Cockroach allergen (Bla g 1) in school dust

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Background: Cockroach allergen, Bla g 1, is an important indoor allergen. Although household exposure has been documented, little is known about the potential for exposure outside the home.

Objective: We investigated the settled dust concentration of Bla g 1 in 147 samples collected from classrooms, kitchens, cafeterias, and other sites in four primary schools in the city of Baltimore.

Methods: School authorities were questioned about characteristics of schools, teachers, and students, as well as cockroach control and cleaning procedures. Settled dust samples were collected with a hand-held vacuum cleaner from the floors of all classrooms, food-related areas, and other sites of the schools over a 3-week period. A sample collection in each school took 1 to 2 days. Dust samples from each room were pooled and analyzed as a single sample for Bla g 1 by using a two-site monoclonal ELISA.

Results: One hundred two (69%) of the 147 samples had detectable Bla g 1 and were within the range reported by other investigators in inner city homes. There was no difference between the median levels of Bla g 1 in three schools: school 1 (5.2 U/gm), school 2 (3.0 U/gm), and school 4 (2.7 U/gm); but school 3 had a significantly lower level (<0.8 U/gm, $p < 0.001$). The median level from the food-related areas was significantly higher than the median classroom level ($p = 0.048$). School 3 had fewer students on subsidized lunch, fewer African-American students, and fewer students per teacher. Bla g 1 levels were compared in the different schools while controlling for potential confounding variables by a stepwise multiple regression analysis with a logit model for ordinal responses. On the basis of this analysis, Bla g 1 levels in schools 1, 2, and 4 differed significantly from levels in school 3 ($p < 0.001$ in each case). Food-related areas had significantly higher levels than classrooms ($p = 0.048$). Floor level, the presence of a sink, and the presence of carpeting did not have significant effects.

Conclusions: We conclude that Bla g 1 is detectable at potentially significant concentrations in some inner city schools. Furthermore, the level of exposure is different between different schools and between sites within individual schools.

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Key words: *Dust analysis, schools, cockroach allergen, African-American, urban*

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Recent increases in asthma morbidity[1-3] have been linked in part to cockroach allergen exposure in patients with atopic asthma living in urban areas.[4-8] Sixty to eighty-three percent of children with asthma are atopic. In these children environmental allergens are important stimuli for chronic airway inflammation.[9, 10] The most important indoor allergens identified by specific IgE responses are those derived from dust mites, pet danders, molds, and cockroaches.[4, 8-12] A recent multicenter study of the home environment in children with asthma living in seven major urban areas revealed that cockroach allergen, Bla g 1, was the predominant indoor allergen in the inner city.[13] Dust mite and cat allergens were found in lower concentrations than previously reported.[4, 5, 14]

Although allergen exposure in the home environment has been well characterized, relatively few studies on indoor allergen levels in public places have been reported.[15-18] It has been found that dog (Can f 1) and cat (Fel d 1) allergens are commonly present in Swedish classrooms, often at concentrations that might induce asthma in children allergic to these pets.[15] Settled dust samples from schools in Norway did not contain significant dust mite (Der p 1 and Der f 1) allergens.[16] Einarsson et al.[17] recently reported significant levels of Der f 1 and Der p 1 in dust from Swedish schools. These investigators have hypothesized that these animal and dust mite allergens may have been brought into the schools by the teachers and students from their homes.[15, 17]

Little is known about the school environment as a potential source of cockroach allergen exposure. There has been only one previous study in which cockroach allergen was measured in dust from day care centers. In that study the kitchen and other food- related areas were not examined. The concentrations of cockroach allergens in these day care centers were less than levels found in homes. In this study we examined the levels of cockroach allergen, Bla g 1, in school dust and have related these levels to various characteristics of the schools, students, and teachers.

METHODS

Schools, students, and teachers

Four urban primary schools were selected with the consent of the superintendent of the area schools and the principals of the individual schools from a list of 36 schools provided by the school system. Principals of nine schools agreed to participate, and four schools were selected for the study. School principals were asked to respond to a questionnaire regarding their school buildings, the students, and the teachers (Table I).

The manager responsible for extermination at the four

TABLE I. Characteristics of schools, students, and teachers

	School 1	School 2	School 3	School 4
Year built	1963	1972	1900*	1962
Classrooms	33	8	22	35
First floor	10	3	4	22
Second floor	11	5	11	13
Third floor	12	0	7	0
Carpet	5	7	22	11
Sink	30	0	4	32
Other rooms	11	11	16	11
Students	588	178	457	484
African-American	588	177	18	484
Other	0	1	439	0
Subsidized lunch	488	172	238	484
Teachers	22	7	25	23
African-American	17	1	2	22
Other	5	6	23	1

*Renovated in 1975.

TABLE II. Cockroach control

	School 1	School 2	School 3	School 4
Cleaning				
Vacuuming	5/wk	5/wk	5/wk	5/wk
Sweeping	5/wk	5/wk	5/wk	5/wk
Shampoo	2/yr	1/yr	1/2 yr	None
Extermination				
Bait*	Every 2 wk	Every 2 wk	Every 2 wk	Every 2 wk
Spray†	1/yr	1/yr	1/yr	1/yr
Visual evidence of infestation	Yes	Yes	Yes	Yes

*Mr Sticky, Maki Bait, or Maxforce Baitor.
†Lo-Ban Residue and Biocease.

schools was given a questionnaire about the frequency and methods of cockroach extermination. Insecticides (Lo-Ban Residual and Biocease [Certified Chemical, Dallas/Fort Worth, Texas]) were applied to the corners of the rooms and the baseboards once a year when the schools were not in session. Baits were placed every 2 weeks throughout the year in all the rooms, and monitoring was done by roach traps concurrently. The custodians responsible for cleaning each school were interviewed. The principals independently responded to a questionnaire regarding cleaning procedures.

The carpets were low pile, and carpeted areas were vacuumed on all school days. Uncarpeted areas were swept every school day. The rooms were cleaned after school hours except for the cafeteria and kitchen, which were cleaned immediately after lunch. Carpets were shampooed twice a year at school 1, once a year at school 2, once every 2 years at school 3, and not at all at school 4. The method and frequency of cockroach extermination were the same for all the schools. Bait extermination was instituted at all the schools every 2 weeks, and spraying was accomplished yearly (Table II). There was visual evidence of infestation, such as dead cockroaches, in each school, especially in the food-related areas. All the custodians also reported that they commonly saw live cockroaches in the schools, especially in the kitchen.

Dust sampling

Dust samples were collected from all 98 classrooms in the four schools and additionally from the kitchens, cafeterias, libraries, offices, teachers' lounges, gymnasiums, and hallways. Samples were collected after school hours from the four corners of each room by using a small hand-held vacuum cleaner. A 1 m^2 area at each corner was vacuumed for 1 minute.[19] The four corners of each room were vacuumed into the same filter bag, and separate filter bags were used to collect dust from each room. Each filter bag was then removed and placed in a separate plastic bag. The vacuum cleaner was cleaned thoroughly with disposable paper towels after vacuuming each room. Dust samples were obtained before routine daily cleaning (Table II) except for cafeteria and kitchen samples, which were obtained 2 to 3 hours after routine daily cleaning. Samples were collected within a week of bait extermination at the schools and were stored at –30° C until extraction.

Extraction and ELISA

Dust extracts were prepared by extracting 100 mg of sieved dust (mesh pore size, 0.3 mm) in 2 ml of borate-buffered saline containing 5% bovine serum albumin, pH 8.0, at 4° C overnight with continuous rotation. The samples were centrifuged at 2000 rpm for 10 minutes; and the supernatant was removed, sterile-filtered to remove all fine particles, and stored in plastic tubes

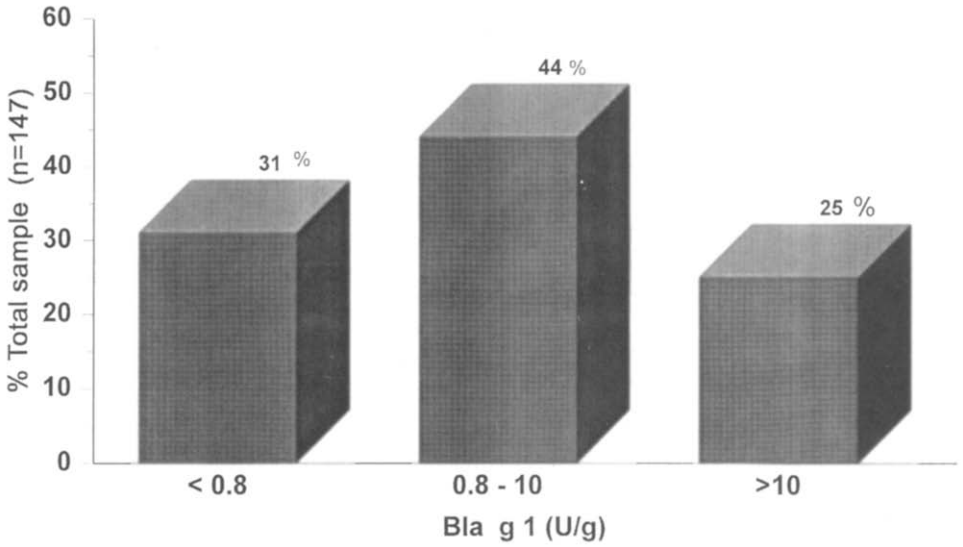

FIG. 1. Percentage distribution of Bla g 1 concentration in 147 dust samples.

at –30° C until assayed. The final extract was assayed for Bla g 1 with a quantitative, two-site monoclonal antibody–based, enzyme-linked immunoassay as previously described.[20] The lower limit of detection of the assay was 0.8 U/gm of fine sieved dust.

Statistics

Nonparametric Kruskal-Wallis and Mann-Whitney tests were used to compare the median concentrations of Bla g 1. To compare the Bla g 1 levels in the different schools while controlling for potential confounding variables (e.g., site of sample collection, floor level, and presence of sink or carpeting), we performed a stepwise multiple regression analysis by using a logit model for ordinal responses, based on a proportional odds assumption.[21] For this analysis, the antigen concentrations were coded at three levels: less than 0.8 U/gm (level 1), 0.8 to 10.0 U/gm (level 2), and more than 10 U/gm (level 3). Under the proportional odds assumption, the ratio of the odds of being at levels 2 or 3 (vs level 1) between, for instance, two different schools, is assumed to be the same as the ratio of the odds of being at level 3 (vs level 1 or 2). Predictor variables were school (no. 1, 2, 3, or 4), site (food-related, classroom, other), floor level (first, second, or third), presence of sink (yes/no), and carpeting (yes/no). Probability *(p)* values less than 0.05 were regarded as statistically significant. The analyses were performed by using SAS 6.11 for Windows 95 (SAS Institute, Cary, N.C.).

RESULTS

Three of the four schools had predominantly African-American students (99% to 100%), in contrast to school 3 in which 18 (3.9%) of the 457 students were African-American (Table I). The proportion of students on subsidized lunch varied from 52% for school 3 to 76% for school 1, 97% for school 2, and 100% for school 4. The number of students per teacher varied from 18 in school 3 to 21 in school 4, 26 in school 2, and 27 in school 1. The classrooms were scattered in the school buildings. In school 1 they were evenly spread on all three floors. Roughly a third of the classrooms in school 2 were located on the first floor, and two thirds of the classrooms were located on the second floor. The reverse was true for school 4 in which 22 (67%) of the 35 classrooms were on the first floor, and the rest were on the second floor. Eleven (50%) of the 22 classrooms in school 3 were on the second floor, four (18%) were on the first floor, and seven (32%) were on the third floor. All kitchens and cafeterias were located on the first floor. Teachers' lounges were scattered on the first, second, and third floors. Food was allowed in classrooms.

Distribution of Bla g 1

Detectable levels of Bla g 1 were found in 102 (69%) of the 147 dust samples (Fig. 1). The median concentration of the 147 samples was 2.6 U/gm of fine dust (range, 0 to 591 U/gm). The highest concentration of 591 U/gm was found in a kitchen. All of the kitchen samples and 70% of the classroom samples had detectable levels of Bla g 1.

The distribution of Bla g 1 in the dust samples in the four schools is shown in Fig. 2. The median concentration of Bla g 1 in the 44 samples from school 1 was 5.2 U/gm with levels ranging from below detection in five samples to 591 U/gm. The median Bla g 1 concentration in the 19 samples from school 2 was 3.9 U/gm with a range from below detection in two samples to 51.3 U/gm. Of the 38 samples collected from school 3, 29 (76%) had antigen levels below detection. The median level was below detection, and the highest concentration was 170 U/gm. In school 4 in which 46 samples were tested, Bla g 1 ranged from below detection in nine samples to 186 U/gm with a median of 2.7 U/gm.

The median allergen concentration in school 3 was significantly lower (Kruskal-Wallis test = 36, $p < 0.001$) than the median levels for the other three schools. The

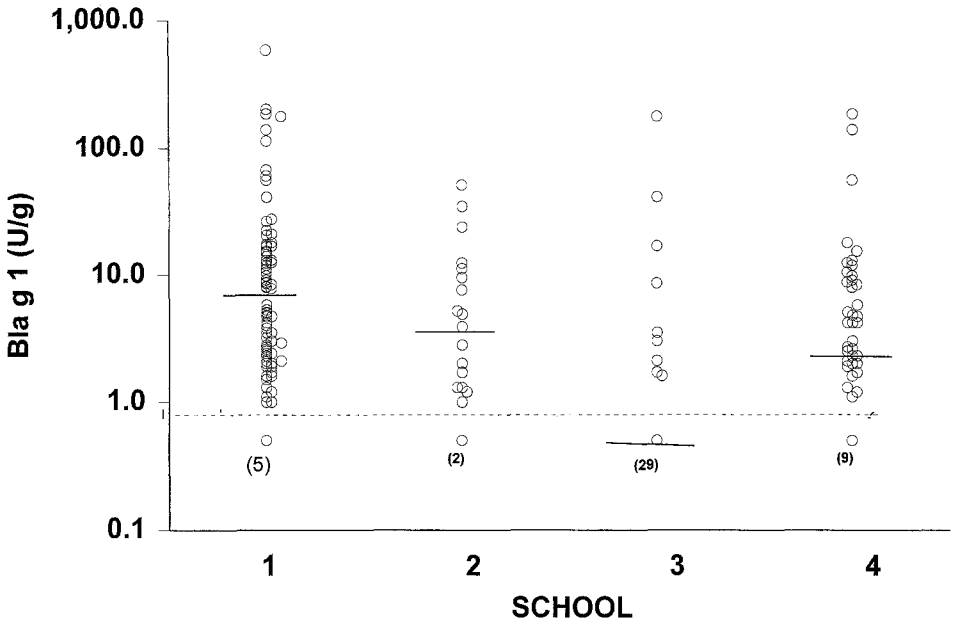

FIG. 2. Distribution of Bla g 1 in four schools. School 1, $n = 44$; school 2, $n = 19$; school 3, $n = 38$; and school 4, $n = 46$. The limit of detection of the assay is 0.8 U/gm. Median levels are shown with bars. Numbers below the dotted line indicate levels below limit of detection.

median concentrations in those three schools (nos. 1, 2, and 4) were not significantly different from each other (Kruskal-Wallis test = 4.0, $p = 0.138$).

Fig. 3 shows the Bla g 1 concentration in the various sites of the schools. Of the 98 classroom samples, 29 (29.6%) had Bla g 1 concentrations below detectable levels. The median level was 2.4 U/gm, and the highest level was 186 U/gm. In the 16 food-related areas of the schools (kitchens, cafeterias, and teachers' lounges), the median Bla g 1 concentration was 5.8 U/gm, with a range from below detection in two samples to 591 U/gm. In the 33 other sites in the schools including offices, libraries, gymnasiums, auditoriums, and hallways, Bla g 1 was detected in 58% of the samples. The median level was 2.1 U/gm, and the maximum level was 66 U/gm. The median level from the food-related areas was significantly higher than the median classroom level (Mann-Whitney U test = 541, $p = 0.048$). The difference in median levels between the other sites and food-related areas was of borderline significance (Mann-Whitney U test = 172, $p = 0.053$).

The relationship of classroom Bla g 1 concentrations to the floor level was also evaluated. Of the 39 classrooms located on the first floor, seven (18%) had levels of Bla g 1 below detection with a maximum level of 52 U/gm and a median level of 3.0 U/gm. On the second floor, 63% of the 40 classroom samples had detectable Bla g 1, with a high of 186 U/gm and a median of 2.4 U/gm. Sixty-three percent of the 19 classroom samples collected from the third floor had detectable Bla g 1 levels. The highest concentration was 114 U/gm with a median of 1.7 U/gm. There was no significant difference in the median concentrations in the classrooms by floor level.

Factors related to cockroach allergen levels

As discussed in the Methods section, to control for potential confounding variables (specifically floor level, presence of sink and carpeting, and site of sample collection), we performed a multiple regression analysis based on a logit model for ordinal responses. The results from this analysis were similar to those reported previously (i.e., there were statistically significant differences among schools and between sites). The effects of floor level, presence of a sink, and presence of carpeting did not reach statistical significance ($p = 0.18$, $p = 0.053$, and $p = 0.46$, respectively); and these terms were subsequently not included in the final model. The final model included schools 1, 2, 3, and 4; food-related areas; classrooms; and other sites.

Parameter estimates and odds ratios from the final fitted model are displayed in Table III. Levels of Bla g 1 in schools 1, 2, and 4 differed significantly from those in school #3. The estimated odds of having elevated Bla g 1 levels were 27-fold greater in school 1 versus school 3 and 12- to 13-fold greater in schools 2 and 4 versus school 3. These effects were highly statistically significant ($p < 0.001$ in each case), although the confidence intervals for the true odds ratios were fairly broad. Finally, the odds of having elevated Bla g 1 levels were threefold greater in food-related areas compared with classrooms ($p = 0.048$). There was no detectable difference between other sites and classrooms; the difference between food-related areas and other sites also did not

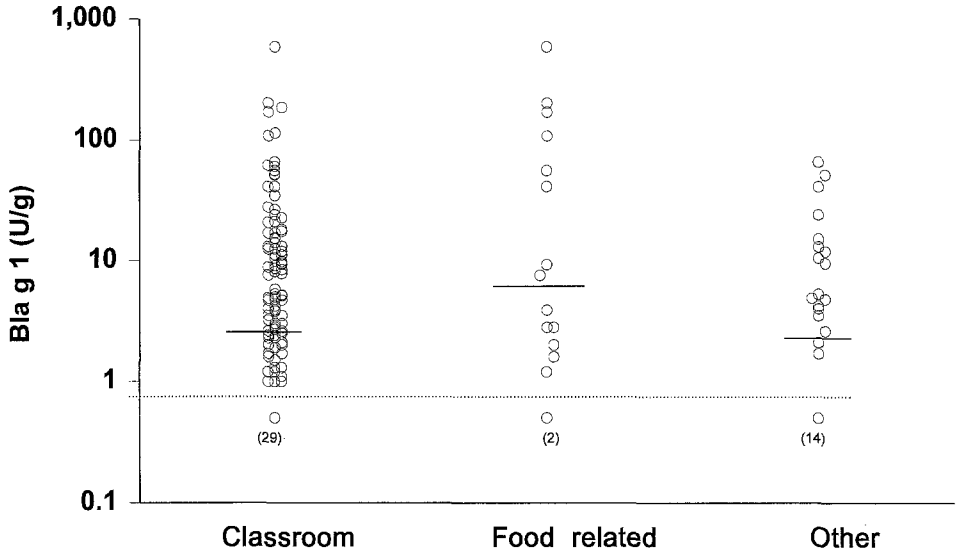

FIG. 3. Distribution of cockroach allergen, Bla g 1, in various sites of schools. Classroom, $n = 98$; food-related areas (kitchen, cafeteria, teachers' lounge), $n = 16$; and other sites (offices, libraries, gymnasiums, hallways, and auditoriums), $n = 33$. Median levels are shown with bars. Numbers below the dotted line indicate levels below the limit of detection of the assay, 0.8 U/gm.

TABLE III. Multiple logistic regression analysis of schools and sites

Variable	Parameter (estimate ± SE)	*p* Value	Odds ratio	Confidence interval (95%)
School				
1	3.302 ± 0.527	<0.001	27.2	(9.7, 76.4)
2	2.605 ± 0.602	<0.001	13.5	(4.2, 44.0)
3*			—	
4	2.474 ± 0.497	<0.001	11.9	(4.5, 31.5)
Site				
Food-related area	1.085 ± 0.549	0.048	3.0	(1.0, 8.7)
Other site	−0.016 ± 0.971	0.971	1.0	(0.4, 2.2)
Classroom*			—	

*Reference category.

reach statistical significance ($p = 0.072$). The score test for the proportional odds assumption did not detect a significant departure from this assumption (chi square = 7.19 on 5 degrees of freedom).

DISCUSSION

This study shows that cockroach antigen is ubiquitous in urban primary school environments. The antigen level was different between schools and within individual schools. The clinical relevance of these findings is yet to be determined.

The concentration of cockroach allergen in school dust was similar to that reported by other investigators in homes.[6, 14, 20] Although no threshold level of Bla g 1 capable of inducing sensitization or exacerbation of asthmatic symptoms has been defined, we and other investigators have suggested that Bla g 1 levels greater than 1 U/gm should be considered clinically significant levels of exposure.[6, 14] In this study over two thirds of all the samples collected from the four schools had Bla g 1 levels of 1 U/gm or greater. This level of antigen detected in school dust is of concern because it may constitute a very important "occupational" risk to students, teachers, and other school workers.

We believe that the cockroach allergen in these schools is predominantly due to current cockroach infestation. All of these schools recognize their problem with infestation and have in place ongoing extermination programs to reduce the problem. Dead roaches were found in each of the four schools by the investigator, and live roaches were also commonly seen by the custodians in each school, especially in the kitchens.

In the home environment, cockroach allergen has been documented to be most prevalent in food-related areas such as the kitchen.[5, 6, 20] In this study kitchens and other food-related areas had the highest levels of Bla g

1, which were significantly higher than the levels in the classrooms. These areas may have been more infested by cockroaches because of cracks in the floors, detachment of baseboards providing sites for proliferation, and the presence of food sources.[7] The finding that many classrooms also had significant levels of allergen may relate to the fact that food was allowed in the classrooms.

In an Ohio study, there was no difference between dust mite allergen concentrations in low-pile carpet and smooth floors, but allergen levels were significantly higher in high-pile carpets.[19] The schools in our study had low-pile carpets, and there were no significant differences between the allergen levels in dust samples collected from carpeted and uncarpeted floors. However, in our study the food-related areas were generally not carpeted, and this may have distorted the level of allergen in uncarpeted areas compared with carpeted areas. This finding requires further study because carpeting is generally regarded as an important reservoir for indoor allergens.

Another factor that may influence cockroach growth is the presence of sinks, which provide a water source. However, in our study presence of a sink did not have a significant effect on the distribution of cockroach allergen in the schools. Moreover, school 2, with no sinks in the classrooms, had high levels of Bla g 1. Our study therefore does not support the concept that sinks independently increase the risk for cockroach infestation.[7]

Einarsson et al.[17] have recently reported the effects of floor levels on the distribution of dust mite antigen in Swedish schools. They noted that because of possible dampness on the first floors, compared with the second and third floors, dust mite antigen levels were higher in first floor classrooms. Our data do not support this finding with regard to cockroaches in that allergen levels were similar on all floor levels.

In a study from France, among 30 day nurseries sampled, only six had measurable cockroach allergen levels, and these were lower than cockroach allergen levels reported from homes.[18] In the nurseries with visible signs of humidity (infiltration of water and presence of molds), mean levels of cockroach allergen on mattresses were significantly higher than those in day nurseries without such signs. In their study food-related areas were not examined, and there were no visual signs of cockroach infestation. We did not find such visible signs of humidity in the rooms we examined.

Presence of air conditioning may be important because schools 2 and 3 had air conditioning, which promotes lower humidity. However, despite the fact that school 3 had relatively lower levels of cockroach allergen, school 2 had high levels of allergen. Other factors that are worth further investigation are the size of the school and the number of students as a measure of overcrowding because cockroach infestation has been linked to overcrowding in homes.[7] In this study there were more students in schools 1 and 4 than in schools 2 and 3. The age of the building or the time since the last renovation may also be an important factor to consider in future studies because schools 2 and 3 were relatively new compared with schools 1 and 4. However, neither "student density" nor age of the building was consistently associated with higher cockroach allergen levels in our study.

Socioeconomic status and race are risk factors for cockroach allergen exposure and sensitization in children with asthma living in the Baltimore metropolitan area.[6] In that earlier study,[6] children from low socioeconomic background were found to be at fourfold risk of being exposed to cockroach allergen in their bedrooms compared with children from middle- or high-income families. Furthermore, an African-American child was 15.8 times more likely to be similarly exposed than a Caucasian child. In this study, school 3, with fewer African-Americans and fewer students with lower socioeconomic background, had significantly lower cockroach allergen levels. This school seemed to be better kept than the other three schools, although it had an extermination protocol similar to that of the other schools. The degree of parental involvement in the upkeep of the schools was not elicited. However, there were fewer students per teacher in school 3.

Cockroach allergens have been found in the homes of children with asthma in metropolitan Baltimore.[6] It could therefore be possible that cockroach allergen is transported on the clothing of these students, teachers, or other school workers as was reported with dust mite antigen in Swedish schools.[17] However, the visual evidence of cockroach infestation in the schools suggests that it is more likely that current infestation is the real problem.

Our data clearly demonstrate that cockroach allergen, Bla g 1, is commonly found in urban primary schools. Differences in the allergen levels were noted between sites within schools and between different schools. The differences between schools may be partly related to factors such as the students' race, socioeconomic status, and the total number of students per teacher. The presence of food sources may also be an important factor in the differences between sites within the school. Further studies are urgently needed to document the effects of these and other risk factors. The prevalence of cockroach antigen in schools and its impact on atopic individuals must also be documented. This would result in the development of appropriate means for controlling cockroach allergen exposure in both the home and school settings.

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