

Dust Mite Allergens: Ecology and Distribution

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Current Allergy and Asthma Reports 2002, 2:401–411

Current Science Inc. ISSN 1529-7322

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The most important allergy-causing mites found in homes worldwide are the house dust mites *Dermatophagoides farinae*, *D. pteronyssinus*, *Euroglyphus maynei*, and the storage mite *Blomia tropicalis*. Most homes contain multiple species. The most prevalent mite species and allergen in homes differ geographically, between homes within a geographical region, and among areas within a home. Therefore, it is important to know which mite species are present in a geographical area when performing diagnostic testing and prescribing immunotherapy. The key factor that influences mite survival and prevalence is relative humidity. Mites are present in homes in humid geographical areas and are rare or absent in drier climates unless humidity is artificially raised. Generally speaking, dust mite allergen levels are low in public buildings and transportation compared to levels in homes.

Introduction

Many species of mites are the sources of allergens that sensitize and induce allergic reactions in genetically predisposed individuals [1•,2]. These include species that are pests in fruit orchards [3–5] and their predators [6]; mites that are parasites of humans such as scabies mites and ticks [7–11]; mites that are parasitic of insects such as Hemisarcoptes and Pyemotes [1•,12]; storage mites found in stored grains, hay, and processed foods, and occasionally in homes [13–19]; and mites commonly found in homes worldwide.

Most notable among this large array of allergy-producing mites are the species that occur in homes and to a lesser extent in schools; daycare centers; seats in automobiles and public transportation; the office workplace; and other public places. These include *Dermatophagoides farinae*, *D. pteronyssinus*, *Blomia tropicalis*, and *Euroglyphus maynei*. In addition, other species may be important sources of allergen in agricultural occupational environments and foods. Keys for the identification of these mites have been published [20•,21].

Mites and Allergen Found in Homes

The most common allergy-causing mites that occur in homes worldwide are the house dust mites *Dermatophagoides farinae*, *D. pteronyssinus*, and *Euroglyphus maynei* (family Pyroglyphidae), and the storage mite *Blomia tropicalis* (family Echimyopidae) (Table 1). In temperate climates, *D. farinae* and *D. pteronyssinus* are usually the most prevalent species. In tropical climates, *Blomia tropicalis* may be the most prevalent species, but small numbers may be found in homes in subtropical and temperate climates. *E. maynei* is also found in homes worldwide, and in some homes in temperate climates they may be very numerous and sometimes the predominate species. The ecology, biology and distribution of *B. tropicalis* and *E. maynei* are not well studied compared with the *Dermatophagoides* species. Small numbers of other storage mite species are found in house dust, but occasionally, under some special circumstances, these may be very numerous. These allergenic storage mites include species of *Blomia*, *Lepidoglyphus*, *Acarus*, *Tyrophagus*, *Glycyphagus*, *Aleuroglyphus*, *Chortoglyphus*, and *Suidasia*. The ecology and distribution of *D. farinae* and *D. pteronyssinus* is reviewed in this article.

Worldwide prevalence of *Dermatophagoides farinae* and *Dermatophagoides pteronyssinus*

D. farinae and *D. pteronyssinus* occur in homes in humid regions worldwide. Their densities vary tremendously between regions, between homes within a region and between locations within a home. They are rare or absent in arid climates unless indoor relative humidity in homes is artificially raised [22–24•,25].

The official common names of *D. farinae* and *D. pteronyssinus* are the American and European house dust mites, respectively. The names, when assigned, were originally intended to indicate that one species was most common in North America and the other in Europe. Unfortunately, these common names were proposed and then approved by the Entomological Society of America before the full distribution of these mites was known. We now know that both species are prevalent in both North America and Europe as well as in most other parts of the world where surveys have been conducted.

Most surveys of mite fauna conducted around the world report that these two species are usually both present in a region and occur together in homes although one species is usually the more prevalent (Table 1). The presence and prevalence of *D. farinae* and *D. pteronyssinus*

Table 1. Representative dust mite fauna reported in homes worldwide.

Location	DF	DP	EM	BT	SM	Study
<i>North America</i>						
United States	X	X	?	?	?	Arlian <i>et al.</i> [26••]; Arlian <i>et al.</i> [59]; Chew <i>et al.</i> [60]; Fernández-Caldas <i>et al.</i> [28]; Hannaway and Roundy [62]; Lang and Mulla [80]; Nadchatram <i>et al.</i> [61]; Nelson and Fernández-Caldas [22]; O'Rourke <i>et al.</i> [23]; Peterson <i>et al.</i> [62]; Squillace <i>et al.</i> [63]
Puerto Rico	?	X	?	X	?	Fernández-Caldas <i>et al.</i> [41]
Barbados	?	X				Barnes <i>et al.</i> [42]
<i>Central and South America</i>						
Costa Rica	?	X				Soto-Quiros <i>et al.</i> [34]
Venezuela (Caracas)	?	X	?	?	?	Hurtado and Parini [35]
Columbia	?	X	?	?	?	Mulla <i>et al.</i> [36]
Bogota		X	?	?	?	Charlet <i>et al.</i> [37]
Peru		?		?		Croce <i>et al.</i> [38]
Brazil	?	X	?	X	?	Rosa and Flechtman [39]
Chile					?	Franjola and Rosinelli [40]
<i>Europe</i>						
Scotland (Glasgow)		X	?	?	?	Colloff [103]
England (Birmingham)		X	?		?	Blythe <i>et al.</i> [48]
Norway	?	X	?		?	Mehl [104]
Sweden	X	X	?		?	Warner <i>et al.</i> [51]; Munir <i>et al.</i> [52]
Finland	?	X	?			Stenius and Cunningham [105]
Estonia	?	X				Julge <i>et al.</i> [106]
Poland	X	?	?	?	?	Solarz [46]; Solarz [86]; Racewicz [107]
Silesia	X	X	?			Solarz [96]
Denmark	X	X	?		?	Mehl [104]; Stenius and Cunningham [105]
Germany	X	X				Hirsch <i>et al.</i> [108]
Switzerland (Basel)	?	X	X		?	Mumcuoglu [49]; Mumcuoglu [50]
Italy						
Pavia	X	?				Moscato <i>et al.</i> [47]
Rome	X	?	?		?	Bigliocchi and Maroli [109]
Spain	?	X				Alvarez <i>et al.</i> [110]
<i>Middle East, Western Asia</i>						
Turkey (Anatolia)	X	X			?	Kalpakioglu [111]
Israel	X	X	?		?	Feldman-Muhsam <i>et al.</i> [112]; Mumcuoglu <i>et al.</i> [58]
Uzbekistan		?			?	Nazrullaeva and Dubinina [113]
<i>Africa</i>						
Egypt	X	X				Morsy <i>et al.</i> [114]; Yassin and Rifaat [115]
Nigeria (Lagos)	?	X		?	?	Somarin <i>et al.</i> [116]
<i>Eastern Asia</i>						
Japan (Nagoya)	X	X	?		?	Suto <i>et al.</i> [117]; Suto <i>et al.</i> [118]
Tokyo	?	X			?	Miyamoto and Ouchi [119]
China (Shanghai)	?	X	?		?	Cai and Wen [120]; Wen and Wang [121]
Taiwan	?	X		X		Sun and Lue [122]; Tsai <i>et al.</i> [123]
Hong Kong		X				Leung <i>et al.</i> [124]
Malaysia		X		X		Ho [125]; Mariana <i>et al.</i> [126]
Singapore	?	X		X	?	Chew <i>et al.</i> [43]; Zhang <i>et al.</i> [44]
Brunei	?	?		?	?	Woodcock and Cunningham [45]
Indonesia (Jakarta)	X	?		?	?	Baratawidjaja <i>et al.</i> [127]
<i>Oceania</i>						
Australia	?	X	?	?	?	Tovey <i>et al.</i> [55••]
New Zealand		X				Wickens <i>et al.</i> [90]

DF—*Dermatophagoides farinae*; DP—*D. pteronyssinus*; EM—*Euroglyphus maynei*; BT—*Blomia tropicalis*; SM—storage mites.
X—prevalent or dominant species.
?—species reported to be present.

allergen in dust in homes worldwide parallels species prevalence. Unfortunately, most studies in which mite allergen concentration in dust was determined have measured only Der p and not Der f allergen even though both species may have been present in homes in the locations where the studies were conducted. Likewise, in many studies patient skin test sensitivity and serum IgE levels have been determined using only one species. Therefore, in some instances, the results of these studies are difficult to interpret without knowing the patient's total and specific mite allergen exposure and sensitivity.

Most studies show that in regions of the United States where dust mites commonly occur, most homes, regardless of geographical location, contain both *D. farinae* and *D. pteronyssinus*; however, one species is usually much more prevalent within a home than the other. Arlian et al. [26••] surveyed 252 homes located in Cincinnati, OH; Memphis, TN; Greenville, NC; Delray Beach, FL; Galveston, TX; New Orleans, LA; San Diego, CA; and Los Angeles, CA. This study sampled multiple locations within the homes at multiple times over several years. It was found that 82% of the homes in the eight different geographical areas were co-infested with both *D. farinae* and *D. pteronyssinus*. In New Orleans and Galveston, two very humid subtropical climates, more homes had greater densities of *D. pteronyssinus* than *D. farinae*. In contrast, in drier climates, more homes had predominately *D. farinae* than had *D. pteronyssinus*. However, within each of these eight geographical areas, some homes contained predominantly *D. farinae* while others contained predominantly *D. pteronyssinus*. Few homes in the eight regions contained solely *D. farinae* or *D. pteronyssinus*. In this study, allergen concentration paralleled mite numbers. Similarly, both *D. farinae* and *D. pteronyssinus* mites and/or allergen were found to be prevalent in homes in Atlanta, GA [27], Tampa, FL [28], the midwest [29], and in southern California [30]. A survey by Nelson and Fernández-Caldas [22] found significant numbers of *D. farinae* in homes using evaporative coolers in Colorado and New Mexico, and in a house with water problems in Kansas.

Another study performed in Dayton, OH [31••], sampled family room carpets, sofas and bedroom carpets in 24 air-conditioned and 24 non-air-conditioned homes multiple times over an 18-month period. This study found both Der f 1 and Der p 1 in most homes, with Der f 1 usually the predominant allergen. However, significant levels of Der p 1 were found in a few homes.

Hannaway and Roundy [32] found *D. farinae* and *D. pteronyssinus* allergen concentrations in 46 homes of patients with chronic asthma in suburban Massachusetts, and documented house dust mite sensitivity in these patients. In all homes, bedroom carpets were sampled, and in 14 homes, both bedroom and family room carpets were sampled. *D. farinae* was the dominant allergen in 78% of the homes, while *D. pteronyssinus* was the predominant allergen found in only 7%. However, 20% of the homes

had significant levels of *D. pteronyssinus*. Fifteen percent of homes contained allergen of both species. In contrast, a survey of 15 homes in nearby Connecticut found *D. pteronyssinus* to be the major species [33].

Comparable surveys have been conducted in other countries, and give a similar profile for *D. farinae* and *D. pteronyssinus* prevalence (Table 1). Data from South America [34–40], the Caribbean [41,42], and Southeast Asia [43–45] show that *D. pteronyssinus* and *Blomia tropicalis* are the predominant species, but *D. farinae* is present in low numbers. A survey of 41 dwellings in Upper Silesia, Poland [46], found most to be infested with both *D. farinae* and *D. pteronyssinus*. *D. farinae* was the most abundant species overall, but in some dust samples, *D. farinae* was the predominant species (33.3%) while in other samples *D. pteronyssinus* was more prevalent (27.5%). In the remaining samples, *D. farinae* and *D. pteronyssinus* were equally prevalent. Both *D. farinae* and *D. pteronyssinus* are present in homes in northern Italy, but *D. farinae* is the predominant species [47]. The predominant species reported in most studies in England and western Europe are *D. farinae* and *D. pteronyssinus*, but *E. maynei* and storage mites are also present [48–50]. Low mite levels are reported in Sweden with *D. pteronyssinus* being the more prevalent [51–54]. A survey by Tovey et al. [65••] of nine locations in Australia found that *D. pteronyssinus* was the predominant mite. *D. farinae* was absent or its abundance was low. Therefore, diagnostic tests for *D. farinae* are probably not required in Australia.

The data on fauna clearly show that in most regions of the world, diagnosis and treatment strategies for house dust mites should be directed at multiple species. Australia is an exception. Even though one species is predominant in a particular region, that species can vary between homes, and the concentration of mites and allergen of the less prevalent species may still exceed threshold levels for sensitization and inducing symptoms for a particular patient. In addition, a patient whose home contains predominantly one species may visit homes that contain predominantly the other species or significant levels of both species.

Ideally, surveys in homes should determine the prevalence of allergen and mites of multiple species. Likewise, diagnostic testing and immunotherapy should utilize reagents of all major species known to occur in a specific region even when a home or most homes in that region contain predominately one species because it is unlikely that patients are exposed to only one species.

Climatic and biological factors

Most of the factors responsible for the varied prevalence of *D. farinae* and *D. pteronyssinus* geographically, among homes and between sites within homes are not completely understood. However, ambient relative humidity is a key climatic factor that determines mite prevalence [56]. Dust mites utilize water vapor in air as their main source of water. They require ambient relative humidities above 55%

for a sufficient period of time daily in order to acquire enough water to survive and for populations to thrive [57]. Therefore, these mites are generally found in homes in humid climates, or locations within homes where relative humidity is elevated.

Longitudinal field studies in humid climates show that mite densities exhibit seasonal fluctuations that parallel those in ambient relative humidity. High mite densities occur during the humid summer months and low mite densities during the late heating season when indoor relative humidity is lowest. Der 1 levels paralleled these seasonal mite patterns [31••,58••]. Surveys in the United States show that, as a general rule, *D. farinae* is more prevalent than *D. pteronyssinus* in drier climates, while homes in humid regions have more *D. pteronyssinus* than *D. farinae* [22••,23,26••,28,30,32,59–63].

Laboratory studies show that *D. pteronyssinus* has slightly higher relative humidity requirements than does *D. farinae*, and that *D. farinae* better survives long periods of low relative humidity [56]. Both species thrive at 75% RH and 22°C; however, *D. pteronyssinus* has a greater population growth rate than *D. farinae* [57].

The differences in relative humidity requirements alone do not adequately explain the differential prevalence of *D. farinae* and *D. pteronyssinus*. Differences in the biology of the two species and the influences of temperature on reproduction and survival also play a role. For example, *D. pteronyssinus* readily completes its life cycle at 16°, 23°, 30°, and 35°C in 122.8, 34, 19.3, and 15.0 days, respectively, at 75% RH [65]. Therefore, it is expected that mite population growth and production of allergen occurs more rapidly in warm sites such as sofas and mattresses than in carpets on cold slab floors. In contrast, *D. farinae* does not develop well at 16° and 35°C [65]. Therefore, this species may develop better on sofas than on cold slab floors or in occupied beds with temperatures near body temperature. Fluctuating dynamic relative humidity and temperature conditions to which each species is exposed may influence survival, duration of the life cycle, and formation of prolonged and desiccation resistant life stages in the life cycle [66,67]. There are also differences in the fecundity of the two species that may favor one species over the other in specific conditions [64–66].

The two species are biologically different although in much of the medical literature they are treated as being the same. A complex combination of interacting climatic factors and the differences in the biology of each species undoubtedly contributes to variances in the prevalence. How the interactions of these climatic and biological factors influence the prevalence of each species is not fully understood. As these interacting factors become better understood new control strategies may be developed.

Importance of Ambient Relative Humidity for Dust Mite Survival and Allergen Production

Regardless of all of the interacting factors that influence mite survival it is clear that relative humidity is the key

factor in their survival because these mites rely on sufficiently high relative humidity around them as their primary source of water [56]. Therefore, sufficiently reducing indoor relative humidity for a long-enough period of time will kill these mites, or stop their reproduction and population development [31••,56]. The absence of these mites in arid climates and seasonal fluctuation in prevalence that parallel the rise and fall of indoor relative humidity are natural evidence of this.

A recent study by Arlian *et al.* [31••] demonstrated that reducing ambient relative humidity below 51% in homes in a temperate climate killed most mites. This, coupled with regular vacuum cleaning, significantly reduced allergen levels over time in carpets and fabric-covered furniture. In this study, dehumidification was only needed during the summer to maintain the desired low relative humidity. Use of forced-air heat maintained relative humidity below 50% from October through March without additional dehumidification. However, laboratory studies have shown that it is not necessary to constantly maintain relative humidity below 51%. *D. farinae* mite population growth is effectively limited even when relative humidity is 75% or 85% for 2 to 8 hours daily, but below 50% for the remainder of the 24-hour day [67,68].

Major Mite Breeding Sites in Homes, and Dispersal of Allergen

In homes, breeding populations of mites and their allergens are most prevalent in locations where shed skin scales collect and serve as the main source of food for the mites. These locations are carpeting, fabric-covered furniture (sofas, chairs), and mattresses. Some live mites may be found in blankets, bed linens (sheets and pillowcases), and on the surfaces of pillows and curtains, but the levels are generally low in these locations compared with mattresses, carpets, and sofas. Food and moisture can collect in cracks between boards of hardwood and tile floors, and support thriving mite populations. This is an exception, but it occurs in older homes with hardwood floors. Mites, eggs, and allergen may be transferred from areas of high concentration (carpets, furniture, and mattresses), and contaminate other locations such as bedding, curtains, automobile seats, seats in public transportation and public places such as schools, day care facilities, and the workplace.

Most mite allergen is associated with dust particles that settle quickly following a disturbance that makes it airborne. Therefore, little mite allergen is found on vertical walls, and the tops of hard surface furniture (*eg.* end tables, bookcases, dressers, bedside tables and chests of drawers) [69,70]. Smooth surface floors (wood, linoleum, and tile) usually contain few mites and little allergen if regularly cleaned and there are few or no cracks (seams).

Sampling for Mites and Allergen

Although many studies report the presence and density of dust mites and allergens, researchers and allergists should

keep in mind that mite species and allergen densities vary seasonally and between locations within a home. A single sample collected in a home only one time may not be an accurate representation of the patient's risk for exposure to allergen nor may it address points of interest such as recommendations for environmental modification.

For example, three sites in 48 homes located in Dayton, OH, were sampled 10 times over an 18-month period, and allergen and mite densities (*D. farinae* and *D. pteronyssinus*) determined [31••]. In March, near the end of the heating season, air-conditioned homes showed a much greater percentage of homes with the highest allergen and mite density in bedroom carpets compared with family room carpets and sofas. In contrast, during humid summer months, the highest allergen and mite densities in most of these homes were in the family room carpets and the lowest in the sofas in these rooms. However, at all sampling times a significant percentage of homes had the highest mite count in the sofa. In comparison, in the same study, most homes without air conditioning that were ventilated by opening windows, had the highest allergen density in the bedroom carpet for all sampling times. Almost half the homes had the highest allergen density in either the family room carpet or sofa. The high site for mite density showed a similar relationship to allergen. Likewise, a study by Hannaway and Roundy [32] found significantly higher levels of allergen in the bedroom carpets compared to the level in the family room carpets. However, two homes had the highest level of mite allergen in the family room carpets. These data illustrate the problem with drawing conclusions about mite and allergen density and distribution in homes that are based on only one or a few samples taken at only one time.

Mite Allergens As Aeroallergens in Homes

Dust mite allergen is associated with both large and small dust particles [71]. Custovic *et al.* [72] reported that 79.4% of Der p 2 is carried on large particles more than 4.7 μm , with the remaining 20.6% associated with small particles of 1.1 to 4.7 μm in diameter. Another study by de Blay *et al.* [73] reported that group 1 and 2 allergens were predominately associated with large particles over 20 μm , and that these settled within 20 minutes after disturbance. Air sampling studies show that most allergen seems to be associated with the large particles, and these settle out of air in less than 30 minutes following a disturbance [73,74]. The smaller particles that take longer to settle can drift throughout the house. However, several studies show that little mite allergen is collected from walls and smooth surfaces of furniture (tables, chests, drawers, bookshelves, etc.), and indirectly suggest that most allergen is associated with large particles and not the smaller ones [69,70,72,76]. Air sampling shows that airborne allergen is low or non-existent in the absence of disturbance [76]. Therefore, air filter appliances used to remove airborne mite allergen

are probably of little benefit unless there is considerable activity in a room.

Concentration of Allergen or Mites As an Index for Exposure

The concentration of mites and/or allergen in settled or airborne dust is generally used as a relative index of exposure and the need for remedial measures. Concentrations of Der p 1 and Der f 1 are usually used as relative measures of total mite allergen and, hence, the presence of dead and live mite bodies and feces of *D. pteronyssinus* and *D. farinae*, respectively. Der p 2 and Der f 2 are also sometimes used but, interestingly, the quantities of these group 2 allergens are usually about half of that for Der p 1 and Der f 1 in the same dust sample. Two μg of group 1 allergen per gram of dust is equivalent to 100 mites per gram of dust; quantities considered to be a risk factor for sensitization of the average predisposed individual [77]. Ten μg of group 1 or 500 mites per gram of dust are generally used as a threshold for inducing an allergic reaction. While these values are useful for comparing results between studies, sites within a home or as a reference, there may be little relationship between these quantities, exposure and the actual risk of sensitization and/or allergic reaction for an individual.

Quantitation of Dust Mites and Allergen in Dust Samples

Mite and allergen levels are reported in micrograms per gram of dust, micrograms per meter squared, or micrograms per total surface sampled. Often, even though many sampled surfaces yield much less than a gram of dust (*eg.*, pillows, clothes, human scalps), the mite or allergen levels are extrapolated and reported per gram of dust. This practice exaggerates mite and allergen levels on surfaces when in fact these sampled surfaces have very few mites and little allergen [78]. Therefore, when only small samples of dust can be obtained from a substrate (*eg.*, <0.05 g) and analyzed, the total number of mites or total amount of allergen obtained from a given sampled surface area or object (*eg.*, wall, smooth floors, pillow surface, garment or portion thereof, etc.) should be reported. For example, one study reported an extrapolated mean of 800 mites per gram of dust collected on scalps of children, which was alarming. However, since an average of 0.0025 grams of dust was collected from each scalp, the actual mean number of mites per scalp was two [79].

Mites found on clothes

A few studies have surveyed clothing for the presence of mites and/or mite allergen. Usually, very little dust is collected from clothing by vacuum sampling (<0.1 g), and in most cases, small amounts of mites or allergen are recovered [80••,81]. Two studies report extrapolated mean Der p 1 allergen densities on various types of clothing

[82,83]. The significance of extrapolated quantities is difficult to evaluate because they represent amounts that do not occur on clothing. Siebers *et al.* [81] sampled the upper garments for 166 school children. The mean amount of allergen (Der p 1) was reported as 2.77 micrograms per gram of dust, although this is only 0.022 micrograms per garment sampled, since the mean weight of dust collected was 0.060 grams per garment for 3-minute vacuum samples.

Neal *et al.* [80••] counted the number of live and dead mites, and determined the total allergen in dust samples obtained from the dorsal sides (neck to knees) of clothing. Of the 62 individual clothes sets sampled, only 10 had mites (live and dead) present (range one to nine). Twenty-seven of these 62 samples had detectable levels of Der 1 allergen (mean = 0.2 µg/sample). There was a significant correlation between the amount of allergen on clothing and in homes. Based on these results it appears clothing is not a significant source of mites and allergen exposure. However, the fact that live mites were found on clothing in this study is evidence that clothing is a vehicle for mite dispersal and colonization in other places. The occurrence of some mite allergen on clothing indicates that clothing is also a vehicle for allergen dispersal.

Mites and allergen on stuffed toys

Toys contain very few mites and little allergen. Dornelas de Andrade *et al.* [84] collected dust samples in French day care nurseries from multiple soft toys, and found that 94% of these had very low allergen levels (<2 µg/g of dust). Similarly, Babe *et al.* [86] collected dust samples from toys found in private homes with substantial mite levels in the bedroom carpets, and determined that the dust mite levels on toys were insignificant and below the level of allergic sensitization (<100 mites/g of dust).

Dust Mites and Allergen in Public Places Workplace/offices

Detectable levels of dust mites and allergen have been reported in office buildings. However, based on published reports, the levels of mites and allergen found in these buildings are usually low, and not of any clinical significance [46,86–89]. However, there are exceptions, and allergists should be aware that isolated cases of mite allergen problems in the workplace may occur as a result of mite and allergen transfer.

Janko *et al.* [87] performed allergen analysis of 127 surface dust samples from offices in 14 buildings. The mean level of Der p 1 in each of 12 of the sampled buildings was less than 0.5 micrograms per gram of dust. For the other two buildings, the mean level was 0.7 and 1.5 micrograms per gram. However, in two of the buildings, the high samples were 7.0 and 3.3 micrograms per gram. Therefore, with the exception of a few samples, allergen

levels were not a health risk. Most likely the allergen was transferred into the building. There was no analysis for the presence of live or dead mite bodies, although the study concluded that nine of the 12 buildings had a dust mite infestation.

Another study by Hung *et al.* [86] sampled 10 carpets and five upholstered chairs in each of five office buildings located in Philadelphia and Washington, DC. Most sites in all of the buildings had low levels of mite allergen. However, 10 of the 75 samples had between 2 and 10 micrograms per gram of either Der p 1 or Der f 1. One carpet sample in one building had 16.1 µg/g of dust. Similarly, Solarz [46] reported that few mites were found in dust samples collected from laboratories and offices at the Silesium Medical Academy in Katowice-Ligota, Poland.

In one situation that we investigated, an office worker complained of atopic dermatitis-like symptoms while at work, and particularly while seated at a desk. Vacuum dust samples were taken from the worker's upholstered chair, several other chairs, file cabinets, desk, and floor. The worker's chair contained large numbers of dust mites but there were no or few mites in other locations in the vicinity. An analysis of dust samples from the individual's home revealed a thriving population of mites and suggested that the mites in the office chair probably were transferred on clothing from the person's home. In a similar investigation, many *D. pteronyssinus* were recovered from an individual's office chair and his office carpet. No home sample was examined, but it is likely that mites were transferred in, because no live mites were recovered. In both of these cases, the mite levels were high enough to be a health concern.

Movie theaters

A study of 10 cinemas in New Zealand found an average of 6.12 micrograms per gram of dust (range 2.6–14.5) in seats [90]. Studies in Japan also reported significant levels of mite allergen in movie theater seats [91]. Based on these two limited reports, it appears that cinema seats can be a significant source of exposure.

Schools, churches, day care centers, banks, libraries, museums

Studies show that the concentrations of mites and allergen in most schools, churches, day care centers, banks, libraries, and museums are very low and not generally of any clinical significance (<2.0 µg/g of dust) [43,44,46,53,54,92–95]. Occasionally, significant levels may be found in isolated locations. Surveys in Norway and Singapore showed very little Der p 1 and Der f 1 (<0.1 µg/g of dust) in dust of carpeted floors in schools [44,93,94]. Likewise, another study [84] found insignificant levels of Der 1 (<2 µg/g) on 100% of smooth floors and pillows and in 94% of the mattresses and soft toys sampled in 30 day care nurseries in Marseille, France.

Hotels and ski lodges

Beds in hotels and ski lodges [90] may be sources of significant exposure to mite allergens although levels in these buildings are generally lower in comparison to the levels in carpets, sofas and mattresses in homes. Wickens *et al.* [90] in New Zealand reported an average of 7.49 micrograms Der p 1 per gram of dust in ski-lodge beds during the skiing season, but about 1 microgram per gram of dust during the summer. Hotel beds in this same area contained 3.57 micrograms per gram of dust in comparison.

Hospitals and nursing homes

Hospital and nursing home beds, floors, and furniture generally show low levels of mites and allergen (<0.5 µg Der 1/g of dust) [44,46,96–99]. This is attributed to frequent cleaning and linen changes, use of encasements and the presence of smooth floors. However, occasionally in these facilities there are locations that may have high densities of allergen. For example, Custovic *et al.* [98] sampled carpeted floors, mattresses and upholstered furniture in 14 hospitals. Carpet and mattress samples contained less than 0.5 micrograms Der p 1 per gram of dust, while upholstered chairs had less than 10 µg Der p 1 per gram of dust. Der p 1 was below detectable levels in airborne samples.

Mite Allergen in Public Transportation and Automobiles

Several studies report the presence of dust mites and/or dust mite allergen on upholstered seats in automobiles and public transportation [80••,91,92, 100,101]. Results of these surveys generally show that mite and mite allergen levels are very low in comparison to the levels found in carpets, sofas and mattresses in homes.

Automobiles

A study by Neal *et al.* [80••] found that most automobile seats had very low levels of dust mites compared with the densities in the homes of the drivers. Some of the mites were alive, which suggested that mites could be transferred on clothing to automobiles and/or to other houses. However, the low levels of mites and allergen suggested they were deposited on the seats from clothing, and that seats were not breeding sites for mites. The mean levels for all automobile seats sampled over five different times was 1.3 micrograms per gram of dust; too low to be a risk factor for sensitization and induction of allergic symptoms. However, the Der 1 densities in some individual automobiles were high enough to be a risk factor for sensitization and induction of allergic reactions. Overall, 22.6% of the automobile seats sampled with detectable Der 1 allergen ($n=198$) had more than 2 micrograms Der 1 per gram of dust. Allergen densities were less than 0.5 micrograms per gram of dust when the mite levels in carpets in homes of the drivers was less than 100 mites per gram of

dust. However, mean allergen concentration in seats was 1.34 micrograms per gram of dust for automobiles associated with homes that had more than 100 mites per gram of carpet dust. Therefore, higher mite and allergen densities in cars were associated with higher levels in homes.

Trains, airplanes

Most studies show there are low levels of mites and their allergens in train seats [81,92,100–102]. Colloff [100] reported few mites from cloth-covered seats of passenger trains in Glasgow, UK. The low number of intact mites suggested these were not breeding sites, but rather mites that were deposited there from clothing. Likewise, Partti-Pellinen *et al.* [102] found insignificant levels of Der p 1, Der f 1 and Eur m 1 from train seats in Helsinki. In contrast, a survey by Uehara *et al.* [101] of commuter night and express trains in Kobe and Osaka, Japan, found the seats of many trains had more than 10 micrograms Der 1/m² and over 50 µg Der 1 allergen per gram of seat dust. The high density of mite bodies found suggested that mites were breeding on these seats. Similarly, a survey of commercial airline seats found very low Der 1 levels (1.62 µg/g of dust) that are probably not significant for most individuals [90].

Conclusions

Allergy-causing mites are ubiquitous in homes worldwide. The species present and their prevalence vary among humid regions, between homes within a region and between locations within a home. *D. farinae*, *D. pteronyssinus*, and occasionally *E. maynei* are the most prevalent domestic mites found in homes in temperate climates. Other mite species (*eg, Blomia tropicalis*) may be present in these homes, and may be the predominant species in homes in tropical or subtropical climates. The interaction of climatic and mite biological factors influence mite presence and prevalence. However, relative humidity is the most significant factor limiting mite occurrence. Aside from the role of relative humidity, most of these interacting factors are not understood.

Breeding populations of mites in homes occur in high-use areas where shed skin scales collect and serve as a source of food. These areas include beds, upholstered furniture, and carpeted areas near these items. Mite allergen is associated primarily with heavy particles that settle quickly after a disturbance, and do not drift far. Thus, low levels of allergen are found on walls and smooth furniture within a home.

Detectable levels of mite allergen are also found in public buildings such as the workplace/office, schools, libraries, daycare centers, hospitals and nursing homes. However, these allergen levels are generally very low compared with those found in homes. Few mites and low allergen levels are found on clothing. However, clothing serves as a vehicle for mite dispersal and significant

quantities can be found in some automobile, train, and theater seats.

Acknowledgments

Some of the research reported in this review was supported by US Environmental Protection Agency Grant No. R825250-01-0.

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