

Short communication

Effects of various vacuum cleaners on the airborne content of major cat allergen (Fel d 1)

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Background It has been shown that a vacuum cleaner (VC) can increase airborne cat allergen levels. This study aimed to compare the degree of leakage of airborne Fel d 1 levels among five different VCs, both under laboratory conditions and in an apartment with cats.

Methods Three of the VCs were marketed as antiallergic: a HEPA filter VC (VC A), a water impingement and HEPA filter VC (VC B), and a foam fabric filter VC (VC C). The other two were standard VCs: VC D and VC E. VCs were tested in a 20 m³, airtight, experimental room and in a 53 m³ living room in an apartment with three cats. Air was sampled with a glass-fiber filter and an impinger at 20 l/min for 30 min before, during, and after vacuuming. Airborne Fel d 1 was measured with a two-site monoclonal ELISA assay.

Results In the experimental room, no airborne Fel d 1 level was measured before using the VCs. After introducing a dust sample containing Fel d 1 in the VCs, we found that VCs A, B, and E did not provoke any increase in airborne Fel d 1. In contrast, VCs C and D significantly increased airborne Fel d 1 levels (GM: 4.9 and 5.3 ng/m³, respectively). In the apartment, all VCs induced an increase in airborne Fel d 1, which was carried by particles greater than 5 µm. However, VCs C and D provoked significantly greater increases in airborne Fel d 1 than VCs A, B, and E ($P=0.0001$).

Conclusions Our results suggest that:

- 1) The two VCs with leakage in the experimental room had greater leakages in the apartment.
- 2) In the apartment with cats, all VCs provoked increases in airborne Fel d 1, primarily carried by large particles.
- 3) Given the increased marketing of "antiallergic" VCs, further studies are needed to standardize methods for testing airborne allergen leakage by VCs.

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Surveys carried out in various countries (1, 2) have shown that cat allergen is one of the most common indoor aeroallergens. In most homes with a cat, a significant proportion of airborne cat allergen can be detected in association with particles of <5 µm (3–5) even in the absence of the cat. In contrast, groups 1 and 2 major mite allergens and cockroach allergens cannot be detected in the absence of disturbance or are present at very low levels and

are found mainly on particles larger than 10 µm (6–9). It has been shown that vacuum cleaners (VCs) cause a significant increase in airborne Fel d 1 associated with small particles (<5 µm), thus possibly increasing symptoms in cat-allergic patients (3, 4, 10). This study aimed to compare the degree of leakage of airborne Fel d 1 levels among five different VCs, both under laboratory conditions and in apartments with cats.

Material and methods

Air sampling

Air sampling was done with an impinger (Research Glassware, UK) (11) and a glass-fiber filter (AP200 3500, Millipore, France), as previously described (3, 9). The sampling duration was 30 min. The airflow at the inlet was adjusted at 20 l/min, for both the glass-fiber filter and the impinger. On completion of sampling, buffer from the impinger was directly assayed, and fiber filters were incubated in 1.0 ml of 1% bovine serum albumin – phosphate-buffered saline (BSA–PBS) Tween 20, overnight at 4°C. In accordance with French norms (12), inlet airflow was adjusted before each sampling with a bubble airflow meter (Gillibrator, Panametrics, France).

Two-site monoclonal antibody enzyme-linked immunosorbent assay (ELISA) for the quantification of Fel d 1

The cat-allergen content of the buffer and glass-fiber filters was assayed by a two-site ELISA using monoclonal antibodies (mAb) specific for two non-overlapping epitopes on Fel d 1, as previously performed (Fd1A and Fd1B) (3). The detection limit for a 30-min sampling period was 0.8 ng/m³ at 20 l/min.

Vacuum cleaners

Three of the VCs were marketed as antiallergic; the first one was a HEPA (High Efficiency Particle Air) VC (VC A): Nilfisk GS 80 (Nilfisk SA, Morangis, France); the second one was a water impingement and HEPA filter VC (VC B): Rainbow D4 (Rexair, Inc., MI, USA); and the third one was a foam fabric filter VC (VC C): Vax (Vax, Arlett SA, Bonneuil, France). The two others were standard VCs; VC D: Philips T 720 (Philips, Suresne, France); VC E: Progress 562 (Menalux SA, Senlis, France). All of them were canister VCs.

Experimental design

Experimental room. The VCs were tested in a 20 m³, airtight, experimental room with a draft-proof window, a single door, and a tiled floor. All VCs were identically placed in the experimental room, 1 m from the impinger and filter. A dust sample with a geometric mean (GM) weight of 27.7 g (range: 7.2–100 g) containing a GM of 16.3 mg (range: 5.4–37.4 mg) of Fel d 1 was introduced into the VCs through the inlet nozzle, from outside the room; the nozzle went through a hole in the door. The VC was switched on for 15 min.

Airborne Fel d 1 was sampled with an impinger and a parallel filter placed inside the room at a height of 1.5 m above the floor. The impinger and parallel filter were connected to a vacuum pump which remained outside the room. Air was sampled for 30 min before each test to determine background levels of airborne Fel d 1. Air was sampled for a total of 30 min: 15 min during VC functioning and 15 min thereafter. To avoid airborne Fel d 1 background, we used a HEPA air cleaner (Enviracaire, EV1, Enviracaire Corp., MD, USA) for 8 h at 400 m³/h in the experimental room.

Homes with cats

Air samples were performed in the 53 m³ living room of an apartment housing three cats. The living room had two doors and one window; it was selected since it was the room in which the cats spent most of their time. Levels were measured when the cats had been absent for at least 1 h. A 14 m² carpet was vacuumed for 15 min with a new dust bag in the cleaner or, in the case of the water-filter VC, with clean tap water in the reservoir. Air was initially sampled for 30 min before vacuuming to obtain a baseline airborne cat-allergen level, using a glass-fiber filter at 20 l/min. Sampling was then carried out for 15 min during vacuuming and 15 min after switching off the VC (total sampling time of 30 min). Dust from the VC bag was weighed and extracted in borate-buffered saline, pH 8, overnight at 4°C, and assayed for Fel d 1. An aliquot of the content of the water-filter VC reservoir was assayed directly.

Statistics

Multiple comparison of means was done with a multifactorial analysis of variance for repeated measurements of log-transformed data and considering eventual interactions between the factors. We used the Scheffe test to determine the significant difference in mean values.

Results

Airborne Fel d 1 in the experimental room (Fig. 1 and Table 1)

In all experiments, no measurable Fel d 1 levels were found before using the VC in the experimental room ($n=34$). VCs A, B, and E appeared to be the most efficient for Fel d 1 retention, since no increase in airborne Fel d 1 was observed. In contrast, the use of VCs C and D significantly increased airborne Fel d 1 (Fig. 1). For VCs C and

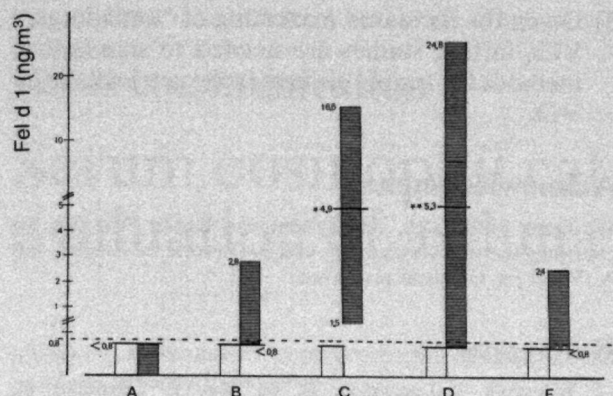


Fig. 1. Airborne Fel d 1 levels expressed as range (□) and GM (—) of values. (---) Sensitivity threshold for assay. * Values obtained with VC C were significantly different from VCs A, B, and E; $P=0.0001$. ** Values obtained with VC D were significantly different from VCs A, B, and E; $P=0.0001$.

D, airborne Fel d 1 was mainly carried on large particles ($>5\mu\text{m}$): 60% and 84%, respectively ($P=0.0001$) (Table 1). No statistical difference was found between the dust samples introduced in the five VCs, either in Fel d 1 concentration or in weight.

Airborne Fel d 1 in an apartment with cats (Fig. 2)

The five different VCs were tested on different days, once a day, on 18 occasions. Measurable levels of Fel d 1 were found in the living room before testing the VC, with a GM of 0.8 ng/m^3 (range $<0.8\text{--}1.7$; $n=18$). However, no significant difference was found in airborne Fel d 1 background between the different VCs ($P=0.4$). No significant difference was found in dust Fel d 1 levels recovered after vacuuming among the five different VCs. Three VCs (A, B, and E) provoked a moderate increase in airborne Fel d 1. In

contrast, the use of VCs C and D dramatically increased airborne Fel d 1 levels. No significant differences in airborne Fel d 1 levels associated with particles of $<5\mu\text{m}$ were found among the five VCs.

Water impingement VC with or without a HEPA filter

In the experimental room, when we used VC B with no filter at the exhaust, a GM of 7.7 ng/m^3 of total Fel d 1 was measured, and 7.3 ng/m^3 of airborne Fel d 1 was carried on particles of less than $5\mu\text{m}$. In contrast, when a HEPA filter was added at the exhaust, a dramatic decrease in total airborne Fel d 1 level was observed (GM: $<0.8\text{ ng/m}^3$) and also in airborne Fel d 1 carried on particles of $<5\mu\text{m}$ (GM: $<0.8\text{ ng/m}^3$, $P=0.03$).

Discussion

In recent years, certain manufacturers have tried to market their VCs as antiallergic. It has been shown (3, 10) that important differences in Fel d 1 retention could be found between different VCs. Our study is the first to test VCs under two different conditions: in an experimental room and in the living room of an apartment with three cats. According to the data obtained in the experimental room, VCs A, B, and E had no leakage. The increase in airborne Fel d 1 when using VCs C and D in the experimental room could be explained by a leakage through the connection of the various VC segments or leakage from the dust bag. In the living room, the increase in airborne Fel d 1 using VCs A, B, and E could be explained by disturbances created by the nozzle, tube, and wheels of the VCs. Use of VCs C and D in the living room provoked a 10-fold greater increase in Fel d 1 than VCs A, B, and E, confirming the important leakage of these two

Table 1. Particle size distribution of airborne Fel d 1 using an impinger with five different VCs in experimental room

		A HEPA n=6	B WI plus HEPA n=4	C Foam filter plus paper filter n=8	D Foam filter plus electrostatic filter n=9	E Inex n=7
Stage 1 $>10\mu\text{m}$	GM	$<0.8^*$	<0.8	1.8	2.5	<0.8
	AM	<0.8	<0.8	2.2	4.7	<0.8
	Range	—	—	1.0–5.2	$<0.8\text{--}22$	$<0.8\text{--}1.8$
Stage 2 2.5– $10\mu\text{m}$	GM	<0.8	<0.8	<0.8	<0.8	<0.8
	AM	<0.8	<0.8	1.2	0.8	<0.8
	Range	—	—	$<0.8\text{--}1.5$	$<0.8\text{--}1.5$	—
Stage 3 plus final filter $<5\mu\text{m}$	GM	<0.8	<0.8	<0.8	<0.8	<0.8
	AM	<0.8	<1.0	<0.8	<0.8	<0.8
	Range	—	$<0.8\text{--}1.75$	—	—	—

(—) No range of values was observed. * Threshold value for measurable airborne Fel d 1 when sampling for 30 min at 20 l/min . GM: geometric mean; AM: arithmetic mean.

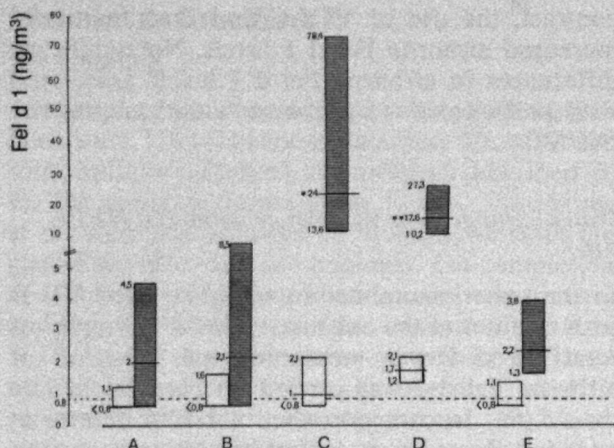


Fig. 2. Airborne Fel d 1 levels expressed as range (□ ■) and GM (—) of values. No statistical difference was found between Fel d 1 background levels (□) in living rooms among five VCs. (---) Sensitivity threshold for assay. * Values obtained with VC C were significantly different from VCs A, B, and E; $P=0.0001$. ** Values obtained with VC D were significantly different from VCs A, B, and E; $P=0.0001$.

devices. The fact that the increase in airborne Fel d 1 was associated with particles of $>5\mu\text{m}$ does not necessarily imply an absence of bronchial effects on cat-allergic patients. It has been shown by Svartengren et al. (13) that 10% of particles of $>10\mu\text{m}$ could reach the alveolar part of the lung. Large particles could partly explain the fact that significantly higher Fel d 1 levels are needed to induce a positive bronchial challenge test than those provoking symptoms at home (14). The role of VCs in mite-allergen exposure has been examined in only two studies (15, 16). These two experiments were done in homes with high levels of mite allergen. Hegarty et al. found that the use of Nilfisk, Vorwerk, Bosch, and Vax VCs did not increase airborne Der p 1 (15). Results obtained with a Vax VC were different from ours; this could be explained by their use of additional filters set above the bag and beneath the motor. Previous publications have shown that without a filter on the outlet, a WI VC produced high levels of airborne Fel d 1, carried primarily on particles of $<5\mu\text{m}$ (3, 10). We have shown that a HEPA filter at the outlet of a water impingement VC can dramatically reduce airborne Fel d 1 to levels not statistically different from those with a HEPA VC, both in the experimental room and in the living room.

In conclusion, our results suggest that:

- 1) VCs with leakage in the experimental room had greater leakages in the apartment.
- 2) In the apartment with cats, all VCs caused increases in airborne Fel d 1 levels, primarily carried by large particles.

- 3) Given the increased marketing of "antiallergic" VCs, further studies are needed to standardize methods for testing airborne allergen leakage by VCs.

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