# Airborne cat (*Fel d* I), dog (*Can f* I), and mite (*Der* I and *Der* II) allergen levels in the homes of Japan

**Masahiro Sakaguchi, PhD,[a] Sakae Inouye, MD,[a] Tatehisa Irie, PhD,[b] Hiroshi Miyazawa, MT,[c] Mika Watanabe, MS,[d] Hiroshi Yasueda, PhD,[e] Takao Shida, MD,[e] Hiroshi Nitta, PhD,[f] Martin D. Chapman, PhD,[g] Carsten Schou, PhD,[h] and Robert C. Aalberse, PhD[i]** *Tokyo, Sagamihara, and Tsukuba, Japan, Charlottesville, Va, Hørsholm, Denmark, and Amsterdam, The Netherlands*

*We measured the airborne and floor dust allergen levels of the cat* (Fel d *I*), *dog* (Can f *I*), *and mite* (Der *I and* Der *II*) *allergens in 13 houses. Airborne allergens were sampled with a low-noise air sampler for 5 to 7 days in the living rooms where the inhabitants were living as usual. The mean levels of airborne* Fel d *I and* Can f *I in houses with cats or dogs were 5960 and 2880 pg/m³, respectively, which were about 160 and 100 times higher than levels of airborne* Der *I. In floor dust the mean levels of* Fel *d I and* Can f *I were 322 and 236 μg/gm fine dust, respectively, which were 59 and 10 times higher than the levels of* Der *I. These results suggest that the airborne cat and dog allergens might be important sources of allergens for persons who live in a house with those animals, because the absolute allergen levels in both the air and dust are significantly higher than those of mite. (J* ALLERGY CLIN IMMUNOL *1993;92:797-802.)*

***Key words:*** *Airborne, cat, dog, mite, allergen*

Cats and dogs are important sources of indoor allergens, in addition to those of mites belonging to the genus *Dermatophagoides.*[1] *Fel d* I has been demonstrated to be a major allergen from cats.[2, 3] Recently, *Can f* I was purified as a major allergen in dog hair and dander extracts.[4, 5]

So far there is much information about airborne mite allergens[6]; the airborne allergen levels are very high in disturbed conditions such as bed-making or use of a vacuum cleaner without a filter. In contrast, the levels in undisturbed or calm conditions are very low or undetectable.[7-9]

There have been some reports about airborne major cat allergens.[10-12] Even in undisturbed conditions, the levels of airborne *Fel d* I are very high. However, there are no data regarding airborne dog allergens in the house.

In this study, to assess the extent of natural exposure to cat and dog allergens in the houses in which these animals are kept as pets, we measured the absolute concentrations of airborne *Fel d* I and *Can f* I allergens in the living rooms where the inhabitants had been living as usual and compared the levels of airborne cat and dog allergens with those of airborne mite allergens.

*Abbreviations used*
BSA: Bovine serum albumin
PBS: Phosphate-buffered saline

From [a]the Department of Epidemiology, National Institute of Health, Tokyo; [b]Department of Architectural Hygiene Engineering and Housing, The Institute of Public Health, Tokyo; [c]Department of Medical Technology, Kyorin University, Tokyo; [d]Department of Human Ecology, University of Tokyo; [e]Clinical Research Center for Allergy and Rheumatology, National Sagamihara Hospital, Sagamihara; [f]Regional Environment Division, National Institute for Environmental Studies, Tsukuba; [g]Division of Allergy and Clinical Immunology, University of Virginia, Charlottesville; [h]ALK Research, Hørsholm, Denmark; and [i]Department of Allergy, Central Laboratory of the Netherlands Red Cross Blood Transfusion Service, Amsterdam.

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Reprint requests: Masahiro Sakaguchi, PhD, Department of Epidemiology, National Institute of Health, Toyama 1-23-1, Shinjuku-ku, Tokyo 162, Japan.



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**TABLE I.** Floor dust and airborne allergens in the living room during routine activities

| House | Animal | Dust allergens (μg/gm fine dust) | | | | Airborne allergens (pg/m³) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Fel d* I | *Can f* I | *Der* I* | *Der* II | *Fel d* I | *Can f* I | *Der* I* | *Der* II |
| A | – | 1.2 | <0.8 | 4.1 | 2.3 | <16.6 | <33.2 | 81.5 | 24.5 |
| B | – | 1.6 | <0.8 | 6.3 | 2.4 | <16.6 | <33.2 | 86.8 | 22.0 |
| C | – | 0.8 | 0.9 | 4.2 | 5.5 | <16.2 | <33.4 | 63.4 | 23.0 |
| D | – | 1.5 | <0.8 | 8.4 | 6.6 | <16.5 | <33.0 | 60.3 | 15.0 |
| E | – | 0.8 | 1.3 | 20.6 | 7.0 | <16.5 | <33.0 | 89.6 | 23.9 |
| F | Cat (6)† | 948.0 | <0.8 | 3.0 | 5.0 | 23000.0 | <33.0 | 42.1 | 12.7 |
| G | Cat (1) | 642.0 | 0.9 | 2.0 | 2.1 | 6550.0 | <34.6 | 34.4 | 8.6 |
| H | Cat (1) | 92.3 | 0.9 | 6.5 | 3.8 | 4270.0 | <37.0 | 34.2 | 16.9 |
| I | Cat (1) | 205.0 | <0.8 | 16.0 | 6.6 | 1110.0 | <37.8 | 43.8 | 12.5 |
| J | Cat (2) | 160.0 | <0.8 | 4.2 | 2.2 | 7100.0 | <37.0 | 65.0 | 14.0 |
| K | Cat (2), dog (1) | 600.0 | 80 | 10.7 | 5.9 | 8860.0 | 1110.0 | 18.0 | 5.1 |
| L | Dog (1) | 1.1 | 392 | 35.1 | 32.0 | <16.6 | 10500.0 | 29.6 | 12.1 |
| M | Dog (1) | 2.6 | 420 | 35.0 | 13.5 | <18.5 | 2060.0 | 47.1 | 13.8 |

**Der p* I and *Der f* I add up to *Der* I.
†Numbers in parentheses indicate the number of animals in each house.

## METHODS

### Air sampling for airborne allergens

Samples were obtained from 13 houses in Tokyo and Tsukuba, Japan, during October 1991 and January 1992. In five of the 13 houses no animals had ever been kept as pets. Five other houses contained cats, two contained dogs, and one contained both cats and a dog living in one house (Table I). All of the animals remained indoors. A low-noise portable air sampler (KI-636, Dylec Co. Tokyo, Japan)[9] was used for collection of airborne particles. The sampler is covered with a thick sound-absorbing material. During operation, the noise level is less than 50 dB, and the flow rate is 6 L/min. The sampler was placed on the floor in a corner of the living room, and the air was collected for 5 to 7 days during usual living conditions. Air was sampled in some of the houses every week for 4 weeks between October and November 1991. All airborne particles were collected on a 37 mm diameter fiber glass filter (AP 40, Millipore, Bedford, Mass.) in the sampler. The allergens collected on the filter were eluted with 0.125 mol/L ammonium bicarbonate buffer supplemented with 0.01% bovine serum albumin (BSA). After low-speed centrifugation, the supernatant was lyophilized and then reconstituted in phosphate-buffered saline (PBS) containing 0.05% Tween 20 and 1% BSA.

### Allergens from floor and bedding dust

Dust was collected from each area (~4 $m^2$) of the floor and the surfaces of Japanese bedding (futons) with a vacuum cleaner (HA-10, Panasonic, Osaka, Japan) for 5 minutes. The collected dust was mixed and shaken with glass beads, then sieved through a 0.3 mm mesh screen to obtain fine dust, which was then mixed with 1000 times as much weight of PBS Tween-20 for 2 hours with constant rotation.[13]

### Reference allergens

Reference allergen for *Fel d* I (E3)[14] was kindly provided by Dr. C. Anderson, Food and Drug Administration, Bethesda, Maryland, and 1 U of this antigen corresponds to 4 μg of *Fel d* I. Reference allergen for *Can f* I was prepared by Dr. Schou, and 1 IU of the international standard corresponds to 2 ng (Dr. Schou's data). Reference allergens for *Der p* I, *Der f* I, and *Der* II were prepared by Dr. Yasueda, and 1 IU of the international standard for *D. pteronyssinus* corresponds to 51.6 pg of *Der p* I and 3.1 pg of *Der* II.[15-17]

### Antibodies

Preparation of mouse monoclonal antibodies to *Fel d* I (6F9 for capture and 3E4 for detector antibodies),[14] rabbit antisera (for capture), and monoclonal antibody (for detector) to *Can f* I[5, 18] and rabbit antisera to *Der p* I, *Der f* I, and *Der* II[17] has been described elsewhere.

### Quantitation of allergens

*Fel d* I, *Can f* I, *Der p* I, *Der f* I, and *Der* II allergens were quantified by a fluorometric sandwich ELISA.[19] An Immulon 2 ELISA plate (Dynatech, Alexandria, Va.) was coated with 2 μg/ml of monoclonal anti-*Fel d* I, rabbit anti-*Can f* I, anti-*Der p* I, anti-*Der f* I, or anti-*Der* II IgG preparations in 0.05 mol/L carbonate-bicarbonate buffer (pH 9.5) for 3 hours at 37° C. The plate was emptied, then postcoated with 1% BSA-PBS at 37° C for 1 hour. After washing, several concentrations of standard allergens or diluted samples in 1% BSA-PBS Tween-20 were added to the wells, and the plate was incubated overnight at 4° C. The plate was washed, and 0.2 μg/ml biotinylated corresponding IgG antibodies were added as detector antibodies. The plate was incubated for 1 hour at room temperature. After washing, β-D-galactosidase–conjugated streptavi-

din (Zymed Laboratories, San Francisco, Calif.), diluted 1:30,000, was added. The plate was incubated for 1 hour at room temperature. After final washing, 0.1 mmol/L 4-methylumbelliferyl-β-D-galactoside (Sigma, St. Louis, Mo.) in 0.01 mol/L sodium phosphate buffer (pH 7.0) containing 0.1 mol/L NaCl, 1 mmol/L $MgCl_2$, 0.1% BSA, and 0.1% $NaN_3$ was added to each well. The plate was sealed with adhesive tape and then incubated for 2 hours in a water bath at 37° C. The enzyme reaction was stopped with 0.1 mol/L glycine-NaOH (pH 10.2), and the fluorescence intensity was read as fluorescence units on a microplate fluorescence reader (Fluoroskan, Flow Laboratories, McLean, Va.). The lowest allergen concentrations detected were 0.1 ng/ml in *Fel d* I, 0.4 ng/ml in *Can f* I, and 0.04 ng/ml in *Der p* I, *Der f* I, and *Der* II.

## RESULTS

### Floor dust and airborne allergens in the living rooms

Table I summarizes the levels of floor dust and airborne allergens in the living rooms of the houses studied. The levels of *Fel d* I in floor dust of houses with cats ranged from 92.3 to 948 μg/gm fine dust (geometric mean value, 322 μg/gm fine dust) (Fig. 1, *A*). When compared with mite allergens, the mean value of *Fel d* I was 59 and 83 times higher, respectively, than those of *Der* I and *Der* II. *Fel d* I allergen was found in the floor dust of all seven houses without cats (geometric mean value, 1.3 μg/gm fine dust) (Table I). The levels of *Can f* I in the floor dust of three houses with dogs also ranged from 80 to 420 μg/gm fine dust (geometric mean value, 236 μg/gm fine dust) (Fig. 1, *B*). Mean values were 10 and 17 times higher, respectively, than those of *Der* I and *Der* II. *Can f* I allergens in floor dust were detected in 4 of 10 houses without dogs (Table I).

The levels of airborne allergens in the living roms are illustrated in Fig. 1, *C* and *D*. The airborne levels of *Der* I and *Der* II were very low. In contrast, the levels of *Fel d* I in houses with cats were very high, ranging from 1110 to 23,000 pg/m$^3$ (geometric mean value, 5960 pg/m$^3$) (Fig. 1, *C*). When compared with airborne mite allergens, the mean value of *Fel d* I was 162 and 547 times higher, respectively, than those of *Der* I and *Der* II. Likewise, the airborne levels of *Can f* I in houses with dogs were very high and ranged from 1110 to 10,500 pg/m$^3$ (Fig. 1, *D*). The mean level of *Can f* I was 2880 pg/m$^3$, which was 98 and 303 times higher, respectively, than those of *Der* I and *Der* II.

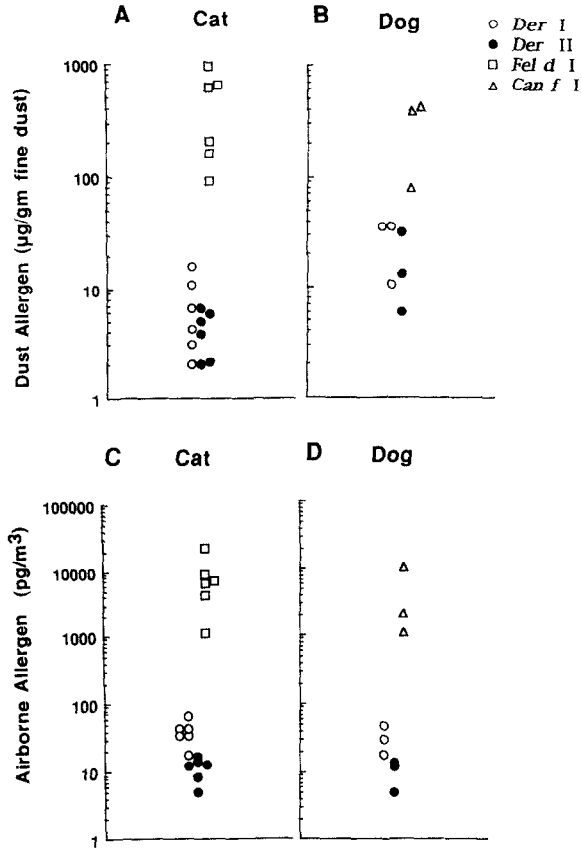


**FIG. 1.** Floor dust and airborne allergens in living rooms during routine activities. **A,** Floor dust allergens in houses with cats; **B,** floor dust allergens in houses with dogs; **C,** airborne allergens in houses with cats; **D,** airborne allergens in houses with dogs.

### Weekly variation of airborne allergens

Airborne allergens were measured weekly for 1 month (Fig. 2). Variations in the airborne allergen levels in weekly air samples were observed in individual houses. For example, there was a slight variation in no. 1 of Fig. 2, *A*. (The mean coefficient of variation of these airborne allergens was 15.8%.) In contrast, there was a relatively significant variation in house no. 2 of Fig. 2, *B*, with a mean coefficient of variation of 55.8%.

### Comparison of bedding dust allergens

Fig. 3 shows the levels of allergens in bedding dust of houses with and without cats. The levels of *Der* I and *Der* II in houses with cats were 10.0 and 7.9 μg/gm fine dust, respectively. In contrast, the levels of *Fel d* I were very high in those houses (geometric mean, 619 μg/gm fine dust).

## DISCUSSION

In this study the absolute concentrations of airborne *Fel d* I and *Can f* I were found to be very high in the living rooms of houses with cats and dogs where the inhabitants had been living as usual. The airborne *Fel d* I levels are consistent

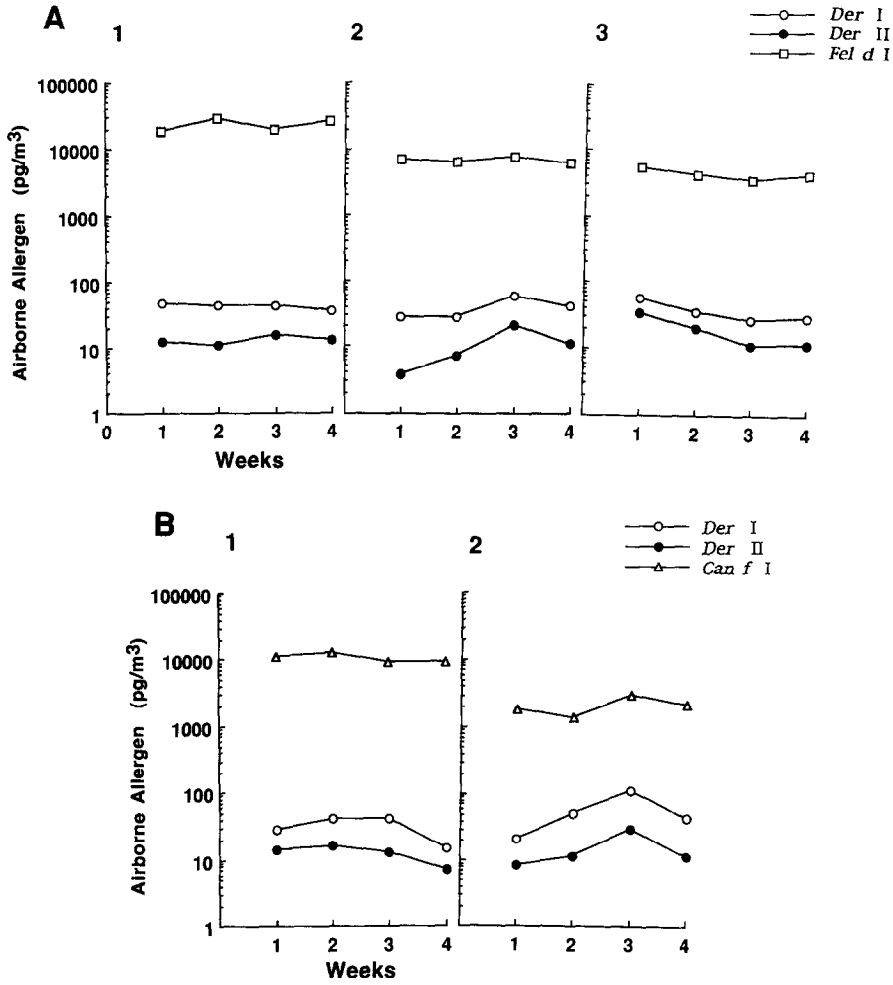


**FIG. 2.** Weekly measurements of airborne allergen levels in living rooms during routine activities. **A,** Houses with cats: *1,* house F in Table I; *2,* house G; *3,* house H. **B,** Houses with dogs: *1,* house L in Table I; *2,* house M.

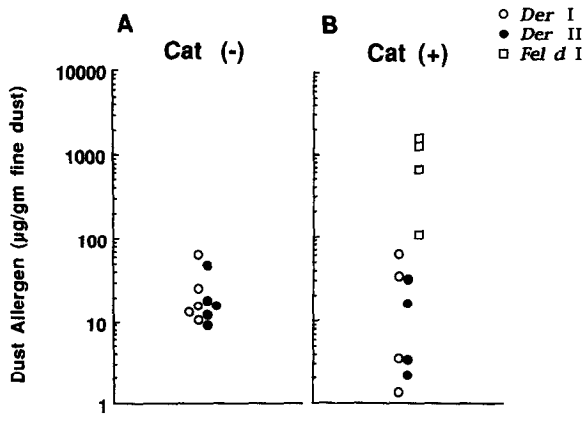


**FIG. 3.** Bedding dust allergens in the bedrooms. **A,** Houses without cats; **B,** houses with cats.

with the results of previous studies.[11, 12] We found that the levels of airborne *Can f* I in houses with dogs were as high as those of airborne *Fel d* I. When compared with the airborne levels of *Der* I and *Der* II, the airborne levels of *Fel d* I and *Can f* I were about 100 times higher than those of mite allergens. We also found that the levels of *Fel d* I and *Can f* I in floor dust were high in houses with cats and dogs, which also reconfirms results of previous studies.[12, 18, 20, 21] When we compared cat and dog allergens with mite allergens in floor dust, we found that the levels of the cat and dog allergens were much higher than those of mite allergens.

As for laboratory animal allergens, high levels of airborne allergens were found in the animal rooms. For example, levels of airborne rat major urine allergens reached hundreds of nanograms per cubic meters, depending on ventilation rate and the number of animals.[22] This high concentration of airborne allergens might result from high production of allergens in animals.[22]

Cats and dogs themselves might be sources of airborne allergens by spreading their hair and dander and disturbing floor dust into the air.

Furthermore, airborne cat allergens fall more slowly than airborne mite allergens.[8, 11] Cats and dogs are among the most popular companion animals in the world. In view of possible heavy exposure to airborne *Fel d* I and *Can f* I, airborne cat and dog allergens might be more important than other allergens in houses with these animals.

In all of the houses without cats, a mean of 1.3 μg/gm fine dust of *Fel d* I was found. Previous investigations have noted the presence of cat allergens in homes where cats have never been.[21, 23] Human beings might bring cat dander into the home on clothing. Many patients with cat allergies have never owned cats. It is possible that low levels of *Fel d* I lead to sensitization to cat allergens. Likewise, we found dog allergens in the floor dust of houses without dogs. These results agree with those of other studies.[18, 21]

Airborne allergen levels varied in weekly samples in all of the houses studied. Also, the levels were variable among the houses. These allergen levels might be influenced by many factors: levels of the allergens present on the floor and furniture, ventilation, and human and animal activity in the room.

Finally, high levels of *Fel d* I were found in bedding dust. A previous study has reported high levels of *Fel d* I in bedding dust; it is suggested that cats spend a lot of time on and around beds.[23] In this study we compared the levels of cat allergens in dust with those of dust mite allergens, and the mean value of *Fel d* I in bedding was much higher than that of *Der* I. These findings suggest that heavy exposure to cat allergens occurs not only during time spent in the living room but also during sleep in bed.

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# Atopic profile of inner-city asthma with a comparative analysis on the cockroach-sensitive and ragweed-sensitive subgroups

**Bann C. Kang, MD, Jessie Johnson, BS, and Chris Veres-Thorner, MD**
*Chicago, Ill.*

**Background:** *Inner-city asthma is well known for its high risk of mortality. To better understand urban asthma, we examined clinical characteristics and aeroallergen sensitivities of 592 of 680 consecutive urban Chicago residents with asthma.*
**Methods:** *A total of 227 male and 453 female subjects who met the criteria for the study were registered. A comprehensive clinical evaluation was followed by allergy skin testing (prick and intradermal testing) with 10 groupings (5 indoor and 5 outdoor) of common aeroallergens. Serum total IgE and selective antigen-specific IgE levels, including cockroach-specific IgE, were routinely measured. A total of 592 (196 male and 396 female) subjects with an average age of 35 years were skin tested. The average duration of asthma was 12.6 years, and 31% of the population was receiving corticosteroids.*
**Results:** *Aeroallergen sensitivity was noted in 85%, and 94 subjects (15%) were nonallergic. House dust sensitivity (76%) was most prevalent, distantly followed by sensitivity to cockroach (48%), ragweed (45%), other weeds (42%), cat (40%), and dust mite (24%). The average number of aeroallergen sensitivities detected was 4 of 10 groupings of both indoor and outdoor allergens. Twenty percent of subjects were allergic to only indoor allergens, whereas 4% were allergic to outdoor allergens only. Serum IgE was 245 ± 17.3 IU/ml (geometric mean + SEM), and 74% of 444 serum samples assayed showed IgE antibody levels greater than or equal to 100 IU/ml. A cockroach-sensitive subgroup (283 subjects) had longer duration of asthma ($p < 0.0001$) and fewer additional aeroallergen sensitivities ($p < 0.0001$) than the ragweed-sensitive subgroup (264 subjects).*
**Conclusion:** *The results indicate that a great majority (85%) of inner-city Chicago residents with asthma have atopic asthma, as demonstrated by highly elevated IgE levels and multiple aeroallergen sensitivities. Sensitivity to indoor allergens is more prevalent than sensitivity to outdoor allergens. The subjects with cockroach-sensitive asthma appear to be a distinctive subgroup characterized by chronicity and elevated serum IgE antibody levels with fewer aeroallergen skin test sensitivities. (J ALLERGY CLIN IMMUNOL 1993;92:802-11.)*

***Key words:*** *Inner-city asthma, aeroallergens, cockroach allergy, IgE antibody, indoor allergen*

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Reprint requests: Bann C. Kang, MD, University of Kentucky, Department of Medicine, K528, Kentucky Clinic, Lexington, KY 40536-0084.

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