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Survey of Pest Infestation, Asthma, and Allergy in Low-income Housing

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Abstract Low-income housing often has multiple indoor health risks. Among them, pest infestation, pesticide use, and pest allergens are recognized as common risks which affect residents' health. Cockroach and rodent allergens are associated with morbidity and mortality of asthmatics. To characterize the levels of pest infestation, residents' attitudes toward pest control, and the relationships among cockroaches, mice, cockroach allergen level, asthma and allergy rate in public housing, we interviewed residents from 358 randomly selected apartments in Gary, Indiana and assessed the environmental conditions. Dust samples were collected from 101 apartment kitchen floors to analyze for cockroach allergen (Bla g 1 and Bla g 2) levels. Eighty one percent of the apartments were found infested by cockroaches, mice, ants, spiders, or flies. In the 101 apartments evaluated, 98% of the kitchen dust samples had detectable levels of Bla g 1 allergen (≥0.4 U/g), 52% had ≥2 U/g, and 33% had ≥8 U/g of Bla g 1. Among the 1,173 residents, 13% and 9% had physician-diagnosed asthma and allergy, respectively. Existence of diagnosed asthmatic was positively correlated with mouse infestations.

Keywords Asthma · Allergy · Cockroach allergen · Pest infestation · Survey

Introduction

Most public housing in the U.S. contains multiple family units per building. Because of socio-economic constrains and lack of adequate maintenance, disproportionately high incidences of pest infestations, environmental hazards and asthma have been reported previously [1, 2]. Surveys using sticky traps in public housing in Gary, Indiana during 2002–2004 indicated about 50% of the residences had cockroach infestations [3]. Based on 235 pest complaints from Gary Housing Authority residents between May and

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August of 2003, 87% and 26% of them requested cockroach and mouse control service, respectively (Wang and Bennett, unpublished data). Chew et al. [4] reported that greater than 40% of the surveyed mothers from three low-income neighborhoods in New York City noticed mouse infestations.

Indoor pest infestations are not only nuisances, but are also allergen sources. Mouse and cockroach allergens are commonly found in homes. In a national survey of 831 U.S. homes, 82% had detectable mouse allergens, 13% had >2.0 U/g cockroach allergen (Bla g 1) [5, 6]. Mouse allergen levels were correlated with mouse infestation levels and structural defects (holes in walls and ceilings) [4]. Lower income homes were associated with higher cockroach allergen levels [2, 6, 7].

A significant health effect associated with pest infestations is asthma. Asthma has been continuously identified as one of the key residential health hazards by the U.S. Department of Housing and Urban Development (HUD). The overall asthma rate for the United States in 1998 was 5.8–7.2% [8]. Cockroach allergen is one of the most prominent allergens in inner-city homes [9, 10]. Exposure to cockroach allergens has been reported to be among the most important risk factors in asthma morbidity and mortality for children from low-income families living in inner cities. Several recent studies have shown that cockroach allergens also play a significant role in urban asthma morbidity among the elderly [11, 12]. Rat allergen sensitization and exposure are associated with increased asthma morbidity in inner-city children [13]. Significantly more asthmatic children were sensitized to mouse allergen when mouse allergen levels in house dust were >1.6 ug/g [14].

There have been three surveys on apartment residents' attitudes to cockroaches and cockroach control [15–17]. These studies revealed high levels of cockroach infestations, low tolerance for cockroach infestations, and uncertainty regarding cockroach elimination. Since the 1990's, highly effective cockroach bait products have become available and have significantly reduced the overall cockroach infestations in the U.S. [18]. Yet, cockroaches remained a common indoor pest in public housing in Gary, IN. Other pests that rank high in terms of infestations reported in public housing by residents were mice and household ants.

Although there is a strong link between cockroach and mice allergen concentrations and asthma symptoms, there are few quantitative studies on the resident's attitudes about pest infestation and the association between pest infestation and prevalence of asthma or allergy. Obtaining such information could help health professionals to predict asthma and allergic disease, improve our knowledge about indoor health hazards, and design more effective programs in order to reduce the pests and the risks associated with pest infestations. The objectives of this study are to: (1) determine the levels of pest infestations; (2) discover residents' perception of pest control; and (3) determine the relationships among cockroaches, mice, allergen levels, and asthma and allergy rates in public housing. This is part of a 2-year study to evaluate the cost and effectiveness of an integrated pest management program to reduce cockroach and cockroach allergen levels in low-income housing.

Methods

Study Site

The survey was conducted in two multifamily housing complexes located in Gary, Indiana. There were a total of 785 apartments, each with 1–3 bedrooms. Approximately

80% of the apartments were occupied. All buildings were 1 or 2 stories, each included 2–6 apartments. They were built during 1940–1950. Nearly 100% of the residents were African-Americans.

Interview of Residents and Inspection of Apartments

An environmental assessment sheet comprised of 15 questions was prepared. Two-person teams, comprised of an interviewer and a technician, conducted the interview and visual inspection during April–May 2006. A total of 358 residents and their apartments were interviewed/inspected. Selection of these residences was not completely random because only those with someone home during the day were accessible. The residents were asked questions to determine the following: (1) known pest infestations, (2) frequency of pest control by professionals or by resident, (3) length of residency, (4) number of adults and children living in the residence, (5) house repair needs, (6) existence of pets, (7) number of occupants with physician-diagnosed allergy or asthma, (8) known allergic reactions to selected sources (dust, mold, cockroach, dog, cat, pollen, other), (9) residents' level of satisfaction toward their pest control service, (10) resident's cockroach control measures, (11) resident's mouse control measures, and (12) suggestions for pest management. While one worker was conducting the interview, the other worker visually inspected the apartment for (1) visible insecticide residue, (2) live cockroaches, and (3) sanitation conditions. The survey received Purdue University institutional review board approval.

Estimation of Cockroach Population

Once an apartment was identified or suspected having cockroaches through interview or visual inspection, sticky traps were placed in the apartment to estimate the cockroach population level [19]. Six traps (8.0×15 cm sticky area) (Trapper® Monitor & Insect Trap, Bell Laboratories, Inc., Madison, WI, USA) were placed in each apartment. Sticky trap locations were: (1) in the cabinetry under the kitchen sink, (2) in the cabinetry above the kitchen sink, (3) beside the stove, (4) beside the refrigerator, (5) around furnace or under the shelves in the utility room, and (6) behind the toilet. Traps were placed in such a way that one edge was touching a wall or a vertical component of adjacent cabinetry. The trap catches were counted after $\approx$24 h placement. Traps in some apartments could not be retrieved at 1 day after placement due to lack of access to the apartments. The cockroach population levels in these apartments were not reported. If one or more traps were disturbed or missing, then the total catches per apartment was estimated by the average count per trap multiplied by the number of valid traps.

Dust Sample Collection and Analysis

One week after cockroach density samplings, dust samples were collected from kitchen floors of 101 selected apartments, which represented various levels of cockroach densities (from 0 to 1,385 cockroaches per apartment after 24-h trapping). Eighty three percent of these apartments had cockroach infestations. The purpose of the sampling was to investigate the relationship between cockroach density and cockroach allergen levels. We used a LineVacer backpack vacuum machine (ProTeam vacuum company, Boise, ID, USA) and 7.6×12.7 cm collection bags attached to the vacuum hose to collect dust samples. Dust samples were collected following HUD's ''Vacuum dust

sample collection protocol for allergens'' (http://www.hud.gov/offices/lead/techstudies/Allergen_Dust_Sample_Protocol.doc). They were collected only from the kitchen floor because this is the area that tends to have the highest allergen concentration [6, 20]. The area around the perimeter of the kitchen floor was vacuumed for 5 min. The crude dust was kept at –20°C upon arrival in the laboratory, then shipped to Johns Hopkins University Dermatology, Allergy and Clinical Immunology Reference Laboratory. Each dust sample was processed through a 50 mesh metal sieve to exclude particles >300μ, and 100 mg of fine dust was extracted overnight with 2 ml of physiological saline buffer containing 5% bovine serum albumin. The extract was then analyzed for the levels of cockroach allergen Bla g 1 using monoclonal antibody based enzyme-linked immunosorbent assays (Indoor Biotechnology, VA, USA). In order to examine the relationship between Bla g 1 and Bla g 2 levels, 28 dust samples were also examined for Bla g 2 concentration. Bla g 1 and Bla g 2 results were reported in U/g based on calibration standards analyzed in each assay. The minimum detection level for cockroach allergens in dust samples was 0.4 U/g dust for Bla g 1 and 1 U/g dust for Bla g 2. Bla g 1 levels above 2 and 8 U/g were associated with increased risk for sensitization and asthma symptoms, respectively, among susceptible individuals [21]. We used these two thresholds to calculate the percentage of dust samples with high cockroach allergen levels.

Data Analysis

Regressions between Bla g 1 and Bla g 2 levels, and between cockroach trap count and allergen (Bla g 1 and Bla g 2) levels were performed using SAS software [22]. The data were natural log transformed to stabilize the variance. Cockroach allergen levels in apartments with asthma patients were compared with those without asthma patients by ANOVA. Odds ratios (OR) were calculated with 95% confidence interval (95% CI) for determinants of asthma rates.

Results

Household Characteristics

Of the 358 interviewed residents, median length of residence was three years. Median number of occupants per apartment was one adult and two children. A total of 245 (68%) residents expressed the need for home repair. Common repair needs were doors, windows and window screens, water leaks, and damaged walls (Table 1). Eighteen

Table 1 House maintenance needs requested by residents during interviews (N = 245)

Repair need	% of the needed apartments
Door, window, or screen	44
Water leaks from pipes or ceiling	36
Furniture or fixture (cabinets, stove, light fixture, sockets, etc.)	21
Damaged wall or ceiling	19
Floor	10
Paint	2

Table 2 House-keeping conditions in the surveyed apartments ($N = 349$)

Sanitation condition	% of the surveyed apartments
Clean (no apparent trash and food residue on floor or counter)	40
Dirty (some trash and food residue; few clutter)	42
Very dirty (some trash and food reside, a lot of clutter)	15
Severely dirty (lots of trash, food residue, and clutter)	4

percent of the apartments had pets. Only 40% of the apartments were considered clean (no trash and food residue on floor or counter) based on our inspection (Table 2). Seventy one percent of the apartments had pests based on interviews. The dominant pest was the German cockroach, *Blattella germanica* (L.), which was found in 49% of the surveyed apartments. It was followed by the house mouse (*Mus musculus* L.), the oriental cockroach (*Blattella orientalis* L.), and ants (Table 3). Mean cockroach distribution (from most abundant to least abundant) within apartments based on glue board trap counts ($N = 150$) was: beside the refrigerator (40%), beside the stove (20%), in the utility room (16%), in the cabinetry under the kitchen sink (11%), behind the toilet (10%), and above the kitchen sink (5%). The areas around refrigerator and stove often had water and food residues which favored the survival and reproduction of cockroaches.

Although the pest infestation rate was high, only 26% of the apartments received monthly or more frequent pest control by residents or the pest control technician. Visual inspections revealed that 67% of the apartments had cockroach bait residue, 10% had cockroach bait stations, and 6% had dust residues ($N = 358$). Only 28% of the apartments did not have visible pesticide residues.

Residents' Attitudes Toward Pest Control

Prior to the start of the survey, professional pest control service was provided by a contractor through Gary Housing Authority based on monthly or bimonthly request from residents. In rating the pest control service ($N = 326$), 59% considered the service good or very good and 41% considered fair or poor. Eighty percent and 58% of the residents tried to control cockroaches and mice by themselves, respectively. Self-administered cockroach control methods were (from most common to least common): bait, spray, trap, and insect bombs. For mouse control, the most commonly self-administered methods were trapping and baiting.

When asked about an open ended question regarding suggestions for future pest control of their residences ($N = 109$), 51% suggested more frequent inspection/intervention, 18% suggested cleaning up inside and outside of the apartments, and 10% suggested servicing the whole building rather than selected individual apartments. Other suggestions by residents included using traps, bait, powder, and fixing structural defects.

Table 3 Pest infestation in surveyed apartments based on interviews ($N = 356$)

Pest	German cockroach	Oriental cockroach	Mice	Ants	Other	No pests
% of the apartments with pest	49	26	36	21	7	19

Cockroach Allergen Levels and their Association with Cockroach Populations

In the 101 apartments evaluated for cockroach allergen concentrations in kitchen dust samples, 83% of them had German cockroaches based on trapping. Oriental cockroaches were trapped in only four apartments. The median and maximum Bla g 1 concentrations in kitchen dust samples were 3 and 4,069 U/g, respectively. Ninety eight percent of the kitchen dust samples had detectable levels of Bla g 1 allergen (≥0.4 U/g), 52% had ≥2 U/g, and 33% had ≥8 U/g of Bla g 1. The median and maximum Bla g 2 concentrations were 31 and 919 U/g, respectively ($N = 28$). There was a strong correlation between Bla g 1 and Bla g 2 levels ($F = 112.6$; df = 1, 26; $P < 0.001$; $r = 0.90$).

Of the 101 apartments where dust samples were collected, 85 apartments had 24-h trap count data. Eighty-five percent of the apartments had trapped cockroaches. The maximum trap catch per apartment (total number of cockroaches in 6 traps) was 1,385. Relationship between Bla g 1, Bla g 2, and cockroach counts are shown in Fig. 1. Regression analysis between Bla g 1, Bla g 2 levels and trap counts indicated significant positive relationships (Bla g 1: $F = 92.0$; df = 1, 81; $P < 0.001$; $r = 0.73$. Bla g 2: $F = 60.4$; df = 1, 26; $P < 0.001$; $r = 0.84$). Regression equations between German cockroach count and allergen levels are:

$$\text{Log (Bla g 1)} = 0.01 + 0.77 \log \text{(trap count)}$$

$$\text{Log (Bla g 2)} = 0.07 + 0.80 \log \text{(trap count)}.$$

Prevalence of Asthma, Allergy, and their Association with Pest Infestations

From interviews with residents, there were 1,173 residents living in the surveyed apartments. Among these residents, 13% and 9% had physician-diagnosed asthma and allergy, respectively. Among the 358 surveyed households, 42% and 30% had physician-diagnosed asthma and allergy patients, respectively. Known allergic reactions were (from most common to least common): dust, pollen, mold, cat, dog, and cockroach.

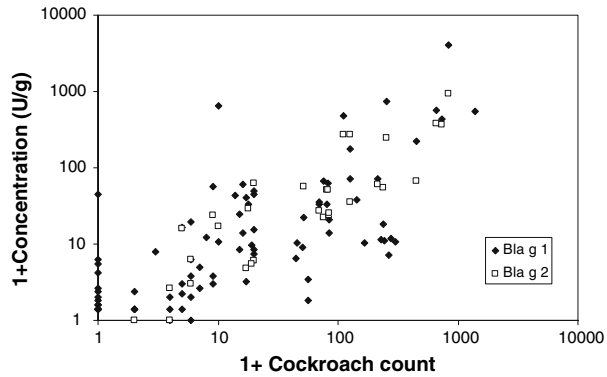

Fig. 1 Relationship between cockroach trap counts and cockroach allergen levels in kitchen dust samples

A statistically significant relationship between resident reported cockroach infestation and the prevalence of physician-diagnosed asthma was not found (OR = 1.5; 95% CI, 0.8–2.5; $N = 242$). ANOVA revealed similar Bla g1 (F = 0.02; df = 1, 82; $P = 0.88$) and Bla g 2 (F = 0.83 df = 1, 27; $P = 0.37$) levels between apartments with a diagnostic asthmatic and those without a diagnostic asthmatic. High Bla g 1 level (≥8 U/g) was not associated with increased prevalence of asthmatic (OR = 0.9; 95% CI, 0.4–2.1; $N = 84$). Households with current mouse infestations were 1.9 times more likely to have a diagnostic asthmatic than those without (95% CI, 1.1–3.3, $N = 242$). There was no detectable association between allergy rate and mice or cockroach infestations.

Discussion

This study provides information on the severity of pest infestation, cockroach allergen level, and asthma disease in the public housing that was studied. The percent of apartments with pests was extremely high (80%). The German cockroach was the dominant pest, corroborating previous monitoring results during 2002–2004 and residents' complaint records [3]. The mouse was the second most frequent pest. The proportion of apartments with high Bla g 1 levels (≥8.0 U/g) was five times the average of the U.S. homes [6]. Asthma occurrence rate was two times the average rate among the U.S. population [8].

Reduction and the elimination of cockroach infestations is the basic procedure for reduction of cockroach allergens [23, 24]. There are a variety of effective pest management tools in the market. For example, gel baits alone can provide 95% control to cockroaches in apartments [3]. As indicated by the interviews and inspections, high pest infestation rates in the surveyed apartments were due to a combination of several factors: lack of proper maintenance of the residences, poor pest control operations, and poor house-keeping by residents. The management office provides free pest control service upon request. Yet, a lot of residents did not report pest problems. During the survey between May and June 2006, we found 159 cockroach infested apartments in one complex. Only 35 of them (22%) were reported by residents to the office. If not treated, those unreported apartments would have served as reservoirs for future spread of cockroaches among neighboring apartments. Education and frequent monitoring is necessary to effectively suppress/eliminate the pests.

The professional pest control service often failed to provide satisfactory control. Only 59% of the residents considered the pest control service good or very good. There was no follow up service to the infested apartments. As a result, pest infestations persisted. Effective control relied on the cooperation of all parties. Contractors need to inspect and treat the apartments thoroughly and follow up until pests are eliminated. Residents need to improve house-keeping and reduce clutter. For the management office, they need to properly maintain the structures to prevent re-entry of pests. An integrated pest management (IPM) approach is needed to effectively solve the chronic pest infestations [3]. The IPM program emphasizes continuous monitoring and the application of a variety of tools (traps, vacuum, baits, bait stations, dust, etc.) when necessary to eliminate cockroaches.

The high prevalence of pest infestations in these units not only poses direct health risks due to the production of allergens and the contamination of food, but also leads to environmental pollution as a result of pesticide use. Eighty percent of the residents used do-it-yourself remedies to reduce cockroach infestations. Fifty eight percent of the

residents attempted to control mice themselves. Because of the lack of knowledge and training, pesticide misuse was common. Dusts, cockroach bait residues or bait stations (either applied by professionals or by residents) were observed in 72% of the apartments. In addition, there were likely unseen insecticide residues as evidenced by empty insecticide aerosol cans in many of the apartments.

This study provides a quantitative estimation between cockroach population and Bla g 1 and Bla g 2 levels. Cockroach population density can be used as a predictor for cockroach allergen levels. High cockroach population levels are a strong indicator of high cockroach allergen levels. Thus, reducing cockroach populations is critical in reducing cockroach allergen levels. This study indicates cockroach allergens can still exist in apartments without current cockroach infestations. Dead roaches, cast skins, and feces from previous infestations might have persisted in these apartments after cockroaches were eliminated. Hence, thorough cleaning to remove dead cockroaches and thorough dust cleaning is also important in reducing cockroach allergens. Eggleston et al. [25] showed that even with professional cleaning followed by professional pest control treatments, cockroach allergens were only partially removed from the apartments. Because exposure to cockroach allergen was closely associated with cockroach sensitivity and asthma morbidity in previous studies, reducing cockroach populations and thorough cleaning will likely to have significant health benefit to the residents.

Children accounted for 2/3 of the residents in the surveyed apartments. Because of their exploratory and other behavior (e.g., frequent mouthing of hands and other objects among toddlers), young children are often more vulnerable to environmental exposures. Thus, it is urgent to improve the indoor environment in low-income housing, including public housing, to protect children's health. This study and previous studies regarding pest management in public housing identified obstacles and methods to reduce the risks [3, 23, 24]. Education of residents and more effective pest management strategies are critical to reduce pests and pest-related risks. A recent study indicates a single educational intervention can be effective in reducing cockroach populations and cockroach allergen levels [26]. Results from these studies will help policy makers, management staff, and residents to design and initiate more effective risk reduction strategies.

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