

---

# Cockroach allergen abatement with extermination and sodium hypochlorite cleaning in inner-city homes

Robert A. Wood, MD\*; Peyton A. Eggleston, MD\*; Cynthia Rand, PhD†; W. Jay Nixon, MS, BCE‡; and Sukon Kanchanaraksa, PhD§

---

**Background:** Although the importance of cockroach allergen in chronic asthma has now been well defined, little progress has been made in the control of cockroach allergen in infested homes.

**Objective:** The objective of this study was to examine the ability of a combination of professional pest extermination and household cleaning using a solution of sodium hypochlorite to reduce cockroach infestation and allergen levels in cockroach infested homes.

**Methods:** Seventeen cockroach-infested homes were studied with three homes serving as controls. In the intervention homes, a professional exterminator applied 0.05% abamectin twice at 2-week intervals at study entry and a professional cleaner cleaned the homes before and after the extermination. All washable surfaces were cleaned throughout the study with a solution of 0.5% hypochlorite. Monthly home visits were conducted to inspect the home, interview the homeowner, place passive cockroach traps, and to collect settled dust samples from the kitchen, bedroom, and TV/living room.

**Results:** The number of cockroaches in the passive traps decreased rapidly after the initial intervention in most homes. Median *Blattella germanica* allergen 1 levels in the settled dust samples fell by 91% in the kitchen, 78% in the bedroom, and 77% in the living room over the course of the study in the intervention homes but gradually rose in the control homes. The overall reductions were very similar to those seen in a previous study with a similar protocol except for the use of the sodium hypochlorite.

**Conclusions:** Successful extermination is possible in most inner-city homes and cockroach allergen levels can be reduced by 80% to 90%. However, 0.5% sodium hypochlorite did not seem to improve allergen reduction, and in many homes, allergen levels remained above the proposed threshold of 8 U/g of dust throughout the study.

Ann Allergy Asthma Immunol 2001;87:60–64.

## INTRODUCTION

Cockroach allergen is now recognized as a major indoor allergen, especially

in urban settings. It has been shown to be the most important allergen for children with asthma living in inner-city environments in the United States, where exposure is associated with both higher rates of cockroach sensitization and increased asthma morbidity.<sup>1,2</sup> It would, therefore, be ideal if cockroach allergen exposure could be significantly reduced in such environments.

We have previously reported that cockroach allergen is difficult to eliminate from inner-city homes, even after successful extermination.<sup>3</sup> Although allergen levels did fall substantially af-

ter intervention with extermination and professional cleaning, they were often still well above the proposed threshold of 8 U/g of dust; therefore, we have continued to try to devise more successful regimens for cockroach extermination and allergen removal. In this study, we used a solution of sodium hypochlorite (chlorine bleach) as a major component of the cleaning regimen after conducting experiments in the laboratory that demonstrated its effect in reducing allergen levels.<sup>4</sup>

## METHODS

### Recruitment of Homes

Families were recruited for this study by advertisement and word of mouth. All families lived in typical inner-city Baltimore homes and reported cockroach infestation. Seventeen homes were studied with three serving as controls. Fifteen homes were rowhomes and two were apartments. There was no requirement that the residents of the home have asthma or allergy. The major entry criterion was the level of cockroach allergen [*Blattella germanica* allergen 1 (Bla g 1)] in a baseline dust sample, which had to exceed 8 U/g of dust in at least one room to be included in the study. The study was approved by the investigational review board of Johns Hopkins University School of Medicine and all participants provided written, informed consent.

### Intervention

Allergen abatement was initiated in the intervention homes over a 1-month period during January 1999. The intervention consisted of a professional cleaning followed by two visits by a professional exterminator followed by a final cleaning visit. All homes had an

---

The Departments of \* Pediatrics and † Medicine and the ‡ School of Hygiene and Public Health, Johns Hopkins University, Baltimore, Maryland; and § American Pest Management, Inc, Takoma Park, Maryland.

This work was supported by Grants ES07527 and ES09606 from the National Institutes of Health, Grant R826724 from the Environmental Protection Agency, and by the Clorox Company. Received for publication July 12, 2000.

Accepted for publication in revised form January 5, 2001.

additional booster treatment consisting of one cleaning and extermination approximately 12 weeks after study entry. The professional cleaner used a chlorine bleach solution for all cleaning on all hard surfaces and each homeowner was provided with a monthly supply of the same solution to be used for all routine cleaning chores. The solution was formulated by Clorox Services Corporation (Pleasanton, CA) and contained 0.5% sodium hypochlorite plus a surfactant in a spray bottle. With cleaning, the professional cleaners and the homeowners were instructed to apply the solution to all hard surfaces, allow it to dry for 10 minutes, and then wipe it off.

The initial extermination was conducted at 2-week intervals using a gel bait containing 0.05% abamectin (Avert; Whitmire Laboratories, St. Louis, MO). Approximately 50 aliquots of gel were applied in the kitchen, concentrating in the area around the refrigerator, trash, and stove. Additional baits were applied in the living room, bedroom, and basement (if present and accessible). At each visit the pest control technician also conducted a standardized home inspection.

The control homes did not receive professional cleaning, extermination, or the bleach solution.

#### Evaluation

An initial home visit was conducted by a research nurse in which dust samples were collected from the kitchen, living room, and bedroom. Three cockroach sticky traps were left for 24 to 48 hours and the total number of roaches was counted after the traps were collected.

A detailed home evaluation was also conducted, including a questionnaire about the home and a standardized home inspection. Data were gathered about the age and type of the home, its state of repair and cleanliness, evidence of cockroach or mouse infestation, the presence of carpeting, and the presence of pets. Subsequent home visits were conducted by the study nurse on a monthly basis for a total of 7 months. At each visit, dust samples were collected from each room, sticky traps were left for 24 hours, and a repeat home inspection was completed.

Settled dust samples were collected from the three rooms as previously described using a vacuum cleaner (model BB870-AD; Oreck Corporation, New Orleans, LA) with a fabric collector (Wondertex GSI, Inc, Brooklyn, NY) fitted into the inlet hose of the vacuum.<sup>3</sup> The entire floor was vacuumed in the kitchen, while in the living room/television room a piece of furniture and the surrounding floor were vacuumed and in the bedroom the bed, the bedding, and the floor adjacent to the bed were sampled. The filters were removed from the vacuum, returned to the laboratory, and stored at  $-20^{\circ}\text{C}$  until they were processed. The dust samples were scraped from the filters and sieved through a  $0.3\text{-}\mu\text{m}$  brass mesh to produce fine dust. The fine dust was weighed and a 100-mg aliquot was extracted in 2 mL of phosphate-buffered saline (pH 7.4) by rotation overnight. Blotting was measured using a noncompetitive ELISA based on a combination of polyclonal and monoclonal antibodies (Indoor Bio-

technologies, Charlottesville, VA).<sup>5</sup> The assay has a lower limit of detection of 1 U/g of settled dust.

#### Data Analysis

Allergen levels were log-transformed to achieve a normal distribution and then analyzed by parametric statistics. The percent change in cockroach allergen was determined by comparing levels at month 6 to baseline. Student's *t* test was used to compare allergen levels at baseline between the intervention and control groups. The paired *t* test was used to compare changes in allergen levels between baseline and month 2. To investigate whether allergen levels declined from month 2 to month 6, we used random effects model that accounted for repeated measure. PROMIXED in the Statistical Analysis System (SAS, Cary, NC) was used in the analysis. In the intervention group, linear regression was used to regress the percent change in cockroach allergen from month 6 to baseline with household characteristics and other covariates.

## RESULTS

#### Cockroach Numbers

Cockroach numbers in the intervention and control homes are summarized in Table 1. At baseline, 10 of the 14 intervention homes had cockroaches present in their passive traps. The numbers ranged from 1 to 24 with a median of 3. In the control homes, all 3 had cockroaches with a range from 58 to 127 and a median of 102. At followup, five intervention homes had cockroaches present in the traps at one or more visit. Of a total of 70 followup

Table 1. Summary of the Number of Cockroaches Caught in Passive Traps

| Group                       | Baseline  | Month 2  | Month 3   | Month 4   | Month 5   | Month 6   |
|-----------------------------|-----------|----------|-----------|-----------|-----------|-----------|
| Intervention                |           |          |           |           |           |           |
| Number of positive traps    | 10/13     | 2/13     | 2/13      | 0/13      | 0/13      | 2/13      |
| Median cockroaches per home | 3         | 0        | 0         | 0         | 0         | 0         |
| Range                       | 0 to 24   | 0 to 1   | 0 to 2    |           |           | 0 to 2    |
| Control                     |           |          |           |           |           |           |
| Number of positive traps    | 3/3       | 3/3      | 3/3       | 3/3       | 3/3       | 3/3       |
| Median cockroaches per home | 102       | 43       | 100       | 96        | 51        | 105       |
| Range                       | 58 to 127 | 34 to 50 | 97 to 174 | 46 to 236 | 35 to 233 | 29 to 167 |

visits in the 14 homes, cockroaches were only present on six occasions and the maximum number of cockroaches detected was two. In the control homes, cockroaches were present in all 15 followup visits with a range from 34 to 236.

Home inspections at each visit also demonstrated a reduction in cockroach infestation in the intervention homes. Although all 14 homes had evidence of infestation at baseline, by month 2 there was only evidence of infestation in three homes and by month 6 only one home had evidence of infestation. The control group had ongoing evidence of infestation throughout the study. The extermination procedure, therefore, seemed very successful in reducing cockroach numbers collected in passive traps and observed by direct inspection.

#### Allergen Levels

Allergen concentrations are summarized in Table 2. At baseline, there were no significant differences in Bla g 1 levels between the control and intervention homes (kitchen,  $P = 0.27$ ;

bedroom,  $P = 0.83$ ; living room,  $P = 0.64$ ). In the control homes, Bla g 1 levels in the kitchen ranged at baseline from 22 to 2,063 U/g of dust (median: 467 U/g). Levels tended to rise over the course of the study, with median levels in the kitchen at months 5 and 6 of 792 and 1,587 U/g, respectively. This most likely reflects an increase in cockroach infestation as the study progressed from winter through spring and summer.

In the intervention homes, baseline allergen levels ranged from 28 to 4,467 U/g of dust (median: 281 U/g) in the kitchen, 15 to 875 U/g of dust (median: 36 U/g) in the bedroom, and from 1 to 1,689 U/g of dust (median: 43 U/g) in the living room. After the initial intervention, by month 2, Bla g 1 levels were significantly reduced in all rooms (kitchen median: 115 U/g;  $P = 0.048$ ; bedroom median: 10 U/g;  $P = 0.0002$ ; living room median: 17 U/g;  $P = 0.049$ ). Although the greatest decrease in allergen levels occurred in the first 2 months, there was a continued decline in all rooms with the lowest median

levels occurring at month 6 (kitchen median: 26.5 U/g,  $P = 0.003$  baseline vs month 6,  $P = 0.10$  month 2 vs month 6; bedroom median: 8 U/g,  $P = 0.0001$  baseline vs month 6,  $P = 0.73$  month 2 vs month 6; living room median: 10 U/g,  $P = 0.05$  baseline vs month 6,  $P = 0.70$  month 2 vs month 6). The overall percent changes from baseline to month 6 were 91% in the kitchen, 78% in the bedroom, and 77% in the living room.

Individual allergen concentrations from the kitchens of the 14 intervention homes are illustrated in Figure 1. At month 2, allergen levels had fallen in 10 homes and risen in four homes with changes ranging from a 99% decline in two homes to a 507% increase in another. At month 6, allergen levels were reduced compared with baseline in 13 of 14 homes (range: 47% to 99%) with only 1 home having a higher level than baseline (+125%). A similar pattern was seen in the bedroom, where cockroach allergen levels were reduced by month 6 in 13 of 14 homes (range: 28% to 97%) and higher in

Table 2. Summary of Cockroach Allergen Levels in the Intervention and Control Groups

| Location    | Group          | Baseline   | Month 2     | Month 3     | Month 4     | Month 5     | Month 6     |
|-------------|----------------|------------|-------------|-------------|-------------|-------------|-------------|
| Kitchen     | Intervention   |            |             |             |             |             |             |
|             | Geometric mean | 324.8      | 103.8       | 190.8       | 90.0        | 133.6       | 33.1        |
|             | Median         | 281        | 115         | 149.5       | 85          | 170         | 26.5        |
|             | Range          | 28 to 4495 | 9 to 1316   | 39 to 1432  | 8 to 1060   | 16 to 1070  | 2 to 879    |
|             | Control        |            |             |             |             |             |             |
|             | Geometric mean | 276.8      | 637.3       | 924.2       | 261.6       | 1163.9      | 1131.7      |
| Bedroom     | Median         | 467        | 881         | 1394        | 304         | 792         | 1587        |
|             | Range          | 22 to 2063 | 118 to 2490 | 180 to 3146 | 54 to 1090  | 791 to 2517 | 465 to 1964 |
|             | Intervention   |            |             |             |             |             |             |
|             | Geometric mean | 60.0       | 13.0        | 28.3        | 36.8        | 29.1        | 9.1         |
|             | Median         | 36         | 10          | 20          | 40.5        | 21.5        | 8           |
|             | Range          | 15 to 875  | 2 to 298    | 5 to 1236   | 5 to 607    | 9 to 226    | BD to 568   |
| Living room | Control        |            |             |             |             |             |             |
|             | Geometric mean | 159.2      | 404.6       | 580.1       | 423.8       | 210.5       | 571.5       |
|             | Median         | 218        | 744         | 481         | 427         | 135         | 450         |
|             | Range          | 50 to 370  | 74 to 1203  | 258 to 1573 | 70 to 2457  | 48 to 1439  | 262 to 1583 |
|             | Intervention   |            |             |             |             |             |             |
|             | Geometric mean | 41.8       | 18.3        | 33.0        | 30.4        | 29.0        | 10.7        |
|             | Median         | 43         | 17          | 42.5        | 52          | 17.5        | 10          |
|             | Range          | 1 to 1689  | 5 to 253    | 5 to 321    | BD to 238   | 2 to 538    | BD to 177   |
|             | Control        |            |             |             |             |             |             |
|             | Geometric mean | 206.7      | 257.2       | 271.7       | 520.6       | 1219.5      | 464.3       |
|             | Median         | 232        | 216         | 237         | 911         | 1383        | 394         |
|             | Range          | 68 to 560  | 134 to 588  | 176 to 481  | 152 to 1019 | 839 to 1563 | 219 to 1160 |

BD, below detection.

Cockroach Allergen In Individual Homes

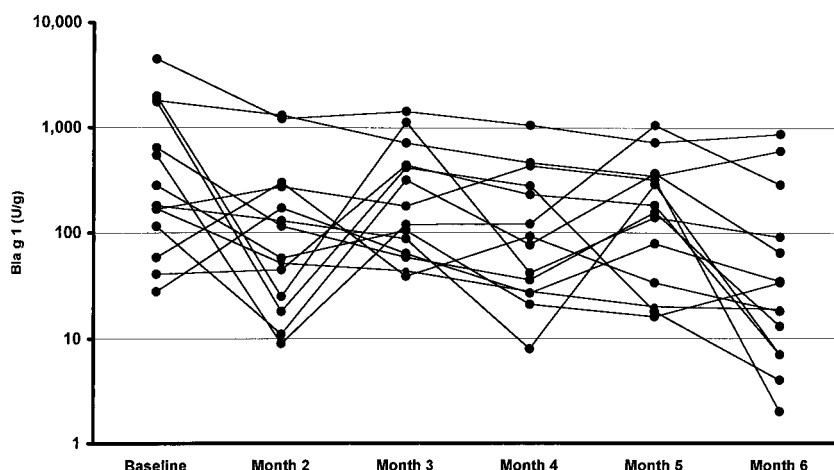


Figure 1. Cockroach allergen (Bla g 1 in U/g) levels in kitchens from individual homes.

only 1 home (+120%). In the living rooms, allergen reduction was somewhat less consistent with levels falling by month 6 in nine homes (range: 60% to 99%), rising in four homes (range: 130% to 200%), and remaining stable in one home. In the three control homes, allergen levels rose in all bedroom and living room samples and in two of three kitchen samples over the course of the study.

As seen in Table 2, median allergen concentrations rose in all rooms between months 2 and 3. When individual homes are considered, between months 2 and 3 allergen levels rose in the kitchen in 7 homes, in the bedroom in 12 homes, and in the living room in 11 homes. Levels then fell between months 3 and 4 in 11 kitchens, 6 bedrooms, and 8 living rooms. This improved trend is presumably because of the fact that all homes had an additional extermination and cleaning between month 3 and 4. In addition, because cockroach numbers remained low throughout the study, it is most likely that it was the cleaning that had the greatest effect on allergen levels. This would also fit with the fact that the greatest effect was seen in the kitchen where there would likely be the greatest opportunity to clean effectively.

### Effects of Covariables

Data were analyzed to determine whether the changes in allergen level were related to any of demographic or environmental variables that were collected. Only a few significant associations were detected, possibly because of the small sample size. It was found that allergen reduction in the kitchen was less if there was evidence of a leaky roof in the home ( $P = 0.0009$ ). There was also a trend toward less effective allergen reduction in the kitchen if there were dirty dishes present at the time of the initial home inspection ( $P = 0.09$ ). In contrast, significantly greater reductions in allergen were seen in the bedroom when there was evidence of cockroaches in the bedroom at baseline ( $P = 0.03$ ) and in the living room when there was evidence of excessive clutter in that room at baseline ( $P = 0.04$ ). At least with this small sample, the effect of other variables, such as the presence of carpeting, uncovered trashcans, or food debris in the home, was not significant in any room.

### DISCUSSION

In this study we have confirmed our earlier report<sup>3</sup> that cockroaches can be effectively eliminated in most inner-city homes with professional extermination.

Further, the combination of extermination and professional cleaning followed by ongoing cleaning by the homeowner using a solution of sodium hypochlorite led to significant reductions in cockroach allergen in settled dust samples. Median reductions of 91% in the kitchen, 78% in the bedroom, and 77% in the living room were seen, which was very different from the overall rise in allergen that was seen in the three control homes. The critical questions that remain, however, are whether these reductions are sufficient to provide clinical benefit for cockroach-allergic patients and whether they represent an improvement over previous interventions.

Median allergen concentrations at the completion of the study ranged from 26.5 U/g of dust in the kitchen to 8 U/g of dust in the bedroom and 10 U/g of dust in the living room. When individual homes were examined, there was a tremendous range, with some having marked reductions in allergen, others showing relatively little effect, and still others even rising. Unfortunately, a majority of homes still had Bla g 1 levels above the proposed threshold of 8 U/g of dust at 6 months, suggesting that the reductions in allergen accomplished in this study may not be enough to have a significant clinical effect. However, although allergen levels are above threshold, it is still entirely possible that the 80% to 90% reductions in exposure seen in this study could lead to clinical improvement in cockroach-sensitive patients. Although there are presently no data to support that notion, we are currently engaged in a controlled trial to answer this important question.

In comparison to previous trials of cockroach abatement, the results of this study are remarkably similar to our previous study with a similar protocol except that the sodium hypochlorite solution was not used.<sup>3</sup> Although both these studies demonstrated greater success than the study by Gergen et al,<sup>6</sup> which was also performed in inner-city homes, the current results suggest that the addition of 0.5% sodium hypochlorite

rite to the cleaning regimen did not improve the success of the intervention. This was somewhat surprising in view of the apparently dramatic effects of the same solution on surface allergen in the laboratory, in which there was no detectable dust mite, cat, mouse, or cockroach allergen after treatment with 0.3% or 1.3% sodium hypochlorite.<sup>4</sup> However, an excess of extraneous protein markedly interfered with the effect of the sodium hypochlorite in other experiments, so it is possible that higher concentrations or more frequent applications would show more success.<sup>7</sup>

There are at least two possible explanations for the lack of added effect of hypochlorite in home environments. First, although the solution was used by the professional cleaner twice at the onset of the study and once midway through the protocol, the remainder of the cleaning was left up to the homeowners. Although they were provided with an unlimited supply of the cleaning solution, its use was in no way supervised. Second, it may be that the level of allergen in homes was such that either the amount or the concentration of the cleaning solution was insufficient and that the experiment in the laboratory was not representative

of the situation in inner-city homes. It is possible that the allergen was simply too concentrated or that the mass effect of other proteins in these homes somehow interfered with the action of the solution on Bla g 1.

We, therefore, conclude that although cockroaches can be effectively exterminated from most inner-city homes and allergen levels can be reduced by 80% to 90%, this still may not be enough to induce a clinical benefit. In addition, although sodium hypochlorite showed promise in the laboratory setting, it did not seem to provide any additional benefit in home environments. Until additional data become available, we recommend that the homes of patients with cockroach sensitivity be approached with a combination of professional extermination and aggressive cleaning, although it is not clear than any one cleaning agent is superior to another.

## REFERENCES

1. Kang B. Study on cockroach antigen as a probable causative agent in bronchial asthma. *J Allergy Clin Immunol* 1976; 58:357–365.
2. Rosenstreich DL, Eggleston P, Kattan M, et al. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. *N Engl J Med* 1997;336:1356–1363.
3. Eggleston PA, Wood RA, Rand C, et al. Removal of cockroach allergen from inner-city homes. *J Allergy Clin Immunol* 1999;104:842–846.
4. Chen PH, Eggleston PA, Smith WL. The effect of bleach (NaOCl) on indoor allergens. *J Allergy Clin Immunol* 2000; 105:S126.
5. Pollart SM, Smith TF, Morris EC, et al. Environmental exposure to cockroach allergens: analysis with monoclonal antibody-based enzyme immunoassays. *J Allergy Clin Immunol* 1991;87: 505–510.
6. Gergen PJ, Mortimer KM, Eggleston PA, et al. Results of the National Cooperative Inner-City Asthma Study (NCI-CAS) environmental intervention to reduce cockroach allergen exposure in inner-city homes. *J Allergy Clin Immunol* 1999;103:501–506.
7. Chen PH, Smith W, Eggleston PA. Allergenic proteins are fragmented in low concentrations of sodium hypochlorite. *Clin Exp Allergy*: in press.

*Requests for reprints should be addressed to:*  
Robert A. Wood, MD  
CMSC 1102  
Johns Hopkins Hospital  
600 North Wolfe Street  
Baltimore, MD 21287  
E-mail: rawood@erols.com