

Cockroach allergen reduction by cockroach control alone in low-income urban homes: A randomized control trial

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Background: We previously reported significant reductions in cockroach allergen concentrations in urban homes by reducing cockroach infestations.

Objective: To determine the effectiveness of pest control performed by professional entomologists, compared with commercial companies, in reducing cockroach allergen.

Methods: This 3-arm randomized controlled trial enrolled 60 cockroach-infested homes in North Carolina. Homes were randomly assigned to a control group or 1 of 2 treatment groups. Treatment 1 had insecticide baits placed by entomologists from North Carolina State University. Treatment 2 received pest control from a randomly assigned commercial company. Vacuumed dust sampling and cockroach trapping were conducted at 0, 6, and 12 months. Dust samples were analyzed by ELISA.

Results: In treatment 1 homes, there were significant reductions in geometric mean trap counts compared with control and treatment 2 homes at 12 months. Relative to control, significant 12-month reductions in Bla g 1 were evident in treatment 1 homes at all sampled sites, except bedroom floor. From baseline to month 12, geometric mean Bla g 1 concentrations (U/g) decreased from 64.2 to 5.6 in kitchen, 10.6 to 1.1 in living room, 10.7 to 1.9 on bedroom floor, and 3.6 to 2.3 in bed. Treatment 2 homes showed no significant 12-month allergen reductions versus control.

Conclusion: Reductions in Bla g 1 in cockroach-infested homes can be achieved by reducing infestations; however, the magnitude of allergen reduction is dependent on the thoroughness and effectiveness of cockroach eradication efforts.

Clinical implications: Elimination of cockroaches is an effective method for reducing exposure to cockroach allergen. (*J Allergy Clin Immunol* 2007;120:849-55.)

Key words: Cockroaches, cockroach allergen, Bla g 1, Bla g 2, indoor allergens, intervention trial

Studies suggest that exposure to cockroach allergens is one of the most important risk factors for asthma in inner-city households. The National Cooperative Inner-City Asthma Study found that asthma morbidity was highest in children with both a positive skin test response and a high exposure to the cockroach allergen Bla g 1 in the bedroom.¹ In addition, a study of elderly patients with asthma in New York City found that the most common sensitization was to cockroach allergen, with 47% of the subjects sensitized. Cockroach sensitization was also associated with a significant reduction in FEV₁ in this population.² The Inner-City Asthma Study (ICAS) found that a significant reduction in cockroach allergen on the bedroom floor correlated with a significant decrease in asthma morbidity, as measured by symptom days, hospitalizations, and unscheduled doctor visits.³ These findings indicate that reducing exposure to cockroach allergens could be a valuable strategy to improve the health of inner-city residents.

We previously reported significant reductions in cockroach allergen levels (Bla g 1 and Bla g 2) in low-income, infested, urban homes after implementing an integrated pest management intervention consisting of resident education, intensive professional cleaning, and extensive insecticide bait treatments that resulted in significant reductions in cockroach infestations.⁴ Surprisingly, Bla g 1 and Bla g 2 concentrations decreased significantly in the study's control homes after these homes were treated with insecticide bait alone at months 6 and 9. At the end of the 12-month study, intervention homes and crossed-over control homes had approximately the same level of cockroach allergen at each location sampled.⁵ The crossed-over control homes received insecticide bait applications at months 6 and 9 but received no other interventions (ie, education or cleaning). Thus, in contrast with other studies, highly effective cockroach eradication alone significantly lowered allergen concentrations.^{6,7}

Urban entomologists associated with the Entomology Department at North Carolina State University (NCSU, Raleigh, NC) performed insecticide applications in our previous studies. The effectiveness of the treatment

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Abbreviations used

ICAS: Inner-City Asthma Study
 NCSU: North Carolina State University

was demonstrated by profound reductions in trapped cockroaches in infested homes (50-500 cockroaches trapped at baseline in 18 traps deployed for 3 nights); between 64% and 75% of the intervention homes had a median of 0 cockroaches trapped at the conclusion of the 2 studies. Gel bait placement was guided by a thorough visual inspection and layout maps of the homes, trap counts, and insecticide label directions. Although we did not actively attempt to prevent infestation (or reinfestation) by repairing cracks, holes, and so forth, and did not educate residents about removing food and water sources in our second intervention,⁵ we successfully reduced cockroach populations in infested homes by 99% to 100% (on the basis of comparisons of medians at baseline and at 12 months).

Our studies show significant allergen reductions after allergen source reduction through intensive cockroach eradication. However, most previous cockroach allergen intervention studies that contracted with commercial pest control companies did not report either the specific pest control tactics they deployed or changes in the cockroach population (measured by trapping) during or after the intervention.⁸ Therefore, we cannot dismiss the concept that failure to significantly reduce cockroach allergen in most previous studies was a consequence of ineffective pest control. It is of paramount importance to compare cockroach and allergen reductions imposed by a cockroach control program conducted by professional entomologists with contract-based services performed by pest control companies. If cockroach population suppression alone—especially conducted by pest control companies—could be shown to reduce cockroach allergen in inner-city homes, this finding could affect the design of many future primary and secondary asthma prevention trials, as well as day-to-day public health practice.

The objective of this study was to determine the effectiveness of pest control performed by professional entomologists, compared with commercial companies, in reducing cockroach allergen in cockroach-infested homes.

METHODS

Enrollment and randomization

The addresses of approximately 150 potentially eligible, cockroach-infested homes were obtained from a real estate management firm. All homes were in multiunit dwellings, either row homes or low-rise apartment buildings, located in the same metropolitan area of North Carolina. The inclusion criteria required 50 to 1000 trapped German cockroaches (*Blattella germanica*) at baseline, using 18 traps deployed for 3 nights throughout the home. Sixty homes were enrolled, randomly assigned to 1 of 3 treatment groups by using a randomized block design, and followed for 12 months. Baseline

characteristics of the enrolled homes are shown in Table 1 and did not differ significantly between treatment groups. Treatment 2 homes were assigned to 1 of 4 local pest control companies by using a randomized block design. Enrollment took place from November 2004 to February 2005 to minimize seasonal variation in cockroach counts. The occupants were compensated for their participation, and the National Institute of Environmental Health Sciences Institutional Review Board reviewed and approved this study.

Dust collection and analysis

In all homes, vacuumed dust samples were collected from the kitchen floor, the living room floor, the bedroom floor, and a bed by a trained technician. Vacuumed dust samples were collected at months 0, 6, and 12 in all homes. Samples were collected using a Eureka Mighty-Mite 7.0-A vacuum cleaner (Eureka Co, Bloomington, Ill) with a dust collector (Indoor Biotechnologies, Charlottesville, Va) placed on the distal end of the vacuum's extension wand. Vacuumed dust samples were sieved through 425- μ m mesh, weighed, and aliquoted. Dust samples were extracted at 50 mg/mL with phosphate-buffered saline containing 0.05% Tween 20/1.0% BSA for 1 hour on a rocker platform at room temperature, cleared by centrifugation, and aliquoted. All aliquots were stored at -20°C until analysis. mAb-based ELISA was performed to determine the levels of the cockroach allergens Bla g 1 (kit lot #2534) and Bla g 2 (kit lot #2499) by using standard published techniques.⁹ Allergen concentrations are presented here in units of allergen per gram of sieved dust for Bla g 1 and micrograms of allergen per gram of sieved dust for Bla g 2.

To monitor the cockroach populations in each home, 6 sticky traps (Victor Roach Pheromone Trap; Woodstream, Lititz, Pa) were set in the kitchen, living room, and bedroom (a total of 18 traps per home) and collected 3 days later. Traps were deployed in intervention homes at 0, 1, 3, 6, 9, and 12 months, and in the untreated control homes at 0, 6, and 12 months. All trapped insects were identified and enumerated, and the number of German cockroaches is reported.

Treatment 1 (professional entomologists)

Within approximately 1 week of each trapping visit, urban entomologists associated with the Entomology Department at NCSU treated the treatment 1 homes with insecticide gel bait. Baits containing 2.15% hydramethylnon (Maxforce Roach Killer Gel Bait; Bayer Environmental Science, Research Triangle Park, NC), 0.05% abamectin (Avert Dry-Flowable Cockroach Bait; Whitmire Micro-Gen Research Laboratories, Inc, St Louis, Mo), or 2.15% imidacloprid (Pre-Empt Cockroach Gel Bait; Bayer Environmental Science, RTP, NC) were placed at months 0, 1, 3, 6, and 9 if any cockroaches were trapped and concentrated in the areas of infestation indicated by the trap counts. At the initial treatment visit, dots or streaks of approximately 100 to 200 mg of bait were placed where cockroaches tend to hide or forage, such as in kitchen and bathroom cabinets, under and behind appliances, around pipes entering walls, under furniture, and in cracks in walls or floors. The total amount of bait used at this visit ranged from 15 to 180 g depending on both the size of the dwelling and the severity of the infestation. At subsequent visits, bait placement was less intense and was guided by cockroach trap counts and visual inspections. When cockroach populations did not decrease satisfactorily at follow-up visits, another formulation that contained a different insecticide was used alone or in conjunction with hydramethylnon. For the percentage of the total mass of bait applied in the treatment 1 homes during the study, hydramethylnon, abamectin, and imidacloprid represented 93.6%, 3.8%, and 2.7%, respectively. Each initial treatment required approximately 1.5 person-hours, and follow-up insecticide application generally required 0.25 to 0.5 person-hours. No other interventions, such as cleaning or education, were performed.

TABLE I. Baseline characteristics of control and treatment homes

Characteristic*	Control (N = 20)	Treatment 1 (NCSU) (N = 20)	Treatment 2 (companies) (N = 20)
	Yes/no	Yes/no	Yes/no
Dwelling/household			
Multiunit dwelling	20/0	20/0	20/0
Homes with poor housekeeping†	0/20	1/19	1/19
Homes in fair or poor condition‡	6/14	7/13	3/17
Cockroach activity			
Homes with cockroach stains in any room	15/5	18/2	17/3
Homes with living cockroaches in any room	15/5	14/6	13/7
Homes with dead cockroaches in any room	15/5	17/3	14/6
Homes that used off-the-shelf products for roach control in past month	8/10	7/10	8/12
Homes that used an exterminator in past month	0/19	0/18	0/20
Median (minimum, maximum) no. of cockroaches trapped	205.5 (50, 909)	426.5 (55, 992)	308.5 (62, 984)

*There were no significant differences between the control and treatment homes.

†No recent cleaning, lack of organization, greasy cooking area, and clutter.

‡At least 1 score of fair or poor condition for walls and ceilings, floors, or windows.

Treatment 2 (commercial companies)

Homes enrolled in the treatment 2 arm received pest control services from 1 of 4 randomly assigned pest control companies. These companies were selected from a list of companies that provide home extermination services under a 1-year contract. Companies that proposed to use total release aerosols (ie, foggers or space sprays) during telephone interviews were removed from the list and thus not selected because this method has been shown to be less effective than residual sprays or baits.¹⁰ After a pest control company was randomly assigned to a home, the study coordinator contacted that pest control company on behalf of the resident. The study coordinator informed the company that the home had cockroaches and the resident wanted to set up a prepaid, 1-year contract for the treatment of the home. The study coordinator did not inform the company that the home was participating in a study. The contract was established in the name of the resident, and the initial treatment appointment was scheduled at the resident's convenience. The study coordinator was present at the initial treatment to make sure the home occupant understood the details of the contract and to give the resident a money order with which to prepay the 12-month contract. Exterminations were based on the details specified in the 12-month contract with each company for each home and were generally calendar-based. The companies followed their own standard operating procedures in providing pest control services to the homes. Two of the companies' annual contracts included 12 visits, 1 included 7 visits, and 1 included 4 visits. All 4 companies used hydramethylnon in their treatments, but never alone. Three companies also used an insect growth regulator, 3 companies used synergized pyrethrins, and 2 companies used residual pyrethroid insecticides. No additional interventions, such as professional cleaning or occupant education, were conducted by the study staff. Any educational materials or instructions provided by the company for the occupants were given to the occupants and verbally translated as needed.

Control homes (untreated)

The control homes received no extermination or intervention from 0 to 12 months. After the 12 month visit was completed, these homes received a thorough pest control service by NCSU entomologists.

Statistical analyses

For dust samples, treated and untreated control homes were compared for each of the 4 sampled locations. Changes from baseline

to 6 and 12 months of the log₁₀-transformed concentrations were analyzed by using a linear model in SAS Proc Mixed (SAS Version 9.1.3; SAS Institute, Cary, NC). Cockroach counts in each room and for the whole residence were analyzed in the same manner, using count + 1 as the outcome to allow for log transforming with 0 counts. Statistical significance from a 2-tailed test was set at $P \leq .05$. Analyses were performed on all data that were available, and no adjustments were made for multiple comparisons.

RESULTS

Baseline characteristics

The treatment and control homes had similar baseline characteristics, as shown in Table I. Evidence of cockroach activity, such as live and dead cockroaches and cockroach stains, was observed in the majority of homes. Less than half of all households had used off-the-shelf products for roach control in past month, and none of the households reported the use of a professional pest exterminator in the previous month.

This study was designed to recruit 20 homes in each of the 3 arms with an expected loss to follow-up of 30% to 40%. With 20 homes per arm, we had greater than 90% power to detect an effect on cockroach allergen levels of the same magnitude as in our previous study.⁵ If 10 homes (50%) from each arm were lost to follow-up, we would have approximately 70% power to detect the same effect. Forty-eight of the 60 homes enrolled completed the first 6 months of follow-up. Thirty-two homes completed the full 12 months of follow-up. At 6 months, 4 homes in the treatment 1 arm, 3 homes in the treatment 2 arm, and 5 homes in the control arm were lost to follow-up, with occupant relocation the predominant reason. At 12 months, an additional 6 homes in treatment 1, 7 homes in treatment 2, and 3 homes in the control arm were lost to follow-up, again with occupant relocation the predominant reason. Within each of the study arms, comparisons of homes that completed the study and homes that were lost to follow-up

TABLE II. Median cockroach counts at the home and room levels*

Location	Month	Median cockroach count (no. with 0 count/total no.)		
		Treatment 1 (NCSU)	Treatment 2 (companies)	Control†
Whole home	0	426.5 (0/20)	308.5 (0/20)	205.5 (0/20)
	1	5.0 (1/19)	127.0 (0/20)	
	3	2.0 (8/19)	106.0 (1/19)	
	6	0.0 (10/16)	56.0 (1/17)	285.0 (0/15)
	9	1.0 (6/13)	95.0 (2/15)	
	12	0.5 (5/10)	51.0 (1/10)	142.0 (0/12)
Kitchen	0	146.0 (0/20)	156.0 (0/20)	123.0 (0/20)
	1	2.0 (2/19)	42.0 (0/20)	
	3	1.0 (9/19)	34.0 (2/19)	
	6	0.0 (10/16)	46.0 (2/17)	170.0 (0/15)
	9	1.0 (6/13)	57.0 (2/15)	
	12	0.5 (5/10)	22.5 (2/10)	45.0 (0/12)
Living room	0	30.0 (0/20)	81.0 (0/20)	48.5 (0/20)
	1	1.0 (7/19)	13.0 (1/20)	
	3	0.0 (14/19)	10.0 (2/19)	
	6	0.0 (11/16)	8.0 (4/17)	47.5 (0/15)
	9	0.0 (8/13)	8.0 (5/15)	
	12	0.0 (8/10)	13.0 (2/10)	2.0 (3/12)
Bedroom	0	9.0 (3/20)	28.0 (0/20)	32.5 (1/20)
	1	0.0 (10/19)	32.0 (1/20)	
	3	0.0 (16/19)	12.0 (3/19)	
	6	0.0 (13/16)	5.0 (5/17)	34.0 (2/15)
	9	0.0 (11/13)	19.0 (3/15)	
	12	0.0 (8/10)	14.0 (3/10)	15.0 (2/12)

*Both treatment arms showed significant reductions at all locations compared with baseline ($P < .001$). In treatment 1 homes, there were significant reductions in geometric mean cockroach trap counts compared with both untreated control ($P < .001$) and treatment 2 homes ($P < .01$) at 12 months.

†Control homes received insecticide bait application only at month 12. Trap counts at month 12 were determined before insecticide application.

did not reveal any significant differences in cockroach counts, allergen levels, or cleaning frequencies at baseline.

Cockroach trap counts

Table II shows the median cockroach counts by group assignment, visit, and sample location. Among treatment 1 homes, median cockroach counts were reduced to 0 by month 6 and remained virtually unchanged from months 6 to 12. Among treatment 2 homes, median cockroach counts for the whole home were reduced from 308 at baseline to 56 by month 6, and to 51 by month 12. The geometric mean cockroach trap counts were analyzed by treatment group and by whole home and room, and both treatment 1 and treatment 2 showed significant reductions at all locations compared with baseline ($P < .001$). For treatment 1, geometric mean cockroach trap counts decreased after 12 months from 183.9 at baseline to 3.3 in the kitchen (98% reduction), 43.5 to 1.9 in the living room (96% reduction), and 19.2 to 1.7 in the bedroom (91% reduction). For treatment 2, geometric mean cockroach trap counts decreased after 12 months from 152.1 at baseline to 28.8 in the kitchen (81% reduction), 62.1 to 11.6 in the living room (81% reduction), and 32.6 to 12.0 in the bedroom (63% reduction). Untreated control homes did not show significant decreases in geometric mean numbers of trapped cockroaches except in the living room, where there was a reduction from 45.2 trapped cockroaches at baseline to 19.7 at month 12 (56%

reduction; $P = .02$). In treatment 1 homes, there were significant reductions in geometric mean cockroach trap counts compared with both untreated control ($P < .001$) and treatment 2 homes ($P < .01$) at 12 months.

Cockroach allergen levels

Fig 1 shows the geometric mean Bla g 1 concentrations (U/g dust) in vacuumed dust by group assignment, visit number, and sample location. In the control arm homes, there were no significant changes in the Bla g 1 concentrations at any location from 0 to 12 months. For treatment 1, there were significant reductions in Bla g 1 concentration at all locations ($P < .001$) at month 12 compared with baseline, and significant reductions in the bed ($P = .01$), kitchen ($P = .006$), and living room ($P < .001$) compared with the untreated control homes. From baseline to month 12, geometric mean Bla g 1 concentrations decreased from 64.2 to 5.6 in the kitchen, 10.6 to 1.1 in the living room, 10.7 to 1.9 on the bedroom floor, and 3.6 to 2.3 in the bed. Treatment 1 also showed significant reductions compared with treatment 2 in the kitchen ($P = .005$) and living room ($P = .02$).

For treatment 2, there were significant reductions compared with baseline in the bed ($P = .01$), bedroom floor ($P = .03$), and living room samples ($P = .02$). From baseline to month 12, geometric mean Bla g 1 concentrations for treatment 2 decreased from 66.9 to 43.0 in the kitchen, 14.3 to 5.7 in the living room, 17.3 to 7.2 on the bedroom floor, and from 5.5 to 1.9 in the bed.

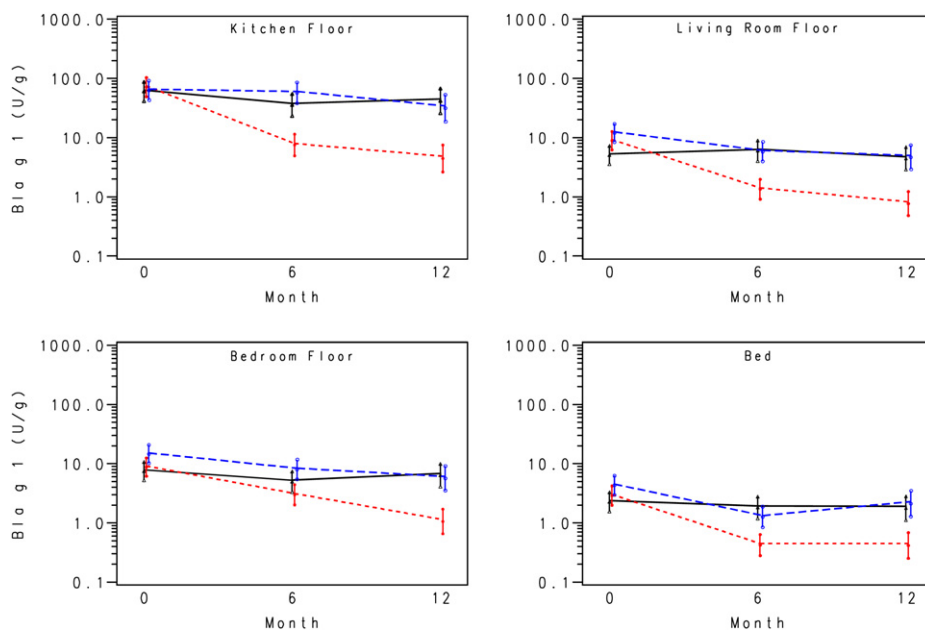


FIG 1. Geometric mean Bla g 1 allergen concentrations (and SEs) from vacuumed dust samples in control (solid line), treatment 1 (red dashed line), and treatment 2 (blue dashed line) homes.

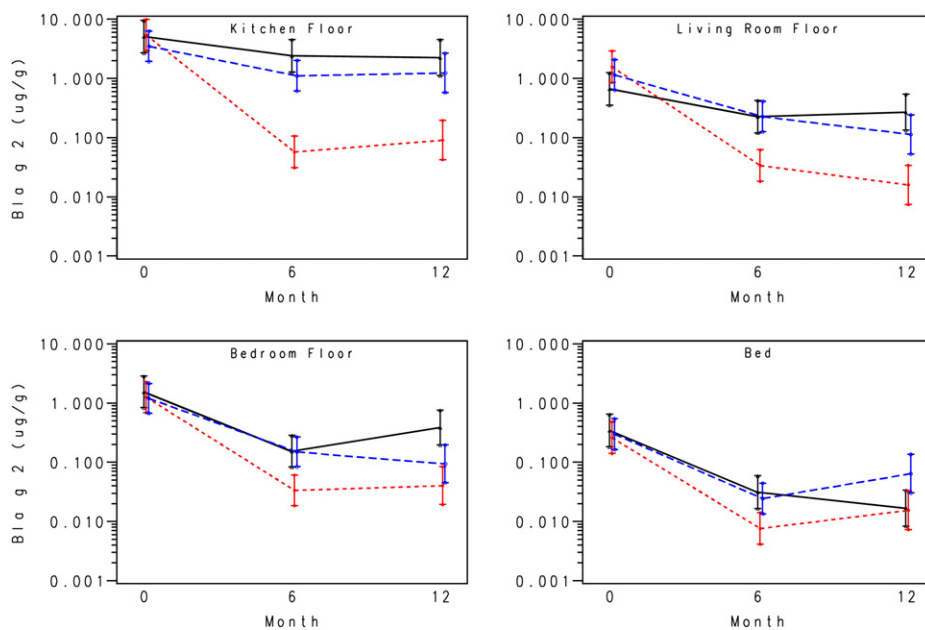


FIG 2. Geometric mean Bla g 2 allergen concentrations (and SEs) from vacuumed dust samples in control (solid line), treatment 1 (red dashed line), and treatment 2 (blue dashed line) homes.

However, these changes were not significant compared with untreated control homes.

As shown in Fig 2, the interventions had a similar effect on Bla g 2. For treatment 1, there were significant reductions in Bla g 2 concentrations ($\mu\text{g/g}$ dust) in the bed, bedroom floor, living room floor, and kitchen floor ($P < .001$ at all sites) at month 12 compared with baseline. At month 12, treatment 1 homes had a significant reduction in

Bla g 2 levels compared with untreated control homes in the kitchen ($P < .001$) and living room ($P = .002$). Treatment 1 also resulted in significant reductions compared with treatment 2 in the kitchen ($P = .002$) and living room ($P = .02$). For treatment 2, there were significant reductions compared with baseline in the bed ($P = .002$), bedroom floor ($P = .001$), and living room samples ($P = .005$). There were no significant reductions in Bla g 2 for

treatment 2 compared with untreated control homes, but there were significant reductions in the control arm from 0 to 12 months in the bed ($P < .001$) and bedroom floor ($P = .006$).

Spearman correlations were calculated between baseline and 12-month cockroach counts and Blag 1 levels. The reductions in cockroach counts were significantly correlated with the reductions in cockroach allergen in the kitchen (Spearman correlation coefficient = 0.46; $P = .008$) and bedroom (Spearman correlation coefficient = 0.43; $P = .01$). There was not a significant correlation in the living room (Spearman correlation coefficient = 0.19; $P = .3$).

DISCUSSION

This study corroborates our previous finding that effective cockroach control alone, which significantly decreases or eliminates cockroach populations, can result in significantly reduced cockroach allergen levels in settled dust samples. Unlike our previous interventions, which consisted of intensive pest control and resulted in large reductions in environmental cockroach allergen concentrations, 2 different approaches of pest control were used in this study, and the magnitude of the allergen reduction was dependent on the thoroughness and effectiveness of the cockroach eradication efforts. The treatment 1 homes received a similar intervention to the crossed-over control homes in our previous study,⁵ and the outcomes (cockroach reduction and allergen reduction) were similar as well. The treatment 2 homes, serviced by commercial pest control companies, also experienced significant reductions in the number of cockroaches trapped, but the magnitude of the reduction was significantly lower than in treatment 1 homes, the cockroach infestation remained relatively high after 12 months, and changes in cockroach allergens were not different from those in untreated control homes.

What are possible reasons for the differences in the 2 treatment arms? We believe the major differences were related to the cockroach monitoring that guided bait placement in treatment 1 homes, the types of pesticides used, and the schedule and intensity of treatment. In the treatment 1 arm, the cockroach populations were monitored throughout the study with 18 sticky traps per home, and homes were treated again if any cockroaches were trapped at months 1, 3, 6, and 9. Treatment 1 also used layout maps of each home, identified problem areas, and targeted aggregations of cockroaches extensively throughout the entire home at baseline and as needed throughout the 12 months of follow-up. Living rooms and bedrooms in these homes harbored significant infestations (Table II) that would likely reinfest other rooms if not eliminated. Treatment 1 used highly effective, reduced toxicity gel baits for every treatment and did not use any spray or dust formulations. Thus, treatment 1 closely approximated the fundamentals of integrated pest management, but with 1 major exception: preventing infestations (sealing cracks

and crevices, caulking, and structural repairs), which is very labor-intensive and expensive, was beyond the scope of this intervention study. The reduction of cockroaches by monitoring-guided insecticide baiting has been previously shown to be similar to that in an integrated program that included cleaning, resident education, and baiting.¹¹ Moreover, the monitoring-guided approach has been shown to be significantly more effective at reducing cockroach populations than baseboard and crack and crevice spray treatments.¹²

In contrast, the commercial pest control companies in treatment 2 used predominantly traditional or conventional treatments, which generally consist of calendar-based (monthly, bimonthly, or quarterly) applications of spray and dust insecticide formulations to baseboards and cracks and crevices.^{12,13} None of the contracted pest control companies used traps to monitor the cockroach infestation. The pest control companies usually treated only the kitchen and bathrooms unless specifically requested by the residents to treat other areas. The majority of their initial treatments relied heavily on spray and dust formulations and used smaller amounts of gel baits. Spray insecticide label directions require that the contents of kitchen cabinets be removed or covered to prevent contamination; such preparations are generally left to residents, and non-compliance may result in less thorough insecticide coverage. The majority of residents in treatment 2 complained about the dusts, sprays, and work involved in cleaning out cabinets, drawers, and so forth in their homes. These complaints were relayed to the companies, and according to resident reports and study staff observations, the types of insecticides used in treatment 2 homes changed over time to include more bait stations and gel baits. Although we had 2 local, 1 regional, and 1 national commercial company involved in this study, treatment 2 results may not be typical of all commercial companies. The homes in this study were all cockroach-infested row homes and low-rise apartments with adjacent units not involved in the intervention. These homes are similar to those found in other urban areas,^{11,12,14-16} although they may not be representative of cockroach infested homes in high-rise apartment buildings.

Despite significant reductions in cockroaches in treatment 2 homes (eg, 83% in the kitchen), allergen levels changed only marginally (eg, 35.7% in the kitchen). This suggests the possibility that there is a threshold level of cockroach infestation, above which drastic decreases in cockroach allergen, like those seen in the treatment 1, are unlikely. This threshold may represent a level of active cockroaches that disseminate allergen in feces and other secretions during normal foraging activities. The treatment 1 homes received additional bait placement after any trapping visit in which more than 1 cockroach was trapped. In other words, the goal of treatment 1 was eradication of cockroaches, not merely population control or management. Although this is likely also the goal of the commercial pest control companies that treated homes in this study, they had no means of assessing their effectiveness without monitoring the pest population.

The total cost of treatment 1 was estimated at \$281 per home for 12 months of follow-up including cockroach trapping, counting, and bait placement. The cost of the bait placement ranged from approximately \$61 to \$124 with a median cost of \$80 for 12 months of treatment. The cost over 12 months for the cockroach traps, labor to place and retrieve the traps, and labor to count the traps was \$201 per home. The median cost for a 12-month contract with the commercial pest control companies in treatment 2 was \$475.

One limitation of this study is the lack of health outcome data to correlate with the reductions in cockroaches and cockroach allergen. This study did not undertake health outcome measures because we felt it was necessary to confirm our intervention methods were effective before enrolling children or adults with asthma into a clinical trial. We are currently planning a multicenter clinical trial with children with moderate to severe asthma who are both sensitized and exposed to cockroach allergen. The intervention from treatment 1 will be implemented in their homes, and health outcomes will be monitored. On the basis of data from ICAS showing a significant correlation between Bla g 1 reductions (44% reduction from a baseline median of 0.2 U/g dust) and decreased asthma morbidity,³ we anticipate that by reducing cockroach numbers and allergen to the degree demonstrated in the current study, a significant improvement in asthma morbidity will be achieved.

In this study, commercial pest control companies were not as successful at removing cockroaches and their allergens from homes in inner-city multiunit dwellings as a group of entomologists; however, these companies did demonstrate effectiveness in reducing cockroach counts compared with control as well as allergen concentrations within homes. To improve their effectiveness, we would suggest additional training for pest control operators to increase their knowledge about the most effective treatments and education of patients to be diligent in reporting cockroach sightings to the companies and requesting additional service visits.

By monitoring cockroach trap counts and intensively treating infested homes with highly effective gel bait preparations, cockroach populations can be dramatically reduced almost to the point of eradication. This reduction in cockroach infestation leads to a large reduction in cockroach allergen as well. The magnitude of the allergen

reduction is dependent on the success of the cockroach eradication efforts.

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