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The influence of sampler height and orientation on airborne *Ambrosia* pollen counts in Montreal

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Airborne pollen concentrations are normally estimated by sampling 10 liters of air a minute at a height of 15–20 meters, e.g. on top of a university or hospital building. It is generally believed that at this height a homogeneous cloud of pollen is sampled, and that the results obtained will be representative of a large area. However, this protocol still leaves some doubts about the actual concentration found at breathing level (1.5 m). Since pollen counts are often used to forecast risk of allergies using threshold values, the height difference in concentrations can have important implications. Many previous studies have tackled this problem, but contradictory results were obtained. In our protocol, personal volumetric Burkard samplers were used at 0, 5, 10 and 15 m and at two different orientation (NW and NE) of a single building in Montreal, Canada. Results from 320 samples show that exposure and sampling hours were non-significant factors of *Ambrosia* pollen variation, but that height was a factor more significant than daily variations (the usual factor investigated in Aerobiology). An interaction was also found between the influences of height and orientation.

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The pollen of *Ambrosia* spp. (*A. artemisiifolia* and *A. trifida*) is the major airborne allergen of southern Québec (Comtois 1990), and causes more than 55% of the symptoms of respiratory allergies (Comtois & Gagnon 1988). Comtois & Gagnon (1988) have determined the minimum daily average concentration of clinical importance for the major pollen seasons: trees (Σ of *Acer*, *Quercus* and *Betula*), grasses (Poaceae) and ragweed (*Ambrosia*). These thresholds (at 15 m above ground level) were found to be 8–23 pollen grains/m³, 4–12 pollen grains/m³, and 1–3 pollen grains/m³ respectively for these three seasons. The question remains however as to the actual concentration found at breathing level (1.5 m).

It is evident that as we progress in the pollen season, lower concentrations are required to develop symptoms, and that *Ambrosia* represents both the last and the worst allergy season. It is for this reason that most of our research has been focused on this genus, such as its biogeography (Collins 1990); the spatial distribution of its pollen (Gagnon 1989, Comtois 1990) and its relation to phenology (Comtois & Boucher 1996).

Comtois & Gagnon (1988) have determined, by the spatial correlation of allergy symptoms and pollen counts, that a single Hirst-type sampler at 15 m above ground was representative of an area of at least 250 km². However, the precise altitudinal variation of the pollen cloud by volumetric suction samplers remains unstudied. When considering thresholds or forecasts, the height of sampling should be of primary importance. Indeed, it is well known that, as there is a decline of concentrations leeward from a source, there will be a decrease of concentrations with height, and concentra-

tions at pedestrian (breathing) levels can be much higher than at higher altitude, as demonstrated by results of Rantio-Lehtimäki et al. (1991), Alcázar (1995), and Galán et al. (1995) for open habitats. On the other hand, studies in urbanized zones showed an increase of concentrations with height, probably due to a screen effect of buildings (Malik et al. 1991, Bryant et al. 1989).

In order to investigate this relationship we have studied, for the first time, two sides of a building (on top of which a regular sampling station is operated) each one carrying an array of personal samplers, all operated at the same time. This sampling strategy allows statistical comparisons of concentrations combining at the same time height and exposure.

MATERIAL AND METHODS

Sampling was done in September 1995, on non-rainy days at the geography department building of the University of Montréal, located at 520 Chemin de la Côte Ste-Catherine, Montréal (73°37'W; 45°31'N). Montréal occupies the largest part of Montréal Island (approx. 400 km²), which is itself part of the Hochelaga archipelago of the upper Saint-Lawrence River. The University of Montréal campus is located on the northern slope of Mount Royal, which culminates at 235 m above sea level. The surroundings are an elevated (60 m a.s.l.) plain, mostly of residential land use, with individual houses and trees bordered streets, the majority of which are *Acer* and *Fraxinus*. The department building itself occupies most of a front lot between two parallel streets (Fig. 1). Although *Ambrosia* will grow almost everywhere in Montréal, at least as individual plants, the nearest important source of *Ambrosia* pollen

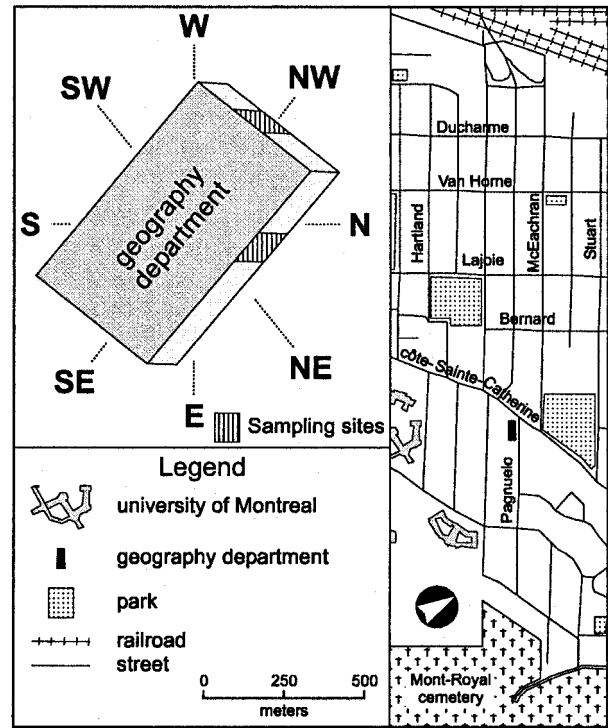


Fig. 1. Orientation of the two sampling arrays on the NW and NE faces of the studied building, and its location in the Outremont district of Montreal.

was a large population of this genus growing at about 1 km to the N-W of the campus, intersected with abandoned railway tracts.

The climate of Montréal is temperate and continental, with long and cold winters, and short and hot summers. The annual mean temperature is 6.5°C, which will sum up, on average, to 2223 degree-days above 5°C. Average precipitation amounts to 939 mm, including 273 cm of snow. The yearly sunshine hours add up to 2032, and average wind speed is 15.6 km/hr, mostly from the West. Normal growing season extends from April to September.

Sampling was done with Burkard's personal volumetric samplers. These are battery operated and draw, vertically, 10 liters of air a minute on a non-mobile 25×75 mm microscopic slide through a 2×14 mm slot. Samplers were run vertically, and therefore, isokinetic sampling may not always have been achieved. The slide was previously coated with a 1:7 gelatin/glycerin medium.

The experiment was done on two vertical sampling arrays. Each array consisted of one sampler on top (15 m) of the building, 2 samplers suspended on a rope on one side of the building (10 and 5 m) and one sampler at street level (0 m). North-West (front door) and North-East (lateral door) sides of the building were investigated at the same time (Fig. 1). With one operator on top of the building and one on the street, using two-way radios, all eight samplers could be run simultaneously (within 15 seconds start time). Samplers were run for 30 minutes (total sampled volume of 300 liters) and were repeated at 9h30, 10h30, 11h30 and 12h30. This time frame represents the diurnal pollen emission profile of *Ambrosia* (from 8h00 to 13h00). A total of 320 samples were taken.

In September 1995, temperature averaged 13.4°C, with absolute maximum and minimum respectively of 25.7°C (on September 5th) and 1.5°C (on September 24th); while the thirty years Normal (1961–1990) for the same month were respectively of 14.5°C, 32.8°C and –2.2°C. There were only 7 days with precipitation, giving a total of 59.6 mm, the Normal being 86.5 mm. This was a particularly sunny September, with only one day without sunshine, and 57% (215 hrs) of the total possible hours with sunshine (27% above the

average). Average wind speed was 11.2 km/hr (for a Normal of 12.4 km/hr), and the highest gust was of 57 km/hr, blowing from the West on September 22nd.

Slides were mounted using gelatin and basic red fuchsin, and all *Ambrosia* pollen were counted under a 400× magnification. Counts were multiplied by 3.52 to obtain numbers of pollen grains/m³/hour. Because the distribution of pollen concentrations per cubic meter and per hour did not show a normal distribution, comparisons were done using the naperian logarithm of the pollen counts plus one. This restored a normal distribution and allows the use of parametric tests.

The two samplers on top of the building can be seen as controls: the height, exposure and time frame were the same. Therefore, they can be used to calculate the sampler to sampler difference. No attempt to discriminate pollen counts by different categories of weather variables was undertaken. What we wanted to discover was the pollen count profile along an altitudinal gradient, representative of a mix of different meteorological conditions (except rainfall that will wash pollen grains from the atmosphere), so that it could have as much “universal” meaning as possible.

RESULTS

Table I shows the average situation of *Ambrosia* pollen for each hour and each height (mean = 18/m³). On a time scale, highest concentrations were found at 11h30 (= 22/m³), while on the altitudinal scale, highest concentrations were found at street level (25/m³). Minimum concentrations were found at 5 m and re-increased from there to 15 m.

If orientation is taken into account (Table II), maximum concentration is still found at 11h30, but this time, the altitudinal behavior is different for both orientations. On the front (NW) side of the building, the airborne *Ambrosia* pollen concentration increases with height, with a maximum

Table I. Average *Ambrosia* pollen concentrations for each hour and height.

hour	grains/m ³	height (m)	grains/m ³
9.30	16	0	25
10.30	17	5	13
11.30	22	10	15
12.30	17	15	17

Table II. Average *Ambrosia* pollen concentrations discriminated for for each orientation, hour and height.

	9.30	10.30	11.30	12.30	mean
NW					
0 m	19	11	15	15	15
5 m	7	15	13	6	13
10 m	18	14	31	22	21
15 m	15	20	24	23	20
mean	17	15	21	17	17
NE					
0 m	26	40	43	32	35
5 m	11	18	17	8	13
10 m	8	5	13	17	10
15 m	16	13	19	9	14
mean	15	19	23	16	15

attained at 10–15 m, while on the lateral (NE) side of the building, pollen concentrations were higher at ground level. However, these two different height distributions gave similar averages per orientation ($17/\text{m}^3$ for NW and $18/\text{m}^3$ for NE; Fig. 2).

The comparison of the two “control” samplers at 15 m (using a Student “*t*” test (Table III) shows that their difference (mean: $5.31/\text{m}^3$) was not significant ($p > 0.05$). Repeated measures without the influence of height or orientation showed similar results.

An analysis of variance (ANOVA) applied to the whole data set identified the factors governing the sampling to sampling differences (Table IV). Clearly there are differences from day to day, as the season progresses. However, no difference could be found between orientation (if the mean of each height and hour is considered), neither between the different sampling hours. A Mann-Whitney “U” test was also used to see if, not only the mean (the parameter tested by the ANOVA), but also the whole frequencies distribution by height for each orientation was similar. No significant difference was found (Table V).

Although, if there was no difference for the whole data set for each orientation, an analysis by height revealed differences for certain orientation couples (Table VI). For instance, ground level and 10 m paired samples showed a difference

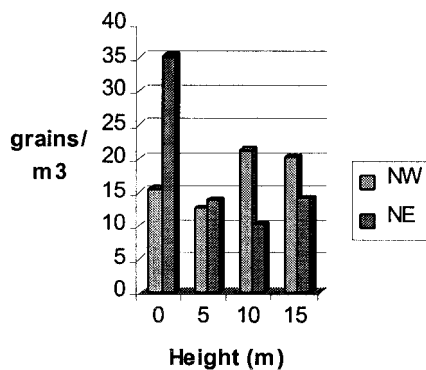


Fig. 2. Average *Ambrosia* pollen concentrations at each height for each orientation.

Table III. Student “*t*” test comparing the mean for the two “control” samplers at 15 m.

	mean difference	DF	t-value	p-value
NW/NE (15 m)	5.312	31	1.839	0.0756

Table IV. Simple Analysis of Variance (ANOVA I) for different days, hours and orientations.

CLASS	DF	Sum Squares	Mean Square	F-value	p-value
DAY	9	100.561	11.173	7.179	<0.0001
residual	306	476.258	1.556		
ORIENTATION	1	0.365	0.365	0.202	0.6539
residual	250	453.202	1.813		
HOUR	3	4.760	1.587	0.865	0.4593
residual	312	572.059	1.834		

Table V. Mann-Whitney test comparing data distribution for each orientation.

U-value	U-prime	Z-value	p-value
7583.0	8289.0	− 0.610	0.5417

large enough to be significant (at the 0.05 threshold level). It can also be seen that only above 10 m does the NW orientation gives more pollen than the NE. Therefore it is not surprising that an ANOVA applied to the height factor shows significance (Table VII) and that there was a significant interaction between height and orientation, but not between height and sampling hours.

Therefore, if we compare the means at both extreme altitudes (0 and 15 m) which was the primary objective of this study, there are significant differences if the NE side is considered, with highest concentrations found at ground level. NW comparisons yielded no significant differences.

DISCUSSION

The NW orientation seems to register a delay in the variation of pollen counts with height. Early in the morning, the concentration decreases with height (although the differences are small), while later the concentrations increase with height and the differences are larger. The daily average shows a pollen load higher at a height of 10 to 15 meters. This could be due to the different sources of pollen contributing at different times of the day. The largest pollen sources are found at some distance from the sampling site. Therefore the emitted pollen arrives suspended at a certain height and after some delay. The pollen concentration will then be higher at 10 to 15 m at the last hour of the morning. At 0 to 5 m, the pollen concentration is higher in the morning, when contributing pollen sources are small and near.

Collins (1990) previously indicated the South-West part of Montréal Island, where railway tracks, airfields and highways are interlocked, as the largest source of *Ambrosia* pollen. And a comparison of sources and deposition sites of *Ambrosia* pollen has allowed Comtois & Gagnon (1990) to conclude that the St Lawrence river (surrounding Montréal Island) and Mount Royal (dominating the South-Center part of the Island) were the most influential features of the general West-East air masses movement and pollen dispersal.

However, these seem unlikely to generate significant differences between 0 and 15 m. On the other hand, at the NW of the site there are the old Canadian National Railway

Table VI. Student "t" test and correlation analysis between orientations for all heights, and then discriminated by height.

	mean NW	mean NE	mean diff.	r-value	prob.	t-value	prob.
	17.20	18.30	- 1.10	0.908	0.000	- 0.80	0.443
0 m	15.40	35.10	- 19.70	0.659	0.038	- 4.49	0.002
5 m	12.66	13.77	- 1.11	0.841	0.005	- 0.62	0.556
10 m	21.20	10.20	11.00	0.793	0.006	3.51	0.007
15 m	20.20	14.10	6.10	0.445	0.197	1.58	0.149

Table VII. Multiple Analysis of Variance (ANOVA II) for orientation & height, then for hour & height, also showing interaction between factors (*).

CLASS	DF	Sum Squares	Mean Square	F-value	p-value
ORIENTATION	1	0.220	0.220	0.146	0.7028
HEIGHT	3	38.075	12.692	8.423	<0.0001
Orient. * height	3	47.991	15.997	10.616	<0.0001
HOUR	3	4.731	1.577	0.879	0.4521
HEIGHT	3	20.794	6.931	3.865	0.0098
hour * height	9	13.264	1.474	0.822	0.5965

Table VIII. Student "t" test comparing mean values at 0 and 15 m for each orientation.

	mean 0 m	mean 15 m	mean diff.	r-value	prob.	t-value	prob.
NW	15.40	20.20	- 4.80	0.305	0.391	- 0.98	0.354
NE	35.10	14.10	21.00	0.514	0.129	4.21	0.002

tracks, which constitute a small but nearby source. The NE site will be on the lee side of the dominating W and SW winds and concentrations will be significantly higher at ground level (Table VIII)

These results are corroborated by those of K  pyl   (1983) and recently by Gal  n et al. (1995). Both conclude that, on the lee side of a building, concentrations are higher at lower altitudes due to the turbulence created by the building. The sampling conditions reported in the paper by Gal  n et al. were the same as ours: a sampler located at the SE of a building with dominant winds coming from the WSW. Their own Student "t" test also reflects the same amount of significance.

In contrast, the NE orientation seems to favor the contribution of more local sources. From the first hours of the morning there are differences between ground level and the rest of the sampling transect, and these differences become larger as the quantity of pollen also increases (at 11h30 and 12h30) to account for an average difference of 57% (with a range from 46 to 65%) on behalf of ground level.

CONCLUSIONS

Previous studies on the variations of pollen concentrations of a variety of taxa with height have yielded different results: some authors reported higher concentrations with height (Bryant et al. 1989, Malik et al. 1991) while others concluded higher pollen concentrations at ground or pedestrian levels (Rantio-Lehtim  ki et al. 1991, Lyon et al. 1984).

In this paper, we have shown that height, but even more the height-orientation interaction, brings significant

differences in airborne *Ambrosia* pollen concentrations, and that these differences were higher than the day to day pollen counts variations. Orientation in itself, or the interaction of height with time of the day, were not significant.

Our conclusions were reached after studying the urban environment and *Ambrosia* pollen. It may be difficult to generalize to other situations. However, both this type of environment, and the characteristics of *Ambrosia* pollen (an almost spherical pollen of 22   m of diameter; a density of 0.55; a terminal velocity of 1.56 cm/sec.) are not uncommon in aerobiological studies. Therefore the sampling array orientation and its relationship with dominant winds may explain some of the differences found in previous papers dealing with the same topic.

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