

Can pollen match shoes to a previously visited indoor location?

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Abstract

This paper is part of an investigation dedicated to indoor pollen from a forensic point of view. Previous studies documented the ‘natural’ pollen content of a flat and how it was ‘artificially’ altered by ornamental plants. The present study investigated if this ‘artificial pollen trace’ can be transferred to shoes. Brand new sneakers were worn in the flat and afterwards examined for pollen on their soles. The results showed that the shoes gathered pollen and that some pollen types correlated to those found in the flat. Afterwards, some of these shoes were worn while walking through the city for approximately 1.8 km. On these shoes, flat pollen was also detectable, but in low abundances. This study shows that, from a palynological point of view, shoes are worth a look at when a crime is investigated. Uncommon pollen grains on shoes can point to an indoor location with the corresponding ornamental plants.

Keywords: *forensic palynology, pollen spectrum, shoe, ornamental plant, indoor, outdoor, urban*

Forensic palynology is the applied science of pollen and spores (and other palynomorphs) in legal cases (Bryant et al. 1990; Mildenhall et al. 2006). The first documented case in which pollen played an important role was a murder investigation in Vienna, Austria (Erdtman 1969; Bryant et al. 1990). Throughout the last decades, pollen has been used more frequently to answer questions concerning legal cases. It has helped solve crimes of rape (Mildenhall 2006a) and theft (Mildenhall 2006b), determine the location of bodies of a missing couple (Brown et al. 2002), war crimes (Brown 2006) and many other cases (Bryant & Mildenhall 1998). Furthermore, scientific studies without a connection to legal cases have been done, including pollen on clothing and shoes (Horrocks et al. 1999; Bull et al. 2006; Riding et al. 2007; Jantunen & Saarinen 2011). Pollen is also present in indoor locations (Tormo-Molina et al. 2009; Preusche & Weber 2014), but extensive investigations on the benefit of indoor pollen for legal questions are rare (Morgan et al. 2008, 2014; Nguyen & Weber 2015). The transfer of indoor pollen to shoes has not been studied before. This investigation was

designed to find out if indoor pollen transfers to shoes. Another goal was to evaluate if such a trace remains on the shoes after walking an ‘escape route’. A pre-arrangement to this study was to thoroughly document pre-existing pollen in the flat (Preusche & Weber 2014), and the modification of these pollen spectra by introducing ornamental plants to add locally unusual pollen types (Nguyen & Weber 2015). Most of the plants introduced are not indigenous in Austria. Therefore, these pollen types are not frequently found in pollen samples, unless there is a direct connection to such a plant. For example, when such plants are used as an ornamental plant (indoors or outdoors), it is possible to find these pollen types near to the plant. With the introduction of ornamental plants, the pollen content of the flat changed. Prior, the flat was dominated by pollen from wind-pollinated plants (Preusche & Weber 2014). After that, the pollen content of the flat became more specific as pollen types like *Spathiphyllum* or Myrtaceae were abundant (Nguyen & Weber 2015). Without such an alteration, the pollen spectra of the flat would have remained common and hardly

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distinguishable from spectra gathered outdoors. Since the ornamental types are unlikely to be picked up outdoors, they can be related to the flat when found on shoes used to walk the escape route.

The aims of this study were to find out if indoor pollen transfers to shoes, if indoor pollen can be detected on shoes after they were used outdoors and finally, if pollen traces on shoes can be used to correlate them to an indoor location. An investigation like this has never been undertaken before and such information can be very valuable when the travel history of a person is relevant in a legal case.

Material and methods

Sampling was undertaken in one month intervals from January to September 2013 (at this time, astronomical winter in Austria began on 21 December 2012 and ended on 19 March 2013, spring ended on 20 June, summer on 21 September and autumn on 20 December). On every sampling day, three pairs of pristine shoes, obtained from the manufacturer (made in Vietnam), were used (Figure 1). One pair served as a reference sample and was stored in zip bags (one for each shoe). These are further referred to as 'reference shoes'. A second pair was worn for eight minutes while walking through a private flat ('indoor shoes'). The flat had six rooms: entrance hall, bath room, toilet, bedroom, living room and kitchen. Great care was taken not to linger at one place, but to walk through every room. This was done to evaluate if the shoes gathered pollen at all. Afterwards, these shoes were also stored in zip bags. After that, the third pair was worn through the flat for eight minutes, followed by a 1.8 km walk through the streets of Vienna to simulate an escape route ('outdoor shoes'). At the final destination (Figure 2), the shoes were stored in zip bags. The route was the same on each sampling day. The surrounding flora was documented (Table I) and graphically illustrated on a street map of the area in Vienna used for the experiment (Figure 2). After the shoe sampling took place, the floors of the living room and the kitchen were sampled using duster sheets, to document the pollen content of the flat. These two rooms were chosen, because most ornamental plants could be found there. The floor was not sampled directly before shoe sampling took place, because it might have removed most pollen grains from the flat.

Throughout the study, the flat was inhabited by two persons (no pets) and was used in a 'normal way' to simulate real life conditions. Electric fans were used occasionally, windows and doors were



Figure 1. Shoes used in this study. Synthetic sole, Euro Size 43 (27.5 cm).

opened at irregular intervals and vacuum cleaning was done once a week. Some floors in the flat were made of stone floor tiles, others of laminate. The following ornamental plants were present in the flat during this study: *Alstroemeria* sp. (Alstroemeriaceae, October 2012–April 2013), *Callistemon* sp. (Myrtaceae, April 2013–August 2013), *Clivia miniata* (Lindl.) Bosse (Amaryllidaceae, November 2012–April 2013), *Euphorbia leuconeura* Boiss. (Euphorbiaceae, October 2012–September 2013), *Lilium* sp. (Liliaceae, July–September 2013) and *Spathiphyllum* sp. (Araceae, October 2012–April 2013) (Nguyen & Weber 2015).

The left shoe of each pair was processed in the laboratory, the right one was retained in case the processing of the left shoe was disrupted by an accident in the laboratory. The soles were washed with a mixture of distilled (pollen sterile) water and some drops of Tween 20 and afterwards rinsed with ethanol (99.8%). The washing water was filtered (260 µm mesh size) to eliminate debris bigger than pollen grains. Centrifugation (3000 rpm) was used to separate the solids from the liquid. The solid remains were processed using a modified acetolysis technique (Erdtman 1943; Hesse et al. 2009) as in the previous studies (Preusche & Weber 2014; Nguyen & Weber 2015): rinse with acetic acid (100%), decant acetic acid and add acetolysis mixture: nine parts acetic acid anhydride (99%) and one part sulphuric acid (96%), heat in a water bath (100 °C) for approximately eight minutes, rinse with acetic acid (100%), rinse with distilled water (several times), heavy liquid separation: mix the sample with zinc-bromide-dilution [250 g zinc-bromide with 25 ml of 10% hydrochloric acid HCl and 100 ml distilled water], carefully add distilled water

to the specimen (zinc-bromide and water must not mix), centrifuge for ten minutes at 3000 rpm, gather the organic material, which is now floating between the phases, with a pipette. The inorganic part remains on the bottom of the centrifuge tube, rinse with distilled water (several times), rinse with ethanol (99.8%) to dry the sample, add glycerine to the sample and fill it into vials. During sample processing, the laboratory was monitored for pollen contamination.

Approximately 20–25 µl of the glycerine/pollen mixture were put on each microscope slide, covered with a cover-glass and observed with a light microscope (Olympus BX53F). To preserve the microscopic slides for future controls, the cover-glass was fixed after counting. With the help of the literature (Reille 1992; Beug 2004; Hesse et al. 2009) and the pollen database PalDat (2000 onwards), the pollen grains were assigned to different pollen types. Additionally, comparative samples were produced from herbarium and fresh material. Provided that the samples delivered enough material, 300 pollen grains were counted (and in two cases more) per sample excluding unidentifiable palynomorphs and saccate pollen. The reason for this exclusion was that saccate pollen was floating on the surface of the decanted water and was therefore, lost in unknown numbers during sample processing.

Results

Pollen spectra of the flat

The pollen spectra of the flat have been studied thoroughly earlier (Preusche & Weber 2014; Nguyen & Weber 2015). At the sampling dates of this study, *Alstroemeria*, *Callistemon*, *Clivia*, Liliaceae and *Spathiphyllum* pollen was common in the flat (Table II). These pollen types are further to be referred to as ‘ornamental pollen’.

Reference shoes

In four out of the nine reference shoe samples, pollen was found (the reference shoes were processed in the same way as all other shoes). Altogether nine pollen grains (four Poaceae, one *Alnus*, one Liliaceae, one Pinaceae and two polyades) and three unidentifiable palynomorphs were documented. The polyades were categorised as ‘Mimosoideae-type’. Throughout this and related studies (Preusche & Weber 2014; Nguyen & Weber 2015), more than 400 samples were examined from the flat and the shoes. The Mimosoideae-type was found in 12 sam-

ples only (13 pollen grains/more than 120 000 pollen grains were counted). All these samples were taken from shoes that belonged to the same batch. The shoes used in this study also belonged to this batch.

Indoor shoes

The amount of pollen that could be gathered from the indoor shoes was generally low. In some cases, less than 300 grains were found, so the right shoe was processed as well. Still, three pairs of shoes did not deliver the desired number of 300 grains. For two of them (the samples from 2 February and 30 August), approximately 150 grains were documented, on one pair (28 February), only 30 grains were found. Ornamental pollen was common on all indoor shoes. On three of them, these types were even dominant (e.g. *Spathiphyllum* in January and February, *Callistemon* in July). Pollen from outdoor plants (Table II, ‘Others’) was also present and correlated to the flowering season. The Mimosoideae-type was found in three samples.

Outdoor shoes

A great variety of pollen types was documented on the outdoor shoes (Table III). None of the samples was dominated by a single pollen type. The highest percentage was *Alnus* on 2 April (40%). The most abundant pollen type throughout all samples was *Tilia*. Ornamental pollen was rarely found (Table III). In seven out of nine samples, ornamental pollen was found on a count to 300, but in low numbers (1–7 grains). In two samples (2 April, 2 May) no ornamental pollen types were detected and therefore, further counts were made. In the sample from 2 April, approximately 1500 additional grains were counted, including two *Alstroemeria*, one *Euphorbia leuconeura* and one grain of the Mimosoideae-type. In the sample from 2 May, no ornamental grains could be found in the remaining material (approximately 1600 grains).

Other findings

Other pollen types (Caryophyllaceae, *Fuchsia*, *Ilex* and Lamiaceae) were documented in the flat in a previous study (Nguyen & Weber 2015). These types were also found in the flat in the present study, but only in a very few samples and in low abundances. With the exception of the Lamiaceae and Caryophyllaceae (a single grain each), these types were never found on the outdoor shoes.



Figure 2. Map of the escape route. X, endpoint of the route; A, *Acer*; P, *Platanus*; R, Rosaceae; T, *Tilia*; e, *Fraxinus excelsior* L.; o, *Fraxinus ornus* L. Upper Scale bar: 100 m, lower scale bar: 10 m. Map obtained from Stadt Wien – ViennaGIS: <http://www.wien.gv.at/viennagis/>

Discussion

Pollen spectra of the flat

The influence of the various ornamental plants on the pollen content of the flat was quite diverse. The simple differentiation between the pollination types (Milne et al. 2004) is not enough to estimate how much pollen an ornamental plant will deposit on the floor. The influence of an ornamental plant depends on many factors. Of course the pollen production per anther and the total number of anthers/flowers per plant is important (Reddi & Reddi 1986), but another important factor is the amount of pollenkitt (Pacini & Hesse 2005). Pollenkitt increases the ‘stickiness’ of pollen grains, and can therefore prevent the pollen grains from leaving the anther (or flower) and fall to the ground. This and a previous study (Nguyen & Weber 2015) show that zoophilous plants like *Spathiphyllum* or *Callistemon* will deposit huge amounts of pollen. Others, like *Lavandula* produced abundant pollen (which was determined by taking samples from their flowers), but deposited only a few grains.

Reference shoes

Most reference shoes had none or very few pollen grains on their soles. Some of this contamination

(e.g. Poaceae and *Alnus*) might have happened during repacking into zip bags or during sample processing in the laboratory (Mildenhall 1990). More interesting is the occurrence of the Mimosoideae-type, because it was only found on shoes from the same batch. Contamination can also occur during the production process or its importation (Bryant et al. 1996; Milne et al. 2004). Such contamination has been used to clarify the origin and travel history of drugs (Stanley 1992). Since the shoes were made in Vietnam, where plants from the Mimosoideae subfamily are quite common, contamination during production (or packaging, shipping) is likely.

Indoor shoes

The pollen spectra of the indoor shoes are comparable to those of the flat in respect of the pollen types, but not always their abundance. For example: in January and February, the shoes were dominated by *Spathiphyllum* pollen (88%, 75%, respectively), which was also very abundant in the living room on these dates (93%, 95%). However, the values for *Clivia* on the shoes (3%, 4%) were far below those documented in the kitchen (83%, 75%). The same is true for *Callistemon*, which had its peak in the kitchen from May to August (46%, 93%, 85%, 87%), but the abundances on the shoes were clearly below that

Table I. Vegetation.

Planted trees and large shrubs (≥ 5 m) along the escape route (quantity)
<i>Carpinus</i> (5), Rosaceae (29), <i>Fraxinus ornus</i> L. (53), <i>Fraxinus excelsior</i> L. (10), <i>Pinus</i> (2) <i>Platanus</i> (3), <i>Aesculus</i> (5), <i>Tilia</i> (29)
Other plants along the escape route
Amaranthaceae, <i>Artemisia</i> , Asteraceae (liguliflorae + tubuliflorae), <i>Berberis</i> , Brassicaceae, <i>Cornus</i> , Cupressaceae, Fabaceae, <i>Hedera</i> , Oleaceae, <i>Parthenocissus</i> , Poaceae, Polygonaceae, Ranunculaceae, Rosaceae, <i>Rumex</i> , <i>Sambucus</i> , Urticaceae, <i>Viburnum</i>
Common taxa in adjacent streets
<i>Aesculus</i> , <i>Acer</i> , <i>Ailanthus</i> , <i>Betula</i> , <i>Carpinus</i> , <i>Catalpa</i> , <i>Corylus</i> , Cupressaceae, <i>Fagus</i> , <i>Fraxinus ornus</i> , <i>Fraxinus excelsior</i> , <i>Hedera</i> , <i>Juglans</i> , Oleaceae, <i>Platanus</i> , <i>Picea</i> , <i>Pinus</i> , <i>Populus</i> , <i>Robinia</i> , Rosaceae, <i>Robinia</i> , <i>Sophora</i> , <i>Taxus</i> , <i>Tilia</i> , <i>Viburnum</i> .

Note: Plants are given to the taxonomic level that is reached by pollen identification. For example: *Prunus subhirtella* Miq. or *Pyrus* sp. are both categorised as Rosaceae. Various Betulaceae were distinguished further, such as *Carpinus* or *Betula*.

(9%, 17%, 78%, 6%; Table II). The expression of data in percentages is standard in forensic palynology (Wiltshire 2006), but does not give information about the absolute number of pollen grains in a sample, or in this case, a room. Therefore, it is unknown to what extent the various rooms affected the shoes. This varying impact is the most plausible reason for the diverging abundances between indoor shoes and flat. Such differences must therefore, always be expected in an investigation where a trace is gathered from multiple sources, which is the nature of pollen spectra on shoes (Wiltshire 2006).

There are many additional factors that influence mixed pollen spectra, for example the surface conditions of the floor, the type of shoe sole, pollen characteristics (stickiness, ornamentation) or an uneven distribution of pollen within an area. The impact of one of these factors is already hard to evaluate, but the multiplicity of these taphonomic factors (Wiltshire 2006) make it almost impossible to draw predictions for individual case studies. Therefore, it cannot be predicted how a pollen spectrum of a shoe worn indoors will look like. However, this study shows that shoes can pick up indoor pollen. The resulting spectra can contain information valuable for forensic investigations if they have specific features, for example pollen from ornamental plants.

Outdoor shoes

Most differences between indoor and outdoor shoes originate from the loss and gathering of pollen while walking an escape route. For two reasons, it becomes apparent that the latter factor is much more important. Firstly, more debris is gathered from outdoor shoes during sample preparation. Secondly, on the

outdoor shoes, the ornamental pollen types will be outnumbered by air borne pollen (Table III). Most of these types correspond to the actual season, e.g. *Corylus* and *Alnus* in spring. Others can be related to the flora along the escape route. For example: *Tilia* was the most abundant pollen type on the outdoor shoes. *Tilia* is also the most abundant tree at the end of the escape route (Figure 2, Table I). This goes along with the findings of Riding et al. (2007), as in the present study, the shoes also reflect the last visited location. From a forensic point of view, this is interesting, because it suggests that there are local differences in urban areas, which is also reported by Horrocks and Walsh (1999). Especially in cities with a lot of planted and non-indigenous trees, pollen could be used to answer legal questions.

Ornamental pollen was also detectable, but in low abundances. In seven of nine samples, ornamental pollen was present on a count to 300. For the sample of 2 April, further counts were necessary to detect them. In the sample from 2 May, no ornamental grain was found. The reason might be that they did not gather much of these types in the flat, because the indoor shoes from that date also had a relatively low amount of ornamental pollen. The nature and difficulty of forensic investigations is that every case is different, because of multiple variable factors (Wiltshire 2006). Therefore, the most important question is: How applicable are these results to legal investigations?

An important issue in this context is the low abundance of the ornamental pollen types. Such low abundances cannot doubtlessly match an item to a crime scene, but that is rarely possible (Horrocks & Walsh 1998; Horrocks et al. 1999). On the up side, ornamental pollen could be found in all samples but one. This shows that even after wearing shoes for a while, indoor pollen is likely to be found on their soles. Thus, shoes are always worth investigating, because such pollen types can hint to an indoor location, especially if the associated plant is not indigenous in the region. Even if such low abundances might not qualify as evidence in court, they could help to disprove alibis or steer police investigations into the right direction.

Another problem is that crimes are almost never committed with pristine shoes and pre-existing debris might complicate the analysis. Even if Riding et al. (2007) report that pollen on shoe soles mirrors the last visited location most, this might not be true when the last visited location was indoors. The low amount of pollen on the indoor shoes indicates that it could easily be overshadowed by pollen from previously visited sites. Nevertheless, it might also be possible that dirty shoes are capable of gathering more pollen grains than

Table II. Pollen counts: flat and shoes.

Alstroemeria				Callistemon				Clivia				Liliaceae				Spathiphyllum				Others				Grains counted			
Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes	Living room	Kitchen	Indoor shoes	Outdoor shoes
02.01.2013	+	2	1	+	-	3	-	1	83	-	-	-	93	4	88	1	6	10	7	97	964	312	306	304			
01.02.2013	-	6	3	-	-	4	+	+	55	+	-	-	95	8	75	-	4	31	16	99	315	312	252	309			
28.02.2013	-	23	+	2	-	+	-	-	10	-	-	-	92	4	+	1	8	63	+	96	326	306	30	309			
02.04.2013	-	13	83	-	-	-	-	-	1	-	-	-	89	12	3	-	11	73	14	97	674	306	166	308			
02.05.2013	-	-	-	-	+	-	-	-	-	-	-	-	2	1	2	-	98	53	80	99	308	311	315	309			
31.05.2013	-	-	-	-	4	93	17	+	-	-	-	-	5	+	1	-	89	7	81	99	308	1618	311	314			
01.07.2013	-	-	+	-	4	85	78	2	-	-	-	-	1	+	-	-	95	15	21	97	315	1064	309	308			
01.08.2013	-	-	-	-	+	87	6	-	+	-	1	31	1	-	+	-	99	9	63	98	308	2414	309	311			
30.08.2013	-	-	-	-	2	29	1	1	-	-	-	2	3	12	-	1	94	68	86	98	302	341	124	306			

Note: Percentages of pollen types (rounded to integer) from ornamental plants and Mimosoideae; 'Grains counted' gives the total number of pollen grains counted in this sample; - pollen type was not documented in this sample; + pollen type was present, but below 0.5%; Due to the low amount of pollen in the indoor shoe sample from 28.02.2013 no percentages are given; Presence of the plants in the flat (LR = Living room, K = Kitchen): *Alstroemeria* (K), *Clivia* (K), *Spathiphyllum* (LR): October/November 2012–April 2013, *Callistemon* (K): April–September 2013, *Lilium* (K): September–August 2013, *Euphorbia leuconeura* (LR): October 2012–September 2013.

Table III. Pollen counts: outdoor shoes.

Pollen types	Sampling dates									
	02.01.2013	01.02.2013	28.02.2013	02.04.2013	02.05.2013	31.05.2013	01.07.2013	01.08.2013	30.08.2013	
<i>Tilia</i>	18	6	18	2	1	7	33	14	16	
<i>Corylus</i>	2	38	30	18	2	2	1	2	1	
<i>Alnus</i>	5	18	9	40	2	5	–	3	2	
Poaceae	6	2	4	1	–	5	34	21	11	
<i>Betula</i>	15	7	6	3	10	4	4	3	3	
<i>Fagus</i>	1	+	1	–	24	15	1	2	1	
<i>Platanus</i>	5	1	3	1	16	6	2	2	2	
<i>Quercus</i>	3	1	5	+	16	7	2	1	+	
<i>Aesculus</i>	5	4	2	–	+	17	1	2	3	
<i>Fraxinus</i>	4	3	1	1	7	6	2	3	2	
Amaranthaceae	5	4	6	+	–	–	–	4	9	
<i>Carpinus</i>	1	1	2	+	10	5	1	3	2	
<i>Populus</i>	2	1	–	17	2	1	+	–	–	
<i>Plantago</i>	1	–	–	–	+	–	3	7	5	
Cupressaceae	3	3	2	2	1	1	+	2	3	
<i>Ambrosia</i>	2	2	1	2	–	1	–	+	7	
Urticaceae	2	2	–	+	–	–	1	3	6	
<i>Sophora</i>	–	–	–	+	–	–	–	8	4	
Polygonaceae	3	1	2	1	–	–	–	–	3	
Rosaceae	3	1	+	+	1	3	1	1	+	
<i>Ailanthus</i>	+	–	+	–	–	–	4	3	3	
<i>Acer</i>	1	–	1	+	1	2	2	2	1	
Asteraceae, Tubuliflorae	1	1	–	+	+	+	1	4	1	
<i>Salix</i>	1	1	1	1	2	1	+	1	2	
<i>Ulmus</i>	+	–	–	5	2	1	–	–	+	
Others	10	5	5	3	3	12	7	11	11	
Ornamental types										
<i>Alstroemeria</i>	+ (1)	–	2 (6)	+(2)	–	–	–	–	–	
<i>Callistemon</i>	+ (1)	–	–	–	–	+ (1)	2 (7)	–	1 (3)	
<i>Gleichenia</i>	–	+ (1)	–	–	–	–	–	–	–	
<i>Euphorbia leuconeura</i>	–	–	–	+(1)	–	–	–	–	–	
Liliaceae	–	–	–	–	–	–	–	1 (4)	–	
<i>Spathiphyllum</i>	1 (4)	–	1 (2)	–	–	–	–	–	–	
Grains counted	304	309	309	1839 ^a	1939 ^a	314	308	311	306	

Note: Percentages of pollen types (rounded to integer); Values in brackets give the absolute number of grains; 'Grains counted' gives the total number of pollen grains counted in this sample; – pollen type was not documented in this sample; + pollen type was present, but below 0.5%. ^aHigher counts were made, because no ornamental grains were found in the initial count to 300.

pristine ones. Further studies with used shoes could help to evaluate this factor.

Another issue is the documentation of an 'ornamental' *Callistemon* pollen grain on 2 January – five months before a *Callistemon* plant was introduced to the flat. Neither was *Callistemon* pollen documented in the flat nor was it found on indoor shoes on this date. Therefore, the possible origin of single grains must be considered with increased awareness and the possibility of other origins must be taken into account.

Additionally, the escape route can differ in length, ground conditions and if it is covered by foot or a vehicle. In the present study, the route walked was 1.8 km long, which is a good opportunity to gather pollen. Shorter routes (or escapes with vehicles) cause less contact between soles and any ground and therefore, less pollen can be collected (or lost).

Conclusion

The present study gives insights on the usefulness of shoes in forensic investigations from a palynological point of view. It shows that even brand-new shoes can be contaminated with pollen. The study further shows that indoor pollen adheres to shoes. Pollen spectra of shoes and indoor locations might not be an ideal match, but uncommon pollen types can link them. Pollen picked up indoors can still remain on shoes after an extensive outdoor usage. Therefore, shoes can provide information about their travel history. However, it has to be expected that such a trace will get more and more blurred with every metre walked. Thus, it is advisable to sample shoes as early as possible.

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