

Environmental and occupational disorders

Removal of cockroach allergen from inner-city homes

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Background: Allergen avoidance has been shown to improve the morbidity and physiology of asthma. Although cockroach allergen has been implicated in chronic asthma, little work has been reported on the feasibility of allergen removal from infested homes.

Objective: The objective of this study was to examine the effect of professional pest control and home cleaning on cockroach infestation and allergen concentrations in settled dust samples from the kitchens, bedrooms, and television-living rooms of inner-city homes.

Methods: Thirteen homes in inner-city Baltimore, Maryland, received a professional cleaning, with vacuuming and a thorough cleaning in the kitchen. Pest control technicians applied abamectin 0.05% gel to the kitchen and, to a limited extent, to the rest of the home and the cleaning was repeated. Technicians visited monthly from month 2 to month 8 to inspect, collect dust samples, and place passive cockroach traps. Bla g 1 concentrations in dust extract were measured by means of ELISA.

Results: The number of cockroaches captured in passive traps decreased rapidly in 11 homes, but complete extermination was achieved in only 7 homes. Bla g 1 concentrations were reduced by 93% in kitchens, 77% in television-living rooms, and 74% in bedrooms. The relative reduction in cockroach allergen was not related to successful extermination or to signs of poor housecleaning.

Conclusion: We concluded that cockroach extermination is feasible in inner-city homes but that standard housecleaning procedures are only partially effective in removing residual allergen over 8 months. (*J Allergy Clin Immunol* 1999;104:842-6.)

Key words: Cockroach allergen, inner city, homes, insecticides

Cockroach allergen is recognized as important in the pathogenesis of asthma, at least among children living in the inner cities of the United States.^{1,2} With other allergens that have been associated with asthma, such as house dust mite allergen, reducing exposure in the home

has been shown to reduce asthma morbidity and physiology in sensitized asthmatic subjects.^{3,4} In general, these studies show that allergen must be reduced by at least 10-fold and that these reductions must be sustained for 6 months or more to reduce morbidity.

At present there is no proven method of reducing cockroach allergen in infested homes. Although it is known that insect populations can be reduced successfully with available pesticides,⁵⁻⁷ it is not clear that household allergen exposure will be reduced as a result. In previous studies conducted in an urban dormitory, we were able to show that concentrations of cockroach allergen Bla g 2 were reduced in settled dust samples from the floor after effective extermination and vacuuming⁸; it is not known whether this degree of effectiveness can be achieved in inner-city homes. Williams and Reinfreid⁹ were able to reduce cockroach populations in rural homes, but allergen levels did not decrease. This study was conducted as a pilot study for a controlled intervention trial and was intended to evaluate the effect of extermination and professional housecleaning on cockroach numbers and allergen concentrations in inner-city homes.

METHODS

Recruitment of homes

Using advertisement and word of mouth, we recruited 13 families who reported cockroach infestation. The families lived in typical inner-city Baltimore homes. Most of the homes were over 50 years old and included 10 row homes, 1 detached home, and 2 apartments. One apartment did not have a bedroom that was separate from the television-living room. Only 2 families had functioning vacuum cleaners. On inspection, 4 homes had kitchens with an overflowing 50-gallon garbage can in the kitchen, 11 had significant grease accumulation on the kitchen floor and stove, and 6 had food debris in the rest of the house. None of the residents had asthma. The study was approved by the Johns Hopkins University human investigation committee, and all participants provided written, informed consent.

Intervention

Allergen abatement took place over approximately 1 month beginning in December and January. It consisted of 2 cycles of professional cleaning followed by professional pest control treatments; a booster abatement was provided during month 4. The cleaning focused on the kitchens where the cleaners scrubbed all surfaces, including the stove top and the area around the stove, with a detergent (Pinesol, Clean-up, or Fantastik) and a mop to remove food

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TABLE I. Summary of the number of cockroaches caught in passive traps and the settled dust allergen concentrations

		Baseline	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8
Roach traps	Homes	13	12	12	13	13	13	13	13
	Homes with positive traps	9	4	3	4	3	3	3	5
	Median cockroaches per trap	5	0	0	0	0	0	0	0
	Range	0-63	0-63	0-9	0-45	0-20	0-4	0-5	0-37
Roach allergen	Kitchen	No.	13	11	13	13	13	13	12
		Geometric mean	341	204	103	75	35	61	24
		Median	745	281	109	71	50	99	36
		Range	ND-2333	6-1147	8-627	ND-550	1-812	5-2858	ND-1576
	Bedroom	No.	12	10	10	12	12	12	12
		Geometric mean	21	20	26	23	18	27	7
		Median	82	55	39	31	37	31	14
		Range	ND-548	ND-378	ND-221	1-139	ND-485	3-217	ND-87
	Television-living room	No.	13	11	11	13	13	13	12
		Geometric mean	49	11	15	19	20	29	16
		Median	65	10	25	22	18	19	15
		Range	ND-1908	ND-109	ND-262	1-107	1-249	3-645	3-142

ND, Below detection limit.

debris and grease. In the rest of the home they vacuumed thoroughly and scrubbed hard surfaces, such as floors and woodwork, with the same detergent solution.

Extermination was conducted by pest control technicians who treated the home twice at approximately 2-week intervals during January and February; a single additional treatment was provided during month 4. At each visit, the technicians inspected the home with a checklist and applied gel bait containing abamectin 0.05% (Avert; Whitmire Laboratories, St Louis, Mo). Approximately 50 aliquots of the gel were applied in the kitchen, concentrating in the area around the refrigerator, trash, and stove. Additional baits were applied in the television-living room, in the bedroom, and in the basement if that was accessible.

Evaluation

Home evaluations were conducted before abatement and then at monthly intervals from month 2 through month 8. A technician who was not involved with the abatement inspected the home with a checklist, placed passive traps, and collected dust samples. Three passive traps (Catchmaster; Atlantic Paste and Glue Company, New York, NY) were placed in the kitchen and then collected by the technician 24 hours later. Dust samples were collected with a vacuum cleaner (model BB870-AD; Oreck Corporation, New Orleans, La) with a fabric collector fitted into the inlet hose of the vacuum. The collector was made of a nonwoven fabric (Wondertex; GSI, Brooklyn, NY) and was fabricated as a sleeve with a heat-seal device. Three settled dust samples were collected in each home: one in the kitchen, sampling the entire floor; a second sample from the television-living room, vacuuming a piece of furniture and the surrounding floor for 4 minutes; and a third from the bedroom, sampling the bed and bedding and the adjacent floor.

Filters were removed from the vacuum and stored at -20°C until they could be processed. In the laboratory, samples were scraped from the filter and sieved through a 0.3-μm brass mesh filter to produce fine dust. The fine dust was weighed, and a 100-mg aliquot was extracted in 2 mL of PBS (pH 8.0) by rotation overnight. The extracts were then centrifuged, and the supernatants were removed and stored at -20° C. Samples yielding less than 100 mg of fine dust were extracted in a proportionately smaller volume of buffer, as

described previously.¹⁰ Bla g 1 was measured by using a noncompetitive ELISA assay based on a combination of polyclonal and monoclonal antibodies (Indoor Biotechnologies, Charlottesville, Va). In our hands the assay has a lower detection limit of 1 U/g settled dust.⁸

Data analysis

Allergen data were log transformed to achieve a normal distribution and then analyzed by using parametric statistics. Successful extermination was defined as no reported cockroaches and an absence of cockroaches in passive traps on months 6, 7, and 8. The percentage change in cockroach allergen was determined by averaging the settled dust concentrations at months 6 through 8 in each room and expressing that as a percentage change from the baseline measurement in the same room.

RESULTS

Roach populations

Cockroach populations in the 13 homes are summarized in Table I. Although all families initially reported infestation, cockroaches were recovered in the passive traps in only 10 homes (range, 0-63 cockroaches; median, 5 cockroaches); all were identified as *Blattella germanica*. Within 2 months of treatment, 8 homes had no cockroaches in traps, and another home had decreased from 63 to 3 cockroaches recovered. In another home numbers increased from 44 cockroaches at baseline to 63 cockroaches at 2 months and then continued at high levels until month 6. Despite another extermination and cleaning, sticky traps in this home contained 4 cockroaches at month 8.

As defined (no cockroaches reported in any room and no cockroaches found in passive traps at months 6, 7 or 8), cockroach extermination was successful in 6 of 13 homes. Five other homes had cockroaches in traps only occasionally after abatement.

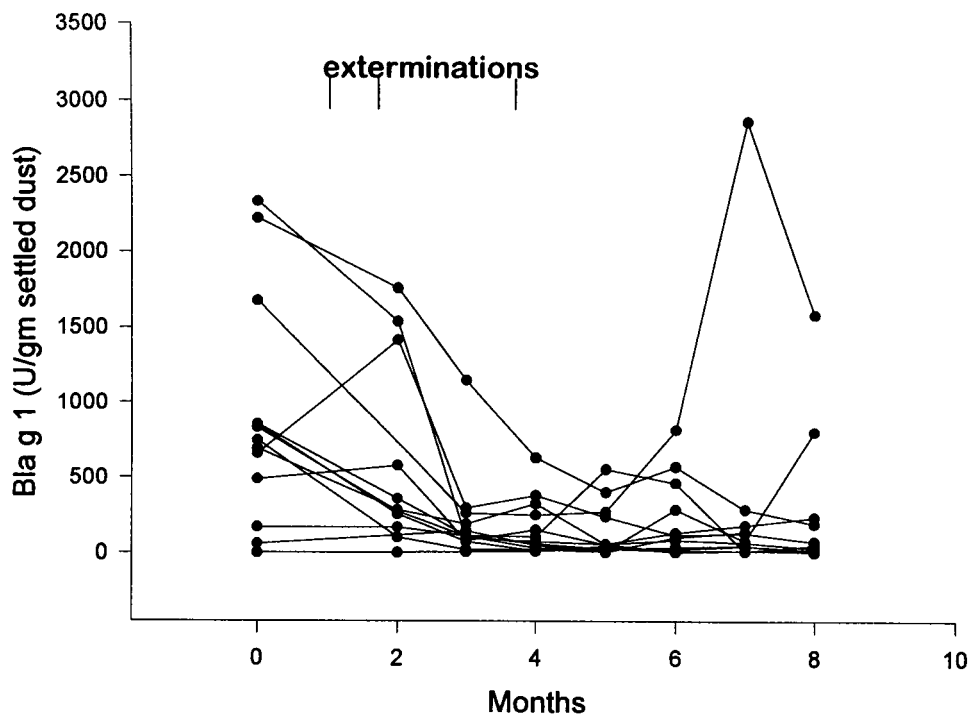


FIG 1. Bla g 1 concentrations in kitchen dust samples from 13 homes. Each symbol represents a single sample obtained at a monthly home visit, and a line without a symbol represents missing values. Undetectable levels are represented by a symbol at zero.

Allergen reduction

Allergen concentrations are summarized in Table I. At baseline, Bla g 1 concentrations in the kitchen ranged from undetectable to 2233 U/g (median, 745 U/g), in the bedroom levels ranged from undetectable to 548 U/g (median, 82 U/g), and in the television-living room levels ranged from undetectable to 1908 U/g (median, 65 U/g). In one home Bla g 1 was undetectable at baseline in any room sample; allergen in this home remained at a low but detectable level throughout the rest of the study. Levels tended to correlate between the various rooms in individual homes ($R_s = 0.44$ to 0.61) but reached statistical significance only between the television-living rooms and bedrooms.

Median allergen levels at month 2 were lower in all rooms and continued to decrease in subsequent samples (Table I). Median concentrations in the kitchen decreased to 109 U/g by month 3 (an 85% reduction) and continued to decrease to 36 U/g (a 95% reduction) at month 8. Levels in other rooms showed a similar trend, but the reduction in Bla g 1 concentration was somewhat less than that found in the kitchen. In the bedroom, concentrations decreased by 52% by month 3 and then decreased to 21 U/g (74% reduction) by month 8. Because the bedroom in one home was not separate from the television-living room, only 12 bedrooms were sampled. In the television-living room median levels decreased by 62% by month 3 and decreased slowly to 15 U/g (a 77% reduction) at month 8.

Individual allergen concentrations in the kitchens of the 13 homes are shown in Fig 1. Here it can be seen that levels decreased in most homes according to the general pattern described in Table I but that some variation was found in individual homes. This was especially apparent at month 2, when dust samples were not available from 2 homes and were undetectable in a third sample. Allergen was undetectable in 2 kitchens at months 7 and 8, and concentrations ranged as high as 1576 U/g. In the home in which cockroach populations reappeared at month 8, allergen levels in dust samples from the kitchen increased from 2 U/g at month 5 to 436 U/g at month 6, 1 month before cockroaches appeared in the passive traps. Bla g 1 concentration was 812 U/g at month 6 and 2858 U/g at month 7 but fell again to 1576 U/g after a second extermination and cleaning. Because allergen levels were so variable, the change in allergen level was calculated by averaging the concentration at months 6, 7, and 8 and then comparing this average to the baseline level.

Important covariables

We compared the frequency of successful extermination in homes with or without a given variable by using the definition that no cockroaches were collected in sticky traps and participants saw no cockroaches during months 6 to 8. Of the 4 homes with overflowing garbage cans in the kitchen, extermination was accomplished in 2 (50%) compared with 4 (44%) of the homes without problem garbage cans. Extermination was accomplished

in 3 of 7 homes with persistent grease on the kitchen floor compared with 3 of 6 without greasy floors. Extermination was accomplished in 1 of 6 homes with food debris in the bedroom and in 5 of 7 without debris. None of these differences were statistically significant.

Although the sample was too small to examine the determinates of successful allergen removal with much discrimination, several obvious factors were examined. To do this the percentage change in allergen from baseline was determined for each dust sample obtained. There were undetectable levels in one kitchen sample, 3 bedroom samples, and one television-living room sample at baseline; another home had no separate bedroom, and therefore this comparison could not be made. As a result, the sample size for allergen changes ranged from 9 (bedrooms) to 12 (television-living rooms or kitchens). The change in allergen concentration in each room did not depend on the initial concentration found in that room. Spearman correlation coefficients were 0.26 in the bedroom ($P > .1$), 0.19 in television-living room, and 0.06 in the kitchen. The magnitude of changes seen in one room did not relate closely to that seen in other rooms (eg, comparing the changes in the bedroom with those in the kitchen: $R_s = 0.53$ [$P > .01$]; comparing with changes in the television-living room: $R_s = 0.23$).

The relationship between a successful extermination and change in allergen levels was mixed. Bla g 1 in kitchen dust was reduced by 84% in homes with complete extermination compared with 49% in samples in which extermination was incomplete. In other rooms the relationship was even less clear. For example, Bla g 1 was reduced by 13% in the bedrooms of homes with successful extermination compared with 73% in bedrooms with less complete extermination. In the television-living room, Bla g 1 was reduced by 27% in homes with successful extermination and 72% in those partially controlled.

Evidence of cleaning also had little relation to allergen reduction. In kitchens with overflowing garbage cans, Bla g 1 concentration was reduced by 50% compared with a 63% reduction in the kitchens without overflowing garbage cans. Levels were reduced by 50% in kitchens with persistent problems with accumulated grease in the kitchen compared with an 81% reduction in homes with continued hygiene. Kitchen levels of Bla g 1 fell 20% in homes with food debris in the bedroom compared with 67% when there was no food debris. None of these differences were statistically significant.

DISCUSSION

We have shown that cockroach populations can be eliminated in most inner-city homes by using an effective insecticide applied by a professional pest control technician. Initial cleaning combined with education for the family regarding continued cleaning and techniques to prevent reinfestation resulted in a rapid decrease of cockroach allergen throughout most homes. This treatment was not effective in some homes, and reinfestation

occurred in some homes after 4 months. Allergen decreased by 78% to 93% in the homes during the 8-month study. At the end of the study, however, the mean concentration was still above 20 U/g, a level found to be associated with increased morbidity in asthmatic children in the National Cooperative Inner City Asthma Study.²

This study demonstrates somewhat greater success than that found in previous studies. In urban dormitories extermination and cleaning led to 85% reduction in Bla g 2 levels in settled dust, but this change was lost within a few months.⁸ In the National Cooperative Inner City Asthma Study intervention¹¹ cockroach abatement was included in the global intervention for families with asthmatic children, and home visits were conducted in a 10% sample to monitor compliance and effectiveness. The abatement included a single application of abamectin gel combined with patient education regarding appropriate cleaning. Cockroach populations decreased slightly, with 30% of kitchens having living cockroaches at baseline, 23% at 2 months, and 35% at 1 year. Bla g 1 concentrations in kitchen dust decreased somewhat; the median baseline concentration of 69 U/g decreased to 34 U/g. However, this decrease was only seen at 2 and 6 months, with a rebound to preintervention levels by a year. Williams and Reinfreid⁹ reported a small controlled study in infested homes in rural North Carolina in which bait stations containing hydramethylnon were used without providing professional cleaning. Cockroach numbers in passive traps were reduced with treatment but not with placebo, and Bla g 1 concentrations were reduced from 56 U/g to 21 U/g. Our intervention was based on the results of these studies and included initial professional cleaning to avoid questions of family adherence, as well as reextermination when needed, and continued education for the family. We believe that these increased cleaning efforts were responsible for the greater success in our study. Taken together, these studies demonstrate that current pesticides are effective when applied to inner-city homes but that methods of subsequent allergen removal are not adequate.

We were surprised to find that cockroach allergen remained at high levels 8 months after successful extermination. These allergens would appear to be more stable than animal allergens, which have been shown to be quite adherent to clothing and home interiors but do fall to very low levels within 6 months after the animal is removed.¹² This difference may relate to the ecology of the cockroach. Cockroach allergen is associated with secretions and feces from the insect.¹³ In addition to their obvious mobility, the insects collect in hiding places throughout the home, in small cracks and under appliances, where residual allergen may be difficult to reach but may still gradually enter the general environment. In addition, the allergen is widely distributed in infested homes, with the highest concentrations in the kitchen but also with highly detectable levels in bedding.^{11,13} As in the case of house dust mites, particles containing cockroach allergen become airborne to a limited extent,¹⁴ and

therefore an intervention strategy directed at reducing exposure should treat the bedding to be effective. However, our data indicates that allergen removal requires that successful extermination be sustained for several months if cleaning is to be effective. Our inability to reduce allergen below 20 U/g settled dust even after 8 months of successfully reducing the allergen is of concern. This suggests that the reservoir of allergen exists that will require different cleaning techniques, perhaps including protein denaturants.

There are several caveats regarding this study. First, it relied on the homeowners to continue the cleaning and pest control, although they were supported monthly by study personnel throughout the study to monitor compliance and to provide additional instruction. Although they were generally cooperative, participants in our study had obvious socioeconomic barriers to cleaning; for example, only 2 of the homes had a working vacuum cleaner. It is likely that allergen removal could have been more effective if we had achieved better compliance with routine cleaning procedures. The study was too small to have adequate power to examine likely variables such as this. Finally, we did not include a control group that received no treatment, and therefore we cannot comment on the stability of allergen levels with repeated sampling only. However, we can say that allergen concentrations did not decrease in the 2 homes with the least successful extermination, and we can point to Gergen's data,¹¹ which showed that allergen levels did not change in an experiment in which cockroach populations did not decrease.

The reductions of allergen levels that we were able to achieve were less than those reported in successful mite allergen avoidance trials but were still substantial. In successful house dust mite avoidance trials, in which a reduction in disease morbidity can be demonstrated, bedding dust allergen levels have been reduced by at least 90%^{3,4} and have been maintained at these levels for 6 months or more. A single treatment can reduce exposure for 6 months, which is long enough to reduce asthma

symptoms, but we do not know whether the magnitude of change is adequate to modify asthma in sensitized individuals. That question will be tested in the intervention protocol that is currently underway.

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