

Reduced mite allergen levels in dwellings with mechanical exhaust and supply ventilation

M. WICKMAN*†§, G. EMENIUS*, A-C. EGMAR*, G. AXELSSON* and G. PERSHAGEN*†

*Department of Environmental Health and Infectious Diseases Control, Karolinska Hospital, Stockholm, Sweden, †Department of Paediatrics, St. Göran's Children's Hospital, Stockholm, Sweden,

‡Institute of Environmental Medicine, Karolinska Institute, Stockholm, Sweden and

§Department of Environmental Hygiene, Karolinska Institute, Stockholm, Sweden

Summary

Seventy similar bungalows constructed between 1968 and 1970 in the same suburban area of Stockholm were investigated regarding the content of house dust mite allergen, absolute indoor humidity, type of ventilation and basement construction. Houses with mechanical exhaust and supply ventilation had an indoor humidity above 7 g/kg less often than houses without this type of ventilation (Odds ratio 0.1, 95% confidence interval 0.0–0.2). Furthermore, only five of the 24 houses with exhaust and supply ventilation contained mattress dust mite allergen concentrations exceeding the median value (98.5 ng/g) compared with 30 of 46 houses which did not have such ventilation (odds ratio = 0.1, C.I. 0.0–0.5). Houses with both natural ventilation and crawl space basement harboured significantly less mattress mite allergen than houses having the same type of ventilation, but with a concrete slab basement. In a cold temperate climate, type of building construction and ventilation seem to be important for the occurrence of house dust mite allergens in dwellings. Our results indicate that modern energy-efficient houses should be equipped with mechanical exhaust and supply ventilation to reduce indoor air humidity during the dry winter months and the risk of mite infestation.

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Introduction

Indoor environmental conditions have proved to be of importance for the development of allergic disease with manifestations in the respiratory system [1–3]. For example, damp housing promotes infestation of house dust mites (HDM) [3–5], which increases the risk of sensitization and development of allergic disease [6–9]. Different measures to reduce HDM growth have been proposed, including enhanced cleaning and airing, and use of mattress encasings [10–13]. Recently Arshad *et al.* demonstrated that a combination of hypoallergenic diet, the use of acaricides and mattress encasings prevents atopy and the development of asthma in high risk infants [14]. In Fennoscandian countries mite infestation in dwellings is associated with poor ventilation and increased air

exchange has been suggested for the prevention of house dust mite allergy [3,6]. The aim of this study was to investigate house dust mite occurrence in relation to type of ventilation and basement construction, possibly affecting indoor humidity.

Methods

The study was performed in a small residential area (300 × 500 m) with 250 single-storey, one-family semi-detached houses, located in northern Stockholm. All houses had similar exteriors, but were of two types: (a) alum shale brick walls and crawl space basement (basement with gap under floor) or (b) ordinary brick walls and concrete slab basement. The houses were constructed with flat roofs and a residential area of 108 or 125 m², accommodating 4–5 rooms besides kitchen and bathroom. All houses had an extractor fan in the kitchen, and were built between 1968 and 1970 by the same company.

Correspondence: Dr M. Wickman, Department of Environmental Health and Infectious Diseases Control, Karolinska Hospital, S-171 76 Stockholm, Sweden.

Table 1. Ventilation and basement characteristics of 70 bungalows under study in Stockholm, Sweden

Construction	Ventilation	Improved** natural ventilation	Original natural ventilation	Total
	MESV			
(a) Crawl space	15	1	7	23
(b) Concrete slab	9	9	29	47
Total	24	10	36	70

* MESV refers to mechanical exhaust and supply ventilation;

** Improved by instalment of mechanical exhaust ventilation or extra open air intakes.

A questionnaire was mailed to all families in the study area and 123 replied. Thirty-three refused participation and 70 of the remaining households fulfilled the criteria of inclusion: habitation of the family > 1 year in the house, family size ≥ 2 persons, no renovation of the house with the exception of instalment of a ventilation system and no allergen avoidance undertaken within the house. Furthermore, there should be a mattress in the household which was at least 1 year old, and in regular use during the last 2 months.

Twenty-three of the houses were of construction type *a* and 47 of type *b*. Of the selected families, 24 (15 of the *a*- and nine of the *b*-type houses, respectively) had had their houses additionally supplied with a continuously running mechanical exhaust and supply ventilation (MESV), i.e. in- and outlet of air achieved by fans (Table 1). A major reason for improving ventilation in type *a* houses was the awareness of alum shale as an important source of indoor radon [15]. Furthermore, in 10 houses the natural ventilation had been improved by installation of mechanical exhaust ventilation in bathrooms ($n=6$) or extra open air intakes ($n=4$). In the remaining 36 residences no changes in the original natural ventilation had been made.

Between 16.00 hours and 20.00 hours on one of five occasions during a fortnight in November 1991, two of the authors inspected the houses, interviewed one adult family member, measured the relative indoor air humidity and temperature, and collected dust from mattresses and living room floor for detection of mite allergens. Absolute outdoor humidity on these five occasions ranged between 3.7 and 5.0 g/kg (official data from Arlanda Airport—20 km from the residential area). Single registrations of the relative indoor humidity and temperature were performed (Rotronic GV2, Bern, Switzerland) about 1 m above floor level in the middle of the living room. The absolute indoor humidity (AIH) was calculated from the relative indoor humidity and temperature.

Dust from living room textile floors and bedroom mattresses was collected in a standardized way using a nozzle attached to the hose of the vacuum cleaner (Volta Lite U1840, Volta, Stockholm, Sweden) and separate filter cassettes [16]. Two square metres of living room floor were vacuumed during 2.5 min and followed by vacuuming during the same period of the mattress surface after removal of the sheets. After each use the nozzle was washed, dried and cleaned thoroughly. Bedroom floor dust was not collected due to risk of mite allergen contamination from mattress dust. Paired mattress dust samples were collected in 19 houses with both box-spring beds and polyether foam mattresses. Further, 18 paired dust samples from down and synthetic pillows were collected from homes, where both types of pillows were in use. The pillows were vacuumed during 1 min on each side. Dust samples were analysed for group I major allergen concentration of the HDM species found in Sweden [3], i.e. *Dermatophagoides pteronyssinus*, *D. farinae* and *D. microceras* by an enzyme-linked immunosorbent assay (ALK, Hörsholm, Denmark) [17] and expressed in ng/g of dust. Detection limit was 7 ng per gram of dust. After analysis of the dust samples another seven pillows from beds were vacuumed where mite allergens had not been found in mattress dust. Thus, 13 pillow dust samples from all 'mite allergen negative' mattresses were collected. Ten pillows were randomly selected from beds having mattresses with detectable levels.

The maximum-likelihood method was used to calculate odds ratios, and to estimate 95% confidence intervals [18]. In addition, Wilcoxon's two-sample and Spearman's rank tests were employed, using two-tailed *P*-values.

Results

Dust samples from box-spring beds and polyether foam mattresses held similar mite allergen concentrations, with a median of 48 ng/g for both types. For down and synthetic pillows the median concentrations were 158 ng/g and 131 ng/g, respectively ($P=0.38$). Twelve of 13 pillows from beds having mattresses without mite allergen contained detectable allergen, whilst all pillows from beds having mattresses with detectable mite allergen contained such allergen (Fig. 1). Of the former 12 pillows six came from houses with mite allergen in floor dust (range 53–188 ng/g). In the subsequent analyses the mean of the two mattress dust samples was used from the 19 houses with both box-spring beds and polyether foam mattresses.

Detectable concentrations of mite allergen were found in mattress or living room floor dust in 62 (89%) of the houses. Forty-nine (70%) of the homes harboured mite

Fig. 1. Concentrations of mite allergens in mattress dust and corresponding pillows. Mattresses without mite allergen ($n=13$); mattresses containing mite allergen ($n=10$).

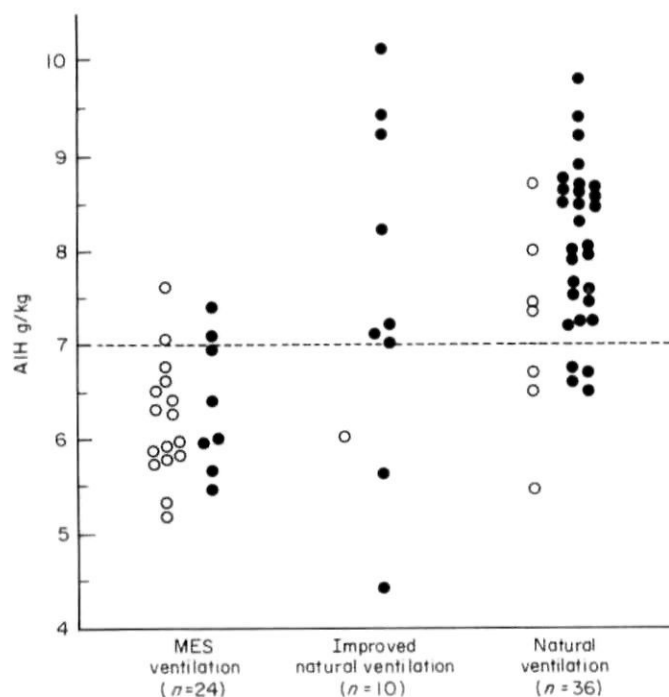
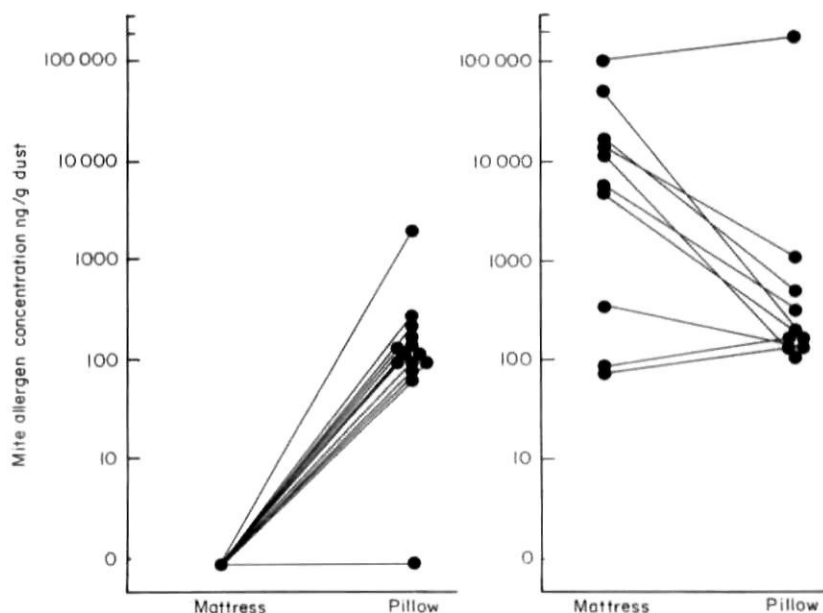


Fig. 2. Absolute indoor humidity and type of ventilation in 70 bungalows in Stockholm, Sweden. ○. AIH levels in dwellings with crawl space basement. ●. Dwellings with concrete slab basement. Improved natural ventilation indicates installation of extra outdoor air intakes or extraction ventilation.

allergen in both mattress and living room floor dust, 57 (81%) in mattress and 54 (77%) in floor dust. Mite allergen concentrations in mattress dust ranged from below detection (7 ng/g) to 100 000 ng/g (median 98) and from below detection to 12 600 ng/g (median 126) in floor

dust. Fifteen mattress dust samples, but only three samples of floor dust exhibited mite allergen concentrations exceeding 2000 ng/g. In the 62 houses with mite allergen in dust samples either from mattresses or floors, no correlation was found between concentration of mite allergen in bedroom mattress dust and living room floor dust ($r=0.18$, $P=0.17$).

Installation of MESV was closely related to low AIH (<7 g/kg) (Fig. 2). Only four of 24 homes with such ventilation held high (≥ 7 g/kg) AIH compared with 30 of 46 bungalows with natural or improved natural ventilation (odds ratio=0.1, C.I. 0.0–0.2).

Adjustment for type of basement did not affect this relation. In the homes having natural ventilation four of seven with crawl space basement exhibited high AIH compared with 25 of 29 constructed with concrete slab basement (odds ratio=0.2, C.I. 0.0–2.1). This difference was not seen in the houses with exhaust and supply ventilation.

Original natural ventilation, concrete slab basement, AIH >7 g/kg and reported winter condensation on the inside of double-glazed windows in bedroom or living-room were all risk factors for mite allergen concentration of mattress dust exceeding the median of 98 ng per gram (Table 2). Adjustment for dwelling area, number of residents, household density (number of persons per square metre), vacuum cleaning habits, use of eiderdowns and airing habits had no effect on the odds ratios. However, the AIH level was slightly associated with the outdoor humidity during the same day (data not shown).

The relation between installation of mechanical exhaust and supply ventilation and low mattress mite allergen concentration was similar to that of AIH (Fig. 3).

Table 2. Risk factors for increased mattress *Dermatophagoides* (*Der p* I, *Der f* I and *Der m* I) allergen concentration in 70 bungalows in Stockholm

	Mite allergen concentration		Odds ratio*	CI*
	<98 ng/g n = 35	≥98 ng/g n = 35		
MESV† not installed	16	30	6.9	2.0–28.3
Concrete slab basement	17	30	6.2	1.8–25.2
Absolute indoor humidity > 7 g/kg	13	27	5.5	1.8–18.7
Window-pane condensation‡	13	26	4.8	1.6–15.5

* Odds ratio (OR) and 95% confidence interval (CI);

† MESV refers to mechanical exhaust and supply ventilation;

‡ Wintertime condensation on the inside of double glazings in bedroom or living room.

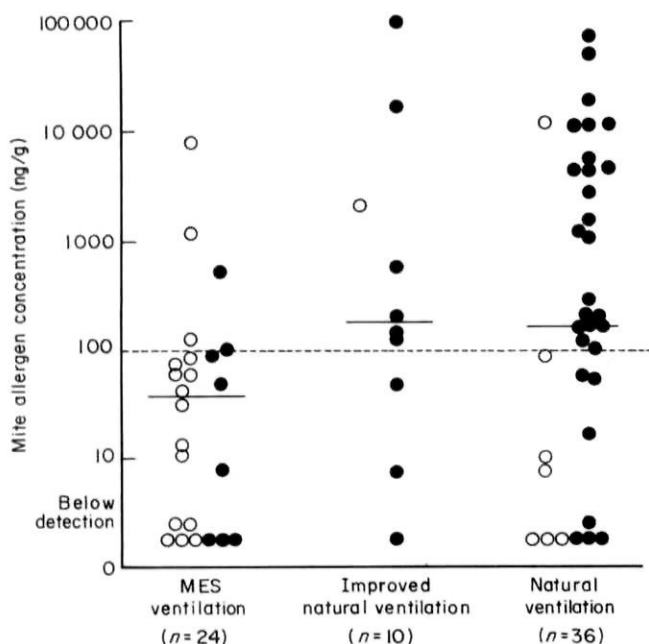


Fig. 3. Mite allergen concentration in mattress dust and type of ventilation in 70 bungalows in Stockholm, Sweden. ○. Mite allergen levels in dwellings with crawl space basement. ●. Dwellings with concrete slab basement. Solid bars denote median values of mite allergen levels.

Only five of 24 mattress dust samples from homes with exhaust and supply ventilation held high (>98.5 ng/g) mite allergen concentration compared with 30 of the other 46 bungalows (odds ratio=0.1, C.I. 0.0–0.5). On the other hand still 16 of 24 (66%) mattress dust samples from homes with exhaust and supply ventilation held detectable mite allergen concentration compared with 36 of 46 (83%) homes natural or improved natural ventila-

tion (odds ratio=0.4, C.I. 0.1–1.3). Adjustment for type of basement had only a minor influence on the relation between type of ventilation and mattress dust mite allergen concentration (odds ratio=0.2, C.I. 0.1–0.7). Furthermore, only one mattress dust sample in seven homes with crawl space basement and natural ventilation contained high mite allergen concentration (median 8 ng/g, range 0–11 900) compared with 22 of 29 homes with such ventilation (median 293 ng/g, range 0–73 000), but constructed with concrete slab basement (odds ratio=0.1, C.I. 0.0–0.5).

In homes with natural ventilation no difference was found in living room floor dust mite allergen concentration between those constructed with concrete slab and crawl space basement (data not shown). Further, mite allergen concentration in living room floor dust was not associated with AIH or ventilation, not even in the 36 homes with original natural ventilation and concrete slab basement.

Reported condensation on double-glazed windows in bedrooms or living rooms was associated with AIH ≥ 7 g/kg, and revealed both high sensitivity and specificity, 77% and 73%, respectively.

Discussion

There was an unexpected high rate for allergen of domestic mites in the investigated dwellings compared with a previous study in Stockholm [3]. However, the median concentration of 98 ng/g in this study is very low when compared with the international threshold level for sensitization [7]. Using the same detection limit for of mite allergen (20 ng/g dust) as in the earlier study, 75% of the mattress dust samples in the present study held mite

allergen compared with 21% of the homes of healthy control children in the previous study. However, in the previous study five (62%) of the eight bungalows held mite allergen in mattress dust. Our data indicate that indoor conditions in such buildings often promote mite growth.

Studies on mite sensitization in Scandinavia performed after the 1973 oil embargo have shown an association between tight housing in heated residences and sensitization to HDM or high mite density [3,19]. Tight housing has also been suggested as a risk factor for asthma among Aberdeen primary school children [2]. On the other hand, in some studies a relationship has been found between older buildings without central heating and high mite counts [5,20,21]. These two circumstances for residential mite infestation in temperate regions are not contradictory—older constructions are more likely to absorb water vapour [20,21] and in modern dwellings built with more impermeable materials, water vapour produced in the household may accumulate because of lower air exchange possibly resulting from poor ventilation.

In this study both natural ventilation and concrete slab basement contributed to high AIH and consequently to growth of mites. On the other hand, mechanical exhaust and supply ventilation and aired basement favoured both low AIH and low mite allergen levels in mattresses. Thus, ventilation seemed to have a major influence on the mattress mite allergen levels which recently has been shown by Harving *et al.* [22]. It is notable that only one mattress dust sample from the homes with exhaust and supply ventilation exhibited mite allergen concentration exceeding the suggested threshold level of sensitization (≥ 2000 ng mite allergen per gram of dust [7]). However, exhaust and supply ventilation in this climatic region did not automatically result in mite allergen concentrations below detection. This may be explained by a malfunctioning ventilation system resulting from faulty installment or inadequate maintenance.

To assess the air infiltration rate technically is expensive. A history of water vapour condensation on the inside of double-glazed windows in bedroom or in living room during the winter appeared to be a useful indicator of enhanced AIH. This confirms earlier data [24] and indicates that water vapour condensation on windows during winter may also be used as a marker of poor ventilation of dwellings in temperate climates.

A correlation was found between bedroom mattress dust mite allergen concentration and AIH measured in the living room. However, no correlation was found between living room floor dust mite allergen concentration and AIH. These findings are in agreement with other studies [21,25] indicating the preference of domestic mites for warm and almost constantly humid conditions which

are found especially in beds, whereas floors dry out more easily during the heating season.

Beddings such as mattresses and pillows are regarded as the major source of mites within houses [8]. Box-spring mattresses, feather pillows and eiderdowns have been considered especially harmful in this context [26]. In our study, however, polyether foam mattresses and synthetic pillows and quilts were not found to favour low replication of mites compared with box-spring mattresses, feather pillows and eiderdowns. Our data confirm those of other recent studies which have failed to show an association between box-spring beds and mite growth compared with polyether foam mattresses [3,27]. In 12 homes only the pillow was infested and not the corresponding mattress. In one of these pillows it is likely to have been a growth of mites (1970 ng/g) and for six other pillows mite allergen was found in living room floor dust of the same home. Thus, contamination from local niches containing mite allergen may to some partly explain why some pillows contained mite allergen, but not the corresponding mattresses. The implication of this is that both mattresses and pillows are preferably vacuumed when mites or mite allergens are looked for.

In conclusion, our results indicate that buildings with insufficient ventilation and humidity-absorbing basements in temperate regions may cause increased infestation of domestic mites. Thus, in such regions 'tight' houses should be avoided or have a sufficient ventilation, and basement constructions should not promote dampness. In highly mite allergic individuals a combination of avoidance measures may be recommended e.g. functional ventilation, use of semi-permeable pillow and mattress encasings [27] and reduction of the mite allergen reservoir within the home.

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