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Indoor Allergens in School and Daycare Environments

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Abstract

Most studies that have examined exposure to indoor allergens have focused on home environments. However, allergen exposures can be encountered in environments other than the home. For example, many children spend a large part of their time in schools and daycare facilities. Over the past two decades, a large number of studies have been conducted in school and daycare environments. However, the role of indoor exposures in allergy and asthma development or morbidity in these settings is not well characterized. The purpose of this review is to evaluate the importance of indoor allergen exposures in school and daycare settings. We summarize the key findings from recent scientific literature, describe exposure characteristics, discuss the role of these exposures in relation to asthma and allergy symptoms, and provide information on the effectiveness of published interventions.

Keywords

allergen; indoor; exposure; asthma; allergy; school; daycare

Introduction

Exposure and sensitization to indoor allergens are important risk factors for asthma and allergic respiratory diseases.[1] Although the role of indoor allergen exposure in the development of allergic sensitization and asthma remains subject to debate, there is strong evidence that indoor allergens play a key role in triggering and exacerbating allergy and asthma symptoms.[2]

Most studies of indoor allergens have targeted home environments because homes are often considered the primary sites of exposure. Over the past decades, the importance of non-residential indoor environments has also been recognized.[3] For example, in schools and daycare facilities, allergen and other indoor exposures may affect children's health because children spend a large part of their childhood and adolescent years in these environments.

This review focuses on the importance of indoor allergen exposures in daycare and school environments. The purpose of this document is to summarize key findings from the scientific literature and to identify future research needs. Studies for this review were searched using the following databases: PubMed, Embase, Web of Science, Scopus, and ERIC. Although inhalation of food allergens may induce allergic reactions in sensitive individuals, food

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allergens – which can constitute important part of allergen exposures in daycare and school settings – are beyond the scope of this review. Furthermore, the relevance of exposures other than aeroallergens (e.g., environmental tobacco smoke, endotoxin, volatile organic compounds, and other irritants) will not be discussed, although these exposures may also affect indoor air quality and occupants' health status.

Exposure to Indoor Allergens in Daycare and School Environments

Study designs and exposure assessment

Indoor allergen exposures in schools and daycare centers have been an area of continuing research interest. Studies have been conducted worldwide;[4-15] the research has been most active in the United States and Scandinavian countries.[16-35] Although most studies have targeted school environments, the number of studies that have assessed allergen levels in daycare centers has increased over the past decade.[7, 9, 11, 15, 19, 22, 24, 28] To date, studies have mainly been cross-sectional in design. Some studies, however, have examined seasonal variation in allergen levels.[16, 20]

Cat (Fel d 1), dog (Can f 1), dust mite (Der f 1, Der p 1), cockroach (Bla g 1, Bla g 2), and mouse (Mus m 1, MUP) allergens and molds have been the most frequently studied allergens. Although sampling and analytical procedures used in the studies vary considerably, allergen concentrations are usually quantified by antibody-based enzyme-linked immunosorbent assays (ELISA).[36] However, methodological differences can contribute to the variability of the findings and complicate comparisons between studies. For example, differences in sampling equipments (e.g., flow rate, vacuum power, collection devices), sampling locations, and used metrics can make comparisons difficult.[36] In general, correlations between different sampling methods have been poor.[37] In most studies, allergen levels have been assessed in settled dust samples collected from various indoor sites. Air sampling techniques have been primarily used for pet allergens (e.g., Fel d 1), which are carried on aerodynamically smaller-sized particles and remain airborne for longer periods of time. Studies that have assessed allergen levels on the surface of clothing have also used tape sampling.[38]

Allergen levels and exposure characteristics

The Online Repository Tables E1-E5 summarize the main findings on cat, dog, dust mite, cockroach and mouse allergen levels from published studies that have examined indoor allergen exposures in daycare and school environments in the past two decades.

Exposure to cat and dog allergens—Numerous studies have shown that animal allergens can be present in environments where no animals reside.[3, 4] In schools and daycare centers, cat (Fel d 1) and dog (Can f 1) allergens are frequently detected, but the levels of exposure vary greatly. In general, these common aeroallergens are found at low levels (Tables E1-E2) in these settings. Nonetheless, although the magnitude of exposure tends to be low, studies have demonstrated that allergen levels in educational facilities can be higher than in homes where no pets are present.[21, 29]

Cat and dog allergen levels have generally been found in higher levels in carpeted and upholstered areas.[4, 10, 18, 19, 23, 26] Levels in carpeting are often significantly lower than levels in upholstered seats.[4, 27] It is not uncommon that allergen levels in these locations sometimes exceed thresholds that have been associated with allergic sensitization (1.0 μg/g for Fel d 1; 2.0 μg/g for Can f 1) or asthma symptoms in sensitized individuals (8.0 μg/g for Fel d 1; 10.0 μg/g for Can f 1).[39, 40] The highest average concentrations have been found in US and Swedish schools; in samples collected from chairs and desks, geometric means reached as high as 11.3 μg/g for Fel d 1 and 15.0 μg/g for Can f 1.[29]

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There is strong evidence that clothing is the primary transfer mechanism and source of pet allergens.[10, 17, 41, 42] Among schoolchildren, allergen levels have been found to be significantly higher in dust collected from pet owners' clothing than from clothing of non-pet owners.[10, 38, 41] Still, allergen levels can be dependent on clothing type and washing frequency.[10, 42] A recent study has suggested that in addition to clothing, human hair may be a source for transfer and deposition of pet allergens among schoolchildren.[43] Several studies worldwide have demonstrated that levels of cat and dog allergens in daycares and schools correlate with the number of children and staff who have either dog(s) or cat(s) at home or have frequent contacts with these pets.[10, 15, 17, 24, 26, 44, 45] Elevated allergen levels have been detected in both dust and air samples. For example, concentrations of Fel d 1 and Can f 1 in settled dust were significantly lower in Swedish daycare centers where neither children nor staff owned pets compared to centers where cat and dog ownership was common (Fel d 1 levels: median 0.64 μg/g vs. 5.45 μg/g; Can f 1 levels: median 0.39 μg/g vs. 2.51 μg/g).[45] In another study, there was a 5-fold difference in median levels of airborne Fel d 1 between classes with many (>25%) and few (<10%) cat owners.[17]

In summary, published data suggest that schools and daycare centers can be important sites of exposure to cat and dog allergens, particularly for susceptible individuals (e.g., sensitized children who do not have pets at home). However, not all studies link these environments to elevated exposure levels. The number of pet owners at school or daycare centers is one of the strongest predictors of elevated cat and dog allergen levels in these settings.

Exposure to dust mite allergens—Studies show that dust mite allergens (Der f 1, Der p 1) are found in low levels in many schools and daycare facilities (Table E3). Reported levels are often similar or slightly lower than in corresponding local homes.[5, 7] As ambient relative humidity is a key environmental factor that influences mite populations,[46] dust mite allergen levels are strongly associated with humidity levels. In order to survive and thrive, dust mites require that the relative humidity of air is above 55% for a sufficient period of time, as water vapor in air is their main source of water. Although mite levels tend to exhibit seasonal fluctuations that parallel those in ambient relative humidity, additional factors – including human activities and heating, ventilation and air conditioning practices – can influence indoor air humidity levels.[46, 47] In the studied facilities, the highest average concentrations were detected in Brazil and in some humid regions in the US (e.g., Florida, Texas, Alabama, North Carolina, and Virginia).[16, 22, 23, 29] In contrast, very low dust mite allergen levels have been found in colder and drier climates (e.g., Scandinavia).[6, 21, 24-26, 29] Levels of Der p 1 were often higher in more humid regions.[16, 22, 34] Although concentrations of Der f 1 and Der p 1 tend to be correlated, they can reflect biological and ecological differences between the two mite species. Furthermore, presence of other mite species may also influence concentrations of Der p 1 and Der f1.[12, 46]

As in residential environments, dust mite allergen levels in daycare centers and schools tend to be significantly higher in carpeted areas.[7, 14-16, 18, 34] Although this is a consistent finding throughout all geographic regions, highest levels are often detected in humid climates. For example, high average concentrations (GM= 7.0 μg/g) in carpeting were reported in rural schools in North Carolina.[23] Furthermore, study sites where dust mite allergen concentrations exceeded a provisional threshold level representing increased risk of sensitization (>2 μg/g) were typically located in humid regions.[48] In Florida, for example, dust mite allergen levels were >2 μg/g in 40% of the studied daycare centers,[22] and in Texas, Der p 1 concentrations exceeded the threshold in all types of schoolrooms, particularly in libraries (68%).[16] However, none of the median or mean concentrations exceeded a threshold (> 10 μg/g) that has been associated with asthma symptoms.[49] In addition to carpeting, upholstered furnishings (e.g., mattresses, pillows, seats, stuffed animals and toys) can also be important reservoirs for dust mite allergens, particularly in daycares and elementary schools.[7, 11, 16] Although dust mite allergens can be transferred passively between environments,[42] it is not known whether the amounts of passively transferred allergen are clinically relevant.

Given that dust mite allergens are primarily associated with larger-size particles that settle rapidly, few studies have examined airborne dust mite allergen levels in daycare or school environments. A recent study demonstrated that airborne mite allergens were present in the majority of the studied daycare centers (80%) where Group 1 mite allergen levels in dust exceeded the clinically relevant threshold (>2 ug/g).[22] Airborne dust mite allergen levels were significantly lower during the night time, suggesting that mite allergens can become airborne because of reservoir disturbance during daily activities in daycare settings. Highest airborne levels were recorded in the daycare center with highest mite allergen level in the carpet (21.8 μg/g).

In summary, dust mite allergen levels in schools and daycare centers are associated with climatic, geographic, and building related factors. Carpeting and upholstered furnishings are important reservoirs and sources of exposure in schools and daycare centers, particularly in humid regions.

Exposure to cockroach and rodent allergens—Most studies that have examined levels of cockroach (Bla g 1, Bla g 2) and rodent (MUP) allergens in schools and daycare centers have been conducted in the US (Tables E4-E5). Cockroach and mouse allergens are commonly detected in schools that serve low-income and inner-city populations, as well as in rural schools.[16, 18, 20, 23, 28, 30, 31, 34, 35] A recent study found detectable levels of cockroach allergen in 71% of the dust samples.[20] In another study, mouse allergen was found in 100% of the samples.[28] Cockroach and mouse allergens have also been present in airborne samples, although the detection frequency has been much lower than in dust samples (21% for Bla g 2; 5% for MUP).[20]

Allergen levels show great variability between and within schools.[18, 20, 35] For example, geometric mean concentrations for mouse allergen varied from 0.21 μg/g to 133 μg/g in a recent study.[20] Although elevated cockroach allergen levels (> 2 U/g) have been found in many schools,[16, 30, 31] low allergen levels are not uncommon in inner-cities.[35] Elevated cockroach allergen levels have also been reported in rural schools in the US and some other countries.[4, 11, 12, 23] However, all median or mean concentrations of cockroach allergen were lower than a threshold of 8 U/g, which has been associated with asthma exacerbation.[50] Some studies have suggested that exposure to cockroach and mouse allergens in schools and daycare centers may be similar to what occurs in homes.[20, 22, 31] On the other hand, a recent study demonstrated that exposure to mouse allergen can be significantly higher in schools than in homes.[35]

Highest levels of cockroach and mouse allergens are often found in cafeterias, kitchens, or rooms where food sources are present.[18, 31, 35] In an inner-city school kitchen, cockroach allergen concentration was reported to be as high as 591 U/g;[31] correspondingly, the highest mouse allergen concentration was found in a school cafeteria (238 μg/g)[35] Visual evidence of cockroach and rodent infestations in schools is another factor that is strongly associated with cockroach and mouse allergen levels.[20, 31] Therefore, indirect exposure to cockroach and rodent allergens in school environments is thought to be less likely.[31, 35] It is important to note, however, that detectable levels of these allergens can be found without visual evidence of infestations.[20] In contrast to pet and dust mite allergens, cockroach and mouse allergen levels have often been higher in non-carpeted areas.[18, 20, 35] Nonetheless, high allergen levels have also been reported in carpeting in rural schools.[23] It is unknown whether this reflects preferences in floor covering choices in different locations; carpeting appears to be uncommon in inner-city schools.[20, 35] Studies have shown that cockroach and mouse allergen levels may also vary by season and region.[16, 20, 30]

In summary, recent studies suggest that schools may be important sites for exposure to cockroach and mouse allergens, particularly in locations where roach and rodent infestations are common. However, information on the relative importance of cockroach and mouse allergen exposures in schools and daycares is limited.

Exposure to fungal allergens—Several molds produce allergens that can be risk factors for allergic disease, including asthma.[51] However, a major limitation in assessing exposure to fungal allergens has been the difficulties in the accurate quantification of the exposure. Exposure to fungal allergens has usually been estimated by indirect methods, considering spores as indicators of the presence of allergens.[51] Nonetheless, spore counts may not accurately reflect allergen exposure because allergen content in spores may vary and fungal allergens can be carried by means other than intact spores (e.g. hyphal fragments).[52] Since availability of fungal immunoassays has been limited, only few studies have assessed antigenic and allergenic components of fungi with immunoassays. One study that examined indoor allergen levels in daycare facilities in the US detected *Alternaria alternata* in 100% of dust samples,[19] whereas in another study in Singapore, Asp f 1 was detected only in 15.4% of the samples.[15]

In summary, the complexity of the fungal exposure assessment, and lack of clearly defined threshold levels for fungi and substances derived from fungi (e.g., allergens) has limited studies of fungal allergen exposures in daycares and school settings.

Indoor Alleregen Exposures in Daycare and School Environments in Relation to Allergy and Asthma

Indoor air quality in schools and daycare environments can affect millions of people including students and staff. In the US, more than 50 million children are enrolled in public and private schools, and more than half of the children ages 3–5 have attended center-based childcare programs over the past decade.[53] Asthma and allergies are important public health concerns, not only in terms of health care costs but also in terms of lost productivity and reduced quality of life. For example, asthma and allergies account for more than 16 million missed school days per year in the US.[54, 55] Among school-aged children, asthma is the leading cause for absenteeism and can influence a child's academic performance and ability to participate in school related activities.[56] Importantly, the burden of asthma in schools extends beyond children; a recent report suggests that asthma within the educational services industry is an occupational health problem, particularly among teachers and teacher's aids.[57]

Although people tend to spend the majority of their time at home,[58] allergen exposures can be encountered in environments other than the home. Schools and daycare centers, where children and teachers spend a large part of their time, may be important sites for indoor allergen exposures. Especially for younger children, the timing of exposure can be critical because IgE-mediated sensitivity to specific aeroallergens develops in early childhood.[59] In daycare and elementary school classrooms, which often have a variety of potential allergen reservoirs (e.g., upholstered furniture, pillows, stuffed animals and toys), exposure levels may be higher than in middle and high school classrooms.[16, 26] Moreover, the disturbance of allergen reservoirs is more likely because children at younger ages are more physically active.

Remarkably few studies to date have evaluated the relationship between asthma and allergy related outcomes and indoor allergen exposures in school and daycare environments. Most studies that assessed allergen exposures in these environments were primarily designed to determine exposure characteristics. Although some studies reported prevalence rates for atopic outcomes, few studies used multivariate analysis to investigate relationships between health outcomes and exposures. Only a small number of the reviewed studies assessed allergen levels simultaneously in school and home environments (Tables E1-E5).

In schools and daycares where occupant density is high, the magnitude of indirect exposure to pet allergens may be sufficient to induce or maintain symptoms. Indeed, several Swedish studies have suggested that indirect exposure to cat and dog allergens in schools may influence asthma morbidity.[25, 60, 61] In a recent study, asthmatic children who had diagnosed cat allergy, but did not report any direct contact with pets, were evaluated after they returned to school following summer break. Those children who attended classes where more than 18% of the students owned cat(s) reported significantly decreased peak expiratory flow rates, more asthma symptom days, and increased use of asthma medication than children who attended classes with fewer cat owners ($\leq$ 18%).[60] Another study demonstrated that asthmatic children with cat and dog sensitivity had significantly increased bronchial reactivity to inhaled methacholine after one school week.[61] In this study, concentrations of cat and dog allergens were found higher in school dust than in dust collected from children's homes, suggesting greater exposure in school than in home. Among Swedish schoolchildren, cat allergen levels in dust samples have also been associated with the incidence of asthma diagnosis.[32] Recently, a German study examined whether exposure to cat allergen in the school environment was associated with allergic sensitization rates.[62] Among school-aged children who did not have regular contact with cats, cat-specific sensitization rates increased with in a dose-response fashion, depending on the percentages of students in class or school reporting regular contact with cats.

In the US, only one study has examined asthma prevalence in relation to the presence of common indoor allergens in the school environment. This study found a positive correlation between asthma prevalence rates and levels of cockroach allergen in schools.[18]

Over the past decades, numerous studies have reported positive associations between respiratory morbidity (e.g., asthma) and exposure to fungi in indoor environments,[63, 64] including schools and daycare centers.[65-68] However, the underlying mechanisms for the observed health effects are not well characterized. Although fungal allergens can induce IgE-mediated hypersensitivity, [69] exposure to fungi may also induce non-IgE-mediated inflammatory and immunological processes; particulates derived from fungi not only contain allergens but also contain a variety of biologically active molecules (e.g., β-1,3-glucans).[3, 70] It has also been suggested that fungal exposure may promote adjuvant effects on allergic immune responses.[71]

In summary, although published studies demonstrate the importance of the school environment, the relationship between allergic respiratory diseases and indoor allergen exposures in schools and daycares is not well characterized. Although studies suggest that exposure to pet allergens in schools may influence asthma morbidity, studies provide limited information on whether exposures to indoor allergens in schools and daycares contribute to the development of allergic sensitization and asthma.

Environmental Control, Remediation and Interventions in School Environments

Most studies designed to evaluate methods for reducing indoor allergen exposures in schools and daycare facilities have been conducted in Sweden and have primarily focused on reducing cat and dog allergen exposures. Swedish researchers found that cat allergen levels were significantly reduced in classrooms that required the use of special school clothing compared to control classrooms.[38] Intervention measures, however, were rigorous; children with and without pets changed clothes separately, school clothes were worn and laundered only at the school, staff changed their clothes before entering the classroom, a separate entrance was used for allergic children and no other children were allowed in the area of the school where the special school clothing classrooms were located. The study also showed that similar reductions in cat allergen levels were achieved by implementing a pet ownership ban, where parents agreed not to keep furred pets or birds at home.

Another intervention study examined whether increased cleaning and reduction of potential reservoirs were efficient measures to reduce cat allergen levels in classrooms.[72] In the intervention classrooms, open shelves, upholstery, carpets, curtains and plants were removed and cleaning was increased. Children were asked to avoid contact with pets in the mornings before school. The intervention classrooms were compared to control classrooms and to allergy-prevention classrooms that had been established prior to the start of the study. The allergy-prevention classrooms, which were located in a separate school building, had implemented extensive allergen avoidance measures for several years. No differences in cat allergen levels were found in the intervention classrooms before and after the intervention. The allergy-prevention classrooms had a trend toward lower levels of cat allergen than both the intervention and control classrooms.

An earlier Swedish study also evaluated whether extensive renovation, installation of a new ventilation system, ventilated floors, cleaning habits, and pet-avoidance measures (i.e., families and personnel avoided direct and indirect contacts with pets) influence cat and dog allergen levels.[73] The intervention measures reduced cat and dog allergen levels substantially (6-fold reduction for Fel d 1; 10-fold reduction for Can f 1) in a daycare facility.

In Australia, a “low-allergen” school was designed in order to reduce exposure to dust and hazardous chemicals.[74] In the “low-allergen” school, several measures were implemented. These included reducing potential dust reservoirs, improving ventilation, introducing materials with lower emissions of VOCs and dust particles, and using central vacuuming and radiant heating systems. To evaluate the effectiveness of this intervention, allergen concentrations and other environmental endpoints were measured in the “low-allergen” school and three other schools. The levels of dust mite and cat allergens tended to be lower in the “low-allergen school”, but differences between schools did not reach statistical significance.

One US study investigated the effectiveness of measures to reduce cockroach allergen levels.[75] In an urban dormitory, which was chronically infested with cockroaches, successful abatement was accomplished by using routine extermination and vacuuming.

A number of interventions have been conducted to reduce exposure to molds and moisture in schools and daycare facilities. Most of the studies have been conducted in Nordic countries.[76-80] Renovations and repairs of moisture damaged classrooms and buildings were found to be effective at reducing mold exposure in schools and daycare facilities and were associated with improvement in building occupants' symptoms. Improvements in ventilation (e.g., increased air-exchange rates) may also affect relative humidity and concentrations of airborne viable molds. In a recent study, new ventilation systems improved indoor air quality and reduced asthma symptoms among students in intervened schools.[81] In the US, a small pilot study that combined dehumidification with HEPA filtration reported reductions in airborne fungal spore counts.[82] Due to the increased concern about indoor mold exposures in school and home environments, a variety of programs and guidelines have been launched over the past decades. For example, in the US, the US Environmental Protection Agency has provided guidance and tools for schools in addressing mold and remediation related issues.[83]

In summary, multifaceted approaches may be needed to lower indoor allergen levels in school and daycare settings. Combined allergen-avoidance measures – such as improving ventilation systems, controlling excess moisture, reducing potential dust reservoirs, regular and thorough cleaning and maintenance, pest control, and use of special school clothing – may help to decrease exposure to indoor allergens in school and daycare environments. However, there is limited information on how to choose and implement the most cost-effective intervention approach and the extent to which reductions in allergen exposures in these environments influence allergy and asthma related morbidity.

Summary and Conclusions

We have summarized the key findings of the review in Table I. Exposure to indoor allergens in school and daycare environments is common. However, published data show that levels of allergens are highly variable. Allergen levels can vary by time, location, and type of room within the building. This is not surprising because variety of physical (e.g., humidity, temperature), structural (e.g., age and type of building/room/surface), and behavioral factors (e.g., pet ownership among children and staff, cleaning and maintenance practices) can influence indoor allergen levels. The relative importance of different allergens can vary in different parts of the world depending on a variety of geographical, climatic, and cultural factors. Allergen levels in schools and daycare facilities are often lower than levels that have been reported in homes. Nonetheless, it is not unusual that allergen levels in these settings exceed thresholds those that have been associated with allergic sensitization and asthma morbidity. It has also been demonstrated that allergen levels in schools can be significantly higher than in the home environment. Carpeting, upholstered furnishings, and clothing are important reservoirs for allergens, particularly for pet and dust mite allergens. Because allergens are also transported passively to school and daycare environments, exposure to allergens can occur either directly or indirectly. Schools and daycare facilities may be important sources of allergen exposures, but there is limited data available to evaluate to what extent these exposures contribute to allergic sensitization and exacerbation of allergic symptoms. Information on cost-effective intervention strategies is also limited; in published studies the effectiveness of the interventions varied substantially.

Research Needs and Recommendations

Over the past two decades, a considerable amount of research has been conducted on indoor allergen exposures in school and daycare environments. While several guidelines have been developed and a variety of programs have been initiated to sustain asthma and allergy-friendly schools in the US and abroad,[84-86] further research is warranted. Studies are needed to assess the extent to which school and daycare environments contribute to allergic sensitization and asthma morbidity. Published data provide limited information on potential additive effects of school or daycare exposures in relation to allergy and asthma outcomes. For instance, few studies have collected information on health outcomes and exposure levels in schools/daycares and homes simultaneously; further studies addressing this issue are needed. Although schools and daycare environments may not be primary sites for exposure and/or sensitization to the dominant local allergen(s), it is essential to establish cost-effective approaches to reduce allergen levels in these indoor environments. Allergen exposures in school and daycare settings may compromise the effectiveness of allergen avoidance measures employed at home. From a public health perspective, it would be important examine the extent to which various interventions are able to influence exposure levels and building occupants', children's and staff members', allergy and asthma related morbidity. Economic analysis would help to evaluate the cost-effectiveness and clinical benefits of future interventions.

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Abbreviations

Asp f 1
: *Aspergillus fumigatus 1* (Fungal allergen)

Bla g 1
: *Blattella germanica 1* (Roach allergen)

Bla g 2
: *Blattella germanica 2* (Roach allergen)

Can f 1
: *Canis familiaris 1* (Dog allergen)

Der f 1
: *Dermatophagoides farinae 1* (Dust mite allergen)

Der p 1
: *Dermatophagoides pteronyssinus* (Dust mite allergen)

Fel d 1
: *Felis domesticus 1* (Cat allergen)

MUP
: Mouse urinary protein (Mouse allergen)

Mus m 1
: Mus musculus 1 (Mouse allergen)

VOC
: volatile organic compound

TABLE I

Summary of the key findings

Exposure to indoor allergens in daycare and school environments

- Exposure to indoor allergens is common in daycares and schools.
- Allergen levels can vary by time, location, and type of room within the building.
- The relative importance of different allergens can vary in different parts of the world depending on a variety of geographic, climatic, and cultural factors.
- Schools and daycare facilities may be important sites of allergen exposures. Studies have demonstrated that allergen levels in these environments can sometimes be significantly higher than in the home environment.
- Carpeting, upholstered furnishings, and clothing are important reservoirs for allergens.
- Exposure to allergens can occur directly or indirectly. For example, clothing is the primary transfer mechanism and source of exposure for pet allergens.

Indoor allergen exposures in relation to allergy and asthma

- The relationship between allergic respiratory diseases and indoor allergen exposures in schools and daycares is not well characterized.
- Exposure to pet allergens in schools may influence asthma morbidity.
- Published data provide limited information on whether exposures to indoor allergens in schools and daycares contribute to the development of allergic sensitization and asthma.

Environmental control, remediation and interventions

- Multifaceted approaches may be needed to lower indoor allergen levels in schools and daycare facilities.
- Information on cost-effective intervention strategies is limited.
- Little is known about the extent to which reductions in allergen exposures in these environments influence allergy and asthma morbidity.