

Six years of observation of airborne and deposited pollen in central European Russia: first results

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Abstract

The aim of the study was to compare the pollen spectra recorded in rural and urban environments in order to examine whether pollen data obtained in the urban environment could also represent the situation in surrounding rural areas and how urban planting affects the regional pollen spectrum. Daily airborne pollen observations were performed with a volumetric Hirst type trap in Moscow (Russia). Modified Tauber traps were located in the Moscow region. The Tauber traps were installed and treated according to Pollen Monitoring Programme (PMP) guidelines. Spearman correlation coefficients were determined between the percentage of total pollen recorded in the Tauber and Hirst type samplers. The data showed that the Tauber spectra are characterised by higher taxonomic variability, mainly due to the greater occurrence of local herbaceous plants. Pollen types registered by Hirst type samplers were predominantly represented by anemophilous arboreal species, used in urban planting. A significant correlation for annual sums was only observed for *Betula* pollen, the most abundant component in both sampler types. Data obtained in big cities for dominant taxa can be extrapolated to the surrounding rural territories. The simultaneous use of volumetric and gravimetric samplers can be very useful for palaeo-ecological studies to evaluate the presence of local and transported pollen.

Keywords: Pollen deposition, airborne pollen, Tauber trap, Hirst type trap, correlation

Data from aerobiological monitoring are widely used to describe and predict the pollen content of the atmosphere. They are not only important for the medical community and people with allergic responses, but also for specialists in plant pathology, reproductive biology, palaeo-ecology, etc. The Hirst volumetric pollen trap is commonly used for determining the composition of atmospheric pollen. It captures pollen directly from the atmosphere (Hirst 1952; Solomon & Mathews 1978) and allows concentrations of pollen and spores per cubic metre of air to be determined. Sampling efficiency is reported to be very high, but is affected by particle size, wind velocity and trap location (Lacey & Venette 1995; Sugita et al. 1999; Levetin et al. 2000; Latorre et al. 2008; Ranta et al. 2008). In distant locations, where electricity is not available, Hirst-type traps are not suitable. The most popular device for long-term stu-

dies in distant locations is the Tauber trap, which is a non-volumetric sedimentary sampler. The Tauber trap is based on gravity and located at ground level, and it has been suggested that its pollen spectra is more local and does not reflect the true content of the air, but biased to heavier pollen types (Peck 1972; Tauber 1974; Fægri & Iversen 1989).

Correlations between data from Hirst type samplers and Tauber traps were studied by Grosse-Brauckmann and Stix (1979) at several locations in Germany, by Levetin et al. (2000) in western Oklahoma, and by Ranta et al. (2007, 2008) in Finland. Grosse-Brauckmann and Stix (1979) showed that the ratio of yearly pollen deposition to airborne pollen concentrations depends mainly on settling velocity, which in turn depends on pollen size. Levetin et al. (2000) published details of pollen accumulation with a Hirst type sampler and a Tauber trap placed side-by-side on

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(Received 26 October 2015; accepted 5 February 2016)

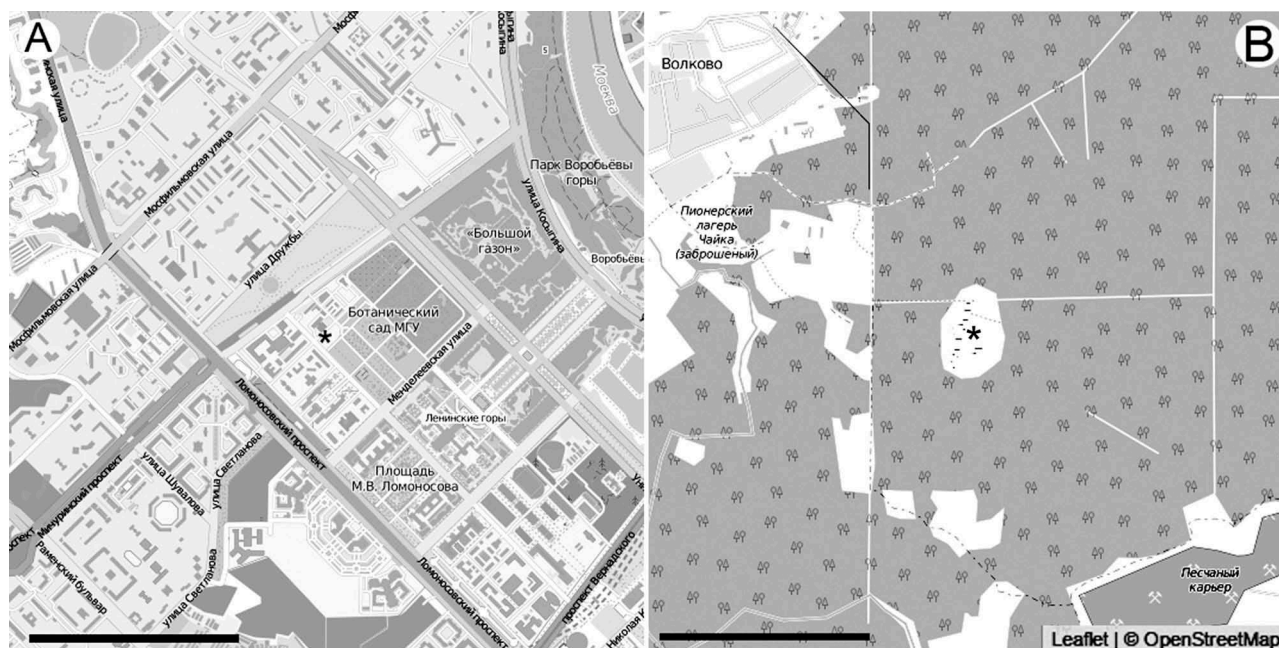


Figure 1. Trap locations. **A.** Hirst type sampler. **B.** Tauber traps. Asterisks indicate trap locations. Scale bar – 1 km.

the roof at a height of 12 m above ground level. The authors compared the taxa and pollen quantities recorded monthly during a one year period and showed a very strong correlation between the pollen influx of Tauber traps and the cumulative sum of daily pollen concentration, recorded by the Hirst type trap for all taxa. The authors assumed that both methods accurately reflect anemophilous vegetation of the region. The difference in the prevalence of some particular pollen types was explained by different pollen size. Ranta et al. (2007), (2008) compared long-term datasets in terms of the presence of plant taxa and their annual quantities. They observed very strong correlations between annual fluctuations of arboreal pollen, mainly for *Betula* and *Pinus*, between traps of different types. For the majority of low-growing plants, which mainly reflect vegetation of the sampling site, no correlation was detected. The only exception was *Urticaceae*. The authors assumed that arboreal pollen and some herbs (*Poaceae*, *Urtica*) reflect vegetation and climatic variation on regional or landscape level. Pidek et al. (2006) compared total annual pollen concentrations of four dominant tree taxa (*Betula*, *Alnus*, *Carpinus* and *Fagus*), obtained by three different methods (Tauber trap, gravimetric and volumetric) during 1998–2004 in two widely separated sample sites. The authors showed similarities between the obtained results that reflected the regional peculiarity of pollen spectra.

The aim of the present study was to compare pollen spectra in rural and urban environments in central European Russia, in order to examine whether pollen data

obtained in the urban environment could also represent the situation in surrounding rural areas and how urban planting affects the regional pollen spectrum. We investigate taxonomic diversity, the proportions of pollen types in each sampler and inter-annual variations of pollen quantity in rural and urban placed traps.

Material and methods

Hirst sampler

Daily airborne pollen observations were performed in Moscow (Russia) throughout the period mid-March through mid-October for the years 2008–2013. Pollen sampling was performed by a Hirst type volumetric sampler (Hirst 1952) on an open rooftop, at 10 m above ground level (55° 42' N, 37° 32' E). The pollen sampler is located in the campus of the Lomonosov Moscow State University, Moscow, Russia, near the Nature Reserve 'Vorob'evy Gory' and close to the University's botanical garden. The vegetation is represented by species used in urban greening and includes dominant trees such as *Fraxinus*, *Acer*, *Quercus*, *Betula*, *Malus*, *Populus*, *Ulmus*, *Picea* as well as *Corylus*, *Alnus*, *Pinus*, *Larix*, *Picea* and *Juglans*, which are planted in the botanical garden and on the Natural reserve territory. Within a radius of 1.5 km around the sampler location, grass lawns occupy about 11.5%, waste ground 3% and the area of tree planting about 10% of the territory. The University botanical garden next to the trap location occupies 30 ha (Figure 1).

Table I. Composition of average pollen spectra of the Hirst type sampler and the Tauber traps.

	Hirst	Tauber		Hirst	Tauber
<i>Acer</i>	3.3	×	Lamiaceae	×	×
<i>Aesculus</i>	×		<i>Larix</i>	×	
<i>Alnus</i>	4.2	2.9	Liliaceae		×
<i>Ambrosia</i>	×	×	<i>Lycopodium</i>		×
<i>Artemisia</i>	2.4	×	<i>Menyanthes</i>		×
Asteroidae	×	×	Moraceae	×	
<i>Betula</i>	37.6	49.7	<i>Picea</i>	×	4.1
Boraginaceae	×	×	<i>Pinus</i>	5.9	23.0
Brassicaceae	×	×	<i>Plantago lanceolata</i>	×	×
Campanulaceae		×	Poaceae	2.5	1.5
<i>Carpinus</i>		×	Polygonaceae		×
Caryophyllaceae		×	Polypodiaceae		5.9
<i>Centaurea cyanus</i>		×	<i>Populus</i>	5.9	×
Cereal		×	<i>Quercus</i>	2.2	×
Chenopodiaceae	×	×	Ranunculaceae		×
Cichoroideae	×	×	<i>Rhamnus</i>		×
<i>Corylus</i>	×	×	Rosaceae	×	×
Cupressaceae	×		<i>Rumex</i>	×	×
Cyperaceae	×	2.2	<i>Salix</i>	2.2	×
<i>Equisetum</i>		×	<i>Scheuchzeria</i>		×
Ericaceae	×	×	Scrophulariaceae		×
<i>Euonymus</i>		×	<i>Sphagnum</i>	×	5.6
Fabaceae	×	×	<i>Thalictrum</i>		×
<i>Filipendula</i>		×	<i>Tilia</i>	×	×
<i>Fraxinus</i>	×	×	Trilete Polypodiales spores		×
<i>Galium</i>	×	×	<i>Typha latifolia</i>	×	×
<i>Hippophae</i>	×		<i>Ulmus</i>	×	×
<i>Humulus/Cannabis</i>	×	×	Umbelliferae	×	×
<i>Hypericum</i>		×	<i>Urtica</i>	28.7	1.7
<i>Juglans</i>	×		<i>Viburnum</i>		×
Juncaceae	×				

Note: Bold numbers reflect average percentage occurrence over 1%, × indicates taxa with average percentage occurrence less than 1%.

The technique of volumetric sampling is a standard procedure used throughout Europe (Galan et al. 2014). Slides were analysed under a light microscope by 12 equidistant transverse strips every second hour. Microscope counts were converted into cumulative concentrations and expressed as the number of pollen grains per cubic metre of air. Daily concentrations were summed for cumulative yearly totals.

Tauber traps

Modified Tauber traps were located in the surroundings of the Zvenigorod Biological Station of the Moscow State University in the Moscow Region (55° 40' N, 36° 42' E). To get a regional spectrum, three pollen traps were established on the oligotrophic bog (8 ha). Within a radius of 1.5 km around the trap location, forests occupy 80%, open and waste land 6% of territory. The dominant vegetation types of this area are secondary *Picea*, *Pinus-Picea* and *Picea-Betula* forests of 80 to 100 years old (Nosova et al. 2015) (Figure 1). The bog is surrounded by mixed *Betula-Pinus* forest with

some *Picea*, *Alnus* and *Populus*. The vegetation of the bog is very poor and consists of Ericaceae and Cyperaceae species plus *Drosera rotundifolia* L. and different species of *Sphagnum*. The distance between the Hirst type sampler and Tauber traps is about 50 km.

During the sampling period in 2008–2013, the traps remained in the field for the entire year and were changed annually at the end of the flowering season (in the middle of October). The data from two traps were lost in 2011 and from one trap in 2009 due to destruction of the equipment. The missing data were approximated by regression analysis. The modified Tauber traps without lid (Hicks et al. 2001) were installed and treated according to Pollen Monitoring Programme (PMP) guidelines (Hicks et al. 1996, 1999; Giesecke et al. 2010). *Lycopodium* tablets were added to each sample before laboratory treatment for calculation of pollen accumulation rate (PAR) (Stockmarr 1971). The slides were analysed under a light microscope; 500 arboreal pollen grains were counted for each sample. The PAR was calculated according to PMP guidelines (Hicks et al. 1999) and expressed as pollen grains/cm²/year.

Statistical analyses

The data were analysed with the software package Statistica 7.1. The averages of the data from the three Tauber traps were counted for statistical analyses. Spearman correlation coefficients were determined between the percentage of total pollen in the Hirst type sampler and Tauber traps.

Results

Fifty-four different pollen and spore types were detected in the Tauber traps during the observation period, whilst in the Hirst type sampler, only 40 pollen and spore types were identified. Thirty-three pollen and spore types were found in the Hirst type sampler and the Tauber traps (Table I). The number of anemophilous taxa was the same in both trap types ($n = 28$), whereas the number of entomophilous taxa was 12 in the Hirst type trap and 25 in the Tauber traps. Pollen types, which were registered by the Tauber trap but were not in the Hirst type sampler, were sporadic in most cases, representing entomophilous taxa of local vegetation. Pollen types only registered by the Hirst type sampler were predominantly anemophilous arboreal species used in urban planting (e.g. *Aesculus*, *Larix*) or grown in the botanical garden (e.g. *Juglans*, *Morus*, *Hippophae*, *Cupressaceae*). The highest values for both cumulative sums of atmospheric pollen recorded by the Hirst type sampler and Tauber influx data were noted in 2012. These were 92 730 and 155 118 pollen grains for the Tauber traps and the Hirst type sampler, respectively (Figure 2). The lowest pollen levels were registered in 2009, which were 19 709 for the Tauber traps and 33 529 for the Hirst type sampler.

The most abundant arboreal pollen types registered in both samplers were *Betula* and *Pinus* (Table I). Together, these two taxa accounted for 70% of the Tauber influx and 43% of the cumulative sums of atmospheric pollen recorded by the Hirst type sampler. In addition to *Pinus* and *Betula*, *Urtica* (28.9%), *Populus* (5.9%), *Alnus* (4.2%), *Acer* (3.3%) and *Poaceae* (2.5%) were abundant in the urban

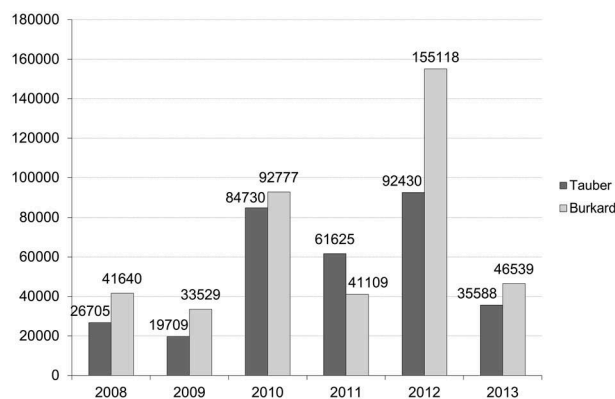


Figure 2. Annual total pollen sums registered in the Tauber traps and the Hirst type sampler (from Burkard Scientific, Uxbridge).

location. In the rural area, high pollen levels were registered in the Tauber traps for *Sphagnum* (5.6%), *Picea* (4.1%), *Polypodiaceae* (5.9%), *Alnus* (2.9%) and *Cyperaceae* (2.2%), whereas *Poaceae* (1.5) and *Urtica* (1.7) were registered in the Tauber traps in lower percentages.

In the Tauber trap spectra, the total arboreal taxa was higher than in the Hirst type sampler. The total percentage of arboreal pollen varied from 61.6 to 93.2% (Table II). Forty-four pollen types did not reach 1% of the total pollen throughout the analysed period. In the Hirst type sampler spectra, the percentage of total arboreal pollen was lower and varied from 44.2 to 86.1%. Thirty-one pollen types did not reach 1% of total pollen in the Hirst type sampler.

The percentage occurrence of the prevailing taxa (those that represent 1% or more of yearly totals) differed with the two sampling methods. This variability reflected in the ratios between percentage occurrence of individual pollen type in the Hirst type sampler and Tauber trap (Table III). Ratio values more than 1.0 indicate greater occurrence in the volumetric sampler, values less than 1.0 indicate greater occurrence in the gravimetric trap.

Acer, *Populus*, *Fraxinus*, *Urtica* and *Salix* always have greater percentage occurrence in the Hirst type sampler than in Tauber trap; the ratios can vary from 1.4 (*Salix* in 2012) to 23.4 (*Urtica* in 2009). *Alnus*, *Quercus*, *Corylus*, *Poaceae* and *Artemisia* also usually have greater percentage occurrence in the Hirst type sampler, with some exceptions. *Artemisia* had a higher percentage occurrence in the Tauber traps in 2010, *Alnus* and *Corylus* in 2012 and *Poaceae* in 2012 and 2013, whereas they were equal to those from the Hirst type sampler for *Alnus* in 2008, *Quercus* in 2010 and *Corylus* in 2013.

Cyperaceae pollen and *Sphagnum* spores represent local bog vegetation and have greater

Table II. Percentage occurrence of total arboreal pollen in the Hirst type sampler and the Tauber trap pollen spectra, 2008–2013.

Year	Hirst	Tauber
2008	53.7	87.3
2009	46.2	78.8
2010	86.1	91.2
2011	74.5	87.5
2012	85.4	93.2
2013	44.2	61.6

Table III. Percentage occurrence of individual taxa in the Hirst sampler type and Tauber trap pollen spectra.

Taxon	Percentage total, Hirst	Percentage total, Tauber	Ratio, Hirst/Tauber	Taxon	Percentage total, Hirst	Percentage total, Tauber	Ratio, Hirst/Tauber
<i>Betula</i>				Poaceae			
2008	26.7	60.4	0.4	2008	3.2	1.9	1.7
2009	18.7	13.2	1.5	2009	5.2	1.2	3.7
2010	66.1	71.6	0.9	2010	1.1	0.8	1.4
2011	24.2	45.9	0.5	2011	2.4	1.3	1.8
2012	76.1	82.1	0.9	2012	0.8	1.0	0.8
2013	13.7	24.9	0.6	2013	2.6	2.8	1.0
<i>Pinus</i>				<i>Urtica</i>			
2008	7.4	14.7	0.6	2008	38.1	2.8	13.6
2009	3.8	58.2	0.1	2009	42.2	1.5	23.4
2010	7.2	13.5	0.6	2010	11.7	0.6	16.7
2011	5.7	23.1	0.2	2011	19.7	1.3	15.2
2012	2.2	6.12	0.4	2012	12.3	1.3	9.5
2013	9.0	22.6	0.4	2013	47.9	2.6	20.8
<i>Picea</i>				<i>Artemisia</i>			
2008	2.3	7.8	0.3	2008	3.2	1.1	3.2
2009	0.1	3.8	0.03	2009	4.4	0.9	4.9
2010	0.1	2.1	0.05	2010	0.5	0.9	0.6
2011	0.7	6.5	0.1	2011	1.6	0.4	4.0
2012	0.2	1.7	0.1	2012	1.1	0.2	5.5
2013	0	2.7	0	2013	3.4	2.0	1.6
<i>Alnus</i>				<i>Salix</i>			
2008	1.3	1.3	1.0	2008	2.8	0.8	4.0
2009	5.4	2.3	2.3	2009	2.0	0.7	2.9
2010	3.7	1.6	2.5	2010	1.5	0.6	2.5
2011	12.6	7.1	1.8	2011	2.9	0.9	3.2
2012	0.2	0.8	0.3	2012	0.7	0.5	1.4
2013	1.9	4.1	0.5	2013	3.2	0.6	4.6
<i>Acer</i>				<i>Fraxinus</i>			
2008	0.6	0.0		2008	1.0	0.0	
2009	5.0	0.0		2009	0.5	0.0	
2010	1.9	0.0		2010	0.1	0.1	1.0
2011	4.2	0.0		2011	1.7	0.6	2.8
2012	0.6	0.0		2012	0.2	0.1	2.0
2013	7.4	0.0		2013	0.5	0.1	5.0
<i>Populus</i>				Cyperaceae			
2008	4.8	1.6	3.0	2008	0.1	2.0	0.1
2009	3.0	0.0		2009	0.1	2.6	0.03
2010	2.2	0.4	4.4	2010	0	0.1	0
2011	19.0	2.2	8.6	2011	0.1	3.4	0.03
2012	3.2	1.1	2.7	2012	0	0.9	0
2013	3.1	0.2	15.5	2013	0.1	4.1	0.02
<i>Quercus</i>				<i>Sphagnum</i>			
2008	4.1	0.2	13.7	2008	0.1	1.1	0.1
2009	3.6	0.2	18.0	2009	0.6	11.5	0.05
2010	1.1	1.1	0.9	2010	0.1	3.3	0.03
2011	0.9	0.6	1.5	2011	0	0.2	0
2012	0.9	0.5	1.8	2012	0	0.4	0
2013	2.7	0.5	5.4	2013	0.4	17.0	0.02
<i>Corylus</i>							
2008	0.5	0.2	2.5				
2009	1.6	0.3	4.0				
2010	0.7	0.0					
2011	0.6	0.0					
2012	0.1	0.2	0.5				
2013	0.7	0.7	0.9				

percentage occurrence in the Tauber trap. The main arboreal taxa (*Betula*, *Pinus* and *Picea*) show higher occurrence in the Tauber trap with one

exception – percentage occurrence of *Betula* pollen was slightly higher in the Hirst type sampler in 2009 (ratio 1.5).

The inter-annual fluctuations in yearly totals of all taxa registered in both areas showed significant correlation ($r = 0.83$; $p = 0.042$). Correlations between annual PAR and cumulative yearly pollen concentrations of individual pollen types were not significant (Table IV). The only exception was *Betula* – the most abundant pollen type ($r = 0.94$; $p = 0.005$). The strong influence of *Betula* totals impacts the strong correlation of yearly totals – the correlation was not statistically significant when *Betula* was excluded ($r = 0.54$; $p = 0.27$).

Discussion

Pollen spectra collected by different methods represent both local and regional vegetation. A higher taxonomical diversity in the Tauber trap is concerned with the trap location and peculiarities of its functioning. A Tauber trap, placed at ground level, collects more pollen originated from local sources in close vicinity to the sampling point. Thus, various pollen of entomophilous plants in Tauber samples reflect the vegetation surrounding the sampling site rather than that of a larger region. Besides that, some over-represented entomophilous pollen can be insect-transported. Almost all pollen types that are only registered in the Hirst type sampler belong to anemophilous trees (except Juncaceae) actively used in city planting. Pollen of exotic plants, typical of the University's botanical garden, is absent in the Hirst type sampler spectra – possibly because of prevailing wind directions. According to meteorological data, west, northwest and southwest winds are predominant in Moscow (Gorbarenko et al. 2003), so pollen transport from the botanical garden cannot be very intensive.

In most cases (except for 2011), the amount of pollen in the deposition samples is lower than that in the air samples but the figures are not comparable because of different units of measurements. Relatively

high deposition in the Tauber traps in 2011 can be connected with trap loss (two of the three traps) and using approximation for missing data. The correlation in the fluctuation of annual totals is due to the synchronous fluctuation of *Betula*, the most abundant component of both spectra. Similar correlations were not observed for the other arboreal taxa, or low-growing plants.

The main taxa present in both the Hirst type sampler and the spectra of the Tauber traps (*Betula*, *Pinus*, *Picea*, *Alnus*, Poaceae, *Artemisia*, *Urtica*) demonstrate large year-to-year variation of pollen abundance. The variation of yearly pollen production, dispersal and depositions has previously been discussed in the literature. It depends on meteorological parameters in current and previous vegetation seasons, flowering cycles, etc. A biannual cycle has been described for *Betula* (Jäger et al. 1991; Emberlin et al. 1993; Dahl & Strandhede 1996) and *Quercus* (Latorre 1999), as well as a three-year cycle for *Fraxinus* (Dahl et al. 2013). Our dataset is not long enough to reveal such rhythms, but essential inter-annual variations are clearly observed.

The dominant tree pollen types in both urban and rural samples were *Betula* and *Pinus*. *Betula* is the most abundant taxon in both locations, *Pinus* is typical for vegetation near the location of the Tauber traps, but is not very common in the city. Excellent aerodynamic characteristics, together with very high pollen production of these species, are the reason to suppose that their presence in the samples mainly reflects vegetation at regional level (Hicks 2001; Ranta et al. 2008). The higher occurrence of arboreal pollen in the Tauber traps can be explained by local reasons – close vicinity of mixed forest to the location of the traps.

Numerous investigations of modern pollen spectra have shown that *Picea* pollen production is quite localised (Gaillard et al. 2008; Pardoe et al. 2010; Pidek et al. 2010; Nosova et al. 2015). The greater occurrence of *Picea* pollen in the spectra from the Tauber traps, as compared to that from the Hirst one, reflects local vegetation in close surroundings of sampler location. Another reason can be related with the certain selectivity of Tauber traps towards larger and heavier pollen types.

Alnus and *Corylus* are not typical for the vegetation around the traps neither in the city nor in the rural location. We consider them as regional components in the spectra of both types. Our data do not support the idea of Grosse-Brauckmann and Stix (1979) and Levetin et al. (2000) that small pollen grains have higher ratios of cumulative levels in the Hirst type sampler compared to Tauber trap PAR. *Betula*, *Alnus* and *Corylus* pollen belong to the same size class, but *Betula* ratios are mostly lower than 1.0 in

Table IV. Spearman correlation coefficients between annual sums of airborne pollen (Hirst type sampler) and annual pollen accumulation rates (Tauber traps).

Taxa	Spearman correlation coefficient	p Values
All taxa	0.83*	0.0415*
All taxa, <i>Betula</i> excluded	0.54	0.27
<i>Betula</i>	0.94*	0.0048*
<i>Pinus</i>	0.14	0.7872
<i>Picea</i>	0.26	0.6228
<i>Alnus</i>	0.6	0.208
Poaceae	−0.49	0.3287
<i>Urtica</i>	0.54	0.2657

*Statistically significant ($p < 0.05$) p -values.

our study, and the ratios for *Alnus* (0.3–2.5) and *Corylus* (0.5–4.0) vary considerably between seasons.

Populus, *Fraxinus*, *Quercus* and *Acer* are very common in urban planting in Moscow and are almost absent in the forests of the rural area. These pollen types are not transported for long distances and represent local vegetation rather than regional. That is reflected in low percentage occurrence (or absence) of their pollen (< 1%) in samples from rural area and in high percentage in the urban spectra.

Salix pollen is more abundant in the Hirst type sampler than in Tauber trap spectra despite its abundance near to both sampling sites. In middle Russia, *Salix* comprises 22 species differing in pollination biology and life form (Maeviskyi 2014). We assume the big trees such as *S. alba* L. and *S. fragilis* L. provide the main contribution to the aerobiological spectrum. These species are typical for riverside vegetation of the natural reserve ‘Vorob’evy Gory’, located close to the Hirst type sampler location and do not inhabit the vicinity of the Tauber traps. *Salix caprea* L. and *S. cinerea* L. are common in the surroundings of the Tauber trap localities. These are small trees or tall shrubs, usually admixed to *Betula* forest. We consider their total pollen contribution is less than that of *S. fragilis* and *S. alba*. In addition, *S. caprea* is at least a partly entomophilous species and its pollen does not fly very well (Skvortsov 1999).

Urtica is closely associated with urbanised environments and anthropogenic activity (Behre 1981); it is the dominant herbaceous pollen type in the Hirst type samples. Nevertheless, it is regularly registered also in Tauber traps. Its constant presence in deposition samplers does not necessarily reflect local conditions, but rather the regional vegetation (Ranta et al. 2008).

Poaceae and *Artemisia* pollen are constantly found in spectra of both types, but their percentage occurrences are higher in the airborne samples, despite the large field areas outside the city and sampling height (Rantio-Lehtimäki et al. 1991). This can partly be explained by the Tauber trap location, as the forest around the bog plays the role of a natural air filter. Another explanation given by Bunting et al. (2004) is a very small relevant source area for Poaceae pollen. However, the permanent occurrence of Poaceae and *Artemisia* pollen (more than 1% in most cases) in the deposition spectra indicates that these pollen types reflect not only local but also regional vegetation (Ranta et al. 2007, 2008).

Conclusions

Cumulative annual pollen levels from the Hirst type sampler located in Moscow and pollen accumulation

rates measured by Tauber traps located in the surrounding rural area were compared in the present study. The data showed that both the qualitative and quantitative composition of pollen spectra differ significantly. The Tauber spectra are characterised by higher taxonomic variability, mainly because of greater occurrence of local herbaceous plants. The main arboreal taxa (*Betula*, *Pinus* and *Picea*) also have greater percentage occurrence in the Tauber traps. Significant correlations were only observed for annual sums of *Betula* pollen, the most abundant component in both sampler types.

Finally, the study confirms that data obtained both by Hirst type sampler and Tauber traps represent both local and regional vegetation. The spectrum from the Hirst type sampler better reflects regional vegetation, whilst the spectra from the Tauber traps correspond better to the local vegetation. Data obtained in big cities for dominant taxa can be extrapolated to the surrounding rural territories. The simultaneous use of volumetric and gravimetric samplers can be very useful for palaeo-ecological studies to evaluate the presence of local and transported pollen.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Russian Science Foundation (RNF) under Grant 14-50-00029 ‘Scientific basis of the national biobank – depository of the living systems’.

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