

Abatement of cockroach allergens (Bla g 1 and Bla g 2) in low-income, urban housing: Month 12 continuation results

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Background: In the first 6 months of this previously published, randomized trial, the combined intervention of occupant education, insecticide bait application, and professional cleaning significantly reduced cockroach numbers and Bla g 1 allergen levels in inner-city homes.

Objective: This continuation study investigated whether the cockroach allergen reductions achieved by month 6 could be maintained through month 12 with insecticide application alone. **Methods:** Because we had agreed to place insecticide bait in control homes at the conclusion of the first study, intervention and control homes were treated with insecticide bait at months 6 and 9. No other intervention was conducted in either arm. Vacuumed dust and swab samples were collected at month 12. Twenty-one of the 31 original homes completed the 12-month study.

Results: Among the original intervention homes, Bla g 1 concentrations remained essentially unchanged from months 6 to 12. However, among the crossed-over control homes, the geometric mean Bla g 1 concentrations (Units per gram of dust) decreased from 287 to 14.4 for kitchen floors (95% reduction), from 28.8 to 5.6 for living room floors/sofas (81% reduction), from 26.7 to 4.7 for bedroom floors (82% reduction), and from 7.2 to 2.4 for beds (67% reduction). At month 12, Bla g 1 concentrations did not significantly differ between intervention and crossed-over control homes ($P > .64$ at each location). Similar results were seen for the allergen Bla g 2.

Conclusions: Reductions in cockroach allergen concentrations achieved through the combined intervention of occupant education, insecticide application, and professional cleaning can be maintained with continued cockroach control. Surprisingly, and in contrast to other studies, insecticide application alone significantly lowered allergen concentrations in the crossed-over control homes. This unexpected result is being tested fur-

ther in another randomized trial. (*J Allergy Clin Immunol* 2004;113:109-14.)

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

Cockroach allergen is one of the most prominent, if not the most prominent, allergens in inner-city homes.¹ In the National Cooperative Inner-City Asthma Study (NCI-CAS), children who were both allergic to cockroach allergen and exposed to high levels of the allergen were more likely to have unscheduled medical visits and hospitalizations for asthma than other children.¹ Because of this, lowering exposures to cockroach and other allergens should be an effective strategy for the primary and secondary prevention of asthma in this population. However, reductions, especially sustained reductions, in cockroach allergen levels have proven difficult to demonstrate. Previously, we reported results from a randomized trial that tested the effects of an intensive intervention on cockroach allergen levels in highly infested, low-income, urban homes.² The intervention consisted of occupant education, insecticide bait application, and extensive professional cleaning. By month 6, median cockroach counts in traps were zero and allergen levels were substantially reduced in kitchens, living rooms, and bedrooms. Cockroach allergen levels were reduced below the sensitization threshold (2 U/g) in beds and below the asthma morbidity threshold (8 U/g) on bedroom floors and living room floors/sofas.^{1,3}

One of the unanswered questions in that study was whether the allergen reductions would persist over time. To address that question, we invited the households to participate in a continuation study in which insecticide bait placement would be the only intervention component performed. Because we had agreed to place insecticide bait in control homes at the conclusion of the first study, intervention and control homes were treated with insecticide bait during the continuation study. The two objectives of the continuation study were to evaluate (1) whether the allergen reductions achieved in the original intervention homes could be maintained with insecticide application alone and (2) whether insecticide application alone could produce any significant reductions in allergen levels among the crossed-over control homes.

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Abbreviation used

NCICAS: National Cooperative Inner-City Asthma Study

METHODS**First study (months 0 to 6)**

Characteristics of the enrolled homes and methods for the first study are published elsewhere² but are briefly reviewed here. All homes were low-income, multiunit dwellings located in the same metropolitan area of North Carolina. The inclusion criteria required 50 to 500 trapped German cockroaches at baseline. Sixteen intervention and 15 control homes were followed for 6 months. In all homes, vacuumed dust samples were collected from the kitchen floor, the living room floor and sofa (combined sample), the bedroom floor, and a bed. Also, 20 swab samples were collected in the kitchen, living room, and bedroom for a total of 60 samples per home. At each swab sample location, the area within a 10 × 10-cm plastic template was wiped with a moistened cotton swab. Vacuum and swab samples were collected at months 0, 1, 2, 4, and 6 in intervention homes and at months 0 and 6 in control homes. In addition, 6 cockroach traps were set in the kitchen, living room, and bedroom (a total of 18 traps per home) and collected 3 days later. Layout maps, which indicated cockroach counts and allergen levels, were created for each room and updated after each visit. The combined intervention consisted of (1) occupant education on cockroach control, (2) insecticide bait placement by an entomologist or his staff from North Carolina State University, and (3) extensive professional cleaning of the home.

Continuation study (months 6 to 12)

At the completion of the first study, 26 of the 31 households consented to participate in the continuation study. In both arms—the original intervention homes and the crossed-over control homes—cockroach traps were set in the kitchen, living room, and bedroom at months 6, 9, and 12. Insecticide baits containing 2.15% hydramethylnon (Maxforce, Clorox, Pleasanton, Calif) were placed at months 6 and 9 if any cockroaches were trapped. At month 6, as at month 0, bait was placed in every room of treated homes. Approximately 100- to 200-mg dots or streaks 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 at cracks in walls or floors. At month 9, bait placement, which was guided by cockroach trap counts and visual inspection, was typically not as extensive. No other component of the original intervention was carried out in either arm from months 6 to 12. Swab and vacuumed dust samples were collected from the kitchen, living room, and bedroom at month 12. In the laboratory, swab and dust samples were analyzed for concentrations of Bla g 1. Dust samples collected at months 0, 6, and 12 were also analyzed for the cockroach allergen Bla g 2, another of the 4 identified allergens from the cockroach *Blattella germanica*.⁴ Results for Bla g 2 were not presented in the first publication of this study. All sampling and laboratory procedures were carried out as previously published.² Vacuum sample results are presented here in Units of allergen per gram of sieved dust (U/g), a measure of concentration, whereas swab sample results are presented in Units of allergen per area swabbed (U/area), a measure of allergen load.

Statistical analyses

A mixed-effect model was used to examine the changes in log-transformed allergen concentrations from months 6 to 12 within each study arm and the differences between the study arms at month 12. Figs 1 and 2 and the mixed-effect models used all available data

at each time point. For swab samples, the highest allergen concentration of the 20 samples within a given room was used as an index for that room. All statistical tests were 2-tailed, with α set at 0.05. Use of the terms “significant” and “significantly” in this report always implies a P value $\leq .05$.

RESULTS

Twenty-one of the 31 original homes completed the continuation study. Five homes in each study arm were lost to follow-up, with occupant relocation being the predominate reason. Within each of the two study arms, comparisons between homes that completed the continuation study and homes that were lost to follow-up did not reveal any significant differences at month 6 in cockroach counts, Bla g 1 values from vacuum or swab samples, or cleaning frequencies.

Table I shows the median cockroach counts by group assignment, visit date, and sample location. Among intervention homes, median cockroach counts, which had been reduced to 0 by month 6, remained unchanged from months 6 to 12 (with the exception of the kitchen, where the median count increased from 0 to 1). However, among crossed-over control homes, in which insecticide bait was applied just after the 6-month trapping, median cockroach counts decreased substantially from months 6 to 12. As reported in the first publication, the decrease in counts from months 0 to 6 among control homes probably was the result of seasonality in cockroach numbers and/or the use of insecticides by householders. At month 12, median cockroach counts were essentially the same in crossed-over control and intervention homes.

Fig 1 shows the geometric mean Bla g 1 concentrations in vacuumed dust by group assignment, visit date, and sample location. From months 0 to 6, as previously reported,² Bla g 1 levels decreased substantially in the intervention homes, whereas levels remained elevated in the control homes. From months 6 to 12, the Bla g 1 level did not significantly change among the intervention homes at any of the four sample locations ($P = .73$ for the kitchen floors, $P = .77$ for the living room floors/sofas, $P = .97$ for the bedroom floors, and $P = .12$ for the beds). However, among crossed-over control homes, there was a significant decrease in the geometric mean Bla g 1 concentration (U/g) at each location: from 287 to 14.4 for kitchen floors (95% reduction, $P < .01$), from 28.8 to 5.6 for living room floors/sofas (81% reduction, $P < .01$), from 26.7 to 4.7 for bedroom floors (82% reduction, $P < .01$), and from 7.2 to 2.4 for beds (67% reduction, $P < .01$). At month 12, the geometric mean concentrations did not differ significantly between crossed-over control and intervention homes at any of the sample locations ($P > .64$ for each location).

As shown in Fig 2, the interventions had a similar effect on Bla g 2. From months 0 to 6, geometric mean Bla g 2 concentrations decreased significantly among intervention homes relative to control homes ($P < .01$ at each sample location). From months 6 to 12, Bla g 2 concentrations remained similar in intervention homes ($P > .32$ each location), whereas concentrations decreased sig-

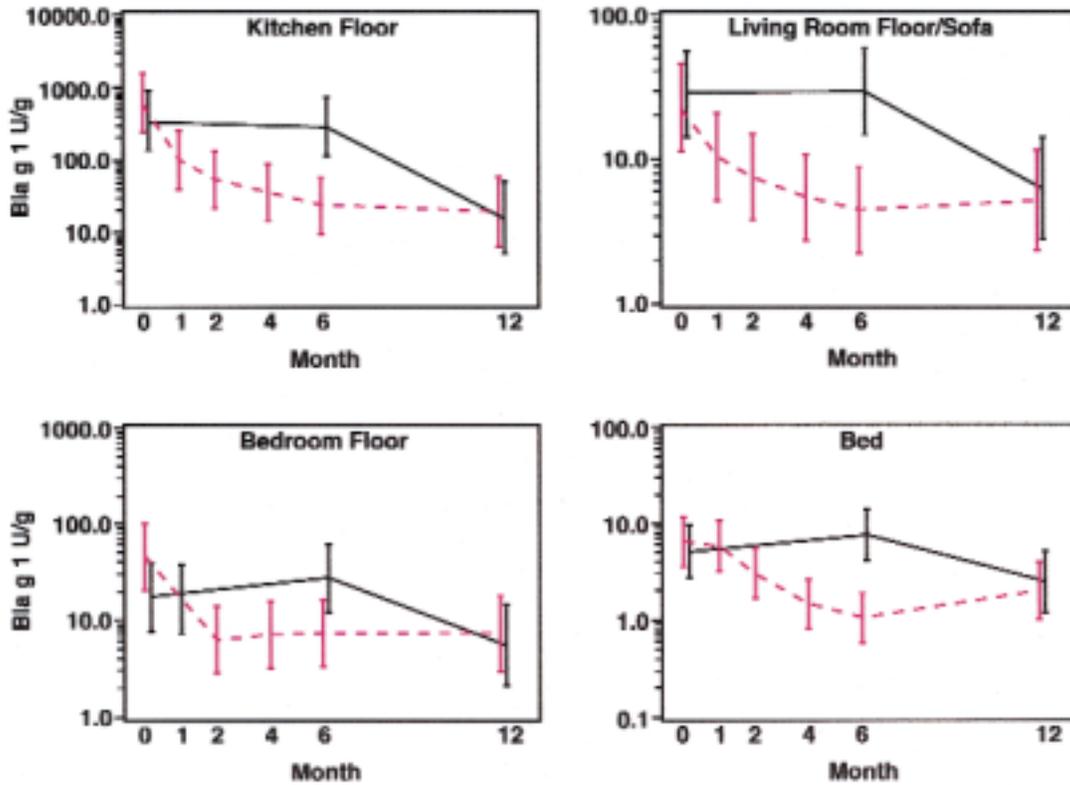


FIG 1. Geometric mean Bla g 1 allergen concentrations (and 95% confidence intervals) from vacuumed dust samples in control (solid black lines) and intervention (dashed red lines) homes. Control homes received no interventions from months 0 to 6 and insecticide bait application at months 6 and 9.

Environmental and occupational disorders

TABLE I. Median cockroach trap counts by group assignment, month of visit, and trap location

Group assignment	Month	n	Median cockroach count (% of homes with 0 count)		
			Kitchen	Living room	Bedroom
Intervention*	0	16	113.0 (00)	76.0 (00)	78.0 (06)
	6	16	0.0 (56)	0.0 (69)	0.0 (75)
	12	11	1.0 (36)	0.0 (73)	0.0 (73)
Control†	0	15	146.5 (00)	58.5 (07)	14.0 (07)
	6	15	46.0 (13)	10.5 (27)	5.5 (20)
	12	10	2.0 (40)	0.0 (70)	0.0 (80)

*Intervention homes received occupant education, insecticide bait application, and professional cleaning from months 0 to 6 and insecticide application alone at months 6 and 9.

†Control homes received no interventions from months 0 to 6 and insecticide bait application at months 6 and 9. Trap counts at month 6 were determined before insecticide application.

nificantly in the crossed-over control homes ($P < .01$, each location). At month 12, geometric mean Bla g 2 concentrations did not significantly differ between crossed-over control and intervention homes ($P > .13$ each location).

The interventions also had similar effects on allergen loads as assessed by swab sampling (Table II). From months 0 to 6, geometric mean Bla g 1 loads decreased significantly in intervention rooms relative to control rooms ($P < .01$ for each room). From months 6 to 12, the load did not significantly change in intervention kitchens

($P = .15$) or living rooms ($P = .44$); however, there was a significant increase in allergen load in intervention bedrooms ($P = .04$). Among crossed-over control homes, the geometric mean Bla g 1 load decreased significantly from months 6 to 12 in each room ($P < .01$, each room). At month 12, there were no differences in geometric mean loads between crossed-over control and intervention homes at any of the sampled rooms ($P > .15$, each room). A secondary analysis that used the mean of the 20 sample values as the index for each room rather than the maximum value gave very similar results (results not

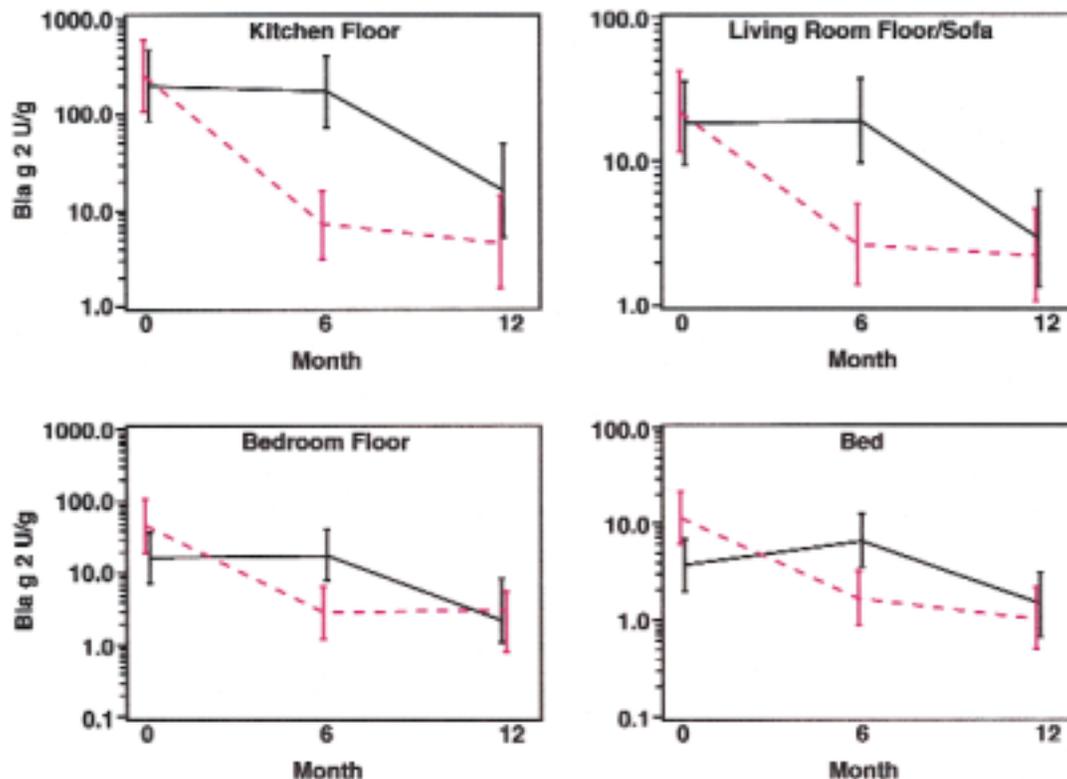


FIG 2. Geometric mean Bla g 2 allergen concentrations (and 95% confidence intervals) from vacuumed dust samples in control (solid black lines) and intervention (dashed red lines) homes. Control homes received no interventions from months 0 to 6 and insecticide application at months 6 and 9.

TABLE II. Geometric mean Bla g 1 loads (U/100 cm²) for swab samples by group assignment, month of visit, and sample location

Group assignment	Month	n	Geometric mean Bla g 1 load (95% CI)		
			Kitchen*	Living room*	Bedroom*
Intervention†	0	16	3.34 (1.71-6.50)	0.26 (0.12-0.54)	0.37 (0.14-0.98)
	6	16	0.08 (0.04-0.16)	0.03 (0.02-0.06)	0.03 (0.01-0.06)
	12	11	0.21 (0.07-0.65)	0.05 (0.01-0.18)	0.09 (0.03-0.25)
Control‡	0	15	2.93 (1.69-5.08)	0.33 (0.15-0.71)	0.19 (0.06-0.64)
	6	15	2.02 (0.88-4.61)	0.20 (0.10-0.41)	0.42 (0.16-1.08)
	12	10	0.48 (0.14-1.62)	0.04 (0.02-0.11)	0.05 (0.02-0.14)

*Each room was assigned the highest of 20 swab sample values.

†Intervention homes received occupant education, insecticide bait application, and professional cleaning from months 0 to 6 and insecticide application alone at months 6 and 9.

‡Control homes received no interventions from months 0 to 6 and insecticide application at months 6 and 9. Load values at month 6 were determined before insecticide application.

shown), with the exception that the mean allergen load remained similar from months 6 to 12 in the intervention bedrooms ($P = .17$).

DISCUSSION

Reductions in Bla g 1 concentrations achieved during the first 6 months with occupant education, insecticide

bait placement, and professional cleaning were maintained through month 12 with insecticide bait placement alone. Surprisingly, Bla g 1 concentrations decreased significantly in the control homes after they were treated with insecticide bait. In fact, at month 12, intervention and crossed-over control homes had essentially the same Bla g 1 concentrations at each sample location. In each group of homes, geometric mean Bla

g 1 concentrations were reduced below the asthma morbidity threshold of 8 U/g in all sampling sites except for the kitchen floors. Throughout the 12-month study, Bla g 2 levels followed a pattern similar to the Bla g 1 levels, which was not surprising, considering the high correlation ($r = 0.92$) that has been reported between the two cockroach allergens.⁵

Among crossed-over control homes, significant reductions were also seen in Bla g 1 loads, as measured with the 100-cm² swab samples. In contrast to concentration, load is a measure of the absolute quantity of allergen within a given area. There has been some discussion in the literature that load may be a better measure of allergen exposure.^{4,6} However, load has typically been determined from vacuum sampling. In this intervention trial, swab sampling for cockroach allergen was an innovation—a method devised to monitor the effectiveness of cleaning. It is quite possible that the bioavailability of allergen determined by swab and vacuum sampling differs. Since vacuum sampling in this study was based on time rather than a measured area, vacuum sample results could not be converted to load. Thus, we could not make load comparisons between the two methods. Regardless, it was reassuring to see similar intervention effects with the two sampling methods.

Our finding among the crossed-over control homes contradicts the conclusions of other studies that have examined the effects of cockroach extermination on cockroach allergen levels. In a study of cockroach-infested homes in North Carolina, Williams et al⁷ were successful in reducing cockroach numbers in homes that were treated with 2% hydramethylnon bait trays. However, at month 6, there was not a significant difference between control and treated homes in kitchen Bla g 2 concentrations.⁷ Although the authors reported a statistically significant difference in kitchen Bla g 1 concentrations at 6 months, they described the difference as “trivial” and concluded that “there is no clinically significant fall in allergen levels if no special cleaning efforts are made.”⁷ However, with a study population of 5 intervention and 2 control homes, the study may not have been sufficiently powered to detect a clinically significant reduction in allergen levels.

In the NCICAS, inner-city homes received 2 professional applications of the insecticide Abamectin (Avert, Whitmire Micro-Gen Laboratories, St Louis, Mo).⁶ In addition, families were asked to thoroughly clean their homes before and after the pest control treatments. At month 12, there were no significant reductions in Bla g 1 concentrations in any room. One of the reasons stated for the lack of success in the NCICAS was the families' poor compliance with cleaning instructions; however, the effectiveness of the cockroach exterminations were not monitored with traps, and it may be that the exterminations, which were conducted by commercial pest control companies, were not as effective as they were in our study.

In contrast to the NCICAS study, insecticide applica-

tions in our study were performed by an entomologist or his staff, associated with the Urban Entomology Laboratory at North Carolina State University (Raleigh, NC). Bait placement was guided by cockroach trap counts and by extensive visual inspection of the home. We believe that our results underscore the view that effective cockroach control should be guided by visual inspection and monitoring with traps.⁸ Since it would not be practical to have an entomologist place bait in a large environmental intervention study or public health program, the level of expertise and effort that would be required to achieve significant allergen reductions through cockroach extermination would have to be determined. In a new study, we are comparing allergen reductions in homes treated by commercial exterminators with allergen reductions in homes treated by an entomologist.

Another potential explanation for the success in the crossed-over control arm is changes in occupant cleaning behaviors between months 6 and 12. Although we did not instruct residents to clean their homes after the insecticide bait applications, they probably performed additional cleaning to rid their homes of dead cockroaches. At months 6 and 12, we inquired about cleaning frequencies in the previous month. Although every household in the crossed-over control arm reported an increased frequency of cleaning the bedroom, cleaning frequencies did not significantly change for the kitchen or living room.

In our previous report, we concluded that “cockroach allergen abatement programs in inner-city homes should include professional control of cockroaches, professional cleaning, and perhaps interior home repair.”² However, the findings of this continuation study bring this conclusion into doubt. Because the cost of the comprehensive intervention is much greater than extermination alone, the question of whether cockroach extermination alone can reduce cockroach allergen levels needs to be answered definitively. In another environmental intervention trial, we are attempting to verify these results and to determine the level of expertise and effort in cockroach extermination that would be required to reduce cockroach allergens in a large asthma prevention trial or public health program.

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