

Vacuum cleaning decreases the levels of mite allergens in house dust

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To investigate the capacity of chemical treatment of surfaces and the difference in capacity among common vacuum cleaners to reduce mite allergen content in house dust, we recruited 52 families with allergic children. Ten families used their central vacuum cleaners. Forty-two families were randomly divided into four groups with 10 or 11 families in each. These families used either new vacuum cleaners with either HEPA (High Efficiency Particulate Air) or micro-filters, or their own vacuum cleaners with either tannic acid or placebo. Dust samples were collected from carpets and upholstered furniture in the living rooms and from the mattresses of the children at Days 0, 7, 21, and 35. *Der p1* and *Der f1* allergens were determined by sandwich ELISA. After one week, tannic acid reduced the concentration of mite allergens/g of dust and the total amount/sampling area by 30% and 34%, respectively ($p < 0.05$), but there was no significant decrease in relation to placebo. After 5 weeks, central, HEPA- and micro-filter vacuum cleaners decreased the mite allergen concentration by 10–50% ($p < 0.05$) and the total amount of mite allergen from the investigated areas by 50–85% ($p < 0.01$). In relation to the placebo group the decrease was significant for HEPA- and micro-filter vacuums ($p < 0.05$). The total amount of mite allergens/sampling area was more significantly ($p < 0.05$) reduced than the concentration/g of dust. We conclude, that tannic acid reduces mite allergen concentrations in dust and total amount/sampling area for a short period of time. Central, HEPA- or micro-filter vacuum cleaners reduce mite allergen concentrations and still more the total amount of mite allergen in house dust when used regularly for long periods. Therefore, when the total house is thoroughly cleaned, tannic acid should be applied to carpets and upholstery and low mite allergen levels maintained by using modern vacuum cleaners.

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Major allergens derived from mites (*D. pteronyssinus*/*D. farinae*) are the common triggering factors for development of sensitization (1, 2) and perennial asthmatic symptoms (3) in children.

Environmental factors especially dampness in homes of atopsics have been shown to be an important 'risk factor' for sensitization (2) and asthmatic attacks (3, 4).

In our previous studies, we found high levels of mite (*Der p1*/*Der f1*) allergens in homes of asthmatic children (5).

Influence of different chemical substances (6, 7), cleaning procedures (8, 9) and education of patients (10) to reduce indoor mite allergen load have been reported by many authors. However, only chemical substances have been shown to sig-

nificantly reduce mite and cat allergens, but for no more than one week (6). Other cleaning devices, e.g. HEPA (High Efficiency Particulate Air) filters, if used for long periods of time have also been shown to reduce both allergen concentrations (7) and asthmatic symptoms (11).

Exposure to dust mite allergen is most often expressed in terms of concentration, i.e. as ng of allergen/g of fine dust. The total amount of allergens depends on the concentration of allergen, but also on the amount of dust in the home. Therefore, it is more important to influence the total amount of allergen than the concentration of allergen by cleaning measures.

The aim of our study was to investigate the capacity of various cleaning procedures including a

chemical substance, tannic acid or placebo, and three different types of efficient new vacuum cleaners to reduce the concentration and the total amount of mite (*Der p I/Der f I*) allergens in homes of allergic children and furthermore to investigate some factors in these homes that might influence allergen concentrations and total amounts of mite allergen in house dust.

Material and methods

Study design

Dust samples were collected from 52 homes of allergic children on four occasions during 5 weeks from late August to early October 1992. The parents of the children were requested to respond to a questionnaire regarding some characteristics of their home environment. The questionnaire focused on the presence of dampness at home, type of dwelling, number of rooms and area of the dwelling. Special emphasis was put on indications of dampness problems or increased humidity as described earlier (5,12).

The 52 families were divided into five groups. Ten families had central vacuum cleaners (Group C). The others were allocated at random to four groups with 10 or 11 families in each group. Two of these groups used their own vacuum cleaners. On Day 0, after an initial sample of dust had been collected, they applied either a 3% solution of tannic acid (Group T, median age of vacuum cleaners, 3 years; 95% confidence intervals, 1–9 years) or a placebo substance (Group P, median age of vacuum cleaners, 4.5 years; 95% confidence intervals, 2–13 years) with a spray. Both tannic acid (Allergy Control Solution™, Medeca, Uppsala, Sweden) and placebo (distilled water) were applied according to Miller et al. (7), with a hand spray pump at the rate of approximately 9 sprays/m². Two other groups were given new vacuum cleaners, either with HEPA filter (Royal, Electrolux), (Group H) or micro-filter (Dolphine, Electrolux) (Group M) with 99.99% cleaning efficiency of out blown air, even for particles less than 1 µm in diameter.

Collection of house dust

Samples were collected from 2 different sites in homes by the parents of the children. Bedroom dust from the child's mattress (1.8 m²) and living room dust from carpets and upholstered furniture (5 m²) were vacuumed for 2 min/m². All families delivered 4 samples from each site *i.e.* totally, 8 samples from each home. Families were instructed not to clean their homes at least 2 days prior to dust collection. Dust was collected on Day 0, *i.e.*

just before the start of the program and subsequently on Days 7, 21 and 35. After the first sample was collected on Day 0, Groups T and P applied the solution to the carpets and upholstered furniture in the living room, but not in the mattress. Group C used their own central vacuum cleaners, Group H and M used HEPA or micro-filter vacuum cleaners for sample collection.

Extraction of house dust

Dust samples were passed through a sieve designed in our laboratory to suit small amounts of dust samples and containing a filter (pore size, 300 µm). Sieved dust was weighed and then extracted. Of an ideal number of 416 samples, 411 samples were available for extraction and analysis. Aqueous extracts of house dust samples were prepared as described earlier (12), using an extraction ratio of 1:10 (w/v) to 1:30 (w/v), depending on the amount of dust obtained.

Assays for dust allergen content

The concentration of the major mite allergens, *Der p I/Der f I* was determined by a sandwich ELISA according to the method described by Luczynska et al. (13). The interassay variation for repeated assays was 18% and 13%, and the intraassay variation was 6% and 9% for *Der p I* and *Der f I*, respectively. The cut off limit for both *Der p I* and *Der f I* assay was kept at 1.6 ng/ml, corresponding to 16 ng/g of fine dust. Values below this cut off limit were given a value of 1 ng/ml in the calculations, corresponding to 10 ng/g dust.

The total amount of mite (*Der p I* plus *Der f I*) allergen collected from each sampling area, *i.e.* concentration × weight of dust collected, was also calculated. The total amount corresponds to the reservoir of total mite allergen per sampling area. The lowest total amount is given as one ng/sampling area. In fact the weight of dust samples varied between 11 mg and 5 g. Thus the detection limit for calculated total amount varied with the amount of dust collected, *i.e.* between 0.2 ng to 6 µg/sampling area.

Statistical analysis

Allergen concentrations in dust were transformed into decimal logarithms. Even after logtransformation the distribution was skewed. Therefore, non-parametric statistical methods were chosen for analysis of data. Kruskal-Wallis test and Wilcoxon-Mann-Whitney test were utilized to test the level of significance of differences between groups and environmental conditions. Wilcoxon signed rank test

Table 1. The concentration and the total amount of mite allergen influence by different cleaning techniques in homes of allergic children. Change (%) from Day 0 within groups. + indicates increase, * $p < 0.05$, ** $p < 0.01$. §, See methods, Group T did not apply tannic acid to mattresses.

Concentration of mite (*Der p1* + *Der f1*) allergen (ng/g dust)

	Mattresses				Carpets and Upholstery			
	n =	Day 0-7	Day 0-21	Day 0-35	n =	Day 0-7	Day 0-21	Day 0-35
Group P	20	+<5	<5	+<5	10	<10	20	19
Group H	11	15	29*	31**	11	42**	60**	44**
Group C	10	+5	<5	<10	10	<5	32*	22*
Group M	11	27*	17	33*	11	50**	50**	52**
Group T	§				10	30*	+<10	<5

Total amount of mite (*Der p1* + *Der f1*) allergen, ng/sampling area

	Mattresses				Carpets and Upholstery			
	n =	Day 0-7	Day 0-21	Day 0-35	n =	Day 0-7	Day 0-21	Day 0-35
Group P	20	12	14	30**	10	65*	5*	43
Group H	11	33*	58*	50**	11	74**	87**	86**
Group C	10	+<10	29*	59**	10	35	82*	77*
Group M	11	53**	45*	53**	11	66**	60**	58**
Group T	§				10	34*	+<5	<10

was used to test or observe any variation between sampling intervals.

Since group T did not apply tannic acid to mattresses group T (n = 10) and P (n = 10) were taken together as placebo group (*i.e.* T+P, n = 20) in calculation on mattress dust. In living room dust only group P (applied placebo spray to carpets and upholstery) was considered as placebo group (n = 10) for comparison. The total mite (*Der p1* plus *Der f1*) allergen concentration in the samples and the total amount of these allergens from each sampling area were used for statistical calculations.

Results

Frequency of mite allergen detection

Mite allergens were detected in at least one sample from 48 (92%) homes and not detected in any of the samples from one home in Group P and three homes in Group C. *Der p1* was detected in 88% of the homes and 33% of the samples whereas *Der f1* was detected in 79% of the homes and 21% of the samples investigated. Levels of *Der p1* were higher ($p = 0.05$, n.s.) than those of *Der f1* in homes, but the difference was more pronounced in living room dust ($p < 0.05$) than in mattress dust ($p = 0.06$, n.s.). On Day 0 (baseline), mite allergen was detected in 44 (85%) homes and 63% of the

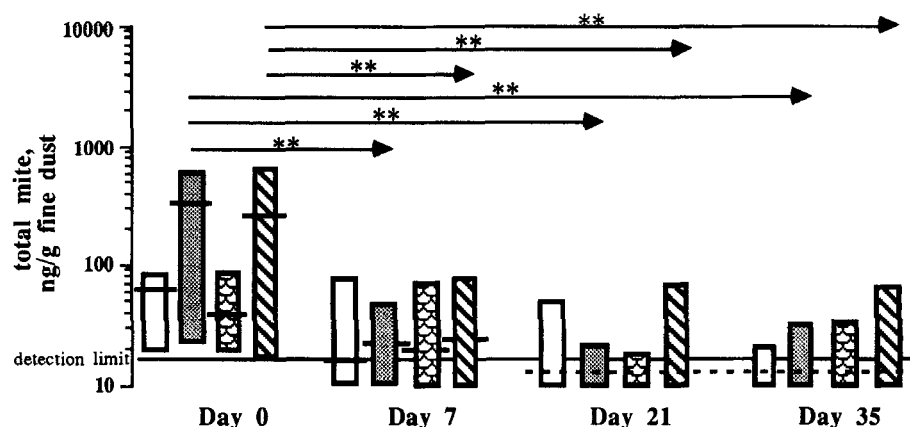


Fig. 1. Influence of different types of vacuum cleaners (□ placebo, ■ HEPA filter, ▨ Central vacuuming and ▩ Microfilter) on the concentrations of total mite (*Der p1* plus *Der f1*) allergen in dust from living rooms. Median and 95% confidence intervals are shown. The arrow (→) indicates significant decrease in relation to placebo. ** $P < 0.01$. All other comparisons in relation to placebo group were non-significant. The dotted line (-----) indicates median <16 ng/g dust.

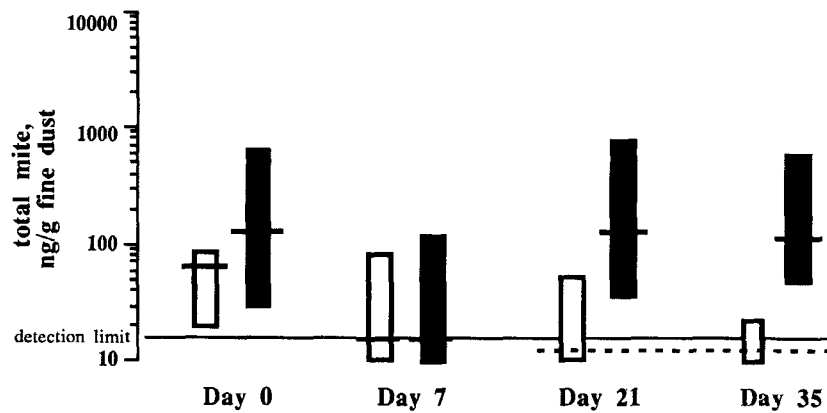


Fig. 2. The effect of placebo (□) and tannic acid (■) spraying on the concentration of total mite (*Der p*1 plus *Der f*1) allergen in dust from living rooms. Median and 95% confidence intervals are shown. The dotted line (-----) indicates median <16 ng/g dust.

samples investigated. Three homes contained mite allergen concentrations >2000 ng/g dust.

Mite allergen concentration

The baseline (Day 0) concentration of mite allergen in mattress dust (median, 15 ng/g; 95% confidence intervals, <15–55 ng/g dust, $n = 52$) before starting cleaning procedures, was similar in all groups, but in Group M, there were higher ($p < 0.05$) baseline concentrations than in Group P. However, during all succeeding sampling occasions, *i.e.* on Days 7, 21 and 35, the concentrations did not differ between the groups.

The change in concentrations of mite allergens in mattress dust in different groups during the study period are listed in Table 1.

In relation to the placebo group, the change in concentration over time in mattress dust from Day 0 to Day 7 was significant ($p < 0.05$) only in Group M, but the changes were similar compared to the other two groups (Groups H and C). From Days 21 and 35, the change was more pronounced ($p < 0.05$) in Groups H and M compared with Group P, but similar compared with Group C.

The concentrations in the living rooms on Day 0 (median, 113 ng/g; 95% confidence intervals, 65 ng–156 ng/g dust, $n = 52$) were significantly higher ($p < 0.01$) in Groups H and M than those in the other groups, but the concentrations found in dust from Groups H and M were similar. The concentrations were similar in all groups on Day 7. The concentrations were significantly higher ($p < 0.01$) in Group T compared with all other groups (Groups P, H and M) on Day 21 or Day 35 (Figs 1, 2).

The change in concentration of mite allergens in living room dust in different groups during the study period is listed in Table 1.

In the living room dust from Group T, who applied tannic acid on Day 0, concentrations on

Day 21 and Day 35 were 35% ($p < 0.05$) and 29% ($p < 0.05$) higher, respectively, in relation to Day 7 (Fig. 2).

In relation to the placebo group, the change in concentration in living room dust from Day 0 to Day 7 was more pronounced ($p < 0.01$) in Groups H and M, but were similar compared with Groups T and C. Although the change in concentration in Group T was more pronounced than in Group P (*n.s.*). From Day 0 to Days 21 and 35, the change was more pronounced ($p < 0.01$) in Groups H and M than in Groups P, but the change in Group P was similar to that of Group C (Fig. 1). The change in Group P was more pronounced ($p < 0.05$) compared with Group T, from Day 0 to Day 21, but the difference in change between Group P and Group T was similar from Days 0 to 35 (Fig. 2).

Baseline concentrations were significantly higher ($p < 0.001$, $n = 52$) in dust from living rooms (median 113 ng, range; <15–3500 ng/g) than in dust from mattresses (median 15 ng, range; <15–10000 ng/g). This difference was not observed on Days 7, 21 and 35.

Higher concentrations were found in dust from damp homes (median, 52 ng/g, 95% confidence intervals, 24 ng–140 ng/g mattress dust, $n = 52$) compared with homes that had no damp problem (median, 15 ng/g; 95% confidence intervals, <15 ng–50 ng/g mattress dust, $n = 52$), but statistical significant difference was observed only in mattress dust ($p < 0.05$). The type of dwelling, number and area of rooms within homes had no influence on the concentration of mite allergen in house dust.

Mite allergen per sampling area

The baseline (Day 0) total amount per sampling area in mattress dust, was similar in all groups, but Group M, who had higher total amount ($p < 0.05$) than Group P. During all succeeding sampling

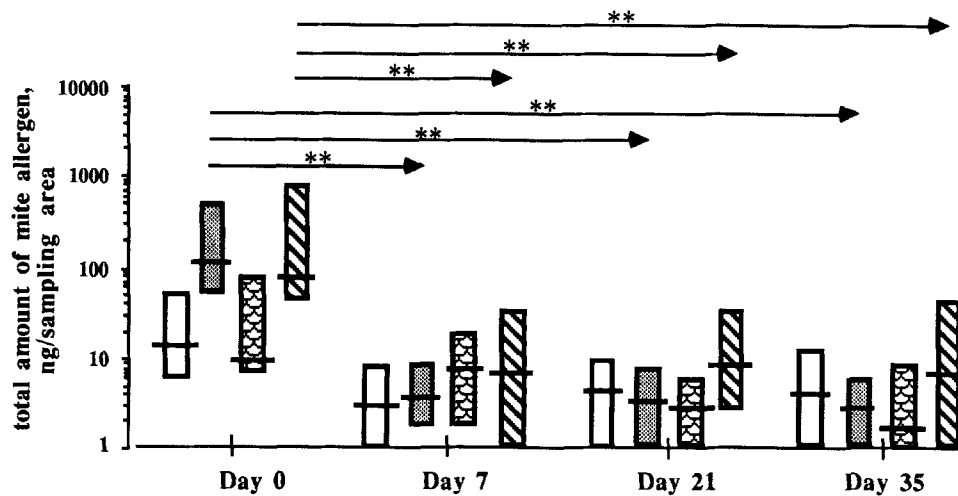


Fig. 3. Influence of different types of vacuum cleaners (placebo, HEPA filter, central vacuuming and microfilter) on the total amount of mite (*Der p I* plus *Der f I*) allergen per sampling area in dust from living rooms. Median and 95% confidence intervals are shown. Symbols as in Fig. 1. Re detection limit, see methods section.

times, *i.e.* on Days 7, 21 and 35, the total amount in mattress dust did not differ between groups.

The change in total amount/sampling area in mattresses in different groups during the study period are listed in Table 1.

From Day 0 to Days 7, 21 and 35, the change in the total amount/sampling area in mattress dust was more pronounced ($p < 0.05$) in Groups H and M than in the placebo group, but was similar compared with that in Group C.

The baseline total amount per sampling area in living room dust was significantly lower in Groups P and C ($p < 0.05$) than in Groups T, H and M, but similar between Groups P and C. On Day 7, the total amount per sampling area in living room dust in Group T was significantly higher than that found in Groups P and H ($p < 0.05$). In Days 21 and 35, Group T also had significantly higher ($p < 0.01$)

total amounts than all the other groups (Figs. 3, 4).

The change in the total amount of mite allergens in the living room dust in different groups during the study period are listed in Table 1.

From Day 0 to Days 7, 21 and 35 there was a significantly ($p < 0.01$) more pronounced change in the total amount per sampling area in living room dust in Groups H and M in relation to the placebo groups, but the change in Groups C, T and P were similar (Figs. 3, 4).

The total amount per sampling area on Day 0 was also higher ($p < 0.05$) in dust from living rooms than in dust from mattresses.

When all families ($n = 52$) were considered together, we observed that the reduction in the total amount per sampling area was always more pronounced than the reduction in the concentration per gram of dust from Day 0 to Day 7 (9%/26% in

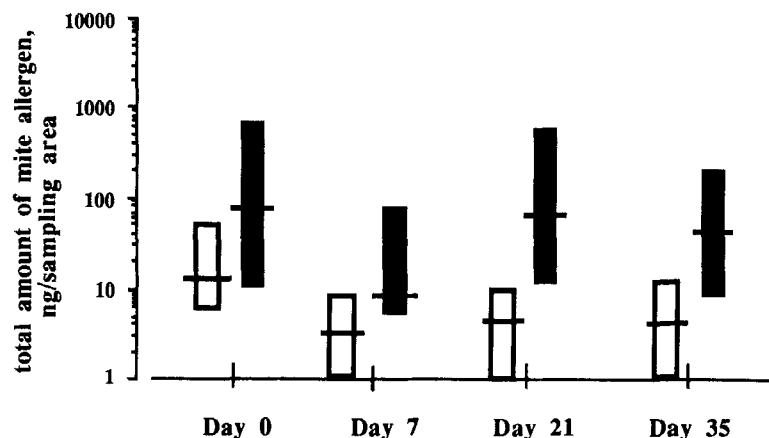


Fig. 4. The effect of placebo and tannic acid spraying on the total amount of mite (*Der p I* plus *Der f I*) allergen per sampling area in dust from living rooms. Median and 95 confidence intervals are shown. Symbols as in Fig. 2. Re detection limit, see methods section.

mattresses and 36%/57% in living rooms), Day 21 (13%/37% in mattresses and 35%/55% in living rooms) and Day 35 (17%/47% in mattresses and 33%/55% in living rooms) ($p < 0.05$ in all cases).

Discussion

This is the first study investigating the influence on mite allergen concentrations in dust and the total amount of mite allergen per sampling area using different types of common vacuum cleaners.

The concentrations of major mite allergens *Der p I* and *Der f I* in homes of allergic children in this study were 2–5 times higher than those found in homes of babies with a family history of allergy (12) and 2–3 times lower than that found in another study of homes of asthmatic children (5) in the same area. *D. pteronyssinus* was the dominant mite species in the same area in all these studies. Variations in the degree of damp problems, cleaning procedures, methods for dust collection and collection of patients are probably factors which may account for the differences observed between these studies.

Many authors have reported high concentrations of mite allergen in bed dust compared with plain floors (14, 15) and carpets (16) or in bedroom dust compared with living room dust (5). Thus, mattress dust is a potent source of mite allergen, but high concentrations have also been found in living rooms and upholstery (5, 17, 18). However, Korsgaard (19), demonstrated no association between the concentration of mite allergen in dust from carpets and mattresses. Arlian et al. (18) reported higher levels of mite infestation in upholstered furnitures and carpets than in mattresses. We also found higher concentrations of mite allergen in dust from upholstered furniture and carpets than in dust from mattresses. The lower concentration of mite allergen in mattress dust in our study compared to other reported studies was probably due to the influence of different types (20) and age (21) of the mattresses than in those studies. Higher levels in carpets and upholstery might also be due to differences in texture (22). However, we did not investigate these parameters in our study.

Dampness is a major indoor environmental factor favouring increased concentrations of mite allergens (5) and higher prevalence of asthma and respiratory symptoms (2, 3). We confirm findings in our previous studies (5, 12), *i.e.* higher concentrations of mite allergens in homes with signs of dampness or increased humidity. This finding is also in agreement with other studies in Sweden (23, 24).

After 7 days, chemical treatment with tannic acid of carpets and upholstered furniture there

was a moderate and temporary reduction in the concentration of mite allergen by about 30% from the baseline level (Day 0). After one week, mite allergen concentrations fell, followed by a gradual return to the initial level over the subsequent 2 to 4 weeks. Probably there would have been a more pronounced reduction in allergen concentrations if samples had been collected earlier than after 1 week. Similar results have been reported by Tovey et al. (6). They observed 26 and 28% reduction of mite allergen concentration in dust from furniture and carpets, respectively, 3 days after application of tannic acid. Twenty-four hours after application of tannic acid (25) the concentrations in carpets were still lower, *i.e.* 50 to 99% from the initial concentration. Miller et al. (25) observed that the mite allergen concentration was reduced from 14 $\mu\text{g/g}$ dust to non-detectable levels, if carpets were sprayed repeatedly with tannic acid for 4 consecutive weeks.

Using HEPA filter, micro-filter or central vacuum cleaners mite allergen concentrations were reduced during a 3–5 week period. We found 30–50% reduction of mite allergen concentration using these three modern types of vacuum cleaners with efficient removal of small particles. Probably combined use of tannic acid spray and any of these three vacuum cleaners would reduce mite allergens effectively.

The significant decrease in total mite allergen collected from the sampling area during the 5-week period indicates that regular efficient vacuum cleaning of the entire house may reduce mite allergen exposure. Fell et al. (26) have reported more than six-fold reduction in the total amount of *Der p I*/m² than the concentration/g of dust. The change in the total amount of mite allergen per sampling area is more important than the concentration of mite allergen per g of fine dust. Since the total amount reflects the total reservoir of the sampling area/house, the total amount of allergen is probably a better measure of allergen exposure than allergen concentrations.

In all groups, the total amounts were reduced during the 5 weeks either in mattress dust and/or in living room dust. In most groups, the decrease was more pronounced during the first week, indicating a placebo effect due to more intensive vacuuming during this period than before entering the trial. Therefore, the difference in change in relation to the placebo group found in Groups H and M is most important, indicating that regular use of modern vacuum cleaners can be recommended to reduce mite allergen exposure.

In Groups C and P mite allergen concentration and total amount of mite allergen per sampling area were already low at the beginning of the trial.

In Group C, this was probably due to regular use of efficient central vacuum cleaners for some time, before the start of the trial. In Group P, the low levels were probably obtained by chance, since the type and age of vacuum cleaners used by Groups P and T did not differ.

It has been reported that tannic acid has a low toxicity (27) and is present in some drinks from which sources some individual may ingest 0.5 to 1 g/day (28). However, the effect of long-term use of tannic acid on child health is unknown. Therefore, tannic acid should be used with caution.

Compared to mite allergen levels in homes in other parts of Europe (15, 29) and USA (18, 30), the levels found in most of the Swedish homes are low (5, 12, 23, 24). Vacuuming decreased these levels further. Whether our results can be extrapolated to areas with high mite allergen levels remains to be investigated.

In conclusion, our study demonstrated that HEPA and micro-filter vacuum cleaners progressively reduced mite allergen concentrations in homes if used for long periods. To reduce indoor mite allergen levels in carpets and upholstered furniture, treatment with 3% solution of tannic acid has a short-lasting effect. Therefore, it should be used in connection with thorough cleaning of the entire house. Then a modern vacuum cleaner should be used at regular intervals to maintain low mite allergen levels.

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