
Environmental allergens and asthma in urban elementary schools

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Background: Asthma in school children is rising, and indoor allergens are very common triggers of asthma attacks; however, the risk of the school environment on asthma has not been well studied.

Objective: To determine the presence and the levels of common aeroallergens in schools, where asthma prevalence rates are high.

Methods: Settled dust samples were collected from 12 Baltimore City public elementary schools, and they were analyzed for the following allergens: cockroaches (Bla g 1/2), dust mites (Der f 1/p 1), dog (Can f 1), cat (Fel d 1), and mouse (Mus m 1). School asthma prevalence rates were correlated with allergen levels, and association between allergen levels and other risk factors present in the schools' environment was examined.

Results: The mean and range levels were 1.49 U/g (0 to 8) for Bla g 1/2; 0.38 µg/g (0 to 11.9) for the Der f 1/p 1; 1.44 µg/g (0.1 to 9.6) for Can f 1; 1.66 µg/g (0.2 to 12) for Fel d 1; and 6.24 µg/g (0.3 to 118.3) for Mus m 1. Dust mite, cat and dog allergens were significantly in rooms with carpet and/or area rugs, compared to rooms with bare floors ($P < 0.05$). Asthma prevalence rates varied from 11.8 to 20.8% between schools and positively correlation with the mean levels of Bla g 1/2 in the schools ($P = 0.001$).

Conclusions: Common allergens that are known to trigger asthma were detected in all school environments, where asthma prevalence rates were high. However, the overall allergen levels were low, indicating that other factors, including exposures in the homes of asthmatic patients, may have more relevance to sensitization and symptoms than school exposures.

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INTRODUCTION

Asthma is a chronic disease that affects more than 14 million people of all ages and races.^{1–3} The percentage of children with asthma is rising,^{3,4} and those living in the inner city are disproportionately affected by asthma with prevalence rates as high as 20% versus the national average of less than 8%.^{4–6} Asthma is the leading cause of school absenteeism attributable to a chronic illness; children with asthma have three times the number of school absences than children without asthma.^{7–9}

Allergies are very common triggers of asthma, especially in children.^{10,11} Studies have shown that at least 80% of asthmatic children will have a positive skin test to at least one

allergen.¹² Both indoor and outdoor allergens can trigger asthma, but indoor allergens can be particularly problematic, as children are exposed to these allergens from birth and they can become sensitized and symptomatic at a very young age.^{11,13,14} In addition, most Americans are spending more time indoors, making exposure to the indoor allergens even more of an issue. Numerous researchers have studied home allergen levels, and indoor allergens such as cockroaches, house-dust mites, mold, cat, dog, and mouse allergens have all been implicated in the sensitization of asthmatic patients and associated with exacerbations of asthma.^{13,15–20} Because schoolaged children spend at least 1,100 hours in the classroom per year, exposure to allergens in the school setting could also play a role in sensitization and symptoms.

The purpose of this study was to identify the presence of environmental allergens in urban elementary schools and to correlate the presence of those allergens with the asthma prevalence rates in the children attending those schools.

METHODS

Twelve Baltimore City elementary schools (kindergarten to fifth grade) were selected for study. They are all located on the west side of the city. Permission from the schools' Chief Executive Officer was obtained to conduct the present study.

The first visit involved a gross inspection of each school. It was conducted in the early fall of 2000. The indoor environ-

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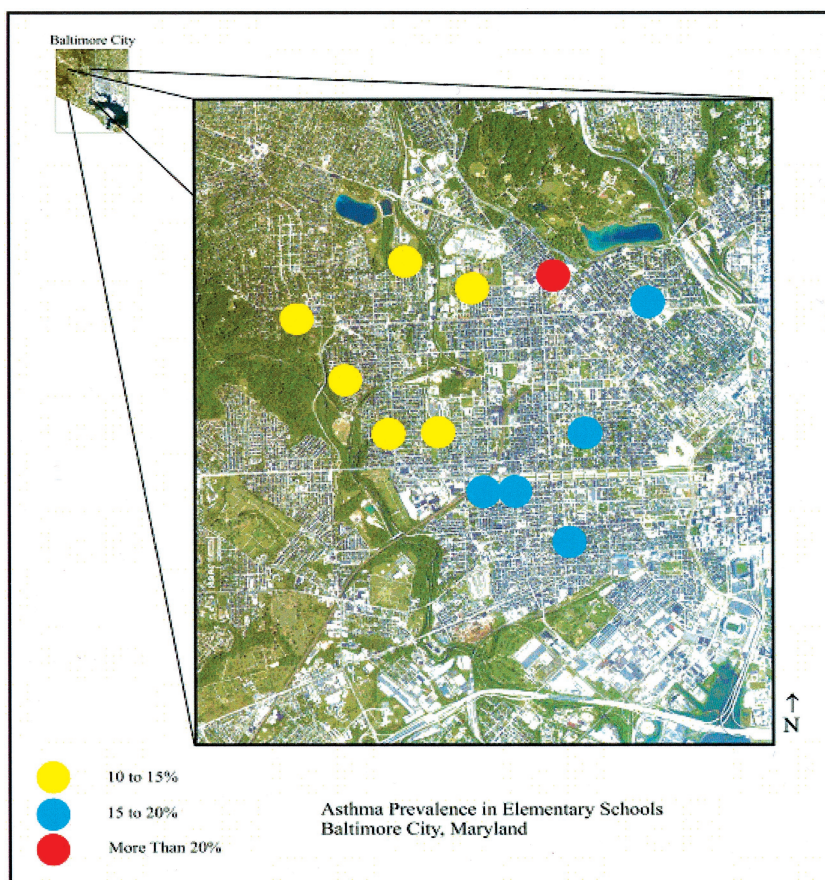


Figure 1. Map of the Baltimore City elementary schools.

ment was evaluated, including the integrity of the building and the status of its components (moldy structures, stained ceiling tiles), the equipment (presence of central heat ventilation and air conditioning [HVAC]) or other type of ventilation), and the furnishings (presence of carpet and/or area rugs). Demographic information with regard to the number of students enrolled in the school and the average daily attendance were obtained.

The second visit to the schools was conducted between December 2000 and February 2001, a time when the heat was turned on. Settled dust samples were collected from 10 sites within each school. Dust samples were collected from the principal's office, cafeteria, teacher's lounge, gym, library, and one classroom from each of the five grade levels that include kindergarten, and grades 2 to 5. All specimens were assigned a unique identifier and were assayed by the Johns Hopkins University Dermatology, Allergy, and Clinical Immunology reference laboratory.

Dust specimens were collected using disposable filters, as previously described.^{21,22} Briefly, the Dermatology, Allergy, and Clinical Immunology filter bag is manufactured using Dupont's Hysurf material (Dupont, Wilmington, DE), which has undergone extensive testing and quality control by the

manufacturer. Its retention efficiency is 97% for particles of 1.1 μm or greater, the sizes of all the known indoor allergens.

A residential canister-type vacuum cleaner was used for all the collections. The dust filter bags were attached to the end of the vacuum cleaner hose, and held with a small nozzle. They trapped the dust before it entered the vacuum bag. The nozzle was thoroughly cleaned with Clorox (The Clorox Company, Oakland, CA) and dried between samples. Each site within each school was vacuumed for 1 to 2 minutes. This involved vacuuming the perimeter of each room and: the area around the desk in the principal's office; the area in front of the vending machines in the teacher's lounge; all accessible corners and a central area in the library; the perimeter of the gym; the area under the counter for the food line and two adjacent corners to the food line in the cafeteria; and the accessible perimeters and the area around the teacher's desk in each of the classrooms. If less than three accessible walls were available, a floor area around the students' chairs was also vacuumed. In furnished sites, vacuuming involved primarily the carpet and/or the rug.

The dust specimen was removed from the filter bag and inserted into a 50-mesh sieve where 300- μm and smaller particles pass. The allergenic protein content of the sieved

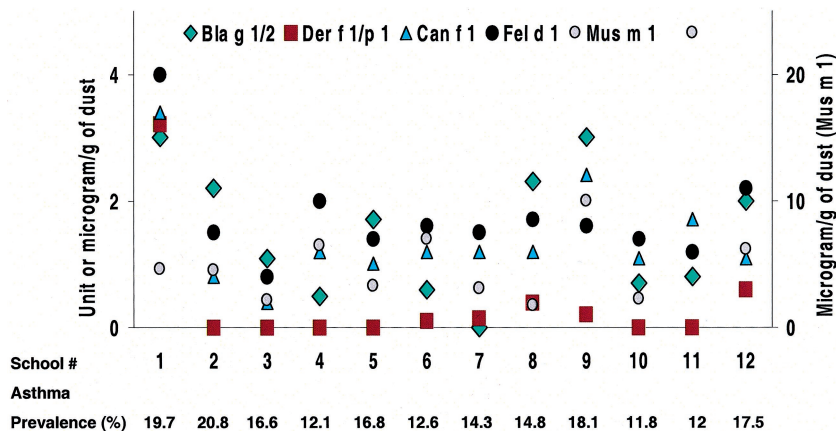


Figure 2. Mean levels of various allergens measured in 10 locations within each of the 12 schools; expressed in unit for Bla g 1/2 or μg for others.

specimen was extracted by adding 100 mg of the sieved dust to 2 mL borate buffered saline (1:20 wt/vol) and the specimen was rotated over 16 to 18 hours at room temperature. Extracts were then centrifuged, sterile filtered, and frozen until the day of the assay.²³

Standard two-site monoclonal antibody-based enzyme immunoassays²⁴ were used to quantify the levels of Bla g 1 & 2 (*Blattella germanica* group 1 and 2 allergens), Der f 1 (*Dermatophagoides farinae* group 1 allergen), Der p 1 (*Dermatophagoides pteronyssinus* group 1 allergen), Fel d 1 (*Felis domesticus* group 1 allergen), Can f 1 (*Canis familiaris* group 1 allergen), and Mus m 1 (*Mus musculus* group 1 allergen), using reagents from Indoor Biotechnologies (Charlottesville, VA). The lower limits of detection were 0.4 Units per gram (U/g) of dust for Bla g 1, 1.0 U/g of dust for Bla g 2, and 20 nanograms per gram (0.02 $\mu\text{g/g}$) of dust for Der f 1, Der p 1, Fel d 1, and Can f 1.

For reporting purposes, any allergen level that was below the assay's detection limit was reported as zero. Der p 1 and Der f 1 levels were summed and reported as total dust mite allergen content (Der f 1/p 1), and Bla g 1 and 2 were summed and reported as total cockroach allergen content (Bla g 1/2). Allergen levels were expressed as $\mu\text{g/g}$ of dust except for Bla g 1/2, which was expressed in U/g of dust.

The prevalence rates of asthma for each school were provided by the Baltimore City Health Department. Briefly, health care professional volunteers visited each school and reviewed health cards that were completed by the caregivers and calculated the number of children with reported asthma versus the total number of health cards completed. Prevalence rates were calculated for each of the 12 schools, based on the student population who attended the specific school. Prevalence rates for each grade were calculated based on the number of students in that specific grade, and mean rates were calculated for the 12 schools.

Statistical Analysis

SAS software (SAS, Cary, NC), version 8.2, was used to analyze the data. Pearson correlation and linear regression

were used to examine the association between different variables. The significance level was set at 5%.

RESULTS

All 12 schools were located in downtown Baltimore City, in a close geographical area on the west side, within three contiguous zip codes (Fig 1). The number of students enrolled in each school varied from 300 to 580, and the average daily attendance reported by the principals was between 87 and 95%. The schools were built between 1957 and 1980. The mean age of the buildings was 35 years. Only four schools had central HVAC and pulsed hot air for heat; the rest of the schools were heated with hot water radiators. Three of the schools with HVAC were built in the late 1970s and early 1980s; 1 was built in the late 1960s.

Of the 120 dust specimens collected, 1 had quantity not sufficient to measure any of the allergens, and another specimen was analyzed for all of the allergens except Bla g 1.

In all 12 schools, allergens were detected in the settled dust. Cockroach allergens were detected in 66%, and dust mite allergens in 48% of the 120 dust specimens collected. The means and ranges of these allergen levels were 1.49 U/g (0 to 8) for Bla g 1/2; 0.38 $\mu\text{g/g}$ (0 to 11.9) for Der f 1/p 1; 1.44 $\mu\text{g/g}$ (0.1 to 9.6) for Can f 1; 1.66 $\mu\text{g/g}$ (0.2 to 12) for Fel d 1; and 6.24 $\mu\text{g/g}$ (0.3 to 118.3) for Mus m 1.

The mean levels of various allergens, measured in 10 different locations within each school, are depicted in Figure 2. They varied between schools; the highest levels of Bla g 1/2, Fel d 1, Can f 1, and Der f 1/p 1 were found in school 1. Der f 1/p 1 levels were low, or not detectable, in all but school 1, whereas Fel d 1 mean levels were $>1 \mu\text{g/g}$ of dust in all but 1 school.

When levels of the allergens measured in different locations were compared, the highest mean levels of Bla g 1/2 were found in the teachers' lounges, the cafeterias, the second grades and the kindergartens classrooms (2.2, 1.9, 1.9, and 1.8 U/g of dust, respectively), and the lowest levels were in the gyms (the mean level was zero), whereas the highest

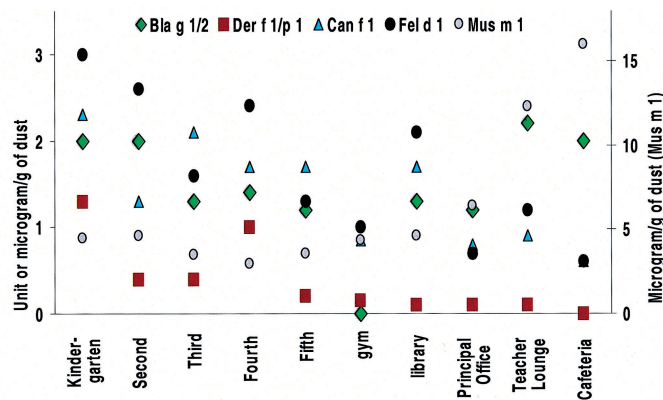


Figure 3. Mean levels of various allergens measured in specific locations of 12 schools; expressed in unit for Bla g 1/2 or μg for others.

Asthma

Prevalence (%) 14.6 14.7 15.4 18.8 13.8

mean levels of Mus m 1 levels were found in the cafeterias and the teachers' lounges (Fig 3).

The effects of carpet and/or rugs versus bare floor on the levels of different allergens were evaluated using regression analysis. We found that the concentrations of dust mites, cat, and dog allergens were significantly higher when carpet or rugs were present ($P < 0.05$; Table 1). Conversely, the mean levels of mouse allergen were significantly higher in those rooms without carpet (Table 1). The existence of HVAC in the school contributed to significantly higher levels of cat (Fel d 1) and dust mite (Der f 1/p 1) allergens (Table 2). The schools with HVAC were 1, 7, 8, and 12, where these allergens were detected clearly and readily.

Correlation analysis indicated no association between the mean levels of various allergens in different schools and the number of students enrolled in these schools.

The prevalence rates of asthma in children attending these schools varied from 11.8 to 20.8% (Fig 2; mean = 15.6%). The mean prevalence rates in different grades varied from 13.8 to 18.8% (Fig 3). There was a significant positive correlation between asthma prevalence rates in each school and the mean levels of Bla g 1/2 within the school ($r = 0.81$, $P = 0.001$), as well as the mean levels of Bla g 1/2 in different grades within the same school ($r = 0.71$, $P = 0.008$; Table 3). The asthma prevalence rates in different grades did not correlate with the mean allergen levels measured in each grade

DISCUSSION

In the present study, we found that Baltimore city elementary public schools, where the prevalence rate of asthma was 15.6%, contained common environmental allergens that are known to trigger asthma. The levels were detectable in the settled dust. The concentrations of dust mites, cat, and dog allergens were significantly higher in rooms with carpet and/or area rugs, compared with rooms with bare floors. There was a significant positive correlation between asthma prevalence rates and the mean levels of cockroach allergens in these schools.

Dust mites, cat, and cockroaches have been identified as common allergic triggers of asthma.^{25,26} These environmental allergens have been found in settled dust collected from schools, hospitals, and homes in the United States and elsewhere.²⁷⁻³³ Compared with the previously reported levels, we found allergen levels that are comparable if not lower. For example, the levels for Fel d 1 were reported to vary up to 185 $\mu\text{g/g}$ of dust in schools,^{31,32} and up to 920 $\mu\text{g/g}$ of dust, in homes.^{12,31,32} In our study the highest level measured was 12 $\mu\text{g/g}$. The levels for Bla g 2, detected in the classrooms, were reported to be as high as 0.56 $\mu\text{g/g}$ (14 U/g),^{31,32} whereas, in our study, the highest level for Bla g 1/2 was 8 U/g. Further, of the 60 samples we collected from the classrooms, we found only 15 (25%) with level above 2 U/g. In a previous study, as many as 65% of the classroom samples were found to have levels above 2 U/g.²⁶

Table 1. Regression Analyses of the Levels of Different Allergens on the Presence of Carpet and/or Rug

Allergen	Intercept	Estimate*	Standard error	P value	R ²
Bla g 1/2	1.32	0.29	0.33	0.38	0.006
Der f 1/p 1	0.07	0.55	0.27	0.04	0.03
Can f 1	0.97	0.81	0.28	0.004	0.06
Fel d 1	0.94	1.26	0.27	<0.0001	0.15
Mus m 1	9.4	-5.4	2.3	0.02†	0.04

* U/g of dust for Bla g 1/2, and $\mu\text{g/g}$ of dust for the other allergens.

† Indicates reverse association.

Table 2. Regression Analyses of the Levels of Cat (Fel d 1) and Dust Mites (Der f 1/p 1) Allergens on the Presence of Carpet and/or Rug and HVAC

Allergen	Intercept	Variable	Estimate*	Standard error	P value	R ²
Der f 1/p 1	−0.12	Carpet/rug	0.34	0.26	0.20	0.12
		HVAC	0.94	0.28	0.001	
Fel d 1	0.82	Carpet/rug	1.14	0.27	<0.0001	0.18
		HVAC	0.57	0.29	0.05	

* $\mu\text{g/g}$ of dust.

Table 3. Pearson Correlation Coefficients and P Value between Asthma Prevalence Rates in 12 Schools and the Mean Levels of Different Allergens in the Schools or in the Classrooms

	Bla g 1/2	Der f 1/p1	Can f 1	Fel d 1	Mus m 1
In the schools	0.81 (0.001)	0.44 (0.14)	0.26 (0.41)	0.40 (0.18)	−0.27 (0.38)
In the classrooms	0.72 (0.008)	0.44 (0.14)	0.31 (0.32)	0.50 (0.09)	0.44 (0.14)

Although, many groups^{12,18,31} believe that higher allergen levels are required to cause symptoms, others^{34,35} have suggested that lower allergen levels are capable of causing symptoms in some children, particularly if exposure occurs over prolonged periods of time. The low levels that we found for Fel d 1, for example, are in the range of levels found in homes without cats, which may still be capable of causing symptoms and sensitization.³⁶

Exposure to $>2\text{-}\mu\text{g}$ group 1 dust mite allergen (or 100 mites) per gram of dust increases the risk of children developing asthma.¹⁸ We found that the mean level of Der f 1/p 1 was $0.38\text{ }\mu\text{g/g}$ for the 12 schools, and 52% of the samples we collected had undetectable or very low levels for dust mite. These results could be attributed to the fact that dust specimens were collected in the winter, when the school heat was on and the humidity low, and dust mites are known to multiply in hot and humid environment. Although we did not monitor the temperature and degree of humidity, the subjective evaluation of the indoor environment of all the schools visited, without exception, was hot and dry.

Considering that these allergen levels are low, compared with levels found in inner-city homes and previously reported by Eggleston et al²⁵ and others,^{12,33} it is possible that the homes of these children contribute more than the schools to the development of sensitization and symptoms.

Dust mite, cat, and dog allergens were found in Baltimore homes.³⁷ Further, our detection of dog and cat allergens in an environment where the animals are not present is consistent with other investigator reports about their ubiquity.^{26,27,38} Most likely, children and staff with pets in their homes are the vectors carrying animals' hair and dander on their clothing. It also indicates how difficult it is to avoid these allergens in the schools. Indeed, earlier study has demonstrated that the task of allergen elimination from indoor environment is extremely difficult, even when the source can be identified and removed.³⁹ Carpets and/or rugs are the effective reservoirs for collecting dust⁴⁰; carpet is also an ideal environment for the reproduction of dust mites.⁴¹ The highest levels of Der f 1/p

1 was found in school 1 (Fig 2), where most of the classrooms were carpeted and in some cases even had additional rugs on top of carpeting. The significant difference in allergen levels, between dust collected from carpets and/or rugs or bare floors, suggests the need for the school system to consider regular and vigorous vacuuming, if not removing carpets, to decrease exposure to allergens from animals and dust mites. Vacuum cleaning has been found to decrease allergen levels,⁴² and reducing mite exposure can improve asthma symptoms in children.^{6,43–45} Further, the levels of allergens for dust mites and cat were higher in areas with both carpet and HVAC. We believe that periodic maintenance of the ventilation system, in addition to regular vacuuming/cleaning of the schools, would contribute greatly to reducing the levels of common allergens in the school environment. A study of school children respiratory symptoms before and after installation of a new ventilation system showed that the incidence of asthmatic symptoms was lower in pupils who attended schools in which new ventilation systems had been installed.⁴⁶

The higher cockroach and mouse allergen levels were detected in areas of the school where food is present. This validates the data collection and indicates the need for thorough cleaning and regular extermination, to help decrease exposure to these allergens.

We found a mean asthma prevalence rate of 15.6% in these Baltimore city schools, a rate that is much higher than the national average of 5 to 8%. It is possible that our estimate is biased (inflated), as the prevalence rates were based on information obtained from health cards; parents of children with disease may be more likely to complete health cards than parents of children without disease. Nonetheless, it is unlikely that this bias alone would account for a prevalence rate that is twice the national average. Further, other groups have noted that asthma impacts a significant number of inner-city children, compared with the general population; some reported as many as 20% or more of city school children are asthmatic.¹²

One of the limitations of this study is that single, not repeated, settled dust samples were collected; and airborne

levels were not obtained. The settled dust reservoir is representative of what is found in the air for these environmental allergens, although the levels in settled dust samples are not always predictive of airborne allergen levels.^{36,47} For example, it is possible to have significant airborne Fel d 1 levels in the absence of readily identifiable reservoirs.³⁶ Further, repeated measurements from each school may have yielded different results. Another limitation is the selection of the schools. Focusing on a cluster of schools located in a small geographical area minimizes the bias introduced by different outdoor environments. Similarly, the choice of elementary schools allows comparison of asthma prevalence between schools attended by children with the same age range. Finally, we collected dust from one classroom representative of a specific grade, and the prevalence rate for each grade reflected the number of children with asthma in the grade.

CONCLUSION

Despite some inherent limitations, this pilot study has merits. It shows how difficult it is to determine the extent to which asthma is related to any or all of the common allergens present in the school environment, and that the home environment, though unknown, is as important. In addition to triggering asthma attack, some home allergens can be transported to schools, indicating that the home environment should be the main focus for implementing an intervention. Keeping the school environment clean reduces allergen exposures for children at risk.

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