most intradiur-



Fig. 4 Vegetation and urban environment at the Motorway Site within a radius of 100 m. Red circle sampling site, yellow circles of different size (big; medium; small) fertile birch trees (>10 m; 5–10 m; <5 m), dark green regularly cut grassed area, light green irregularly cut grassed area, orange uncut grassed area, C cemetery, G roadside greenery, L lawn, P park, R ruderal vegetation, % *Poaceae* cover-abundance; dominant grass species: 1 *Agropyron repens*, 2 *Arrhenatherum elatius*, 3 *Bromus sterilis*, 4 *Calamagrostis epigejos*, 5 *Dactylis glomerata*, 6 *Festuca rubra*, 7 *Hordeum murinum*, 8 *Lolium perenne*, 9 *Poa pratensis*, 10 *Setaria viridis*, blue circles/strips and counts mugwort stems, purple circles/strips and counts field sagewort stems. Cadastral map derived from Geoportal Berlin/Katasterämter, http://fbinter.stadt-berlin.de/fb/index.jsp?Szenario=fbinter_jsc. Transformation by the author: Adding vegetation mapping (colored areas, circles, stripes, and counts, upper case letters C, G, L, P, and R, percentages, and black numerics 1–10). Not protected by copyright: www.stadtentwicklung.berlin.de/geoinformation/download/nutz3ll.pdf

nal peaks of *Artemisia* pollen occurred with easterly to south-easterly winds (Motorway Site) and north-easterly to easterly winds (City Center Site), respectively.

Discussion

The seasonal and intradiurnal variations of *Betula*, *Poaceae*, and *Artemisia* pollen were investigated at two sites in the urban area of Berlin in 2014 and 2015. The sites differed in vegetation, urban density, exposure to wind, and traffic volume. In terms of the particular seasonal courses, there were significantly positive correlations between both sites, despite a distance of nearly 7 km, which accords with another study [16] where grass pollen are discussed. *Betula* pollen showed the strongest correlations. Regarding the absolute counts, higher seasonal pollen sums and daily means were measured at the Motorway Site. *Artemisia* pollen sums showed the greatest



Fig. 5 Vegetation and urban environment at the City Center Site within a radius of 100 m. For legend see Fig. 4. Cadastral map derived from Geoportal Berlin/Katasterämter, http://fbinter.stadt-berlin.de/fb/index.jsp?Szenario=fbinter_jsc. Transformation by the author: Adding vegetation mapping (colored areas, circles, stripes, and counts, upper case letters C, G, L, P, and R, percentages, and black numerics 1–10). Not protected by copyright: www.stadtentwicklung.berlin.de/geoinformation/download/nutz3ll.pdf

differences. Particular local vegetation might be an important factor resulting in different pollen counts. Local sources of all three pollen types were much more abundant at the motorway compared to the city center. Larger ruderal areas, such as roadsides and a nearby railway embankment, account for the frequency of mugwort, field sagewort, and grass. Local sources, which can differ greatly within a city, seem to be very important for local pollen load mainly in the case of low release heights [4]. *Artemisia* pollen are emitted at a height of at most 2.3 m (*A. vulgaris*) [25] in the early morning when air convection and vertical transport are rather low [26], which both might hinder pollen distribution. *Poaceae* pollen mostly deposit within 3 m of the source, and only less than 1% reaches a distance of 1 km [27]. The higher release height of trees (*Betula*), compared to weeds and grasses, seems to result in a decreased importance of local sources and to promote long-range transport [4]. However, local birch trees might enrich local pollen load. Wind directions measured at the intradiurnal peak times of pollen concentration also revealed an impact of local sources. At the Motorway Site, most intradiurnal peaks of *Artemisia* pollen coincided with wind from eastern directions where large plant populations were found. At the City Center Site, the second-most common wind direction at peak time (SW-W) matched the direction where most mugwort

stems were counted. Not cut or irregularly cut grassed areas (roadside greenery, ruderal vegetation) to the west of both pollen traps also correlated with the direction where the wind most commonly came from at peak time (W-NW). Intradiurnal peaks of *Betula* pollen at the motorway did not seem to be directly related to the local trees in the south because southern winds only played a minor role. However, the tall birch tree adjacent to the trap has surely increased local pollen concentrations. At the City Center Site, some intradiurnal peaks could be due to three birch trees to the west of the 100 m radius since westerly to north-westerly winds dominated at peak time.

Seasonal pollen sums of *Poaceae* reached the most similar values between both locations (Table 1), despite much less grassed areas at the city center. Pollen distribution and transport might be promoted by the fact that different grass species emit pollen at different times of day, mostly in the morning, but also in the afternoon and evening [28], so that greater amounts of pollen could be lifted up by air convection, which is increasing in the course of a day, and reach higher atmospheric layers. This phenomenon is described for *Plantago lanceolata* (plantain family) and *Rumex acetosa* (knotweed family), which can also emit pollen at any time of day [26].

Pollen counts at the motorway might be partly influenced by the high traffic volume as well. Resuspension of “old” pollen, deposited on the road surface, by traffic-related air turbulences, might increase local pollen load mainly during dry periods [16]. Thus, allergy sufferers in cities, especially close to busy roads, can be faced both with high pollen counts and air pollution, e.g., PM due to exhaust emissions [15], which might aggravate their symptoms [12].

As to the intradiurnal patterns, *Artemisia* pollen showed the most distinct profile at both sites peaking in the morning (6–8 am; 2014) and late morning (10–12 am; 2015) respectively, which accords with other studies [20, 23, 25, 26, 29]. The sites mainly differed in pollen concentrations between 6 and 8 am (Fig. 3c), i.e., in the period when *A. vulgaris* pollen are released [26]. The Motorway Site patterns, which showed higher counts in this period, might partly reflect local pollen release. At the City Center Site, the patterns appeared to be shifted and prolonged. The main period started two hours later than at the motorway, which might be due to the higher sampling height (roof level) at the city center [26]. Pollen traps that are closer to the ground may detect higher counts and an earlier seasonal and intradiurnal occurrence of *Artemisia* pollen [26, 30, 31]. The later intradiurnal peak at both sites in 2015 might be associated with the late onset and short duration of the season. *A. campestris* pollen that occur later in the season [32] and show an intradiurnal maximum at 11 am [33] might have had a greater share in these profiles. Allergy sufferers should avoid the early and late morning hours to stay outdoors or to air the room.

Poaceae pollen mainly concentrated on the second half of the day and peaked in the evening or at night, which accords with Norris-Hill & Emberlin [34]. Compared to Jäger [23] and Simoleit et al. [20], where three previous years at the motorway are discussed, the intradiurnal patterns were slightly delayed. Grass species that could have contributed to the profiles are, e.g., *Agropyron repens* (couch grass), *Arrhenatherum elatius* (false oat-grass), *Festuca rubra* (creeping fescue), and *Lolium perenne* (perennial ryegrass). These species release pollen in the afternoon and evening (Beddows 1931, Jones 1952, and Emecz 1962 [35]) and occurred at the sampling sites. In 2014, the intradiurnal pattern at the city center was a little more homogeneous than at the motorway, which could indicate that *Poaceae* pollen were well mixed in the air at roof level [36]. On average, grass pollen allergy sufferers in cities might have less symptoms in the morning when concentrations are lower. However, the intradiurnal patterns are dependent on the species [29] and can change from day to day and in the course of a season [35].

Betula pollen offered no clear trend, but the main period mostly started at 8 am and lasted, partly interrupted, until the end of day. Maximum pollen level was reached in the late morning, in the afternoon, or at night. High pollen counts occurred at any time of the day and night, which accords with Kämpylä [37]. Long-range transport and nightly deposition out of higher atmospheric layers are possible explanations. Other studies [20, 23] could not find a clear pattern either. At the most, Jäger [23] observed a morning minimum and, during normal and weak blooming periods, most pollen from noon until late evening. In years with an intense bloom, nightly pollen counts were more pronounced. At the City Center Site, the main period lasted until 2 am, i.e., a little longer than at the motorway (Fig. 3a), which might be due to the well-mixed air at roof level again. Because of the unclear intradiurnal trend, a recommendation to allergy sufferers is difficult to give. At the most, they should prefer the early morning (until 8 am) to air the room, for example, but also keep in mind that high pollen counts can occur at any time.

The intradiurnal patterns at the motorway do not seem to be strongly affected by the high traffic volume because *Artemisia* pollen profiles differed distinctly from the profiles both of *Betula* and *Poaceae* pollen, as mentioned in Simoleit et al. [20].

Pollen counts and intradiurnal patterns can be affected by sampling height, which should be considered when undertaking studies [36]. Higher pollen concentrations and more distinct circadian rhythms can often be found at lower heights [38, 39]. Sampling at heights where humans breathe might partly provide more suitable information for allergy sufferers. However, movement of humans is very individual and irregular. Roof level sampling can be representative for a larger area, whereas ground level sampling

is more influenced by nearby pollen sources [31]. Although the immediate surroundings of allergy sufferers clearly affect their exposure to pollen, a pollen trap that is a few kilometers away can provide useful information on pollen counts [16].

Conclusions

The seasonal courses of *Betula*, *Poaceae*, and *Artemisia* pollen each showed significantly positive correlations between the Motorway Site and the City Center Site, but the absolute concentrations differed. Higher pollen counts at the Motorway Site seem to be associated with the local vegetation that was much more abundant than at the City Center Site. Local sources of weeds (*Artemisia*) and grasses (*Poaceae*) that release pollen at low heights appear to be more contributing for local pollen load than trees (*Betula*) at these sites. In cities, allergy sufferers sensitized to *Artemisia* pollen should expect the highest load in the early and late morning hours, whereas people sensitized to *Poaceae* pollen should prefer morning hours to stay outdoors or to air the room. *Betula* pollen offered no clear intradiurnal trend. However, circadian pollen load can change from day to day depending on several factors, such as release height, intradiurnal time of release, and weather.

Compliance with ethical guidelines

Conflict of interest A. Simoleit, M. Werchan, B. Werchan, H.-G. Mücke, U. Gauger, T. Zuberbier, and K.-C. Bergmann declare that they have no competing interests.

Ethical standards This article does not contain any studies with human participants or animals performed by any of the authors.

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