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Mite fauna in the home and sensitivity to house-dust and storage mites

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In search of potential new indoor allergen sources, all mites in dust from homes of 55 asthmatic children living in three climatic regions in Sweden were counted and identified by light microscope. Antibodies of the IgE class against three house-dust mites and three storage mites were measured in corresponding serum samples. Mites were found in all but two homes from the northernmost area, where levels also were lower than in the other regions. The highest mite densities were most often found in bedrooms (50%) and living rooms (40%). Mite density was increased in homes with high humidity and was higher in bungalows than in flats. House-dust mites predominated in the south and storage mites in the east central area, particularly in kitchens and bathrooms. Mite-density and IgE-antibody levels against house-dust mites were significantly associated. The same association applied to storage mites. Other species numbered around 100 mites/g dust in some homes. Microscopy helps to identify potentially important mites. Analysing home dust only for house-dust mites will underestimate mite exposure. Storage mites may be as relevant to sensitivity as house-dust mites. As other species occasionally were found in high numbers, their relevance should also be assessed.

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Allergic skin reactions to dust from asthmatic patients' homes were demonstrated more than 75 years ago by Kern (1) and Cooke (2). Allergy to an unknown component in house dust was assumed to cause asthma. In 1964, the allergen source was identified by Voorhorst et al. as the pyroglyphid house-dust mite (HDM), *Dermatophagoides pteronyssinus* (3). There is growing evidence that allergy to

HDM allergens and asthma are linked (4), and that early exposure in childhood to HDM allergens causes asthma (5).

Mites are eight-legged arthropods with an incomplete metamorphosis, belonging to the subclass Acari. They are in the class Arachnida and related to spiders, scorpions, and ticks, which specialize to exploit various biological niches. The principal orders of mites found in house dust are Astigmata, Prostigmata, Mesostigmata, and Cryptostigmata (6). To the order Astigmata belong the HDM (Pyroglyphidae) and the storage mites (Acaridae and Glycyphagidae) (6). Pyroglyphidae mites feed on human and animal skin scales. They are also called nidicolous mites because they live in close association with birds and mammals in their nests. Acaridae and Glycyphagidae feed on decaying plants and similar products. They are called storage mites as they are found in large numbers in barns, silos, and other habitats where agricultural products are stored.

In favourable habitats, such as human dwellings, mites produce a large number of offspring. As astigmatic mites lack a respiratory system, their gas exchange and water intake are exercised through the cuticle (7). This makes them dependent on, not only sufficient substance for food, but also humidity in the immediate environment.

Astigmatic mites are generally the principal mites found in dust from human dwellings. The major HDM in our climatic area are the Dermatophagoidinae mites, i.e., *D. pteronyssinus*, *D. farinae*, and *D. microceras*, and members of the subfamily Pyroglyphinae, of which the most common species is *Euroglyphus maynei*. The Acaridae, i.e., *Acarus siro*, *Tyrophagus putrescentiae*, *T. longior*, and other mites are found in larders or other food stores, where mites of the family Glycyphagidae, i.e., *Lepidoglyphus destructor* (the "barn mite") and *Glycyphagus domesticus* (the "house mite"), also are common.

Other mite orders contain species with a vast array of specialization and also other biological functions. The order Prostigmata contains the families Cheyletidae, Demodiciidae, Tetranychidae, and Tarsonemidae. The Cheyletidae are predatory mites. The Tarsonemidae are animal and insect parasites. The Tetranychidae are plant parasites, sucking plant juices. They are often called spider mites, as they spin a kind of silk. Mesostigmata mites live as parasites on other animals, such as insects, rats, and chickens. The Cryptostigmata are soil mites. Some other mites are specialized to live on mammal ears, such as the genus *Otodectes*. In tropical climates, other mite species such as *Blomia tropicalis*, a mite similar to *L. destructor*, are found in human dwellings and are known causes of allergy (8).

Recent data indicate that modern Swedish homes, particularly bungalows, have a low level of air exchange, and that many homes show excessive humidity (9). Buildings in the subarctic area had the lowest level of air exchange, and the highest increase of allergic manifestations was reported from this area (10). In a study of the importance of indoor factors for childhood asthma, we assessed all mites in home dust from different climatic areas of Sweden, including the subarctic area, in search of mite species of interest as allergen sources.

Material and methods

All patients with moderate to severe asthma in the outpatient paediatric allergy clinics of the hospitals in Helsingborg, Linköping, and Umeå were invited to the study. Helsingborg is a city on the southwestern coast of Sweden, with a maritime temperate climate; Linköping is an inland city situated in the east central part of Sweden, with an inland temperate climate; and Umeå in the north, with a subarctic climate, is situated on the east coast near the Gulf of Bothnia. A little over 50% agreed to participate. In all, 148 patients were enlisted in the project, and 55 of them constitute the basis of this paper.

Dust samples were collected by the families in September–November 1989 from three locations of the homes:

- 1) the bedroom: the mattress was vacuumed for 2 min, then the floor, and all corners around the walls and window-sills where mites may be found
- 2) the living room: the sofa and upholstered furniture were vacuumed for 2 min, as well as the carpet and floor, and all corners of the room
- 3) the kitchen and bathroom, where special attention was taken to find dust from near the sink, refrigerator, larder, toilet, and under the bathtub, and also the nooks and corners.

After sieving and extraction for determination of allergen content by ELISA, which is reported separately (11), the remaining dust was used for microscopic examination at Zoo-Tax (Swedish Museum of Natural History, Stockholm), with samples with a large amount of dust.

From each sample, a subsample of 0.25 g dust was taken for counting and identification of mites, other arachnids, and insects. The subsample was distributed into small Petri dishes (diameter 4 cm) with alcohol, and the animals were picked out under a stereo-microscope at low magnification

($\times 25$ – 40). Mites were transferred to lactic acid as clearing agent and incubated at 50°C for about 24 h. After clearing, they were mounted in Hoyer's medium and subsequently counted and identified under a compound microscope ($\times 400$). The mites were classified into the following groups: Astigmata: *D. pteronyssinus*, *D. farinae*, *D. microceras*, *Euroglyphus maynei*, *Acarus siro*, *Glycyphagus domesticus*, *Lepidoglyphus destructor*, and *Tyrophagus putrescentiae*; Prostigmata: Cheyletidae, Tarsonemidae, and Tetranychidae; Mesostigmata; and Cryptostigmata. The identified mite orders that were not astigmatic mites were referred to as "other mites". Odd species, such as *Otodectes*, or specimens difficult to identify exactly, were reported to the nearest order and classified as "other mites".

Microscopy was performed on dust from 55 homes; 19 from Helsingborg, 20 from Linköping, and 16 from Umeå. We collected 52 dust samples from bedrooms, 52 from living rooms, and 53 from kitchens and bathrooms. Generally, the maximal count in the three sampling locations from a house was used as the mite count, except when the sampling locations were compared. Insects and spiders were also identified [Warner et al., in manuscript].

Serum IgE antibodies against the HDM *D. pteronyssinus*, *D. farinae*, and *D. microceras*, as well as the storage mites *L. destructor*, *A. siro*, and *T. putrescentiae*, were measured on serum samples from 50 of the children by the Pharmacia CAP[®] System (Pharmacia & Upjohn, Uppsala, Sweden), according to the manufacturer's instructions. Levels exceeding 0.35 kU/l were regarded as elevated.

A thorough investigation by graduate engineers at Statens Provningsanstalt, Borås, Sweden, was performed in 60 of the 148 homes, 20 from each study site (12). Microscopy was performed on dust samples from 26 of these homes in addition to specification of ventilation type and measurement of relative humidity for 20 h in the bedroom with the child asleep. Using meteorologic data and temperature, the absolute water content of air could be calculated in g/m^3 .

Statistics

For categorical data, chi-square analysis and Fisher's exact test have been used and the chi-square trend calculated for ordered categorical data (13). Comparisons between the three cities are based on 3 by 2 contingency tables unless stated otherwise. The distribution of the mite counts in the respective locations was extremely skewed, and since logarithmic transformation did not normalize them, non-parametric tests, i.e., the Mann–Whitney U-test, the Kruskal–Wallis test, and Spearman's rank correlation test,

were used. When comparing densities, statistical *P* values were based on the Mann–Whitney U-test, unless stated otherwise. To compare the median counts between the species, the calculations were made on the samples with findings, unless stated otherwise, and the maximum count in a home was used. Confidence intervals (CI) of median values were assessed by Wilcoxon's sign test at a 95% level. For significance, a two-sided $P < 5\%$ was used, unless stated otherwise. Minitab Mtb8s statistical software was used with applications (14).

Ethics

Informed consent was obtained from the parents before the children were included in the study. The ethics committee of the University Hospital of Linköping granted approval.

Results

Total mite counts

Mites or parts of mites were identified in dust from all but two homes, both in Umeå. The maximum mite count was 13 000 mites/g dust from a bedroom sample collected in Helsingborg. The median maximal mite count in the homes was 32 mites/g dust (95% CI 15–74); in Helsingborg, 400 mites/g (95% CI 48–845); in Linköping, 37 mites/g (95% CI 15–147); and in Umeå, 4 mites/g dust (95% CI 1–16) (Fig. 1). In Helsingborg, 11/19 (58%) homes had ≥ 100 mites/g dust in a sample; in Linköping, 7/20 (35%); and in Umeå, no home had ≥ 100 mites/g dust in a sample. The difference between Helsingborg and Linköping was not significant, in

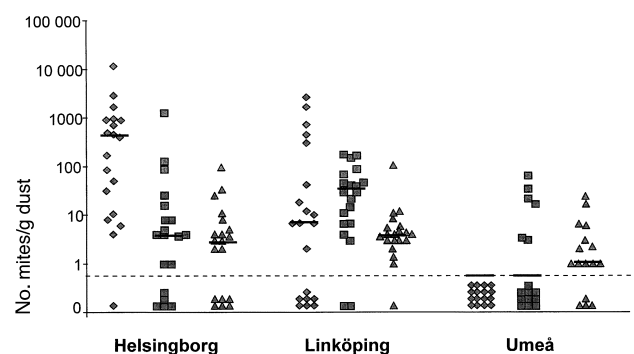


Figure 1. Distribution of three kinds of mites collected in 55 homes of asthmatic children in three climatic regions in Sweden. Symbols used: $\blacklozenge$ house-dust mites; $\blacksquare$ storage mites; $\blacktriangle$ other mites. Median mite density is designated by horizontal line.

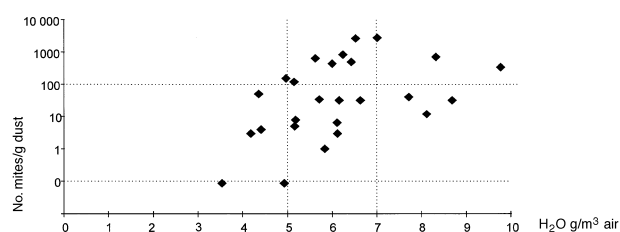


Figure 2. Maximal number of all kinds of mites in homes in relation to absolute water content of the bedroom air (g/m^3). Difference in mite counts between homes with water contents of $<5 \text{ g}/\text{m}^3$ and $\geq 5 \text{ g}/\text{m}^3$ was significant ($P=0.045$ by Mann–Whitney U-test).

contrast to the difference between Umeå and the two other cities ($P=0.001$ by χ^2).

The highest mite count was found in the bedroom samples in 25 of 50 homes (50%), and in 20 homes (40%) in the living-room samples; in five homes, the counts were equal. Median counts in bedroom samples were 11 mites/g dust (95% CI 3–32); in living-room samples, 20 mites/g dust (95% CI 3–32); and in kitchen and bathroom dust samples, 8 mites/g dust (95% CI 3–23).

A significant association was found between the maximal mite count in the home and the absolute water content of the air in the bedroom with a cutoff level of $5 \text{ g}/\text{m}^3$. In 20

homes with a humidity level of $\geq 5 \text{ g}/\text{m}^3$, the median mite count was 37, compared to 3.5 in the six homes with a humidity of $<5 \text{ g}/\text{m}^3$ ($P=0.045$) (Fig. 2). The total maximal mite count was higher in the 42 bungalows (median count 42/g dust) than the 13 flats (median count 8/g dust) ($P=0.016$). The total mite count was marginally higher in 12 homes with self-draft ventilation (median 80/g dust) than with exhaust ventilation in nine homes (median 8/g dust), or supply and exhaust ventilation (five homes, median 32/g dust, $P=0.37$).

House-dust mites (HDM)

HDM findings were dominated by members of the sub-family Dermatophagoidinae, while *E. maynei* was uncommon (found only in two homes in Helsingborg). In all areas, 31 of 55 (56%) of the homes contained some HDM. In Helsingborg, 18/19 (94%) did so; in Linköping, 13/20 (65%); but in Umeå, they were not found (P by $\chi^2 < 0.001$) (Table 1 and Fig. 1). The median counts of HDM were 394/g dust (95% CI 26–587) in Helsingborg and 7/g dust (95% CI 0–36) in Linköping ($P=0.013$).

Table 1. Distribution of mites in dust samples from homes of 55 asthmatic children living in three climatic regions in Sweden. Maximal number of mites/g dust in samples from home is given

	Helsingborg <i>n</i> =19			Linköping <i>n</i> =20			Umeå <i>n</i> =16		
Species/groups of mites	1–9	10–99	≥ 100	1–9	10–99	≥ 100	1–9	10–99	≥ 100
<i>D. pteronyssinus</i>	1	5	6	3	1	3	0	0	0
<i>D. farinae</i>	4	2	9	1	4	3	0	0	0
<i>D. microceras</i>	1	2	0	0	1	2	0	0	0
<i>Euroglyphus maynei</i>	0	2	0	0	0	0	0	0	0
HDM (sum)	3	4	11	4	4	5	0	0	0
<i>Acarus siro</i>	1	0	0	1	0	0	1	0	0
<i>Glycyphagus domesticus</i>	1	0	0	3	2	1	3	0	0
<i>Lepidoglyphus destructor</i>	4	1	2	2	3	0	0	0	0
<i>Tyrophagus putrescentiae</i>	9	2	0	5	11	2	2	3	0
Storage mites (sum)	9	3	2	4	11	3	2	4	0
Cheyletidae	5	2	0	5	0	0	0	0	0
Tarsonemidae	1	0	0	1	0	0	3	0	0
Tetranychidae	3	1	0	7	0	1	0	1	0
Prostigmata mites (sum)	8	3	0	12	0	1	3	1	0
Mesostigmata	9	0	0	14	0	0	4	1	0
Cryptostigmata	4	0	0	11	0	0	6	0	0
Other and unidentified mites	3	3	0	8	1	0	6	0	0
All mites (sum)	1	6	12	5	7	8	7	7	0

Table 2. Distribution of various types of mites by number of mites/g dust in dust samples from three locations in homes of 55 asthmatic children

	Bedroom n=52			Living room n=52			Kitchen and bathroom n=53		
	1-9	10-99	>100	1-9	10-99	>100	1-9	10-99	>100
HDM	8	6	10	4	10	12	4	8	3
Storage mites	12	8	2	13	6	1	13	11	3
Prostigmata	9	1	0	13	2	1	8	2	0
Mesostigmata	11	0	0	13	1	0	18	0	0
Cryptostigmata	14	0	0	5	0	0	11	0	0
All mites	12	16	12	10	16	15	14	16	9

The bedroom dust contained HDM in 24/52 samples (46%), median 50 mites/g dust (95% CI 7–408), and living-room samples in 26/52 (50%), median 65 mites/g dust (95% CI 19–502), while in kitchen and bathroom samples, HDM were found in 15/53 samples (28%), median 40/g dust (95% CI 7–68) (Table 2). Dermatophagoidinae mites constituted 42% of the total mite load in all areas; in Helsingborg, 83% and in Linköping, 33%.

D. pteronyssinus was identified in 19 homes (35%). The maximal count was 11 700 mites/g dust in a bedroom sample, and the median 70/g dust (95% CI 11–308).

D. farinae was found in 23 homes (42%); the maximal count was 2800 mites/g dust, found in a bedroom sample, and the median 110/g dust (95% CI 11–430). In Helsingborg, 15 (79%) and in Linköping, eight (40%) ($P=0.013$ by χ^2) homes had findings.

D. microceras was found in six homes (11%), three from Helsingborg and three from Linköping. The maximal count was 794 mites/g dust found in a living-room sample from Linköping; the median, 71/g (95% CI 14–630).

Storage mites

Storage mites were detected in 38 homes (69%). The maximal count of storage mites in a home was 1300 mites/g (Helsingborg), and the median 5/g dust (95% CI 3–16); there were 4/g in Helsingborg, 30/g in Linköping, and 6/g in Umeå. The storage-mite densities differed significantly between Linköping and the other two cities (Helsingborg-Linköping, $P=0.022$, Linköping-Umeå, $P=0.001$). In homes where storage mites were found, the median count was 20 mites/g dust (95% CI 8–37). In Helsingborg, 14 homes (74%) had findings of storage mites, median 6.5/g (95% CI 4–29); in Linköping, 18 homes (90%), median 35/g (95% CI 13–58); and in Umeå, six homes (38%), median 20/g (95% CI 3–55), $P=0.003$ by χ^2). The densities in

homes where storage mites were found did not differ between the cities. There were findings of storage mites in 22/52 (42%) bedroom, 20/52 (38%) living-room, and 27/53 (51%) kitchen and bathroom samples. Storage mites accounted for 27% of the total mite load. In both the Linköping and Umeå samples, they represented 36% of the counted mites; in Helsingborg, 7%.

Of the homes examined for home characteristics, 18/26 (69%) were infested by storage mites. A significant association was found between the water content of the bedroom air at ≥ 5 g/m³ air and the number of storage mites (median 12.3/g as compared to no mites/g, $P=0.042$). Storage mites were also more numerous (median 27/g) in 12 homes with self-draft ventilation than in nine with exhaust ventilation (median 1/g, $P<0.03$) and five with supply and exhaust ventilation (median 0/g, $P=0.008$). Although the median maximal count of storage mites was higher in 42 bungalows (median 7.3/g) than 13 flats (median 3.1/g), this difference was not significant ($P=0.21$).

Acaridae

Acarus siro was found in three homes in numbers in the range 1–5/g dust. *Tyrophagus putrescentiae* was identified in 34 homes (62%). The maximal count was 170 mites/g dust found in a kitchen and bathroom sample. The median count was 13/g (95% CI 5–27). This mite was more prevalent in Linköping and in Helsingborg, where 18 houses (90%) and 11 houses (58%) had findings, than in Umeå where five homes (31%) contained the mite ($P<0.002$ by χ^2). The densities were significantly higher in Linköping (median 26/g, 95% CI 9–36) than in Helsingborg (median 4/g, 95% CI 1–9). The typical location for *T. putrescentiae* was the kitchen and bathroom, as 23 such samples had findings in comparison with 14 bedrooms and 13 living rooms (Table 2).

Glycyphagidae

Lepidoglyphus destructor was found in 12/55 homes (22%). In Helsingborg, seven (37%) homes and in Linköping, five (25%) homes had findings of *L. destructor* ($P=0.03$ by χ^2). The maximum count was 1300 mites/g dust in a bedroom sample (Helsingborg), and the median count 10/g dust (95% CI 4–48). *Glycyphagus domesticus* was identified in 10 homes (18%). There were six findings in Linköping, three in Umeå, and one in Helsingborg (NS). The maximal count (101 mites/g dust) was found in a bedroom (Linköping), and the median count in homes containing mites was 4.5/g (95% CI 2–23). *G. domesticus* was the predominant species in two bedroom samples, 101 and 18 mites/g, respectively.

Other mites

Mites other than HDM or storage mites were found in 44 (80%) of the homes; in Linköping, 19/20 (95%); in Umeå, 12/16 (75%); and in Helsingborg, 13/19 (68%) (NS) (Fig. 1 and Table 1). The maximal number was 105 mites/g (in Linköping), and the median count in homes containing mites was 4/g (95% CI 3–5). They were found in low numbers in all sampling locations (Table 2). Nonastigmatic mites constituted 29% of the total mite load; least in Helsingborg (4.5%) and Linköping (27%), and most in Umeå (60%).

Prostigmata, i.e., Cheyletidae, Tarsonemidae, and Tetranychidae, were found in 28/55 (51%) of the homes; in Linköping, 14/20 (65%); in Helsingborg, 9/19 (47%); and in Umeå least often, 4/16 (25%) (P by $\chi^2=0.044$). The median count was 2 mites/g (95% CI 1–4).

Cheyletidae, the predatory mites, were found in 12 homes (22%). Seven homes in Helsingborg and five in Linköping, but none in Umeå contained these mites ($P=0.029$). The maximum count was 94 mites/g dust in a living-room sample, and the median 1.5/g (95% CI 1–4). They were highly associated with the presence of all other mites ($P=0.004$, Kruskal-Wallis test) and HDM ($P=0.001$). Tarsonemidae were found in one sample from each of five homes (9%); i.e., four bedroom samples and one from a living room. They were few in numbers: 1–3/g dust. Tetranychidae were found in 13 (24%) homes. The range was 1–100 mites/g dust, and the median was 3/g (95% CI 1–10).

Mesostigmata were found in the dust in 28 houses; i.e., 51%. The maximal count was 24 mites/g dust, in an Umeå living-room sample. The median count was 2/g (95% CI 1–3). They were found in all the sample locations. In five homes, it was the only type of mite found and only in small numbers. The findings of these mites were strongly

associated with the presence of HDM ($P=0.011$) and the total mite count ($P<0.001$, by chi-square and Kruskal-Wallis tests), as well as with the presence of Cryptostigmata (see below).

Cryptostigmata were found in 21 homes (38%). The mites were found in low numbers, the maximal count being 9/g dust, and the median 1/g (95% CI 1–3). They were found in 14 bedroom, five living-room, and 11 kitchen and bathroom samples. Their presence was associated with the presence of Mesostigmata ($P=0.017$ by χ^2).

Parts of mites, i.e., broken pieces, mites in nymph or hypopal stages, and other kinds of mites, such as *Otodectes*, were found in 21 homes. Six of them were from Helsingborg, six from Umeå, and nine from Linköping. Up to 72 mites/g could be counted (*Otodectes*), and the median count was 1/g (95% CI 0–1). The findings came from eight bedroom, 10 living-room, and 12 kitchen and bathroom samples.

Mite sensitivity in relation to the presence of mites in the house-dust samples

Serum IgE antibodies against HDM and/or storage mites were found in 20 children (38%); 10 of them had IgE antibodies against both HDM and storage mites, nine against only HDM, and one against only storage mites.

Elevated serum IgE antibodies against *D. pteronyssinus*, *D. farinae*, and/or *D. microceras* were found in 19/54 (35%) of the children. IgE antibodies were found in 15 of the 31 children living in homes with some HDM (48%) compared to four of the 23 children living in homes without HDM (17%, P by $\chi^2=0.018$). The children with IgE antibodies against HDM and no current exposure to HDM were all from

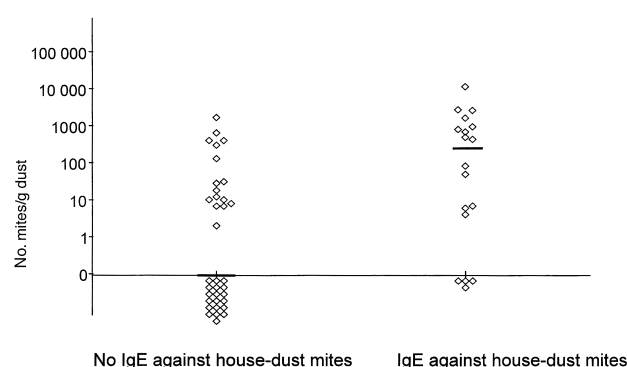


Figure 3. Maximal HDM counts/g dust (*D. pteronyssinus*, *D. farinae*, *D. microceras*, and *Euroglyphus maynei*) in samples from bedroom and living-room samples in homes of asthmatic children without IgE antibodies against HDM ($n=35$) compared to samples from homes of children with IgE against HDM *D. pteronyssinus*, *D. farinae*, and *D. microceras* ($n=18$). Difference is significant by Mann-Whitney U-test, $P<0.004$. Horizontal line designates median mite density.

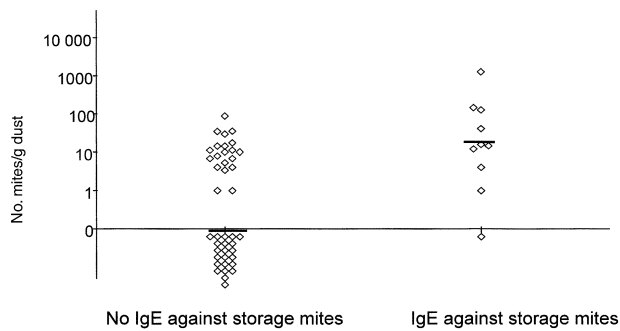


Figure 4. Maximal storage mite counts per g dust (*Acarus siro*, *L. destructor*, *G. domesticus*, and *T. putrescentiae*) in samples from bedroom and living room in homes of asthmatic children without IgE antibodies against storage mites ($n=43$) compared to samples from homes of children with IgE against storage mites *Acarus siro*, *L. destructor*, and/or *T. putrescentiae* ($n=10$). Difference was significant by Mann–Whitney U-test, $P<0.0025$. Horizontal line designates median mite density.

Umeå [and in their homes, small numbers of various other mites were found]. The presence of IgE antibodies was associated with the number of HDM/g dust found in the home ($P=0.007$, Fig. 3). The magnitude of the specific IgE response to HDM was associated with the HDM count/g dust by the rank correlation test (Spearman's $\sigma=0.52$, $P<0.01$).

Serum IgE antibodies against storage mites were found in 11/52 children (21%); six in Helsingborg, four in Linköping, and one in Umeå (NS) (Fig. 4), of whom 10 were exposed to storage mites at home. There was a significant relationship between antibodies against storage mites and the presence (P by $\chi^2=0.013$) and the density of storage mites in bedroom and living-room dust samples ($P=0.002$).

Specific IgE antibodies against *A. siro* were found in 3/54 children (5%), but none of them had these mites in their dust samples. In contrast, 7/46 children (15%) had raised IgE antibodies against *T. putrescentiae*, which was associated with the presence of the mite in the bedroom and the living-room samples (P by $\chi^2=0.014$), but not with the presence of the mite in the kitchen and bathroom samples, where it was most abundant. Serum IgE antibodies against *L. destructor* were found in 8/51 children (16%), five of them from homes with findings compared to three in homes without findings of *L. destructor* ($P=0.016$ by Fisher's exact test).

Discussion

Mites or pieces of mites were found in all but two of the 55 homes. There were great regional differences in the numbers and types of identified mites and moderate differences in the

three sampling sites from the homes. Our data support earlier findings that mites are more numerous in damp homes, as in northern Norway (15). An absolute water content of ≥ 7 g/m³ in the indoor air is considered a health hazard (9), but we found that with ≥ 5 g/m³ absolute humidity, mites were more numerous. The density of mites was higher in bungalows (median 42/g dust) than in flats (median 8/g dust), as found by Wickman et al. (16).

The predominance of *Dermatophagoides* mites found in the earlier studies (3, 4) was confirmed in dust samples with a relatively high density of mites; i.e., in the southern region where they represented 80% of the mites. *D. farinae* was slightly more prevalent than *D. pteronyssinus*, but the latter species had higher numbers per g dust. The similarity between *D. farinae* and *D. microceras* may have caused misidentification (6) of *D. microceras* as *D. farinae*. This notion is supported by our findings of a considerable amount of Der m 1 allergen in the dust samples from the whole group of homes under study (17). Unlike in the UK and USA (18, 19), *E. maynei* was rarely found (only in two homes).

HDM were found in a little more than 50% of all the homes, but none in the northernmost region. In Linköping, HDM represented only 1/3 of the mites found, while storage mites and nonastigmatic mites represented 1/3 each. Measurement of mite allergens in house dust by commercially available monoclonal antibodies in ELISA is now standard (4). Cross-reactivity between different types of mites is only moderate (20), and using commercially available monoclonal antibodies in ELISA for assessment of mites would greatly underestimate the content in the Linköping samples (17). However, in spite of no findings of *Dermatophagoides* mites, we found HDM allergens in some samples from the northern area. Microscopy in a limited number of samples might underestimate the prevalence of some mites (17). Monoclonal antibodies to storage-mite allergens, e.g., from *L. destructor*, *A. siro*, *G. domesticus*, and *T. putrescentiae* (21), are not yet commercially available. Our findings indicate that a screening procedure with microscopy of house dust from relevant home sources in a region may be worthwhile for identification of its most prevalent mites before routine measurement of major mite allergens with available monoclonal antibodies in ELISA is started in that region. Microscopy may identify almost all mites in a dust sample, but it is time-consuming and needs a specialist. Mite-allergen measurements may then also modify the picture of dominance of morphologically similar species, as we found with *D. farinae* and *D. microceras*, which were difficult to identify accurately by microscope. An analysis of the content of guanine in house dust from a

new region compared to the allergen level estimated with monoclonal mite antibodies might help explain a discrepancy between the true mite infestation and the allergen level (22, 23).

Unlike in other studies (24, 25), the density of the *Dermatophagoides* mites was not greater in bedroom dust than in living-room dust. It is possible that families of asthmatic children in Sweden take special measures in their bedrooms to lower the mite infestation, while the living rooms get less care, or are more difficult to manage. At least in our area, it seems important to sample from upholstered furniture and carpets in other locations than the bedroom to find relevant sources of mites in a home. As the counts from the kitchens and bathrooms were generally lower, these locations are not sampling sites of choice for *Dermatophagoides* mites.

The IgE antibodies against HDM correlated well with the current density of HDM at home, and some association was found also with the magnitude of the IgE response. Voorhorst et al. regarded counts of >500 mites/g dust as high (3), while Harving et al. use the limit of 100 mites/g as the risk level for sensitization (26). We found that HDM counts above 100 mites/g were associated with an increased prevalence of IgE antibodies against HDM, but the trend started at levels below 100 mites/g. This is in accordance with findings in the whole group of asthmatic children, where a significant association was found between current Der 1 allergen levels in dust and circulating IgE antibodies to *Dermatophagoides* mites (17). This association was detected already at levels well below the suggested threshold level of 2 µg/g dust (27). In spite of the predominance of *D. farinae* in the dust, serum IgE antibodies were more prevalent to *D. pteronyssinus* than to *D. farinae*. The reason for this remains obscure.

Storage mites were found more often, but in smaller numbers than HDM in our samples. In the UK, microscopy of dust from asthmatic children's homes as well as controls revealed the common presence of *Dermatophagoides* mites as well as of storage mites, but the latter were found in smaller numbers (28). The predominant storage mites in our samples were *L. destructor*, *T. putrescentiae*, and *G. domesticus*. They did not number as many as the HDM, but large numbers were occasionally found. In the Linköping homes, the most characteristic finding was of storage mites. They were commonly found in the kitchen and bathroom dust, especially *T. putrescentiae*. The storage mite *L. destructor* has been found to cause asthma among farmers (29), and is found in great numbers in farm dust (30). In our study, IgE antibodies against storage mites were found

in 21% of the children, most often to *L. destructor* and *T. putrescentiae*. In spite of the small numbers, as well as relatively low numbers per g dust, we found an association between exposure and IgE antibody response. An association between sensitivity and exposure was detected for storage mites found in the bedroom and living-room samples. The more humid environment in kitchens and bathrooms than in bedrooms may be relevant to their being the reservoirs for storage mites in the home environment. *Acarus siro* was not prevalent in the dust samples, and few children had IgE antibodies against *A. siro*. In western Norway, 12.5% of 22 773 adult patients investigated for allergy were skin prick test positive to one or several storage mites, i.e., *A. siro*, *T. putrescentiae*, or *L. destructor* (31). Ebner et al. found that the storage mites *G. domesticus*, *L. destructor*, *T. putrescentiae*, and *A. siro* were allergen sources also in urban settings, in patients already sensitized to *D. pteronyssinus* (32). In our study, too, children with IgE antibodies to storage mites were mostly (19/20) found among those already sensitized to HDM.

Storage mites have previously been found especially in damp or mouldy homes (33), as, to some extent, confirmed by our findings. The increased number of storage mites in homes without a ventilation system suggests that storage mites may also proliferate in asthmatic children's homes when "the climate is right", and should be sought for in homes of asthmatic children with mite sensitivity, but we do not know yet whether we can control them, like HDM, by the ventilation system (26, 34).

Other mites were also found. The genera *Tarsonemus* and *Cheyletus* were also found in asthmatic patients' homes in the UK (28). Tarsonemidae mites were reported to be prevalent in Danish houses, especially homes with a high relative humidity (35). We found very few such mites. Plant parasites, such as Tetranychidae mites, also appeared occasionally, and could be regarded as possible allergen sources. In occupational settings, Tetranychidae mites have been found to be allergenic (36). Predatory mites such as the Cheyletidae were common, but since they were found only in the homes already infested with other mites, they may not contribute much to the allergen load. Cryptostigmata such as Oribatidae (soil or beetle mites) were also present in small numbers in many homes. Surprisingly, Mesostigmata were found in most of the homes, although in small numbers. This group contains predators and species associated with rats and insect pests, a fact which possibly explains its common presence. These two orders are unlikely sources of mite allergens in view of their low density. To our knowledge, the Mesostigmata (for example,

rat and chicken mites) is an order of mites not reviewed in the context of dust-mite allergy [37, 38].

Thus, mites in the homes of asthmatic children from three different climatic regions differed in number, order, and species. The southern region around Helsingborg had the highest number of mites/g dust, and a mite fauna which was dominated by HDM, but which contained also storage mites. The region around Linköping had a variety of different mites; the most typical finding was of storage mites, but also HDM. In the northern area around Umeå, significantly fewer mites were found. The sensitization reflected the pattern of mites found in the homes. Like HDM, storage mites, in particular *L. destructor*,

T. putrescentiae, and *G. domesticus*, should be regarded as relevant allergen sources in homes of asthmatic children. Tetranychidae, Mesostigmata, and Cryptostigmata should be further assessed, as they may occasionally be indoor allergen sources.

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References

- Kern RA. Dust sensitization in bronchial asthma. *Med Clin North Am* 1921;5:751–758.
- Cooke RA. Studies in specific hypersensitiveness. IV. New etiologic factors in bronchial asthma. *J Immunol* 1922;7:147–162.
- Voorhorst R, Spijksma-Boezeman MIA, Spijksma FThM. Is a mite (*Dermatophagoides* sp.) the producer of the house-dust allergen? *Allergie Asthma* 1964;10:329–334.
- Platts-Mills TAE, Chapman MD. Dust mites: immunology, allergic disease, and environmental control. *J Allergy Clin Immunol* 1987;80:755–775.
- Sporik R, Holgate T, Platts-Mills TAE, Cogswell J. Exposure to house-dust mite allergen (*Der p* I) and the development of asthma in childhood. *N Engl J Med* 1990;323:502–707.
- Colloff MJ, Spijksma FThM. Pictorial keys for the identification of domestic mites. *Clin Exp Allergy* 1992;22:823–830.
- Arlian LG. Biology and ecology of house dust mites, *Dermatophagoides* spp. and *Euroglyphus* spp. *Immunol Allergy Clin North Am* 1989;9:339–356.
- Arlian LG, Vyszynski-Moher DL, Fernandez-Caldas E. Allergenicity of the mite *Blomia tropicalis*. *J Allergy Clin Immunol* 1993;91:1042–1050.
- Andersson K, Norlén U, editors. ELIB-rapport Nr 7, Bostadsbeståndets innemiljö [in Swedish with English summary]. 1993 SIB forskningsrapport TN:30.
- Åberg N, Hesselmar B, Åberg B, Eriksson B. Increase of asthma, allergic rhinitis and eczema in Swedish schoolchildren between 1979 and 1991. *Clin Exp Allergy* 1995;25:815–819.
- Munir AKM, Björkstén B, Einarsson R, et al. Mite allergens in relation to home conditions and sensitization of asthmatic children from three climatic regions. *Allergy* 1995;50:55–64.
- Ekstrand-Tobin A. Samband mellan astma och inomhusmiljö? Undersökning i 60 unga astmatikers bostäder [in Swedish]. Bygghälsningsrådet R35 1993.
- Altman D. *Practical statistics for medical research*. London: Chapman & Hall, 1991.
- Zehna PW. *A Minitab companion with macros*. Menlo Park, CA: Addison Wesley, 1992.
- Dotterud LK, Korsgaard J, Falk ES. House-dust mite content in mattresses in relation to residential characteristics and symptoms in atopic and nonatopic children living in northern Norway. *Allergy* 1995;50:788–793.
- Wickman M, Nordvall SL, Pershagen G, Sundell J, Schwartz B. House dust mite sensitization in children and residential characteristics in a temperate region. *J Allergy Clin Immunol* 1991;88:89–95.
- Warner A, Boström S, Munir AKM, Möller C, Schou C, Kjellman N-IM. Environmental assessment of *Dermatophagoides* mite-allergen levels in Sweden should include *Der m* 1. *Allergy* 1998;53:698–704.
- Walshaw MJ, Evans CC. The effect of seasonal and domestic factors on the distribution of *Euroglyphus maynei* in the homes of *Dermatophagoides pteronyssinus* allergic patients. *Clin Allergy* 1987;17:7–14.
- Arlian LG, Bernstein D, Bernstein IL, Friedman S, Grant A. Prevalence of dust mites in the homes of people with asthma living in eight different geographic areas of the United States. *J Allergy Clin Immunol* 1992;90:292–300.
- Stewart GA. Dust mite allergens. *Clin Rev Allergy Immunol* 1995;13:135–150.
- Härfast B, Johansson E, Johansson SGO, van Hage-Hamsten M. ELISA method for detection of mite allergens in barn dust: comparison with mite counts. *Allergy* 1996;51:257–261.
- Bischoff E, Schirmacher W, Schober G. Farbnachweis für allergenhaltigen Hausstaub. 3 Mitteilung: Anwendung in der Praxis. *Allergologie* 1985;8:97–99.
- Quoix E, Le Mao J, Hoyet C, Pauli G. Prediction of mite allergen levels by guanine measurements in house-dust samples. *Allergy* 1993;48:306–309.
- Ferguson P, Broide DH. Environmental and bronchoalveolar lavage *Dermatophagoides pteronyssinus* antigen levels in atopic asthmatics. *Am J Respir Crit Care Med* 1995;151:71–74.
- Price JA, Pollock I, Little SA, Longbottom JL, Warner JO. Measurement of airborne mite antigen in homes of asthmatic children. *Lancet* 1990;336:895–897.
- Harving H, Korsgaard J, Dahl R. House-dust mite exposure reduction in specially designed, mechanically ventilated "healthy" homes. *Allergy* 1994;49:713–718.
- Warner AM, Björkstén B, Munir AKM, Möller C, Schou C, Kjellman N-IM. Childhood asthma and exposure to indoor allergens. Low levels are associated with sensitisation. *Pediatr Allergy Immunol* 1996;7:61–67.
- Maunsell K, Wraith DG, Cunningham AM. Mites and house-dust allergy in bronchial asthma. *Lancet* 1968;1:1267–1270.
- van Hage-Hamsten M, Ihre E, Zetterström O, Johansson SGO. Bronchial provocation studies in farmers with positive RAST to the storage mite *Lepidoglyphus destructor*. *Allergy* 1988;43:545–551.

30. Boström S, Johansson E, Härfast B, Lundqvist L, Bäckman I, von Rosen E, van Hage-Hamsten M. Characterization of the mite fauna (Acari) in Swedish barn dust. *Int J Acarol* 1997;**23**:127–132.
31. Finsnes KA. Förmiddallergi på Vestlandet [in Norwegian with English summary]. *Tidsskr Nor Laegeforen* 1995;**115**:3274–3275.
32. Ebner C, Feldner H, Ebner H, Kraft D. Sensitization to storage mites in house dust mite (*Dermatophagoides pteronyssinus*) allergic patients. Comparison of a rural and an urban population. *Clin Exp Allergy* 1994;**24**:347–352.
33. Wraith DG, Cunningham AM, Seymour WE. The role and allergenic importance of storage mites in house dust and other environments. *Clin Allergy* 1979;**9**:545–661.
34. Colloff MJ. Dust mite control and mechanical ventilation: when the climate is right. *Clin Exp Allergy* 1994;**24**:94–96.
35. Korsgaard J, Hallas TE. Tarsonemid mites in Danish house dust. *Allergy* 1979;**34**:225–232.
36. Burches E, Pelaez A, Morales C, et al. Occupational allergy due to spider mites: *Tetranychus urticae* (Koch) and *Panonychus citri* (Koch). *Clin Exp Allergy* 1996;**26**:1262–1267.
37. Spieksma FThM. Mite biology. *Clin Rev Allergy* 1990;**8**:31–49.
38. Hart BJ. The biology of allergenic domestic mites. An update. *Clin Rev Allergy Immunol* 1995;**13**:115–133.