
Cockroach counts and house dust allergen concentrations after professional cockroach control and cleaning

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Background: It is known that cockroach allergen exposure is both frequent in inner-city homes and associated with asthma severity in children living in those homes. However, there have been few studies of interventions to reduce exposures in this setting.

Objective: To evaluate the effect of short-term professional cockroach control and intensive cleaning on allergen concentrations.

Methods: Families of children from a school-based asthma treatment program who had skin test results positive to cockroach allergen were enrolled if the home had cockroaches. Forty-nine homes were randomly assigned to receive professional cleaning with bait traps containing insecticide, professional cleaning with bait traps without insecticide, or no cleaning or bait traps. In all homes, dust was collected repeatedly to evaluate cockroach allergen Bla g 2 in the kitchen and bedroom, and cockroaches were trapped and counted repeatedly for more than 11 weeks.

Results: Median cockroach counts were reduced in the homes treated with insecticide bait traps but not in other groups. There were significant reductions in allergen concentration in the kitchen in homes that received professional cleaning and had higher initial cockroach counts (54), regardless of whether bait traps had insecticide or not.

Conclusions: We conclude that intensive cleaning can produce significant reductions in cockroach allergen in homes with heavy initial cockroach infestations.

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INTRODUCTION

Studies have found asthma to be more severe in homes of children both allergic and exposed to indoor allergens, such as house dust mites or cockroaches, and it has been suggested that the increased severity of asthma found in inner-city children may be explained in part by exposures to cockroach allergens.¹ Low socioeconomic status has been associated with increased concentrations of cockroach allergen in house dust. In a recent study in southern New England, being African American or Hispanic, being of lower socioeconomic status, and living in multiple-family dwellings were shown to be associated with higher exposure to cockroach allergen and lower exposure to dust mite, cat, and dog allergen.² In studies of inner-city residents with asthma, up to 60% have been found to be allergic to cockroaches.³ Therefore, cockroach

allergen exposure is potentially an important public health problem in urban areas.

Interventions to control house dust mite allergen have emphasized encasing bedding in allergen proof covers and washing sheets and bed covers in hot water (to kill dust mites and remove allergen). There is increasing evidence that such measures can successfully reduce allergen exposure and result in improvements in clinical parameters of asthma, especially bronchial responsiveness.^{1,4–7} However, there has been little study of the effect of interventions to control exposure to cockroach allergen in the homes of inner-city asthmatic children. Although professionally applied insecticides have rapidly reduced the number of live cockroaches, little reduction in allergen occurred in house dust, in the absence of aggressive cleaning.⁸ Even with professional cleaning, cockroach allergen persisted at levels previously associated with increased asthma severity.⁹ Previous studies that examined the effect of professional cockroach control have been limited by small sample size, lack of an appropriate control group, or by the fact that families were not selected contingent on a resident with allergy or asthma, conditions that might result in more motivated participants.

In this study, we examined the feasibility of cockroach allergen reduction in inner-city Los Angeles homes with professional pest control and professional cleaning. A relatively larger sample of inner-city residences was recruited than in previous trials using professional cockroach control. Participating families had at least 1 child allergic to cock-

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roach, and we included both a control group and a sham insecticide treatment group to evaluate placebo effects.

METHODS

Population

Families were recruited through the Breathmobile, a school-based, mobile asthma clinic, or the allergy clinic at the Los Angeles County/University of Southern California Medical Center. Eligibility criteria included a child who had a skin test result positive to mixed cockroach allergen (American and German) and a parent or caretaker report of any cockroaches in the home. The study was approved by the institutional review board at the University of Southern California, and informed consent was obtained from all participants. Twenty-four sticky traps were placed in the kitchen and bedroom in areas where cockroaches congregate (horizontally next to walls, next to or behind appliances, and in cabinets) and left for 7 days, after which they were collected. The number of trapped cockroaches were counted. At least 1 cockroach had to be trapped for the family to be enrolled in the study. Exclusion criteria included a history of professional cockroach control or professional cleaning services in the home within the previous 6 months. Forty-nine eligible families were enrolled.

Intervention

Each participating family was randomly assigned to 1 of 3 groups at the time cockroach sticky traps were collected: (1) an insecticide treatment group received professional cleaning (The MAIDS Home Services, Los Angeles, CA), placement of 24 enclosed bait traps containing the insecticide fipronil, and application to open cracks and crevices of a gel containing the insecticide hydramethylnon by a commercial pesticide applicator; (2) a sham treatment group received professional cleaning and placement of 24 enclosed bait traps and application of gel containing no insecticides; and (3) a control group received no professional cleaning or bait traps.

The pesticide applicator and the study staff were not informed as to whether the bait containers contained insecticide or not. In all homes, the child's caretaker and other household members present at the time of randomization received instructions about controlling cockroaches by restricting access to food by keeping food in cockroach-proof containers, cleaning dishes and eating areas after eating, and depriving cockroaches of places to hide by disposing of newspapers and clutter.

Homes were visited a total of 8 times during the 11-week study period (Table 1). At the initial visit, housing type (detached single family or multiple unit) was noted by study staff. At the time of the randomization of each family (visit 2), the pesticide applicator noted whether food was left uncovered outside the refrigerator or if there were dirty dishes. The month of each visit was coded as part of the rainy season (November 1 to February 28) or summer (the rest of the year), and the time between each visit was recorded. The participants in the 2 groups of treated homes received 1 additional visit in week 6 (5 weeks after treatment with insecticide-laden or sham

Table 1. Activities at Each Home Visit

Activity	Visit									
	1	2*	3	4	5†	6	7	8	9	10
Week No.	0	1	4	5	6	7	8	10	11	
Roach count		X		X			X		X	
Dust collection	X		X			X		X		
Bait containers (treatment groups only)		X					X			

* Families randomized.

† Cleaning (treatment groups only).

bait), at which time the homes were professionally cleaned. During repeat visits, sticky traps were placed in homes in all 3 groups and in the same locations as on the first visit, using a diagram made by the pesticide applicator at the time of the first home visit. The traps were collected 7 days later and cockroaches were counted. Eight weeks into the study (2 weeks after cleaning), the treatment homes were re-treated (with sham or insecticide bait containers) to see if any cockroaches were found in cockroach sticky traps.

The cleaning procedure involved a team of 4 persons. Hard surfaces within the residence, including floors, floorboards, counters, door and window frames, appliances, bathroom surfaces, and around wall hangings, were scrubbed and washed with a commercial bleach solution. All surfaces that could not be washed were vacuumed thoroughly with a HEPA, triple filter equipped vacuum.

Cockroach and Allergen Monitoring

Cockroaches were counted at the time of randomization, at study week 5 (immediately before cleaning), and at weeks 8 and 11 (2 and 4 weeks after cleaning, respectively) (Table 1).

Two dust samples were collected during the first home visit and at 4 weeks (3 weeks after treatment), 7 weeks, and 10 weeks (1 and 4 weeks after cleaning), using a Li'l Hummer vacuum cleaner (Miracle Marketing Corp, Salt Lake City, UT). One composite sample was collected in the child's bedroom or sleeping area from the floor, under the bed, bedding and mattress (or impermeable cover), pillowcase (or pillow if there was no pillowcase), baseboards, air vents, clock, and other furniture and appliances. In the kitchen, another composite vacuumed sample was collected from counters, tops of clocks and molding, appliances, walls, baseboards, window sills, floors, and, if possible, behind and under the stove and refrigerator, on the refrigerator condensing coils, and inside the vent on the front of the refrigerator. Between rooms, the vacuum bag was removed, folded over itself, and placed inside a ziplock freezer bag. Between each sample, the attachments and the tubing exiting the vacuum into the collector bag were cleaned with a wet wipe. Samples were stored frozen until shipping for processing and analysis. Vacuum attachments were cleaned between homes with soap and water.

Dust samples were sieved through a 300-mm, mesh wire sieve (Newark Wire Cloth Company, Newark, NJ). A

100-mg sample of fine dust was extracted overnight in 2 mL of borate-buffered saline, pH 8.0. Allergens were assayed in the supernatant using a monoclonal antibody–based enzyme-linked immunosorbent assay for the *Blattella germanica* allergen (Bla g 2).^{10,11} Allergen concentrations were expressed as international units (U) of Bla g 2 per gram of dust.

Statistical Analysis

Descriptive statistics were examined for bedroom and cockroach allergen over time. We examined the correlation between cockroach counts and allergen concentration, using the Spearman rank correlation test. Repeated-measures analysis of variance was used to test for differences in cockroach counts and allergen concentration between intervention groups over time. Because these outcomes were not normally distributed and log transformation resulted in variance in outcomes that were not homoscedastic between groups at all times, each outcome was ranked (across all visits) to allow for parametric hypothesis testing.¹² Each model contained a within-group term (visit), a between-group term (intervention group), and an interaction term (visit $\times$ group), which evaluated whether the change between visits was different in the different groups. For some analyses, the 2 groups receiving professional cleaning were collapsed into a single group to examine the effect of cleaning. Results were considered statistically significant if $P < .05$; for these results, the analyses were repeated after restricting to homes with measurements at all visits to see if the pattern of effects was influenced by loss to follow-up.

To evaluate whether initial cockroach count modified the results of intervention on allergen concentration, some analyses were stratified by baseline cockroach count (arbitrarily dividing homes at the median for all homes to compromise power as little as possible). Although dust was collected for allergen analysis at 4 of the 9 visits (Table 1), for some analyses the first 2 allergen concentrations were averaged to

obtain more stable precleaning allergen values. In these analyses, time since the visit made to all homes immediately preceding cleaning (visit 4 in Table 1) also was evaluated as a continuous variable to evaluate the effect of time since cleaning. (Time was not calculated starting with the day of cleaning itself, because the nontreatment control group homes were not cleaned.) Confounding was assessed by including initial cockroach count (ranked across all 3 groups), the presence of food in the home, type of housing (detached or multiple unit), or season at each visit in additional models.

RESULTS

There were fewer subjects randomized to the group receiving sham bait traps ($n = 12$) than to the group receiving insecticide bait ($n = 19$) or to the control group ($n = 18$). There was moderate loss to follow-up during the study, with 78% still enrolled at week 11. Differences in loss were not significant between groups ($\chi^2 = 2.66$, $P = .26$). The participants were almost exclusively inner-city residents who spoke Spanish as a first language. Mean age of the asthmatic children in the participating households was 11.3 years (SD, 3.36 years), and they were primarily Hispanic (Table 2). There was no difference between groups in type of housing or exposed food at baseline. However, those in the control group were more likely to be female and were more likely to have the first visit in the winter than children in the other groups. Season of entry into the study, type of housing, and exposed food at baseline were not associated with either ranked cockroach count or ranked kitchen or bedroom Bla g 2 at study entry (results not shown).

Median cockroach count on sticky traps at study entry in homes in the group randomly assigned to treatment with insecticide was higher (median, 136) than in either the sham treatment (median, 55) or control (median, 19) group (Table 3), although these results were not significantly different

Table 2. Selected Demographic and Housing Characteristics of Participants by Group

Participant characteristics	Group, No. (%)			χ^2	P value
	Control	Sham bait	Insecticide bait		
Sex of child					
Male	10 (55.6)	11 (91.7)	16 (84.2)	6.35	.04
Female	8 (44.4)	1 (8.3)	3 (15.8)		
Ethnicity					
Hispanic	18 (100)	11 (91.7)	18 (94.7)	1.39	.49
Other	0	1 (8.3)	1 (5.3)		
Housing					
Detached, single family	10 (58.8)	6 (50.0)	10 (52.6)	.25	.88
Multiunit	7 (41.2)	6 (50.0)	9 (47.4)		
Food present at entry					
Yes	7 (38.9)	3 (25.0)	9 (47.4)	1.55	.46
No	11 (61.1)	9 (75.0)	10 (52.6)		
Season at entry					
Winter	13 (72.2)	3 (25.0)	8 (42.1)	7.01	.03
Other	5 (27.8)	9 (75.0)	11 (57.9)		

Table 3. Cockroach Counts and Allergen Concentration in Different Groups during Follow-up

Group	N*	Median (IQR)		
		Cockroach count	Kitchen Bla g 2, U/g	Bedroom Bla g 2, U/g
Controls				
1 wk	18	19 (7–298)	104 (9.3–297)	15 (5.3–79)
5 wk	16	8.5 (2–301)	31 (12–150)	16 (9.5–57)
8 wk	14	10 (2–136)	52 (7.1–129)	13 (7.9–26)
11 wk	13	22 (0–249)	61 (18–247)	10 (6.3–32)
Sham bait				
Baseline	12	55 (32–215)	214 (13–1,403)	21 (4.5–41)
Preclean/post-treatment	10	85 (54–157)	173 (16–672)	12 (5.0–25)
Postclean	10	124 (66–271)	44 (32–132)	15 (4.8–27)
Postclean/post-re-treatment	8	68 (31–244)	25 (4.8–197)	7.3 (3.8–24)
Insecticide bait				
Baseline	19	136 (14–1,600)	136 (73–402)	32 (11–83)
Preclean/post-treatment	19	26 (4–173)	171 (28–279)	28 (7.5–80)
Postclean	19	21 (2–95)	179 (63–377)	17 (13–106)
Postclean/post-re-treatment	17	14 (0–26)	66 (26–197)	19 (7.8–57)

Abbreviation: IQR, interquartile range.

* No. of participants (varies by visit).

($F = 0.99$, $P = .38$). During subsequent visits, the median cockroach counts changed little over time in the control group and the sham treatment group. However, there was a consistent decrease in the cockroach count in the homes treated with insecticidal bait. By the final visit more than 25% of the homes in the insecticide bait group were free of cockroaches, although half of the homes still had 14 or more cockroaches trapped at the last visit. There was a significant interaction of group with visit ($P < .001$). All visits subsequent to baseline in the group treated with insecticidal bait had significantly lower cockroach count ranks than at baseline ($P < .001$ for all comparisons with baseline count). Within other groups, there was no significant difference between cockroach count rank at baseline and at any subsequent visit. The overall pattern of effects of treatment was similar after adjusting for housing type, observed presence of food in the home, or season at each visit or after restricting to homes included in all visits.

The median concentrations of Bla g 2 were considerably higher in the kitchen, where cockroaches congregate, than in the bedroom (Table 3), as has been observed in other studies.⁹ The correlation of initial cockroach count to allergen concentration was moderately strong and highly significant in the kitchen (Spearman $r = 0.53$, $P < .001$) and in the bedroom ($r = 0.63$, $P < .001$). Nevertheless, there were no significant differences in the change in ranked allergen load over time among the 3 randomly assigned groups, when analyzed based on the original design. The P value for the interaction of group with visit was .51 for kitchen and .54 for bedroom. Adjustment of these analyses for season, exposed food, and housing type also did not result in any different pattern of change in allergen concentration, nor did restricting the analysis to homes for which allergen concentration was measured at all visits.

The pattern of change in kitchen cockroach allergen concentration was examined in groups stratified by high and low initial cockroach count (Table 4) to see if there might be an effect of intervention in either of these subgroups. In the homes with high initial counts, there was a decline in allergen concentration by the final visit among both groups of homes that were cleaned. However, the decline in either of the cleaned groups was not significantly different from that in the control group (P value for interaction = .65). We next averaged the 2 precleaning kitchen allergen concentrations to provide a more stable estimate of concentration, the 2 groups that were cleaned were combined, and time since visit 4 (just before cleaning in the cleaning groups) was considered as a continuous variable. In this analysis, the decline in the cleaning groups was significantly larger than in the control group ($P = .02$ for the interaction between time and cleaned compared with not cleaned homes). The decline from precleaning to the final allergen measurement within the group of homes that were cleaned was highly significant ($P = .003$). The pattern of effects was similar after adjusting for initial (ranked) cockroach count, housing type, observed presence of food in the home, or season at each visit and after restricting to subjects present at all visits, and the decline in the homes that were cleaned was significantly different from that in the control group not cleaned ($P < .05$ for interaction of time with cleaned compared with not cleaned homes). Although the decline in the median allergen concentration in the sham-treated homes was larger than in the insecticide-treated homes, these differences were not significant.

In homes with lower initial cockroach counts, there was little evidence of any decrease over time associated with treatment or cleaning (Table 4). There was an unusual 4-fold reduction in median allergen concentration in the kitchen allergen concentration in the control group with low initial

Table 4. Kitchen Cockroach Allergen Bla g 2 during Follow-up by Group and Initial Cockroach Count

Group	Kitchen Bla g 2 (low initial cockroach count)		Kitchen Bla g 2 (high initial cockroach count)	
	N*	Median (IQR), U/g	N*	Median (IQR), U/g
Controls				
Baseline	12	85 (8.4–241)	6	203 (92–643)
4 wk	9	21 (6.5–31)	4	350 (184–754)
7 wk	7	10 (6.0–126)	5	120 (9.5–133)
10 wk	7	22 (8.0–91)	5	345 (78–1,323)
Sham bait				
Baseline	5	13 (6.8–214)	6	1037 (139–1,634)
Preclean/post-treatment	4	29 (8.4–357)	5	357 (173–754)
Postclean	4	78 (26–168)	5	44 (32–132)
Postclean/post-re-treatment	4	34 (15–203)	3	13 (3.0–197)
Insecticide bait				
Baseline	7	76 (8.0–162)	12	281 (109–549)
Preclean/post-treatment	7	27 (25–28)	11	258 (154–695)
Postclean	5	47 (16–63)	12	253 (149–530)
Postclean/post-re-treatment	5	60 (13–73)	11	79 (28–225)

Abbreviation: IQR, interquartile range.

* No. of participants (varies by visit).

cockroach counts. This was not explained by greater loss to follow-up among those homes with higher initial allergen concentration, because the reduction was similar when the sample was restricted to those homes sampled at all visits. The most likely explanation for this anomalous result was random variation resulting from small sample size, since the change over time was not significantly different from that in other groups (P for interaction = .45). There was no evidence for differences in patterns of change in bedroom allergen concentration between groups in homes with either high or low initial cockroach counts (results not shown).

DISCUSSION

We demonstrated clear decreases in cockroach counts, which were restricted to the insecticide-treated group. In those homes with high initial cockroach counts, there were large reductions in Bla g 2 cockroach allergen concentration in kitchens of homes professionally cleaned, and in some analyses these changes were significantly different from changes that occurred in the homes that were not cleaned. However, after 11 weeks of follow-up and 2 professional insecticide applications, there continued to be significant cockroach infestations in treated homes and high concentrations of allergen in homes that were professionally cleaned. Reductions in kitchen allergen were not observed in homes with initially lower cockroach counts. There were only modest reductions in allergen concentration in the child's bedroom, and these reductions did not differ significantly by treatment or cleaning group. At the conclusion of follow-up, more than half of all kitchens and bedrooms in cleaned homes had cockroach allergen concentrations above 8 U/g, a level above which more severe asthma has been observed among children allergic to cockroach.¹³

This study had a larger sample of homes and larger control group than in previous cockroach allergen intervention studies involving professional cockroach control and cleaning. A sham treatment group with blinding of both the insecticide applicator and participants controlled for placebo effects of treatment. Nevertheless, our results are consistent with the results of previous efforts to control cockroach allergen concentrations in homes. Reduction in cockroach counts in homes treated with insecticides has been demonstrated previously for up to 6 months of follow-up in a study of 8 homes.⁸ However, there were no reductions in Bla g 2 and only modest reductions in Bla g 1 by 6 months. In 48 homes treated with insecticide in the National Cooperative Inner City Asthma Study, there was a modest reduction in allergen concentration in the kitchen 2 months after treatment, but allergen levels remained high throughout the study and returned to pretreatment levels by the end of the 12-month study.¹⁴ There was no nonintervention comparison group. In another uncontrolled trial, 13 homes were twice professionally cleaned and then treated with insecticide.⁹ There were decreases in cockroaches trapped, although more than half of those homes with cockroaches at the beginning of the study continued to have cockroaches at the 8-month follow-up. There were sustained reductions in Bla g 1 (93% in the kitchen and 74% in the bedroom); however, concentrations in more than half of the homes continued to exceed 20 U/g. In a recent, larger, well-designed intervention in inner-city Atlanta, GA, which did not involve professional cockroach control, there was no effect on cockroach allergen of providing insecticide bait containers and instruction on cockroach control to families.¹⁵

There were no overall reductions in allergen concentrations in homes treated with pesticides and/or cleaned based on the

original design. Therefore, the interpretation of the large reduction in kitchen allergen observed in cleaned homes (but not in homes not cleaned) in the subgroup of homes with high initial cockroach counts should be interpreted cautiously. It is possible that this observation was a spurious result of conducting post hoc analyses on this subgroup. However, among those homes that were cleaned (and treated either with sham or with active pesticide), there was a moderately strong association between the reduction in cockroach count at the final visit from the count at study entry and the reduction in the final allergen measurement from the average of the 2 precleaning measurements. This association was observed in both the kitchen (Spearman $r = 0.47$, $P = .03$) and the bedroom ($r = 0.41$, $P = .05$). This observation provides a strong rationale for the subgroup analysis, because it makes it more plausible that cleaning would be more effective in homes with more cockroaches. (These homes have more possibility for reduction in cockroaches.) Another potential limitation to this study was the relatively small number of homes in each group, a limitation of greater importance because there was some loss to follow-up. It is possible that small effects of treatment or cleaning were not identified in this study, because statistical power was not adequate. It is also possible that the observed reduction in allergen concentrations in the homes with higher initial cockroach counts resulted from loss to follow-up of homes with high (or low) allergen concentrations, which affected one group more than another. However, this source of bias is less likely, because the same overall pattern of effect of treatment and cleaning was observed when the analysis was restricted to homes for which measurements were made at every visit.

To guarantee sufficient sample for analysis, we thoroughly vacuumed all surfaces in the kitchen and bedroom on each visit. Therefore, the results are not strictly comparable to other studies, which have sampled a specific area or limited sampling to bedding. It is possible that reservoir allergen sampled from areas relatively inaccessible to cleaning, such as behind appliances or deep in carpets, may have accounted

for the continued high concentrations in our study. These areas may be less biologically relevant than allergen in locations more accessible to children, for example, in bedding, which were not sampled separately in our study. Alternatively, reservoir allergen may have redistributed throughout the home, or allergen concentration may have been replenished from remaining cockroaches. The dust sampling strategy did not permit an evaluation of these questions.

The reduction in allergen concentration after cleaning in homes treated with insecticide was smaller and occurred later than in sham-treated homes. One possible explanation for this result is the larger allergen load, which may have continued to be generated in homes where cockroaches were dying. If so, cleaning might be more effective if it occurred after cockroaches were eliminated. A larger reduction after cleaning in those homes in which cockroaches were eliminated by the final visit (Table 5) suggests this might be the case. Although there were few homes with no cockroaches, the median bedroom concentrations were reduced to below 8 U/g by cleaning.

Our study suggests that short-term professional insecticide application to individual housing units results in a reduction in the number of cockroaches and elimination of cockroaches in some homes. Given that a dose-response relationship between cockroach allergen exposure and asthma exacerbation likely exists,¹⁶ the reduction in allergen concentrations achieved with intensive cleaning in those homes with the highest initial cockroach infestations may be beneficial to asthmatic patients. A professional intervention is attractive, because repeated treatment by participants and the work involved in depriving cockroaches of food, a key feature of long-term control, requires an effort that can be difficult for busy parents to sustain. However, the observed reductions were unlikely to be sufficient to eliminate the exacerbation of asthma known to be associated with allergen concentrations remaining in most homes. In addition, the cost of this approach limits its widespread applicability for longer-term intervention, which might result in better control of cock-

Table 5. Cockroach Allergen Bla g 2 during Follow-up among Cleaned Homes by Final Visit Elimination of Cockroach Count

Area	Bla g 2 (cockroach present at final visit)		Bla g 2 (cockroach not present at final visit)	
	N*	Median (IQR), U/g	N*	Median (IQR), U/g
Kitchen				
Baseline	18	153 (76–306)	6	87 (13–161)
Preclean/post-treatment	17	154 (28–279)	6	130 (22–258)
Postclean	16	126 (55–250)	6	76 (16–222)
Postclean/post-re-treatment	17	79 (25–225)	6	24 (13–30)
Bedroom				
Baseline	18	25 (9.1–81)	6	25 (5.8–65)
Preclean/post-treatment	17	25 (7.5–69)	6	13 (6.0–48)
Postclean	16	22 (14–86)	6	12 (5.5–22)
Postclean/post-re-treatment	17	18 (7.5–43)	6	7.4 (3.8–20)

Abbreviation: IQR, interquartile range.

* No. of participants (varies by visit).

roaches and reduction of allergen. Therefore, alternative approaches are needed that focus on longer-term strategies with more participant involvement in the process of controlling cockroaches and reducing allergen. Several such trials are under way.

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