

Cat (*Fel d* I), dog (*Can f* I), and cockroach allergens in homes of asthmatic children from three climatic zones in Sweden

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We have investigated the levels of cat (*Fel d* I), dog (*Can f* I), and cockroach (*Per a* I) allergens in dust from bedrooms, living rooms, kitchens, and bathrooms from 123 homes of asthmatic children in three zones of Sweden with varying climates. Absolute indoor humidity (AIH), relative humidity (RH), rate of ventilation in air changes per hour (ach), and number of airborne particles were also measured. *Fel d* I, *Can f* I, and *Per a* I allergen contents were determined by mab ELISA, and the levels were related to various environmental factors. The major cat allergen, *Fel d* I, was detected in all homes, and the concentrations varied between 16 ng and 28 000 ng/g fine dust. The dog allergen, *Can f* I, was detected in 85% of the homes, and the levels varied from 60 ng to 866 000 ng/g dust. Cockroach allergen was detected in only one home (40 ng/g). *Fel d* I and *Can f* I allergens were equally distributed geographically. Dust from living rooms contained significantly higher ($P < 0.05$) concentrations of both *Fel d* I and *Can f* I allergens than dust from bedrooms, kitchens, and bathrooms. The levels tended to be higher in homes with poor ventilation (< 0.5 ach) and in homes with wall-to-wall carpets. Significantly higher ($P < 0.01$) numbers of airborne particles were found in homes with high humidity (i.e., $\text{AIH} \geq 7$ g/kg or $\text{RH} \geq 45\%$). We conclude that pet allergens are ubiquitous in different climatic regions, being found in bedrooms, living rooms, kitchens, and bathrooms. Current or previous presence of a cat or dog, high indoor humidity, presence of wall-to-wall carpets, and poor ventilation all increase the risk for high allergen exposure. In contrast, cockroach allergens are rarely found in a temperate climate.

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Cats and dogs are the most common household pets in Sweden, and more than 50% of all Swedish schoolchildren and 25% of asthmatic children keep furred pets at home (9). It has been reported that 70% of Scandinavian children with perennial asthma are sensitized to cat and/or dog dander, as determined by skin prick test (SPT), conjunctival provocation test (CPT), and *in vitro* tests (5, 29).

The prevalence of asthma and other allergic diseases appears to be increasing in Sweden (1, 2). A remarkable increase has been noticed in northern Sweden (1, 18). One explanation for this regional increase may be changes in indoor environment caused by the construction of well-insulated, air-tight buildings, often poorly ventilated, resulting in

increased exposure to mites, animal proteins, and dust particles.

In previous studies (14, 15), we have found that the major cat (*Felis domesticus*; *Fel d* I) and dog (*Canis familiaris*; *Can f* I) allergens are the predominant indoor allergens in Sweden. This is in contrast to warmer and more humid areas, where mite and cockroach allergens are predominant (3). The prevalence of pet allergens is independent of climatic factors; they are ubiquitous in the environment (25), even in places where cats and dogs have never been kept (15, 22, 25).

No exact standards exist for the clinical significance of *Fel d* I or *Can f* I allergen levels in dust. However, it has been suggested that a level of

≥ 8 μg of the major allergen from cat, *Fel d I*, per gram of fine dust, should be regarded as the threshold level for both sensitization and acute asthma (7, 35). For *Can f I*, threshold levels for sensitization and triggering of asthma have not been identified.

In the Scandinavian countries, recommendations have been made for the standard of ventilation in private homes (8, 13). It has also been reported that a ventilation rate above 0.5 air changes/h (ach) reduces mite allergen levels in dust (10). It is not known whether this rate of ventilation has any effect on the concentration of cat or dog allergens in house dust.

The purpose of our study was to analyze the levels of indoor allergens in dust from the homes of asthmatic children in three climatic zones of Sweden, and to assess the importance of some conditions, including humidity and ventilation in the homes, that could influence the allergen levels in house dust. In a separate paper, we reported on mite (*Der p I* and *Der f I*) allergen levels in these homes (16). Here we report on the major cat (*Fel d I*), dog (*Can f I*), and cockroach (*Periplaneta americana*; *Per a I*) allergens.

Material and methods

Selection of homes

From September to December 1989, 390 house-dust samples were collected from 130 homes of children with moderately severe perennial asthma. The patients were selected on the basis of medication score. All patients were on medication (inhaled steroids

and/or sodium cromoglycate) throughout the year. Clinical details on the asthmatic children and the relation between exposure and sensitization, severity of symptoms or use of medication will be published in a separate paper (Warner et al., in manuscript). They lived in three different climatic zones of Sweden. Umeå is situated 300 km below the Arctic Circle and has a subarctic climate; Linköping is situated inland, 200 km south of Stockholm; and Helsingborg in southern Sweden has a maritime climate, as it is a coastal town.

Data were collected on home environments by questionnaires to the parents at all the homes and by objective measurements of residential ventilation, humidity, and airborne particles in 60 homes. These measurements were done from October 1990 to January 1991.

The parents of the children were encouraged to respond to a questionnaire on dampness in the home, the presence of furred pets (e.g., cats and dogs), smoking habits, and other factors (Table 1) which may influence indoor allergen concentrations. The four indices of damp housing were persistent visible damp spots in the home (on either walls, floors, or ceilings), visible mold growth in the home, water condensation on double windowpanes, and foul smell in the home perceptible by dwellers or visitors (14, 16). Homes showing at least one of the first three indices, with or without foul smell in the home, were considered to be damp homes. None of the homes fulfilled all the criteria for dampness.

Table 1. Relation between certain environmental conditions and concentrations of *Fel d I* and *Can f I* allergens in bedrooms (BR) and living rooms (LR) of 123 homes of asthmatic children from three different climatic parts of Sweden. All comparisons were not statistically significant. Two observations are missing in all factors for *Can f I*

Environmental factors	No. of homes	Allergen concentration (ng/g dust); geometric mean (± 1 SD)			
		<i>Fel d I</i>		<i>Can f I</i>	
		BR	LR	BR	LR
Private houses (bungalows)	95	279 (47–1656)	472 (81–2735)	74 (<60–1987)	220 (<60–5539)
Apartments and apartment buildings	28	331 (46–2404)	857 (207–3548)	92 (<60–2864)	463 (<60–7053)
Home on first floor	51	236 (34–1626)	474 (85–2642)	77 (<60–2819)	344 (<60–9016)
Home on upper floor	72	335 (59–1914)	594 (110–3221)	78 (<60–1770)	212 (<60–4582)
Home with wall-to-wall carpet	20	524 (82–3357)	798 (118–5383)	117 (<60–1963)	371 (<60–4583)
Home with no such carpet	103	258 (43–1567)	501 (96–2618)	71 (<60–2148)	240 (<60–6281)
Dampness in home	67	288 (37–2244)	581 (102–3296)	84 (<60–2421)	253 (<60–6398)
No dampness	56	282 (64–1334)	497 (94–2618)	71 (<60–1062)	264 (<60–5715)
Homes with smoker	55	281 (48–1637)	526 (102–2716)	62 (<60–1355)	201 (<60–4809)
Homes with no smoker	68	297 (45–1950)	553 (96–3199)	94 (<60–3091)	316 (<60–7262)
Ventilation by draft	37	218 (43–1104)	506 (104–1449)	92 (<60–3350)	382 (90–8110)
Ventilation by central exhaust fan §	51	399 (53–3027)	662 (111–3954)	75 (<60–1968)	203 (<60–6082)
Mechanical and/or regulated ventilation §	34	255 (47–1380)	459 (84–2500)	75 (<60–1706)	242 (<60–4519)

§: One observation missing.

Technical measurements of homes

Measurements of ventilation, humidity, and airborne particles were done in 20 homes in each region.

Ventilation was measured by passive trace gas infiltration, i.e., the PFT (perfluorocarbon)-method (21), developed at Brookhaven National Laboratory (BNL), and known as BNL/AIMS (air infiltration measurement system). From three to five gas containers of a synthetic tracer gas, perfluorocarbon, were placed in each home. The tracer gas was allowed to spread inside the building for at least 24 h to obtain homogeneous diffusion. Then from six to eight collector probes were placed inside each home and exposed to the tracer gas for 20 h. The tracer gas was analyzed by the National Building Research Institute (SBI) (Copenhagen, Denmark), with gas chromatographic equipment. The results reflect an average of total outdoor air-change rate in the building over 20 h. From these values, air changes per hour (ach) were calculated.

Absolute indoor humidity (AIH) and relative humidity (RH) were measured in 20 homes in each region as described previously (16).

Airborne particles were collected from the bedrooms of the children in 20 homes in each region with a Nucleopore filter (0.4- μ m pore size) connected to a vacuum pump. A volume of 1 m³ air was sampled over 15–20 h from the central area of the bedroom. Two different particle diameters were analyzed, i.e., 0.4–1 μ m and > 1 μ m. The particle size distribution was analyzed by Analytica AB, Stockholm.

Allergen determinations

Samples of house dust were collected from the bedroom of the child, the living room, the kitchen, and the bathroom by the parents with their own vacuum cleaner. A fresh disposable paper bag was placed in the vacuum cleaner before collection of each sample. Parents were asked not to clean their homes for 7 days before collection of the dust samples. Dust sampling was standardized by time. Dust in the bedroom, designated location one, was collected from the child's mattress for 2 min, under and in front of the bed for 2 min, and inside the windowpane and in each corner of the room for 2 min. Dust from the living room, designated location two, was collected for 2 min from sofas and other furniture, and for another 2 min from the carpets (if any), floor, and window frames. Dust collecting from the kitchen and bathroom, designated location three, including floors and every corner, was done for 2 min.

In all, 390 dust samples were collected, and 369 of them were available for laboratory analysis. The dust samples from eight of the 60 objectively investigated homes either were lost (four homes) or were

not sufficient in amount for analysis (four homes). Dust samples were passed through a sieve designed in our laboratory for small dust samples and containing a filter (pore size, 300 μ m). Sieved dust was weighed and then extracted. Aqueous extracts of the house-dust samples were prepared, as described earlier (14), with an extraction ratio of 1:10 to 1:30 (w/v) by dissolving the dust sample in phosphate-buffered saline (PBS), pH 7.6, at 4 °C overnight under constant rotation. The extracts were stored frozen at –20 °C until analysis.

The concentration of major cat and dog allergens was determined by sandwich ELISA, according to the methods of Chapman et al. (4) for *Fel d I*, and Schou et al. for *Can f I* (23) and *Per a I* (23). The allergen concentration for each room was the concentration obtained from all samples collected from that room.

The ELISA test kit for *Fel d I* was kindly supplied by Dr Chapman (Charlottesville, VA, USA). The kit consisted of a monoclonal antibody against *Fel d I* (clone 6F9 A4-H1), and a second monoclonal antibody (biotinylated) against *Fel d I* (clone 3E4 C4-C10). The reference preparation of *Fel d I* (10.5 units/ml) was obtained from the Office of Biologics, Food and Drug Administration (Bethesda, MD, USA).

For *Can f I* ELISA, both capture and detection layers of antibody against *Can f I* were monospecific rabbit antibodies. The detection layer of antibody was peroxidase-labeled. The reference preparation of *Can f I* was as previously described (15).

The ELISA test kit for cockroach allergen was based upon a rabbit anti-*Per a I* and -*Bla g I* (capture layer), a polyclonal peroxidase-labeled rabbit anti-*Per a I* and -*Bla g I* (detection layer), and a reference preparation of purified *Per a I* of defined protein concentration (23). The antibody preparation used for cockroach ELISA reacts with determinants shared by the allergens *Per a I* and *Bla g I*; i.e., the assay does not distinguish between *Per a I* and the homologous major allergen, *Bla g I*, from the German cockroach, *Blattella germanica*. The avidity for *Per a I* is, however, higher than for *Bla g I* (23). The measured cockroach allergen concentrations were expressed as ng equivalents of *Per a I* protein per gram of dust, i.e., *Per a I* eq/g. The lower detection limits were 16 ng/g dust for *Fel d I*, 60 ng/g dust for *Can f I*, and 1 ng eq/g for *Per a I*.

Statistical analysis

The ELISA results were transformed into decimal logarithms. The Wilcoxon-Mann-Whitney test and the Kruskal-Wallis test were used to test the level of significance of differences between variables. The Wilcoxon signed-rank test was used to assess any

variation between sampling locations. The Spearman rank-order correlation coefficient (r_s) or simple linear regression was used to test possible association between variables and environmental indices.

Ethics

Informed consent, oral or written, was obtained from all participants. The study was approved by the Ethics Committee for Human Research at the University Hospital of Linköping.

Results

Cat allergen

The major cat allergen, *Fel d I*, was detected in all homes and in 91% of the samples. The *Fel d I* allergen concentrations were similar in all three regions (Fig. 1). The concentrations varied between 16 ng and 28 µg/g dust (median, 861 ng/g). In 38 homes (31%), the concentrations were <60 ng/g dust, and in 11 homes (9%) ≥ 8 µg/g dust. These 11 homes were equally distributed in the three regions.

The concentration of *Fel d I* allergen was higher in living room dust (geometric mean 541 ng/g, range <16 ng–28 µg/g) than in dust collected from bedrooms (geometric mean 290 ng/g, range <16 ng–16 µg/g) ($P < 0.001$; $n = 123$), where, in turn, the concentration was higher than in dust from kitchens and bathrooms (geometric mean 71 ng/g, range <16 ng–18 µg/g) ($P < 0.001$) (Fig. 1). However, this was not true for all the homes. Thus, the highest levels were

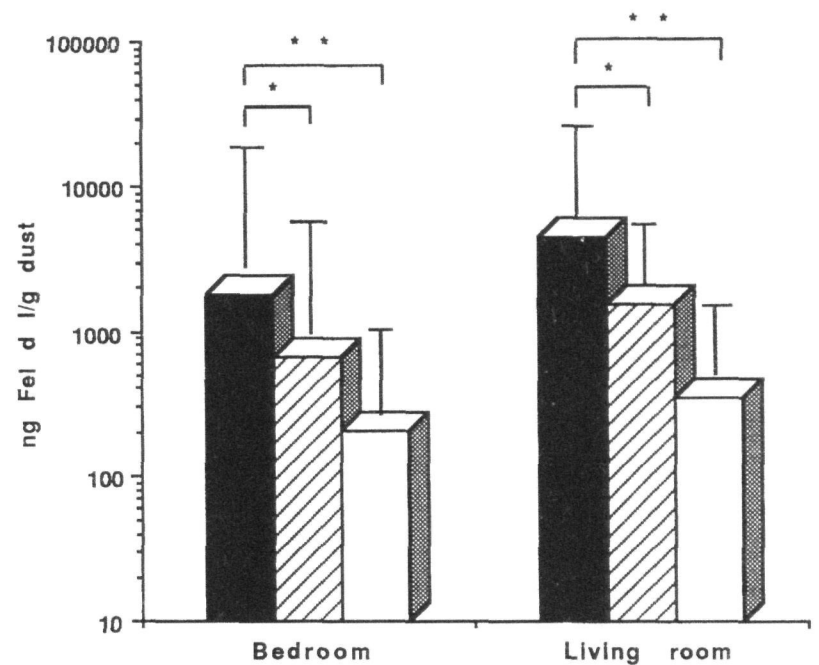


Fig. 2. Concentration of major cat (*Fel d I*) allergen in homes with cat present (■, $n = 10$), homes that had had cat before (▨, $n = 19$), and homes that never had cat (□, $n = 94$). * $P < 0.05$; ** $P < 0.01$.

recorded in the bedrooms in 39 (32%) homes and in dust from kitchens and bathrooms in five (4%) homes.

The concentrations of *Fel d I* allergen were significantly higher ($P < 0.01$) in homes with, than in homes without, a cat (Fig. 2). Homes in which a cat had previously lived had significantly higher ($P < 0.05$) levels of *Fel d I* allergen than homes that never had a cat.

The *Fel d I* allergen concentrations were not significantly influenced by any of the environmental

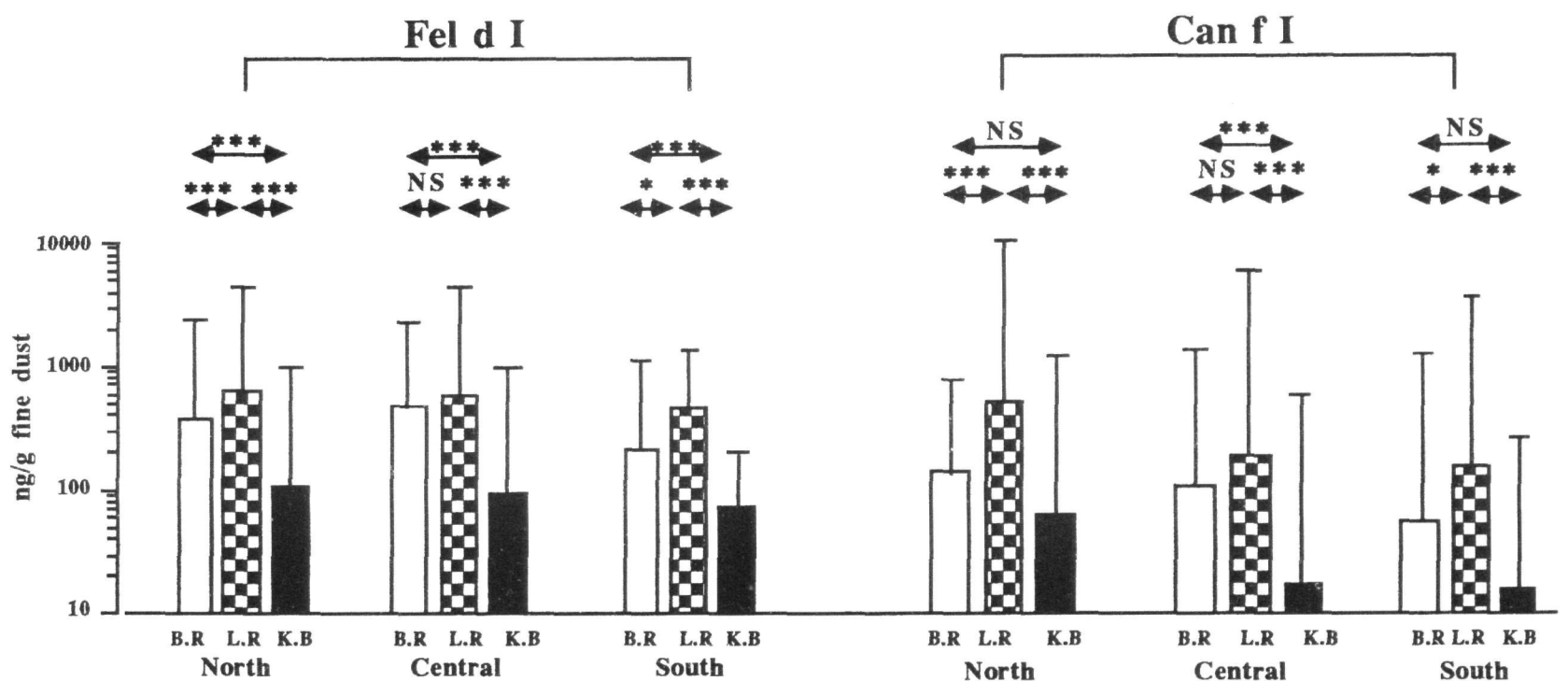


Fig. 1. Concentration of major cat (*Fel d I*) and dog (*Can f I*) allergens in homes of asthmatic children in northern ($n = 40$), central ($n = 38$), and southern ($n = 45$) Sweden. Geometric mean plus 1 SD is given. * $P < 0.05$, *** $P < 0.001$; NS, not statistically significant. Comparisons between regions were not statistically significant. BR, bedroom; LR, living room; KB, kitchen and bathroom.

factors and housing conditions listed in Table 1, although the allergen concentrations tended to be higher in homes with a wall-to-wall carpet than in homes with no such carpets.

The cat allergen concentrations tended to be lower in homes when the rate of ventilation was ≥ 0.5 ach (Table 2, Fig. 3).

Dog allergen

The dog allergen, *Can f* I, was detected in 85% of the homes and in 58% of the samples in concentrations from 60 ng to 866 $\mu\text{g/g}$ of fine dust (median, 1202 ng/g). There were no geographic differences in concentrations of dog allergen (Fig. 1). Fourteen homes (11%) had *Can f* I allergen concentrations ≥ 8 $\mu\text{g/g}$ dust. These 14 homes were equally distributed among the three regions. The geometric mean concentration of *Can f* I (836 ng/g) was significantly lower ($P < 0.01$; $n = 123$) than that of *Fel d* I (1180 ng/g).

The concentrations of *Can f* I allergen were significantly higher ($P < 0.001$; $n = 123$) in the living room dust (geometric mean 258 ng/g, range < 60 ng–866 $\mu\text{g/g}$) than in dust from the bedrooms (geometric mean 77 ng/g, range < 60 ng–746 $\mu\text{g/g}$), which, in turn, had higher concentrations ($P < 0.01$; $n = 123$) than dust from kitchens and bathrooms (geometric mean 24 ng/g, range < 60 ng–240 $\mu\text{g/g}$) (Fig. 1). However, this was not true for all the homes. Thus, the highest levels were recorded in the bedrooms in 22 (18%) homes and in dust from kitchens and bathrooms in 11 (9%) homes.

The *Can f* I allergen levels were significantly higher ($P < 0.05$) in homes with, than in homes without, a dog (Fig. 4). Homes that had kept a dog previously contained significantly higher ($P < 0.05$) levels of *Can f* I than homes that never had a dog.

No significant association was observed between the *Can f* I allergen content and the other environmental factors and housing conditions listed in Table 1. As in the findings for cat allergen, however, there was a trend toward higher mean *Can f* I allergen concentration in homes with a wall-to-wall carpet.

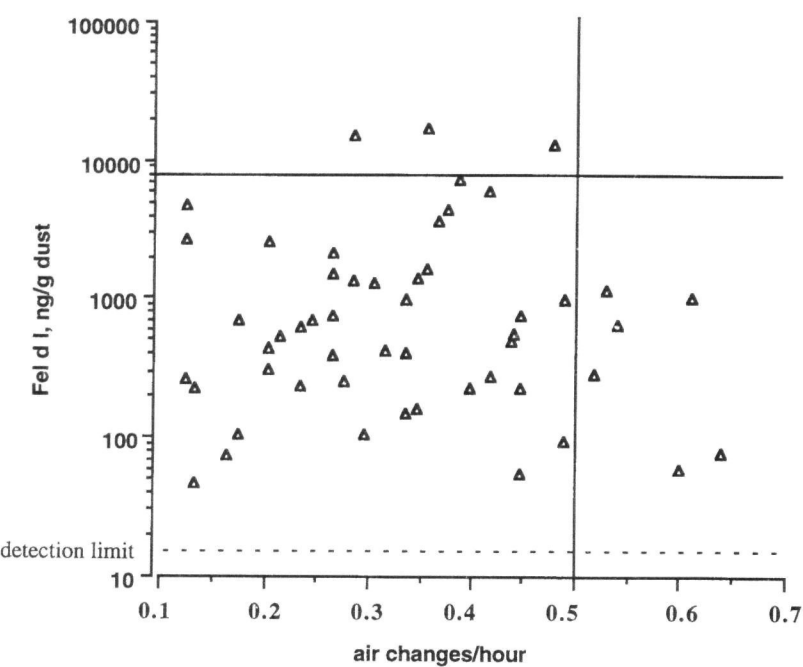


Fig. 3. Relation between major cat (*Fel d* I) allergen concentrations (peak values in homes were considered) in fine dust (ng/g) and rate of ventilation, as air changes per h (ach), in homes of 52 asthmatic children. Horizontal line indicates suggested level for cat sensitization (8 $\mu\text{g/g}$). Vertical line indicates suggested level for minimum ventilation rate (0.5 ach).

Ventilation did not influence the concentration of *Can f* I allergen in the homes (Table 2).

Cockroach allergen

The major cockroach allergen, *Per a* I, was detected in only one dust sample from a bedroom in southern Sweden (40 ng/g of fine dust). This home had high indoor humidity (AIH > 8 g/kg; RH = 60%) and a ventilation rate of only 0.3 ach.

Airborne particle number and size distribution inside homes

The number of total airborne particles in the bedrooms varied between 52×10^6 and 1426×10^6 particles/ m^3 . There were significantly more small particles (0.4–1 μm) than large particles ($P < 0.001$). The airborne particle counts tended to be lower in homes with a ventilation rate ≥ 0.5 ach than in

Table 2. Cat (*Fel d* I) and dog (*Can f* I) allergen concentration in relation to indoor ventilation from homes of asthmatic children in three climatic parts of Sweden. All comparisons were statistically nonsignificant. One observation is missing in all cases

			Allergen concentration (ng/g dust); geometric mean±SD		
	Air changes/h	<i>n</i>	Bedroom	Living room	Kitchen and bathroom
<i>Fel d</i> I	<0.5	46	244 (47–1253)	508 (99–2612)	65 (< 16–485)
	≥0.5	6	184 (47–723)	166 (41–682)	22 (< 16–52)
<i>Can f</i> I	<0.5	46	68 (< 60–1906)	287 (< 60–7162)	32 (< 60–802)
	≥0.5	6	122 (< 60–3320)	262 (< 60–3091)	25 (< 60–409)

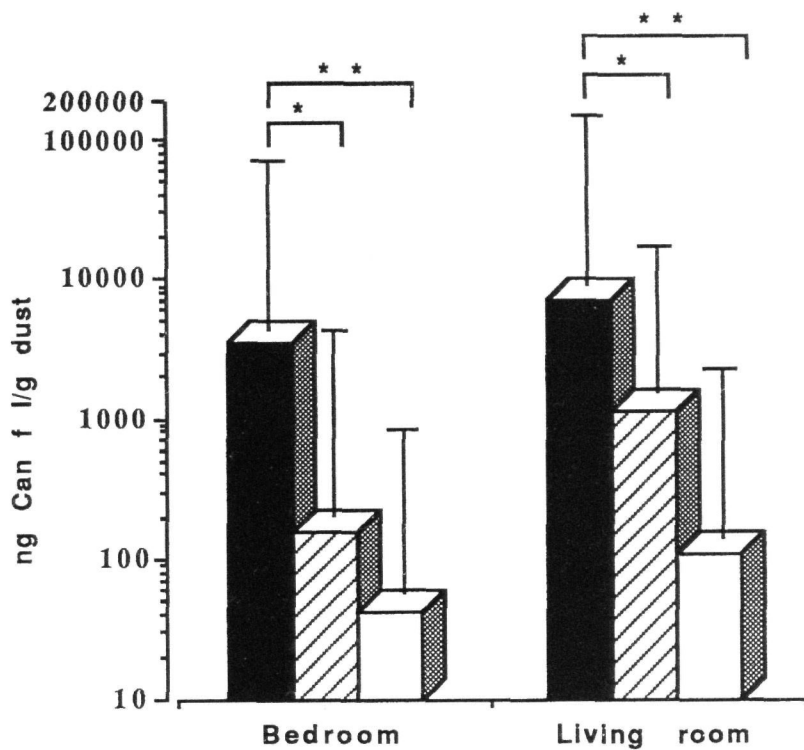


Fig. 4. Concentration of major dog (*Can f I*) allergen in homes with dog (■, $n = 9$), homes that had had dog before (▨, $n = 28$), and homes that never had dog (□, $n = 84$). Two observations missing. * $P < 0.05$; ** $P < 0.01$.

homes with a lower ventilation rate (Table 3). This seemed to be true only for the small particles.

There was a statistically significant correlation between the number of small airborne particles in living rooms or kitchens and bathrooms, and the concentrations of *Fel d I* in dust ($P < 0.05$, in both cases). However, the correlation coefficient was only 0.3 in both cases. No significant correlation was seen between the number of airborne particles and the concentration of *Can f I* in dust.

The number of airborne particles of all sizes was significantly higher ($P < 0.01$) in homes with high AIH (i.e., ≥ 7 g/kg) than low AIH (i.e., < 7 g/kg) (Table 3). High RH (i.e., $> 45\%$) tended to be associated with high numbers of airborne particles, but this was statistically significant only for kitchens and bathrooms ($P < 0.05$).

Discussion

We found similar levels of both cat and dog allergens in three different climatic areas. In a parallel study in the homes of the same children (16), we observed that mite allergens were more prevalent in southern than northern Sweden, except in damp homes. The fact that cat and dog allergen levels were similar in all areas indicates that they are independent of climatic influence.

Studies from northern (19), central (5), and southern (11) Sweden showed a higher prevalence of cat and/or dog sensitization among children than sensitization to mites and other indoor allergens. These findings support the clinical experience that cats and dogs are more important than mites as allergen sources in Sweden.

The concentrations of the major cat allergen, *Fel d I*, were higher in homes of the asthmatic children in this study than in homes of babies at high risk of allergy (14) and in Swedish schools (15) analyzed by the same methods. The levels were similar to those previously reported from homes of allergic patients in Minnesota (26) and Baltimore, MD, USA (32). The concentrations of the major dog allergen, *Can f I*, were also higher than in dust from Swedish schools (15), and were similar to levels in homes in the USA (22).

The fact that cat allergen was found in all homes but dog allergen only in 85% of homes may be due to the lower detection limit for *Fel d I* (16 ng/g) than for *Can f I* (60 ng/g). This notion is further supported by the fact that the *Fel d I* levels in 38 homes were between 16 ng and 60 ng/g dust. The difference in detection limits is due to the variation in sensitivity of the two ELISA assays (15). Alternatively, the difference in the prevalence of these two allergens may be a result of the nature of cat allergen; i.e., it is harder to eliminate from an indoor environment (33) than dog allergen.

The concentrations of both *Fel d I* and *Can f I* were higher in dust from living rooms than in dust

Table 3. Airborne particle size distribution in relation to absolute indoor humidity (AIH), relative humidity (RH), and ventilation (ach) in 56 homes of asthmatic children in three climatic parts of Sweden. * $P < 0.05$; ** $P < 0.01$. All other comparisons were not statistically significant. One or two observation(s) are missing in all cases

			Particle counts (particles/m ³); geometric mean $\pm$ SD		
		n	0.4–1 μ m	> 1 μ m	Total airborne particles
AIH	< 7 g/kg	26	7 (2–20) $\times 10^6$	198 (100–390) $\times 10^3$	210 (108–408) $\times 10^6$
	≥ 7 g/kg	28	18 (6–56) $\times 10^6$ **	315 (171–579) $\times 10^3$ **	369 (210–647) $\times 10^6$ **
RH	< 45%	20	8 (3–23) $\times 10^6$	200 (96–417) $\times 10^3$	214 (104–439) $\times 10^6$
	$\geq 45\%$	34	14 (4–47) $\times 10^6$	288 (156–535) $\times 10^3$	330 (182–600) $\times 10^6$ *
ach	> 0.5	48	35 (1–167) $\times 10^6$	318 (69–567) $\times 10^3$	354 (88–620) $\times 10^6$
	≥ 0.5	7	21 (2–40) $\times 10^6$	316 (60–572) $\times 10^3$	337 (78–596) $\times 10^6$

from bedrooms. As all homes were those of asthmatic children, presumably either the pets had no access to the bedroom, or the bedrooms were more often or more efficiently cleaned than the living rooms. High allergen levels in dust from living rooms could also be explained by occasional visits by a cat or dog, as this increases the concentrations of *Fel d I* or *Can f I* allergens (17). Furthermore, cat and dog owners visiting the home could bring in pet allergen on their clothes, and rub it off during their visit (15, 17).

We found higher levels of cat or dog allergens in homes with a cat or dog than in homes that had kept a cat or dog in previous years or homes that had never had a cat or dog. This finding agrees with other studies (14, 22, 28, 32). Cat allergen is not easy to remove from an indoor environment (33), and it was even found in homes from which the animal had been removed > 5 years before (28). Cat allergen is ubiquitous in homes, as demonstrated by our study; it is attached to wall surfaces (34) and can be introduced into the home by the occasional visit of a cat or a cat owner (17). Recommendations for cleaning and clearing of houses as a part of the treatment of asthma with known allergy to mites have been given to patients in Denmark (20), but no such recommendations or suggestions have been given for cat/dog-allergic patients. Our results suggest that a previous history of resident cats or dogs in a house is an important factor for indirect exposure to *Fel d I* or *Can f I* allergens which might induce symptoms in sensitized patients. Therefore, along with removal of cats or dogs, we recommend extensive cleaning of the entire house and reduction of indirect contacts with pets for cat/dog-allergic patients. Extensive cleaning may also be necessary when moving to a house or apartment with unknown history.

It has been assumed that airborne cat allergen concentrations are influenced by the rate of ventilation in homes (26). Wood et al. (31) demonstrated higher airborne *Fel d I* allergen levels at a low rate of ventilation, and lower levels at a high rate of ventilation in a cat-challenge model. Luczynska et al. (12) reported that a significant amount of airborne *Fel d I* allergen was associated with particles ≤ 2.5 μm in diameter. We found higher numbers of small airborne particles in homes with poor ventilation (i.e., <0.5 ach) and significantly higher amounts of airborne particles of all sizes in homes with high AIH (i.e., ≥ 7 g/kg) and/or high RH (i.e., $\geq 45\%$). We also observed a significant correlation between the concentration of *Fel d I* allergens in dust and the number of small airborne dust particles. In the homes of the same asthmatic children, we found a higher concentration of mite allergen in homes with high humidity and poor ventilation (16). Our findings suggest that poor ventilation and high humidity not only

influence mite growth but also contribute to accumulation of pet allergens indoors. We did not find any relation between the concentration of *Can f I* in dust and the rate of ventilation or the numbers of airborne dust particles. The airborne concentrations, particle size distribution, and aerodynamic characteristics of allergen derived from domestic dogs (*Can f I*) have not been studied so far.

A level of *Fel d I* ≥ 8 $\mu\text{g/g}$ dust has been proposed as the risk level for acute asthma and cat sensitization (7, 35). Only 11 of the homes in our study (9%) contained *Fel d I* allergen levels ≥ 8 $\mu\text{g/g}$ of dust, but between 34% (in Helsingborg) and 74% (in Umeå; $P < 0.01$) of the children were in fact sensitized to cat (30). Similarly, it was recently reported (6) that about 50% of children with at least one atopic parent were sensitized to cat (*Fel d I*) already at 1 year of age, as judged by specific serum IgE against cat dander. None of these sensitized children were exposed to more than 300 ng of *Fel d I/g* of dust in their homes. In a previous study (14), we analyzed *Fel d I* allergen levels during four seasons in 39 homes of babies with a biparental history of allergy; i.e., those at high risk of allergy. All homes contained *Fel d I* allergen concentrations <3.5 $\mu\text{g/g}$ dust. These findings suggest that levels well below 8 $\mu\text{g/g}$ dust might be enough to sensitize and induce symptoms. Our ongoing prospective study of infants with a family history of allergy will show whether this is true (14).

Cockroach allergens have been reported from humid areas (23), and an increased prevalence of sensitization has been reported in areas with high population density and impoverished neighborhoods (24). We could detect the major cockroach allergen, *Per a I*, in only one (0.8%) of the homes investigated, and it showed high indoor humidity and poor ventilation. In the same home, the concentration of *Der p I* and *Der f I* allergen was high, i.e., 58 $\mu\text{g/g}$ dust (16). As the assay for *Per a I* also reacts with *Bla a I* from the German cockroach, it is probable that the German rather than the American cockroach is the one found in Sweden. Low or undetectable levels of cockroach allergens have been reported from homes with a similar climate in Minnesota, USA (27). Cockroach allergen has not been found in the arctic climate of Greenland (23). Thus, a cold climate with dry winters is not favorable for cockroaches, but poor ventilation and increased indoor humidity may facilitate cockroach infestation.

In conclusion, the major cat (*Fel d I*) and dog (*Can f I*) allergens were common in homes of asthmatic children, and the highest levels were usually found in the living rooms. Cat and dog allergens were also found in the kitchen and bathroom. The levels tended to be higher in living rooms with a wall-to-wall carpet than in those without a carpet. The cat and dog allergen concentrations were simi-

lar in all climatic zones, suggesting that, unlike mite allergens, pet allergens are not influenced by the climate. Cat allergen concentrations tended to be higher in homes with poor ventilation (<0.5 ach), but this was not true for dog allergen levels. High numbers of small airborne dust particles were observed in homes with high humidity and poor ventilation. The data indicate that an increased rate of ventilation, i.e., >0.5 ach or even higher, and maintenance of indoor humidity below 7 g/kg may be needed, among other measures, to reduce indoor pet allergen exposure. Current or previous presence of a cat or a dog, respectively; a wall-to-wall carpet; high humidity; and poor ventilation increase the risk of high cat/dog allergen exposure at home. Cockroach allergen is rare in Sweden, but may occasionally be found in a home with high indoor humidity and poor ventilation.

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