

Inference of the pollen penetration and remanence into dwellings using seasonal variation of indoor/outdoor pollen counts

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Abstract Humans now spent most of their time indoor where they can be exposed to various aerocontaminants, among which pollen. The question of remanence of pollen grains indoor is important because allergic patients could get symptoms from these indoor pollen far away from the pollination period but the temporal relationship between both phenomena is poorly documented. In this study, we monitored pollen counts both in house dust samples and outdoor pollen traps during the whole pollen season in Southern France and computed the influx and remanence of various

pollen species throughout the pollen season. Five families living in the same street volunteered to participate. Monitoring of indoor pollen counts was performed at four occasions through sampling of house dust from the living room. During the same period, outdoor pollen counts were monitored using a Burkard pollen trap. Pollens from 73 taxa were identified on the house dust samples collected indoor. For each pollen type, indoor pollen count dynamics were consistent with the observed pollen counts in Burkard traps over the whole pollination period. Two groups of pollen types can be defined on the basis of these results: the first group includes *Platanus*, *Quercus* and *Cupressaceae* which exhibit high remanence and a low penetration, and the second group contains species with high penetration but various remanence. Date of sampling was the main factor affecting penetration coefficients very low in winter, to moderate in spring and huge in summer. Pollen type, housing and sampling time period have bearing on penetration and remanence of pollen grains indoor.

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1 Introduction

Humans now spent most of their time indoor (Zeghoun et al. 2010) where they can be exposed to various

aerocontaminants which may affect human health (Chang and Gershwin 2004). Among indoor allergens, most studies have been devoted to molds, mite, cat and cockroach allergens. Most recently, several investigations have reported the presence of indoor pollens and concluded that the ratio of indoor to outdoor pollen is highly variable (2–6 %, up to 35 %) according to the sampling site, the sampling time period and the sampling technique (Lebowitz et al. 1982; O'Rourke and Lebowitz 1984; O'Rourke et al. 1989; Stock and Morandi 1988; Enomoto et al. 2004; Takayashi et al. 2009; Sharma et al. 2009; Farrera et al. 2002). All published studies, but two have performed sampling in a single point in time, during pollination of the species under study. The first exception is the study realized in Badajoz city, Spain (Tormo-Molina et al. 2009) which evaluated in a hospital setting the overall indoor to outdoor pollen ratio throughout the year. The second one is the study by Farrera et al., which monitored indoor and outdoor pollens over several weeks in a single. The question of remanence of pollen indoor is important because allergic patients could get symptoms from these indoor pollens far away from the pollination period. Except for pollen from flowering plants which are introduced into houses, indoor pollens come from outdoor pollination but the temporal relationship between both phenomenons is poorly documented. In this study, we monitored pollen counts both in house dust samples and outdoor pollen traps during the whole pollen season in Southern France and modeled the influx and remanence of various pollen types throughout the pollen season.

2 Methods

2.1 Experimental design

Five families living in the same street of a suburban community near Marseille, France, volunteered to participate. All the houses were located within 155 m distance. None of these five dwellings were equipped with a mechanical ventilation system. Monitoring of indoor pollen counts was performed at four occasions (February 24, April 6, May 31 and August 31, 2008) through sampling of house dust from the living room. These sampling times were chosen according to the main pollen seasons: *Cupressaceae* pollen in January–February, *Platanus* pollens in April, grass pollens in May–June and *Ambrosia* pollens in late August–September. On each

occasion, the tiled living room ($\sim 20 \text{ m}^2$) was vacuum-cleaned for 1 min/m^2 using a 1,400 W vacuum cleaner (Panasonic MC-E603) equipped with a nozzle (ALK Laboratories, Denmark) supporting a polyurethane filter with $3 \mu\text{m}$ pores. The sampling was performed by the same technician using the same vacuum cleaner. Fine dust was taken apart and weighed. The family was asked not to vacuum-clean the living room 48 h before sampling. The sampled dust was treated by H_2SO_4 sifting, acetolysed and 10 % KOH. A 50- μl sample was analyzed through a 630 photonic magnification for pollen identification. Results were expressed as number of pollen grains of each identified taxa per gram of sampled dust.

During the same period, outdoor pollen counts were monitored using a Lanzoni volumetric spore trap (Hirst 1952; Mandrioli et al. 1998) located on the roof of the University hospital located 500 m away from the street where were located the five houses under study. Results were expressed as number of pollen grains of the different taxa per m^3 of sampled air (Tormo-Molina et al. 2009). These counts provide an estimation of the mean pollen airborne concentration ignoring local variations attributable to the proximity of specific pollen sources. In both cases (pollens from the Lanzoni trap, or pollens from dust samples), the amount of pollens per taxa was determined on a subsample of the collected material by the identification of individual pollen grains through a photonic magnification. Results are either expressed as the number of pollen grain (per taxa) per m^3 of sampled air or as the number of pollen grain (per taxa) per gram of sampled dust. Although results were expressed in two different units (per m^3 or per gram), the same procedure was applied for count and identification of pollen from the two origins (Lanzoni and dust).

2.2 Indoor pollen counts modeling

The used model is based on the fact that the observed indoor pollen (at a given time ' t ') is the sum of the newly entered outdoor pollen and of the remaining indoor pollen (at previous time ' $t - 1$ ').

In order to estimate the coefficients of pollen penetration and of pollen remanence into the dwellings, we hypothesized (a) that the mean concentration of pollen over a week (from the Lanzoni trap) gives a good estimate of the amount of outdoor pollen at the sampling date and (b) that the indoor pollen count estimated at our previous sampling date is representative of the quantity of pollen before the new

sampling. Due to the time between sampling dates, the remanence coefficient represents a mean value over several weeks. Consequently we modeled the indoor pollen counts (IPC) at time t as follows:

$$IPC_t = A * OPC_t + B * IPC_{t-1} \quad (1)$$

where OPC_t is the outdoor pollen counts at time t , A is the penetration coefficient, IPC_{t-1} is the indoor pollen counts at time $t - 1$ and B the remanence coefficient.

Considering that IPC and OPC are not expressed in the same units, the A coefficient does not correspond to the percentage of pollen entering the house, but is proportional to it.

For all but the first sample date, the IPC_{t-1} values were set to the indoor pollen count measured at the previous sampling date. Considering that the first sample date (February 24) was, for all taxa, before the pollination period, we set the IPC_{t-1} to the minimum counts observed over the four occasions.

The variability of the penetration and remanence coefficients among taxa (t), dwellings (d) or period (p) where checked by the estimation of A_t (A_d , A_p) and B_t (B_d , B_p) parameters for each levels of these three factors.

2.3 Statistical analysis

A generalized linear model with a log link function is commonly used for count data analysis. However, this Poisson GLM model leads to a multiplicative effect of the independent factors and variables. Consequently, in order to keep the additivity of the contribution of outdoor (OPC) and indoor (IPC) variables and to take account of heteroscedasticity, we estimated A and B coefficients by the Iterative Reweighted Least Square (IRLS) regression procedure. Hypothesizing that pollen counts follow a Poisson distribution, weights were chosen as the inverse of the expected values. At first step, weights were set to the inverse of the observed counts. The probability of the observed statistical values was computed under the null hypothesis (i.e., lack of effects) and expressed as the “ p value”.

3 Results

3.1 Variation of pollen counts over time

Pollens from 73 taxa were identified on the house dust samples collected indoor. Relation between outdoor

and indoor pollen counts were analyzed for the six more frequent taxa (Table 1) which accounted for 76 % of the whole pollen counts (*Pinus* 27 %, *Cupressaceae* 20 %, *Olea* 18 %, *Quercus* 4 %, *Poaceae* 4 % and *Platanus* 4 %). *Brassicaceae*, *Celtis*, *Alnus* and *Tilia* (2 % each) were also in the top-ten taxa of pollen counts. All other species contributed to 1 % or less of the total pollen counts.

Figure 1 provides the dynamics of outdoor pollen counts (grains per m^3) and indoor pollen counts (relative scale) for each taxon over time. For each pollen type, indoor pollen count dynamics were consistent with the airborne pollen load over the whole pollination period estimated by the pollen counts from Lanzoni traps. This similarity of OPC and IPC trends suggests a strong penetration of airborne pollen into dwellings. However, IPC decreases slower than OPC, especially for *Cupressaceae* and *Platanus*. Away from the pollination period, there was still high amount of pollen for the main allergenic taxa. Considering *Cupressaceae* pollens, which are the most prevalent allergenic pollens in South-East France, Fig. 1 demonstrates that the outdoor concentration of this pollen is maximum during the *Cupressaceae* pollen season, then decreases very sharply afterward. The trend for *Cupressaceae* pollens in house dust is somewhat different, with a more gentle decrease following pollination.

3.2 Between species differences

IRLS regression of total IPC_t (from all the species) on OPC_t and IPC_{t-1} gave evidence for a strong effect of outdoor airborne pollen on pollen concentration in house dust (p value = $1e-05$), and a less important effect of remanence estimated from previous indoor pollen concentration (p value = 0.045).

When taking into account pollen taxon, highly significant penetration coefficients were observed for *Poaceae*, *Olea*, *Quercus* and *Cupressaceae* and moderately significant for *Pinus* (p value = 0.11, Table 2). *Platanus* and *Cupressaceae* exhibited the two lowest values for this penetration coefficient. Intermediate value was observed for *Quercus*. By contrast, *Olea*, *Poaceae* and *Pinus* are associated with very high values of pollen penetration into dwellings. A moderately significant remanence effect was observed for three taxa: *Poaceae*, *Quercus* and *Cupressaceae*.

Table 1 Indoor pollen counts performed on each sampling time and for each dwelling (number of pollen grains per gram of fine dust collected in the living room)

	<i>Cupressaceae</i>	<i>Pinus</i>	<i>Olea</i>	<i>Poaceae</i>	<i>Platanus</i>	<i>Quercus</i>
<i>Dwelling1</i>						
February 24	10,480	1,866	431	431	287	718
April 6	10,660	77,873	561	2,469	7,069	785
May 31	1,733	3,178	39,575	10,544	1,444	8,955
August 31	5,338	24,781	3,431	4,575	2,288	1,906
<i>Dwelling2</i>						
February 24	92,337	3,259	155	2,483	0	310
April 6	93,000	295,359	1,212	2,726	34,837	3,635
May 31	10,525	4,625	47,841	6,538	2,711	11,482
August 31	23,172	54,068	12,015	8,582	11,157	27,463
<i>Dwelling3</i>						
February 24	3,096	459	0	573	0	229
April 6	4,332	23,184	176	468	527	293
May 31	26,645	13,816	362,911	40,461	1,727	39,967
August 31	8,915	14,744	3,086	7,886	2,057	6,172
<i>Dwelling4</i>						
February 24	288,943	12,999	2,819	6,264	313	1,253
April 6	52,748	399,301	1,093	10,659	44,276	4,100
May 31	3,562	6,234	157,026	26,121	2,968	20,185
August 31	4,750	3,563	3,563	5,938	1,188	2,375
<i>Dwelling5</i>						
February 24	45,902	3,909	3,027	2,900	3,153	1,513
April 6	2,231	5,205	744	3,532	1,673	1,115
May 31	7,425	16,265	9,900	8,840	27,579	22,629
August 31	3,284	4,379	438	1,533	985	1,861

Two groups of species can be defined on the basis of these results: the first group includes *Platanus*, *Quercus* and *Cupressaceae* which exhibit a high remanence (0.4) and a low penetration, and the second group contains species with a high penetration but various remanences (Fig. 2).

3.3 Between houses differences

Penetration coefficients also varied according to houses. Two dwellings did not exhibit significant relation between OPC and IPC. On the contrary in the other three dwellings, pollen in house dust was significantly related to outdoor airborne pollen counts ($A = 8.7, 9.1$ and 17.23 ; p values = $0.012, 0.012$ and 0.0005). Although variable (from 7 to 49 %), remanence coefficients were never significant.

3.4 Time period effect

Date of sampling is the main factor affecting penetration coefficients, and increasing values were observed along seasons: from very low (2.6, p value = 0.03) in winter, to moderate in spring (13–15, p value = 0.001 and 0.001) and huge in summer (204, p value = 0.10). Remanence coefficients were never significant.

4 Discussion and conclusions

In order to increase the statistical power of the comparison between indoor and outdoor pollen counts, only the six most frequent taxa, representing 76 % of the total pollen counts, were analyzed. All of them are commonly observed in the Mediterranean region. A similar feature was observed in the study

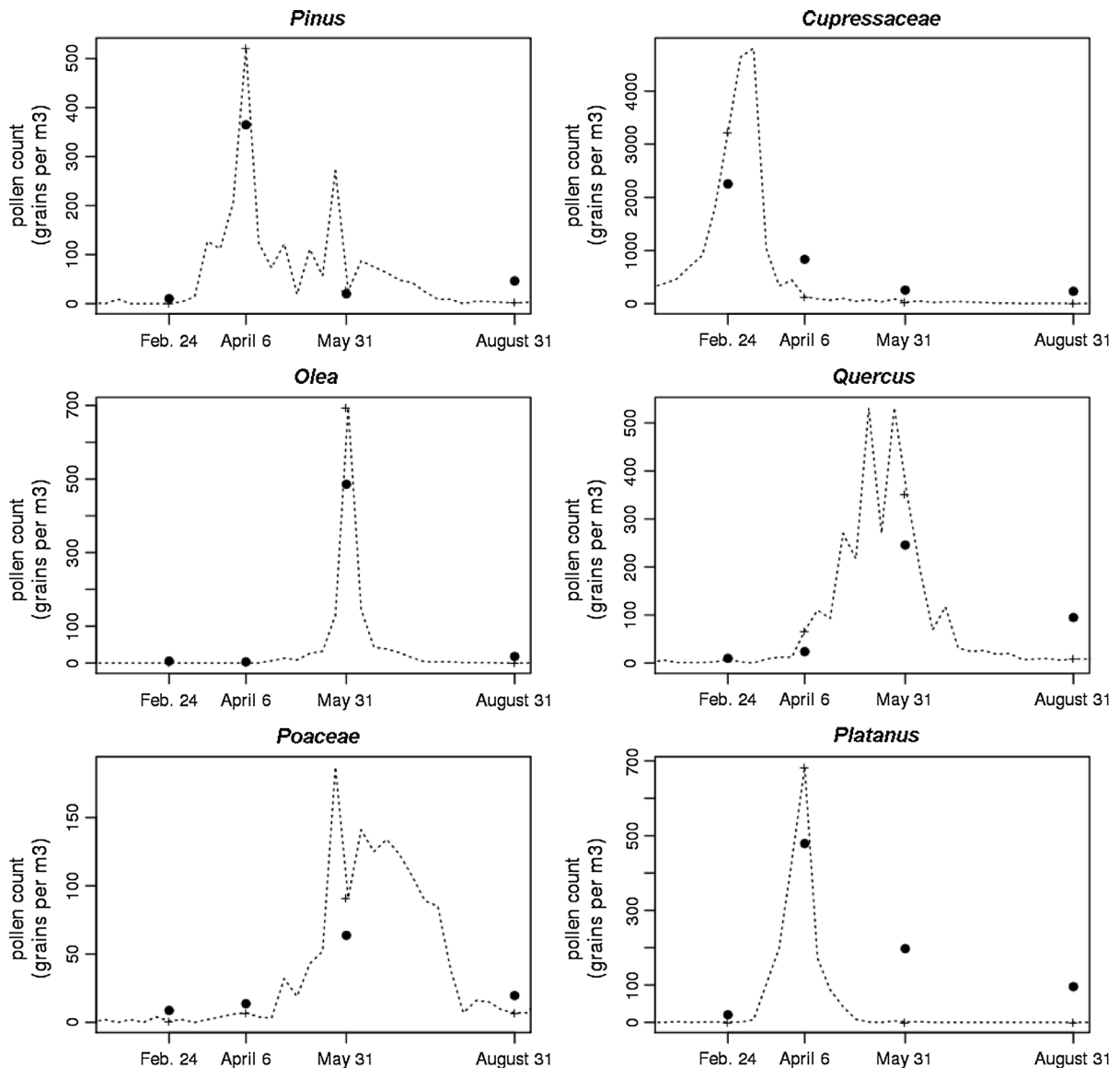


Fig. 1 Indoor pollen counts in house dust at sampling occasions (full circle) and weekly outdoor pollen counts in traps over the pollination period (dotted line). Outdoor pollen counts are expressed as the number of grains per m³ of air;

conducted by Tormo-Molina et al. (2009) where 75 % of the pollen counts were attributed to only five taxa (*Quercus*, *Cupressaceae*, *Poaceae*, *Olea* and *Plantago*). Pollination periods of these six taxa were in good agreement with the usually observed pollen calendar (Bıçakçı et al. 2004).

Most of the published studies have performed sampling at a single point in time, during pollination of the species under study. Only two studies monitored

indoor pollen counts (pollen grains/g fine dust) are plotted on a relative scale ensuring that max (indoor pollen count) = 0.7 outdoor pollen count of the same week

pollen counts over several weeks or months. In Badajoz city, Spain (Tormo-Molina et al. 2009), the overall indoor to outdoor pollen ratio was evaluated in a hospital setting throughout the year. In the second study, the indoor to outdoor pollen ratio was evaluated in the vicinity of Lyon, France (Farrera et al. 2002). The strength of our study lies in the fact that several samples have been collected in a standardized way throughout the pollination period and that

Table 2 Estimation of the “Penetration coefficient” (A) and “Remanence coefficient” (B) of pollen into dwellings for the six studied taxa

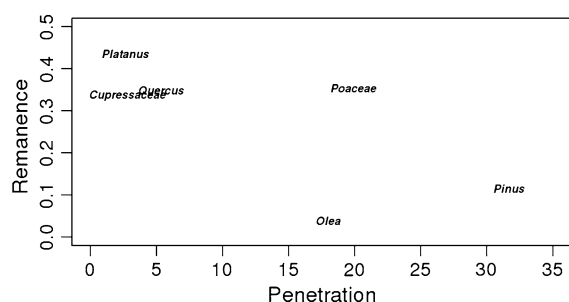
Taxon	A	A pval	B	B pval	Mean pollen size (µm)	Pollen terminal velocity
<i>Pinus</i>	31.66	0.11	0.11	0.62	55	0.031 ^a
<i>Cupressaceae</i>	2.78*	0.018	0.34 [#]	0.09	25	0.016 ^{b,c}
<i>Olea</i>	18.0**	0.002	0.04	0.50	23	0.015 ^c
<i>Quercus</i>	5.3**	0.004	0.35 [#]	0.08	38	0.035 ^{a,b}
<i>Poaceae</i>	19.9***	0.0007	0.35*	0.023	31	0.035 ^b
<i>Platanus</i>	2.61	0.23	0.44	0.37	20	0.035 ^c

*** 1/1,000; ** 1 %; * 5 %; # 10 %

^a Matthias et al. (2012)

^b Fredh et al. (2012)

^c McMillan (2013)

**Fig. 2** Penetration versus remanence coefficients of pollen for the six most pollinating taxa

computation has allow, for the first time to the best of our knowledge, for an estimate of the penetration and remanence for each pollen taxa.

The limits lie in the lack of standardisation of cleaning activities between samplings, although we asked the house cleaner not to clean during 48 h before sampling. Besides, it was not possible to get data about air renewing through natural ventilation. Lastly, we only assessed intact pollen grains, not pollen fragments which could also bear allergens. Despite these limits, our study demonstrated that pollen type, housing and the sampling time period have bearing on penetration and remanence of pollen grains into the houses.

Except for houseplant and flowers for home which are directly introduced into houses, pollens get into dwellings through door and windows, ventilation openings (Jantunen and Saarinen 2009) and clothes worn

(Saarinen et al. 2011) or dried up outside (Takayashi et al. 2009). The level of pollen penetration into dwellings would depend on the aerobiological characteristics of pollen as well as on pollination period. Similarly, the indoor to outdoor ratio is higher for spores from fungi than for pollen (Grinshpun et al. 2005; Lee et al. 2006). In all experimental studies, the indoor pollen concentration is always lower than the outdoor pollen concentration (D’Amato et al. 1996; Lee et al. 2006; Tormo-Molina et al. 2009), and the low indoor to outdoor ratios are generally attributed to pollen size (Hugg and Rantio-Lehtimäki 2007).

Due to variation in their shape, surface texture, size and density, pollen produced by different taxa exhibits different terminal velocities and buoyancy (Lacey and West 2007).

Thus, it can be hypothesized that as compared to early flowering taxa, late flowering taxa will more easily enter houses because doors and windows are more frequently opened in late spring and summer seasons.

For four species, our results are in agreement with this putative pollination period effect. Indeed, penetration coefficients are very low for the two earliest species (*Cupressaceae* and *Platanus*) and high for *Olea* and *Poaceae*, two late pollinating species. The highest penetration coefficient is observed for *Pinus*. Due to its two outer air-sacs, pine pollen exhibits an unusual degree of buoyancy in the air (Lacey and West 2007) which allows pollen transport over long distances (Williams 2008). The low penetration coefficient estimated for *Quercus* (as compared to the

penetration of *Olea* which shares the same pollination period) would be attributable to the higher terminal velocities of its pollen (Matthias et al. 2012; Table 1).

Among dwelling, differences of pollen penetration are unlikely to be related the environment because houses were very close to each other and exposed to similar pollen sources. It would not be neither attributable to house architecture or ventilation systems, because no house had a mechanical ventilation system but could be related to the inhabitant activity and to individual cleaning habits.

The increment of pollen penetration coefficients from winter to summer strongly supports the hypothesis that the opening of doors and windows facilitates the penetration of pollen into dwellings. We estimated that pollen penetration in summer is one hundred times higher than in winter. House-cleaning practices and air renewal will also modify pollen penetration, and we suggest that, in spring, opening of windows for air renewal should be done very early, before the daily pollen release.

Although the amount of pollen which persist into dwellings would be less important than the amount of pollen coming from outside, it may have a significant effect on allergic symptoms in sensitized individuals, all the more so that it has been shown that pollen which have been kept indoor remain allergenic for years (Ariano et al. 2006; Shahali et al. 2013). The estimated remanence coefficients averaged 30 %. The among-species variability of pollen remanence (from 4 to 44 % among species) should be confirmed by specific experiments using control pollen lots, but may be attributed to pollen physical characteristics.

In conclusion, this study demonstrated that both pollen type, housing and the sampling time period have bearing on penetration and remanence of pollen indoor. These pollens could then interact with the allergic patients who could get symptom away from the pollination period. Thus, patients should be advised to prevent outdoor pollens to get into the house by closing windows and doors, vacuum-cleaning more frequently during the pollination periods, clean up the surfaces, vacuum-cleaning linen which has been stretched on a clothesline and wash their hair.

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References

- Ariano, R., Mistrello, G., Mincigrucci, G., Bricchi, E., Lannotti, O., Frenguelli, G., et al. (2006). In vitro and in vivo biological activities of old and fresh *Cupressus arizonica* pollen. *Journal of Investigational Allergology and Clinical Immunology*, 16, 177–182.
- Bıçakçı, A., Olgun, G., Aybeke, M., Erkan, P., & Malyer, H. (2004). Analysis of airborne pollen fall in Edirne, Turkey. *Acta Botanica Sinica*, 46(10), 1149–1154.
- Chang, C., & Gershwin, M. E. (2004). Indoor air quality and human health: Truth versus mass hysteria. *Clinical Reviews in Allergy & Immunology*, 27, 219–239.
- D'Amato, G., Russo, M., Liccardi, G., Saggese, M., Gentili, M., Mistrello, G., et al. (1996). Comparison between outdoor and indoor airborne allergenic activity. *Annals of Allergy, Asthma & Immunology*, 77, 147–152.
- Enomoto, T., Onishi, S., Sogo, H., Dake, Y., Ikeda, H., Funakoshi, H., et al. (2004). Japanese cedar pollen in floating indoor house dust after a pollinating season. *Allergology International*, 53, 219–225.
- Farrera, I., Calleja, M., & Déchamp, C. (2002). Indoor and outdoor pollen sedimentation in the Rhone-Alpes region during the ragweed pollination season. *Revue Française d'Allergologie et d'Immunologie Clinique*, 42, 750–753.
- Fredh, D., Broström, A., Rundgren, M., Lagerås, P., Mazier, F., & Zillén, L. (2012). The impact of land-use change on floristic diversity at regional scale in southern Sweden 600 BC–AD 2008. *Biogeosciences*, 10, 3159–3173.
- Grinshpun, A., Lee, T., Martuzevicius, D., Adhikari, A., & Reponen, T. (2005). Relationship between indoor and outdoor exposure to airborne fungi and pollen in single-family homes, in indoor air 2005. In X. Yang, B. Zhao, & R. Zhao (Eds.), *Proceedings of the 10th international conference on indoor air quality and climate (Beijing, China September 4–9, 2005)* (pp. 1734–1738). Beijing: Tsinghua University Press.
- Hirst, J. H. (1952). An automatic volumetric spore trap. *Annals of Applied Biology*, 39, 257–265.
- Hugg, T., & Rantio-Lehtimäki, A. (2007). Indoor and outdoor pollen concentrations in private and public spaces during the Betula pollen season. *Aerobiologia*, 23, 119–129.
- Jantunen, J., & Saarinen, K. (2009). Intrusion of airborne pollen through open windows and doors. *Aerobiologia*, 25, 193–201.
- Lacey, M., & West, J. S. (2007). *The air spora: A manual for catching and identifying airborne biological particles*. Berlin: Springer.
- Lebowitz, M. D., O'Rourke, M. K., Dodge, R., Holberg, G., Hoshaw, R., Pinnas, J., et al. (1982). The adverse health effects of biological aerosols, other aerosols, and indoor microclimate on asthmatics and non asthmatics. *Environment International*, 8, 375–380.
- Lee, T., Grinshpun, S. A., Martuzevicius, D., Adhikari, A., Crawford, C. M., Luo, J., & Reponen, T. (2006). Relationship between indoor and outdoor bioaerosols collected with a button inhalable aerosol sampler in urban homes. *Indoor Air*, 16, 37–47.
- Mandrioli, P., Comtois, P., Domínguez-Vilches, E., Galán Soldevilla, C., Syzdek, L. D., & Issard, S. A. (1998).

- Sampling principles and techniques. In P. Mandrioli, P. Comtois, & V. Levizzani (Eds.), *Methods in aerobiology* (pp. 47–112). Bologna: Pitagora Editrice.
- Matthias, I., Nielsen, A. B., & Giesecke, T. (2012). Evaluating the effect of flowering age and forest structure on pollen productivity estimates. *Vegetation History Archaeobotany*, 21, 471–484.
- McMillan, A. (2013). *A GIS approach to palaeovegetation modelling in the Mediterranean: The case study of south-west Turkey*. Ph.D. Thesis, University of Birmingham.
- O'Rourke, M. K., & Lebowitz, M. D. (1984). A comparison of regional atmospheric pollen with pollen collected at or near homes. *Grana*, 23, 55–64.
- O'Rourke, M. K., Ouackenboss, J. J., & Lebowitz, M. D. (1989). An epidemiological approach investigating respiratory disease response in sensitive individuals to indoor and outdoor pollen exposure in Tucson, Arizona. *Aerobiologia*, 5, 104–110.
- Saarinen, K., Jantunen, J., & Haahtela, T. (2011). Pollen transport by clothes. *Aerobiologia*, 27, 339–343.
- Shahali, Y., Brazdova, A., Calleja, M., Charpin, D., & Poncet, P. (2013). Indoor long-term persistence of cypress pollen allergenic potency: A 10-month study. *Annals of Allergy, Asthma & Immunology*, 111, 428–430.
- Sharma, D., Dutta, B. K., & Singh, A. B. (2009). Pollen, fungus and house dust mites survey at the residence of 90 allergic patients in Greater Silchar Area of Assam, India. *Research Journal of Allergy*, 1, 1–11.
- Stock, T. H., & Morandi, M. T. (1988). A characterisation of indoor and outdoor microenvironmental concentration of pollen and spores in two Houston neighbourhoods. *Environment International*, 14, 1–9.
- Takayashi, Y., Tanako, K., Suzuki, M., Nagai, S., Yokosuka, M., Takeshita, T., et al. (2009). Two routes for pollen entering indoors: Ventilation and clothes. *Journal of Investigational Allergology Clinical Immunology*, 18, 382–388.
- Tormo-Molina, R., Gonzalo-Garigo, A., Silva-Palacio, I., & Fernandez-Rodriguez, S. (2009). Seasonal and spatial variations of indoor pollen in a hospital. *International Journal of Environmental Research and Public Health*, 6, 3169–3178.
- Williams, C. G. (2008). Aerobiology of *Pinus taeda* pollen clouds. *Canadian Journal of Forest Research*, 38, 2177–2188.
- Zeghnoun, A., Dor, F., & Grégoire, A. (2010). *Description du budget espace temps et estimation de l'exposition de la population française dans son logement*. Rapport de l'Observatoire de la qualité de l'air intérieur, pp. 49.