

Mite sensitization in the Scandinavian countries and factors influencing exposure levels

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Mites are the common sources of indoor allergen and play a major role in sensitization and elicitation of allergic disease. In the Scandinavian countries, mite infestations in the home were not common in the past decades. Recent studies show that sensitization to mites among children, particularly in Sweden, is increasing. Similar trends have also been reported in Norway. Poor indoor climate, e.g., high humidity and poor ventilation as a consequence of energy-saving measures, are cited as a possible explanation of this increase. Modern furnishings, e.g., carpets and various kinds of upholstery, may also serve as reservoirs of indoor allergens. At least 2 µg of mite allergen per g of dust is considered to be a risk level for sensitization and symptoms of asthma. As compared to experience from other parts of the world, mite-allergen levels are generally low in the northern Scandinavian regions. Recent studies from Sweden and other European countries show that mite sensitization may occur below 2 µg/g dust. Various environmental adjuvant factors may affect the threshold levels of allergen. In this review, the importance of the indoor environment for the accumulation of mite allergens, sensitization to mites in the Scandinavian countries, and various environmental factors that could influence exposure levels will be discussed.

Key words: environmental factors; mite allergen; Scandinavian countries; sensitization.

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Mites are common sources of indoor allergens and play a major role both in sensitization and as triggers of asthma in children in various parts of the world (1–7). As determined by positive skin tests and/or the presence of circulating IgE antibodies, a relationship between exposure to mite allergens and sensitivity has been suggested in several studies (1–4). Risk levels for mite sensitization have also been suggested in three consecutive international workshops on indoor allergens and asthma (8–10).

In the Scandinavian countries, particularly Sweden and Norway, mite infestations in the home were not common. In 1979, house-dust mites (HDM) were found in only 1.5% of the dwellings in Sweden (11). Similar findings were reported in Norway (12). Recent studies from these regions show that mites are more commonly found in the home now than during the last decades (Fig. 1) (12–14). Various environmental factors and living habits are cited as reasons for this increase.

The prevalence of mite sensitization in the

Scandinavian countries, mite-allergen exposure, and various environmental factors that could influence exposure levels and mite sensitization will be discussed in the sections to follow.

Mite/mite-allergen exposure in the Scandinavian countries

Mites were previously regarded as uncommon in the Scandinavian countries. Mites in the indoor environment usually consist of several species. In Scandinavia, only a few of them have been studied and identified in house dust. In past years, *Dermatophagoides pteronyssinus*, *D. farinae*, *D. microceras*, and *Tarsonemus spp.*, as well as some storage mites (e.g., *Lepidoglyphus destructor*, *Acarus siro*, and *Tyrophagus putrescentiae*) have been the common mites considered in indoor investigation (11–18). The exposure levels of mite allergens from various geographic areas of three Scandinavian countries are shown in Table 1.

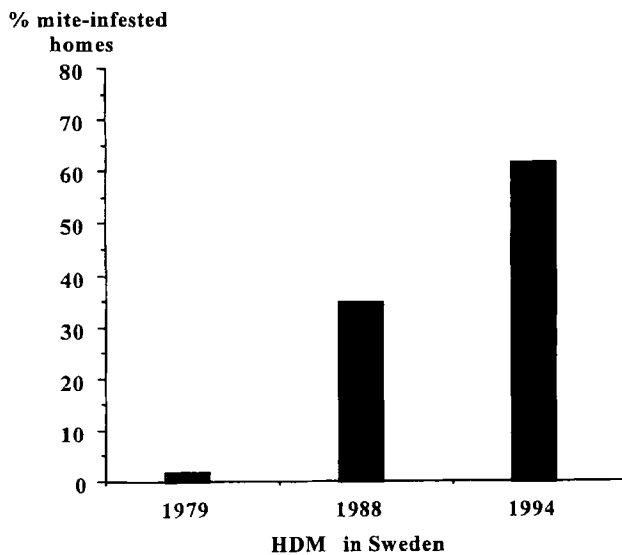


Fig. 1. Increase of house-dust-mite infestation in homes in Sweden. Results from three studies in 1979–94.

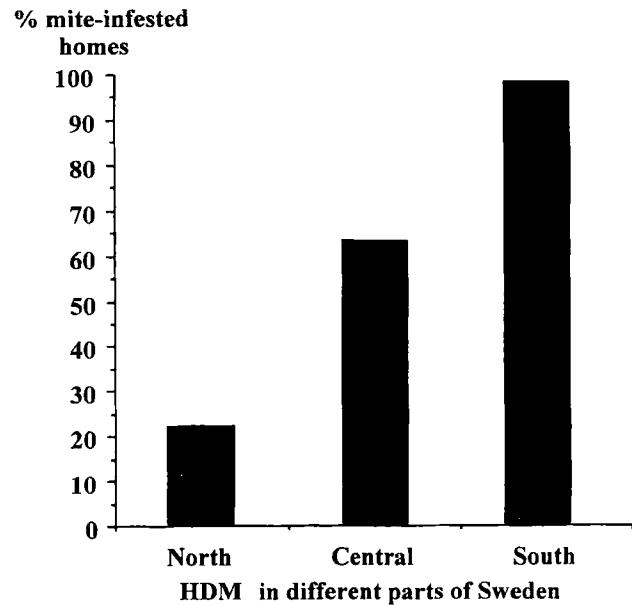


Fig. 2. Percentage of mite-infested homes from three climatic regions of Sweden (adapted from Refs. 14, 27).

In a study from Stockholm, Sweden, from 1979, Pyroglyphidae dust mites were detected in only 1.5% of the dwellings of allergic persons (11). In a 1993 study, mites were detected by a similar technique in 35% of the HDM-sensitized children in northern Sweden (19). Mite-allergen levels were generally low in Sweden when compared with those from other parts of the world (13, 14). Mite-infested homes were more commonly found in southern Sweden than in central and northern Sweden (Fig. 2). In addition, mite-allergen levels (Der p 1 and Der f 1) were higher in southern than in northern Sweden (12, 14, 20–25) (Table 1).

In Denmark, mites in house dust were first reported in 1979 (23). In that study, HDM were found in 87% of the homes within the general

population of Århus. In a separate study performed a few years later, significantly higher mite levels were found in homes of allergic patients than homes of nonallergic patients (26). In a recent report, mite allergens were detected in all homes of HDM-sensitized children. In 90% of these homes, mite-allergen levels exceeded 2 µg/g dust, with more than 50% of the homes exceeding mite-allergen levels of 10 µg/g dust (24). These studies indicate that the prevalence of HDM was significantly higher in Denmark than in Sweden (13–15, 22–27), and that mite infestation was more common in southern Scandinavia. This was further supported by several recent investigations from Sweden, where it was reported that the homes

Table 1. Mite-allergen levels in various parts of three Scandinavian countries (12, 14, 20–25)

Country	Area/location	Sampling sites	Mite allergen levels (µg/g)§	n	Reference
Sweden	Helsingborg	Bedroom	5.2 [†]	45	(14)
	Linköping	Bedroom	0.08§, ^{††}	40	(14)
		Day-care centers	<0.02 ^{†††}	22	(20)
		Schools	0.35 ^{†††}	29	(21)
	Stockholm	Mattress ^{†††}	<0.02	53	(13)
	Umeå	Bedroom	0.03 [†] , ^{††}	41	(14)
Denmark	Copenhagen ^{¶¶}	Mattress	1.6 ^{¶¶}	12	(22)
	Århus	Mattress	3.0 [¶]	75	(23)
	Multicenter	Mattress	≥10 ^{¶††,†††}	62	(24)
Norway	Bergen	Carpeted or smooth floors (schools)	<0.02	60	(25)
	Sør-Varanger	Schools	<0.001	14	(12)
	(northern Norway)	Homes ^{†††}	≥0.025 [§]	19	(12)

§Mean or geometric mean of Der p 1, unless otherwise specified. §§Not mentioned. †Median. ††Der p 1 + Der f 1. †††Der p 1 + Der f 1 + Der m 1. ¶Levels calculated from number of mites/g dust (100 mites = 2 µg/g). ¶¶Der f 1, §ng/m². †††Homes of mite-sensitized children.

located in the regions close to Denmark contained significantly higher levels of mite allergens than those in central and northern Sweden (Fig. 2, Table 1).

Investigations of the importance of mites/mite allergens in other Scandinavian countries (e.g., Norway and Finland) have not been conducted to the same extent as in Sweden and Denmark. Only recently have studies investigating indoor allergens, including mite-allergen levels in house and school dusts, been performed in Norway (28–30). In these studies, very low or undetectable levels of mite allergens were found in the classrooms. In a recent study, a high frequency of allergic diseases among children in a rural community in northern Norway was reported (30). In this study, approximately 7% of the children were considered to have asthmatic problems due to HDM or pollen. More recently, mite-allergen levels have been analyzed in the homes and classrooms of schoolchildren in northern Norway. Mite allergens were found only in the homes of HDM-sensitized children; no mites were found in the school dusts (31).

All the studies from these three Scandinavian countries showed that mites were uncommon in the northern regions of Sweden and Norway. However, very high levels of mite allergens could be found in poorly ventilated homes with high indoor humidity (13, 14), indicating that mite infestation in the homes within a cold climate is a man-made problem. Children with asthma lived more often in homes with poor ventilation, which in turn caused increased humidity indoors (Fig. 3) (13, 14, 27).

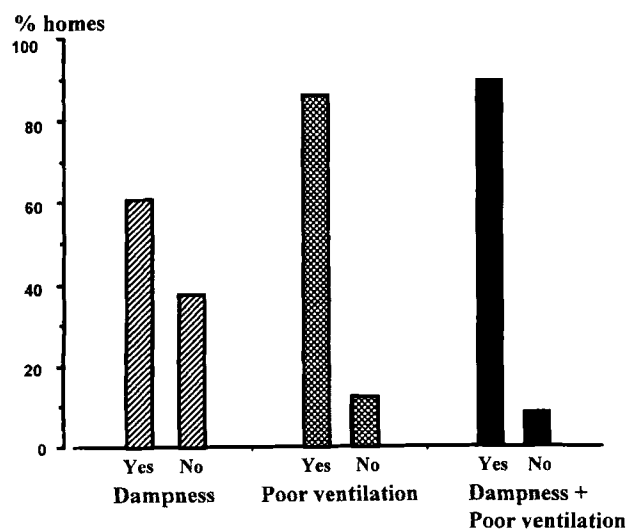


Fig. 3. Characteristics of homes of children with perennial symptoms of asthma in Sweden (adapted from Refs. 14, 27).

Table 2. Prevalence of mite sensitization in Sweden (14, 27), Denmark (15), and Norway (12)

Country	Area/location	Mites/allergens	Sensitization
Sweden	South (Helsingborg)	Der p and Der f	60% [‡]
	Central (Linköping)	Der p and Der f	35% [‡]
	North (Umeå)	Der p and Der f	32% [‡]
Denmark	Århus	Der p	17% [*]
Norway	Sør-Varanger (northern Norway)	Der p	5% [†]

‡Asthmatic children. †Schoolchildren. *Allergic patients.

Mite sensitization in the Scandinavian countries

Sensitization to mites is a worldwide problem (8–10). In the Scandinavian countries, mite sensitization is on the increase (Fig. 1). This increasing prevalence is probably due to a rapid change in the environment (13, 14, 32, 33). During the past decades, the climate in the Scandinavian countries influenced building style, leading to “airtight” buildings with accumulation of indoor humidity; this in turn promoted the growth of domestic mites and mold (12).

The prevalence of sensitization among children and adults in the Scandinavian countries is shown in Table 2. It is obvious from various studies that the rate of sensitization is higher among atopic children (12–14), and that high mite infestation increases the risk of sensitization (1, 3). Thus, higher levels of mite allergens were found in the homes of HDM-sensitized children than in the homes of non-HDM-sensitized children (14, 27).

Risk levels for mite sensitization

A concentration of 2 µg/g of the major mite allergens, Der p 1 and Der f 1, has been suggested as the risk level for mite sensitization (8–10). Several studies during the past years support this risk level as a threshold value for mite sensitization (1–3, 5–7). There are other studies in which such risk levels were not identified (34–37). In recent years, several ongoing cross-sectional and prospective studies within and outside Scandinavia report that mite sensitization also occurs at exposure levels below the suggested threshold level (13, 14, 36–38).

In a UK prospective study of children with one atopic parent, 40% were sensitized to HDM at 5 years of age (1). In that study, the mite-allergen levels were high; i.e., geometric mean of Der p 1, 16.8 µg/g. All the children who developed sensitization to mites were exposed to mite-allergen levels of >2 µg/g dust. In another UK prospective study, Miles et al. reported that about 6% of their

high-allergy-risk children exposed to mite-allergen levels of $<2 \mu\text{g/g}$ dust developed sensitization to mites at the age of 1 year (39).

Studies from Estonia (37) and Linköping, Sweden (38), reported a low prevalence of mite sensitization in children aged 3 and 5 years (i.e., 13% in Estonia and 1% in Linköping). However, the mite-allergen levels in the homes of sensitized children were low: $<0.1 \mu\text{g/g}$ in Linköping and $0.3 \mu\text{g/g}$ dust in Estonia.

In a German study, the cumulative incidence of sensitization to HDM up to the age of 3 years was similar in children who were exposed to mite-allergen levels both below and above $1.2 \mu\text{g/g}$ dust (36). In another recent German prospective population-based study of schoolchildren, Kuehr et al. reported that many of the HDM-sensitized children were exposed to mite-allergen levels of $<0.3 \mu\text{g/g}$ dust (40). The German studies suggest that exposure to even low levels of mite allergens may sensitize and that there is no particular threshold.

Studies from Berlin, Germany (36), and the UK (39), as well as the studies from Linköping, Sweden (38), and Estonia (37), all showed that mite sensitization is apparent among children at levels below $2 \mu\text{g/g}$. These studies thus indicate that mite sensitization appears to occur at lower levels than what was generally suggested by the studies of countries with warmer and more humid climates (8–10). Furthermore, these studies indicate that high allergen exposure increases the risk of early sensitization, whereas low levels might induce sensitization at a lower rate and require a much longer time than at a higher exposure.

Nonspecific, adjuvant factors influencing sensitization

Sensitization, i.e., induction of IgE antibody formation and subsequent allergic disease, is an interaction between a predisposed individual, allergens, and environmental adjuvant factors, (41, 42). IgE-antibody formation is enhanced by various nonspecific, “adjuvant” factors, including exposure to various air pollutants (41–43).

Sensitization to an allergen is influenced by the dose, amount, and duration of allergen exposure, as well as the potency of the allergen. The age at which the individual is exposed, concomitant exposure to adjuvants, and various other host factors are important elements in the sensitization process.

In “airtight” buildings, increased humidity caused by poor ventilation causes accumulation of various adjuvant risk factors, e.g., irritants from tobacco smoking, dust particles, and emissions

from building materials (12, 43). Furthermore, living habits and lifestyles modified by the rapid modernization of society, as well as the introduction of many new chemicals into foods and the environment, may aid the sensitization process (41, 42).

Repeated inhalation of low doses of allergen can induce bronchial hyperreactivity in sensitized subjects (44). In areas of low mite infestation, repeated inhalation of low doses of allergen over long periods of time might induce sensitization influenced by adjuvant factors.

Individual variations in susceptibility

It has been assumed that the biochemical activity of an allergen or any post-translational modifications of it (45), as well as individual physiologic characteristics, may contribute to sensitization (46). Thus, it is likely that the dose of allergen that induces sensitization is influenced by variations in individual susceptibility to react to the particular allergen (47–49). Among sensitized patients, there is a 10 000-fold difference in sensitivity, i.e., in the dose of allergen inducing symptoms (48, 50). There may be a similar difference in the allergen dose inducing sensitization under the influence of various environmental adjuvant factors.

Thus, other risk factors that could possibly influence the sensitization process are variation in individual susceptibility to sensitization, physiologic variation, biochemical characteristics of allergens, and environmental pollution (e.g., infections, foods, food additives, emotional stress, and climate) (12, 41–43, 46).

Environmental factors influencing mite-allergen levels

In preventing allergic sensitization and reducing symptoms of allergic asthma, identification of major indoor allergens and factors influencing their levels are important in order to determine allergen exposure.

During the past years, we examined major allergens from mites (Der p 1, Der f 1) in dust from various environments of children (14). Homes of asthmatic children (27), allergic children (51), and neonates with biparental histories of allergy (52) were studied. Because many small children stay in day-care centers and older children/adolescents daily attend schools, these environments were also included (20, 21). Various environmental risk factors that could influence the allergen levels were also studied. Factors that could influence allergen levels indoors are shown in Table 3 (14, 53).

Table 3. Factors influencing mite-allergen level indoors (8–10, 12–15)

Type of environment
Homes
Day-care centers
Schools
Other public places
Public transport
e.g., bus, train, taxi, and plane
Public meeting places
e.g., film theater, shopping center, bar, etc.
Climate
Indoor climate/environment
Living habits
Household water consumption
Indoor temperature
Indoor humidity
Outdoor climate
Tropical climate
Outdoor temperature
Outdoor humidity
Temperate climates
Outdoor temperature
Outdoor humidity
Seasons (seasonal variations)
Autumn and winter months
Summer months
Indoor reservoirs
Mattresses or bedding and pillows
Carpets and upholstered furniture
Curtains and soft toys
Home characteristics
Dampness indoors
Persistent visible damp spot
Visible mold growth
Water condensation on double glass windows
Basement
Apartment/floors location
Indoor humidity
Indoor absolute humidity (AIH ≥ 7 g/kg)
Indoor relative humidity (RH $\geq 45\%$)
Ventilation
Type of ventilation system
Ventilation rate (< 0.5 air changes/h)
Living habits
Presence of carpets
Cleaning habits
Type of vacuum cleaners
Frequency of cleaning/washing

Compared to other parts of the world, mite-allergen levels were generally low in Sweden. Among 15 sampling sites in the three environments, the reservoir of allergens varied. Carpets and upholstery in homes, and tables and chair surfaces in day-care centers and schools were found to be the most common reservoirs of mite allergens (14).

Mite-allergen levels were higher in the southern coastal region than in northern and central (Linköping) Sweden. In addition, allergen levels were higher during the second half of the year. Similar results have been reported by others (18, 54, 55).

Problems of dampness in homes, increased indoor humidity, poor ventilation, lack of a basement, and presence of carpets all influenced allergen levels indoors. These observations have also been made by other investigators from the three Scandinavian countries (12–15).

Concluding remarks

When compared to the warmer and more humid climates, mite infestation is rare and mite-allergen levels are low in northern Scandinavia. For the most part, the winters in Sweden and Norway are too cold and dry for mites to survive. However, high levels of mite allergens can be found in homes with humidity problems; e.g., secondary to poor ventilation (12–15, 56). This may explain why mite-infested homes are more commonly found in Sweden today than before.

Despite generally low levels of mite allergens in Sweden, the prevalence of mite sensitization is increasing, indicating that low allergen exposure may induce sensitization. Exposure to indoor allergens may occur at any time; however, the conditions under which exposure takes place early in life seem to be particularly important for sensitization. Several recent prospective studies report that low mite-allergen levels induce sensitization in children. Perhaps low allergen exposure, together with various other environmental adjuvant factors occurring early in life, may modify the process of sensitization. However, at a very early stage, high levels of mite allergens increase the risk of sensitization (1).

In recent years, the relationship between exposure to indoor allergens and sensitization or allergic disease has been widely reported. Most of these studies have considered allergen exposure in homes as a model. However, with special attention focused on children, day-care centers and schools should also be considered in addition to the home environment.

Depending on the climatic influence, mite-allergen levels vary between regions within the same country. Mite infestation in homes occurs more frequently during the second half of the year. Consequently, investigations considering the evaluation of mite-allergen exposure should be considered during the autumn and winter months. Textile furnishings (e.g., carpets, mattresses, sofas, and curtains) are major reservoirs for indoor allergens. These should be considered in procedures for the prevention or elimination of indoor allergens.

In cold climates, high levels of mite allergens are found in homes with problems of dampness, increased indoor humidity, and poor ventilation

and in homes lacking a basement, facts which suggest that these factors must be dealt with to avoid indoor allergen exposure.

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