Comparative Study of Integrated Pest Management and Baiting for German Cockroach Management in Public Housing

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ABSTRACT This study assessed the cost and effectiveness of a building-wide cockroach integrated pest management (IPM) program compared with bait alone treatment in public housing. In total, 12 buildings (66 apartments) were treated and monitored for cockroach infestations over 7 mo. The buildings were divided into two groups: bait treatment and IPM. Apartments in the bait alone group were treated with Maxforce FC Select (0.01% fipronil) during the first 12 wk and Maxforce Roach Killer Bait Gel (2.15% hydramethylnon) from 16 wk when necessary. For the IPM group, cockroaches were flushed and vacuumed at the beginning of the study; sticky traps were placed in all apartments to monitor and reduce cockroach numbers; educational materials were delivered to the residents; and Maxforce FC Select and Maxforce Roach Killer Bait Gel were applied to kill cockroaches. Two seminars were presented to the manger, and Community Service Program staff of the Gary Housing Authority to help gain tenant cooperation in the program. Effects of the treatments were monitored using sticky traps (six per apartment) at 2, 4, 8, 12, 16, and 29 wk after treatment. More treatments were applied during each monitoring visit when necessary. Those apartments with high levels of infestations (≥12 cockroaches in six traps) before treatment were used to compare the IPM and bait only treatments. IPM resulted in significantly greater trap catch reduction than the bait treatment. The IPM ($n = 12$) and bait only treatment ($n = 11$) resulted in 100.0 and 94.6%, respectively, reduction in trap catch after 16 wk. At 29 wk, only one apartment in the IPM group had a high level (>12 cockroaches) of cockroach infestation. In contrast, five apartments in the bait treatment group had high level infestations at 29 wk based on overnight trapping counts; thus, IPM is a more sustainable method of population reduction. Sanitation levels in the IPM group significantly improved at 29 wk ($n = 11$) compared with that at the beginning of the study. The sanitation levels in the bait treatment group remained similar throughout the experiment ($n = 9$). The cumulative cost of IPM was significantly higher than that of the bait treatment. The median costs per apartment during 29 wk were $64.8 and $35.0 for the IPM and bait treatment, respectively. The median amount of bait used per apartment in the IPM and bait treatment was 45.0 and 50.0 g, respectively. The cost of the IPM group for the 29 wk service was similar to that of the bait treatment group. We expect that IPM will provide better control at similar cost compared with bait treatment beyond 29 wk.

KEY WORDS *Blattella germanica*, integrated pest management, public housing

The German cockroach, *Blattella germanica* (L.), is a common indoor pest in low-income housing. Cockroaches not only spoil food but also transfer pathogens and cause allergic reactions and psychological distress (Brenner 1995). According to U.S. Department of Housing and Urban Development, cockroach allergens are excessive in 30–50% of the inner city housing (Federal Register Volume 69, No. 94). These allergens are most important in childhood asthma causes (http://www.nih.gov/news/pr/mar2005/niehs-08.htm).

Insecticides are the major tool used by professionals and residents for German cockroach control (Koehler et al. 1995). The advent of highly effective bait products in the early 1990s significantly reduced the overall cockroach infestations in the United States (Greene 1996, Gooch 1999, Hedges 1999). In a study conducted by the U.S. General Services Administration, use of cockroach bait products dramatically reduced liquid insecticide use from 1988 to 1999 (Greene and Breisch 2002). Cockroach complains in 1999 were only 6.9% of the number of cockroach complains 11 yr earlier due to the bait based management program. Through many years of pesticide use, the German cockroach has developed resistance to nearly every class of insecticide (Roslavtseva 2002). Recently, cockroach aversion to gel baits was reported (Harbison et al. 2003, Morrison et al. 2004, Wang et al. 2004, Liang 2005, Miller and McCoy 2005). Some gel bait-resistant cockroaches were highly resistant to a variety of current gel baits in the market (except the new baits and modified

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bait formulations). These lead to increased bait usage and excessive bait residues, which were evident in many public housing areas based on our observations. More importantly, gel bait resistance is inherited and fairly stable even after six generations (Wang et al. 2006). Rotation of gel baits may not overcome the resistant cockroaches because they exhibited adverse behavior to gel baits from different manufacturers with various active ingredients. Given the history of insecticide resistance in the German cockroach, it is inappropriate to rely solely on the use of chemicals for resolving German cockroach problems.

Effective nonchemical techniques include sanitation, trapping, vacuuming, and sealing of harborages (Kardatzke et al. 1981, Frishman 1995, Robinson and Zungoli 1995, Kaakeh and Bennett 1997). Low levels of sanitation and clutter provide more food, water, and harborages to cockroaches. These conditions favor the growth and survival of cockroach populations. Sanitation condition is correlated with cockroach populations (Wright 1979, Schal 1988). Among water, food, and harborages, water was the most important factor influencing the German cockroach populations (Bertholf 1983). Sanitation also is closely correlated to the control result because cockroaches can avoid contacting insecticide dust or spray or feeding on insecticide bait (Gupta et al. 1973, Schal 1988, Lee and Lee 2000). Placing sticky traps in cockroach-infested areas has been a standard method for monitoring the cockroach population level, spatial distribution, and effectiveness of the German cockroach management programs (Owens and Bennett 1983, Kaakeh and Bennett 1997). It supplements the visual inspection method and provides an additional tool for monitoring and reducing cockroach numbers (Bennett et al. 2003). Vacuuming (after using a flushing agent) has the potential to remove significant number of cockroaches (Kaakeh and Bennett 1997). This technique is especially useful for initial clean-out treatment of serious cockroach infestations. Sealing harborages and holes prevents cockroach movement between adjacent buildings and reduces the number of hiding sites, thereby assisting the long-term management of cockroaches.

Because residents' activities have a great impact on the pest abundance and control result, education of the residents should be an important component of an integrated pest management (IPM) program. Educational programs had positive impact on residents' attitude (Robinson and Zungoli 1985). Unfortunately, this is often not a part of the contract set by the management of the public housing properties. Pest management professionals often feel frustrated by the lack of cooperation from the residents. Lack of proper maintenance of the residence, e.g., poor sanitation and presence of unwashed dishes and clutter, in many public housing units contributes to the cockroach infestation and control failure.

Biology- and behavior-based German cockroach IPM programs have been discussed previously (Gupta et al. 1973, Slater et al. 1979, Wood 1980, Hedges 1994, Bennett et al. 2003). The strategy includes an array of independent components: repeated monitoring, integration of multiple control strategies, client education, and use of pesticides only when other practices are not practicable (Greene and Breisch 2002, Brenner et al. 2003). Safer Pest Control (http://www.spcpweb.org) and Environmental Health Watch (http://www.ehw.org/Asthma/ASTH_Cockroach_Control.htm) conducted studies on IPM for controlling indoor cockroaches (pests). Their efforts proved the effectiveness of IPM approach for reducing cockroach infestations and reducing insecticide use. Despite its greater chance of sustainable success for German cockroach management, IPM has never been widely accepted by the pest control industry or by housing authorities. The higher cost of IPM program compared with simple chemical control is a major factor that has hindered the implementation of IPM (Schal and Hamilton 1990, Miller and Meek 2004).

Table 1. Cockroach infestation in public housing units, Gary, IN

Cockroach no.	% apartments		
	2002 (n = 138)	2003 (n = 210)	2004 (n = 211)
≥12 in six traps	33	31	31
<12 in six traps	26	16	14
0	41	53	55

Counts (separated by year) were based on six Trapper glue board traps (8.0- by 15.0-cm glue area) placed in each apartment for ≈24 h.

Most public housing projects in the United States have multiple apartments per building. Shared common plumbing and low levels of sanitation contribute to the severity of cockroach infestations (Gold 1995). Cockroaches remain the single most important indoor pest in public housing units in Gary, IN (Table 1). Inter-apartment movement of up to 30% per week was found where construction design permitted (Owens and Bennett 1982). Plumbing connections between adjacent apartments were main corridors for cockroach movement (Runstrom and Bennett 1984). These factors, together with incomplete coverage by control programs, support the need for area or building-wide cockroach management programs in multifamily housing units. A study supported by the Environmental Protection Agency's Partners for Environmental Stewardship Program (PESP) showed that partial treatment of a building did not eliminate cockroaches in a majority of the test apartments (Kramer et al. 2000). From our experience, partial treatment of a building seldom eliminates the cockroach populations. Many residents and housing authorities have realized the need for an area- or building-wide cockroach management. Yet, there is a lack of practical IPM programs in place for area or building-wide cockroach management in public housing.

In response to the risk of indoor pesticide use and need to promote a safe and healthy environment, we aim to comparatively assess the cost and effectiveness of area or building-wide IPM program compared with bait treatment alone to manage German cockroaches.

An area- or building-wide management plan will prevent the formation of "reservoirs" of cockroaches that lead to repeated infestations after partial elimination. We hypothesize this approach will lead to reduced pesticide use and improved long-term cockroach control. The result will help pest management professionals, public housing authorities, and residents in selecting for optimum strategies in managing indoor cockroach infestations.

Materials and Methods

Survey and Selection of Apartments. The study was conducted in a multifamily apartment complex (Dorie Miller Homes) managed by the Gary Housing Authority, Gary, IN. There were a total of 50 buildings, each with four to six apartments. Each apartment had a family room, kitchen, utility room, bathroom, and one to three bedrooms. Approximately 180 occupied apartments were surveyed using glue board traps (Trapper Monitor & Insect Trap, Bell Laboratories, Inc., Madison, WI). Six glue board traps (each with 8.0- by 15-cm glue area) were placed in the kitchen, utility room, and bathroom of each apartment. Standard trapping 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) beside the shelf or water heater in the utility room, and 6) behind the toilet in the bathroom. The traps were placed such that one edge was touching a wall or a vertical component of the cabinetry. The traps were retrieved after ≈24 h. The numbers of trapped cockroaches were counted. Those buildings with at least 50% of the apartments having ≥12 cockroaches were selected. In total, 12 buildings was selected for the experiment. The buildings were randomly assigned to two treatment groups: IPM and bait treatment. The survey was conducted 10–13 May 2004.

Interventions. In the bait alone treatment group, Maxforce FC Select gel bait (0.01% fipronil, Bayer Environmental Science, Raleigh, NC) was applied to cockroach harborages in all apartments during 0–12 wk. Maxforce Roach Killer Bait Gel (2.15% hydramethylnon) was applied at 16 and 29 wk when necessary. For the IPM group, flushing and vacuuming, trapping, and baiting were applied to those apartments with ≥12 cockroaches. Trapping and baiting were applied to those apartments with <12 cockroaches. Tenants from the IPM group apartments received educational materials on cockroach IPM.

The initial interventions were carried out 25 and 26 May 2004. All apartments with cockroach infestations were treated. The bait was applied to all infested areas in each apartment with the aid of a flashlight. The number of placements, location, and amount of bait applied in each apartment were determined based trap counts and distributions. The mass of a typical bait placement was 0.2–0.4 g. Larger placements were applied to harborages with large number of cockroaches. More bait was applied around the refrigerator and under the sink because these locations often had most cockroach numbers.

Those apartments with ≥12 cockroaches in the IPM treatment group were flushed with CB-38 Extra (0.3% pyrethrin and 2.4% piperonyl butoxide, Waterbury Companies, Inc., Waterbury, CT). The flushing agent was used sparingly and limited to hard-to-reach areas to minimize use and possible contamination of the cockroach bait (Appel 2004). This was immediately followed by vacuuming using a HEPA-filter equipped LineVacer vacuum machine (ProTeam, Inc., Boise, ID) to remove running and dead cockroaches. After vacuuming, 10–30 small Trapper glue boards (6.2- by 7.6-cm glue area) or Victor-M327 glue boards (5.0- by 8.5-cm glue area, Woodstream, Lititz, PA) were deployed in each apartment. Glue boards were placed on the kitchen counter, in cabinets, beside the refrigerator, beside the stove, in closets, in the bathroom, in the utility room, on shelves, and any other infested areas with one side of the trap touching a vertical surface. Maxforce FC Select gel bait was then applied into cockroach harborages to kill the remaining cockroaches. During subsequent visits, the old traps were replaced if they became dirty or had cockroaches. More bait was applied to new harborages if cockroaches were still present as determined by monitoring trap counts. Those apartments with <12 cockroaches were treated by baiting and trapping only. In both treatment groups, Maxforce Roach Kill Bait Gel was used when baiting was necessary from 16 wk to avoid resistance development.

During each visit, the number of small traps, amount of bait and flushing agent used, and time spent on treatment were recorded. Numbers of cockroaches on the small traps and those removed by vacuuming were counted or estimated. Costs of materials and labor were calculated using the following rates: bait, $0.18/g; trap, $0.09/small trap; labor, $60/h; flushing agent, $0.025/g; and vacuum machine, $1.00 per apartment per service. These rates were determined based on the market price of these materials or service.

Tenant and Staff Education. After the initial survey, all residents of the apartments in the IPM treatment group and the management personnel received cockroach IPM education materials. This includes information on cockroach biology, behavior, chemical, and nonchemical control techniques, and IPM principles. During each visit, the residents were asked to cooperate through proper housekeeping, sanitation, and reduction of cockroach harborages. A resident from each building was asked to ensure that all residents in each building would cooperate with the IPM study. These individuals served as mentors to communicate with residents in the same building on issues related to cockroach management. A letter was left with the residents in the IPM group during each monitoring visit to update cockroach control results and recommendations.

We presented two seminars to the residence managers, and the Community Program Service staff (total ≈20) of the Gary Housing Authority on 21 June and 20 July 2004. The seminars provided information on biology, importance, and methods to control cockroaches. Sanitation conditions of the kitchen, living

Table 2. Scales used to rate the degree of sanitation (modified from Schal 1988)

Rating	General condition	Amt of clutter	Amt of trash on floor	Amt of food on floor and kitchen counter
1	Clean	Few	None	None
2	Clean	Many	None	Some
3	Dirty	Few	Some	Some
4	Dirty	Many	Some	Some
5	Severely dirty	Many	Many	Many

room, utility room, and the bathroom in the test apartments were rated (1–5) during each visit and reported to the office (Table 2). Those apartments with a consistently poor sanitation rating (≥4) were referred to the Community Program Service department by the management office. The referred residents were required to attend at least 4 h of housekeeping classes.

Treatment efficacy was monitored using the previously described cockroach sampling method at 2, 4, 8, 12, 16, and 29 wk after treatment. We also conducted visual inspections (using a flashlight) and talked to residents whenever possible to determine the presence of cockroaches at 29 wk. During each visit, more bait was applied to new harborages if cockroaches were still present. Those apartments with <12 cockroaches during initial survey were serviced every 4 or 8 wk.

Data Analysis. Trap catch data were compared with initial survey data to obtain percentage reduction in trap catch. Those apartments with low numbers (1–11) of cockroaches were only compared for cost. They were not used for comparing the treatment efficacy because the trap catch reduction data had very large variances. Data were evaluated using both nonparametric and parametric statistical methods. The Wilcoxon–Mann–Whitney test was used to compare the effect of the two treatments on trap catch reduction. For the parametric method, the numbers of live cockroaches (n) were transformed by $\log(n + 1) - \log(n_0 + 1)$, where n_0 was the initial number of cockroaches before treatment. The transformed data were analyzed using a mixed effects model repeated measures approach (PROC MIXED, SAS Institute 2001). The fitted slopes of the weeks were compared with to determine the overall differences between treatments. Means at each period were assessed to determine differences between treatments for each period. The amount of bait (log transformed) and cost of the two treatments were compared using analysis of variance (ANOVA) (PROC GLM, SAS Institute 2001). Changes in sanitation ratings of the test apartments at the beginning and the end of the experiments were compared using a Student's t-test to evaluate the effect of the intervention programs.

Table 3. Initial cockroach population density in the two treatment groups

Treatment	No. apartments	Cockroach no.			
		Mean	Median	Min.	Max
IPM	12	130.1	113.5	13	354
Bait	11	117.1	146.0	14	312

Those apartments with ≥12 cockroaches after overnight trapping were included.

Results

Initial Infestation Level. In total, 12 buildings (66 apartments) were selected for this study and randomly divided into two groups (IPM and baiting). Among them, 41 and 44% of the apartments had German cockroach infestations based on overnight trap counts, respectively. Among the infested apartments, 23 had ≥12 cockroaches (Table 3). These 23 apartments had similar mean trap counts between the two assigned groups ($F = 0.18$; df = 1, 22; $P = 0.68$). Specimens of the oriental cockroach, *Blatta orientalis* L., were found only in one apartment.

Treatment Efficacy. The IPM treatment resulted in a significantly greater trap catch reduction than the bait treatment (ANOVA: $F = 5.9$; df = 11, 95; $P < 0.001$). Weekly comparisons also showed that the IPM treatment had greater trap reductions at 4 wk ($t = -2.5$, df = 95, $P = 0.013$) and 16 wk ($t = -2.0$, df = 95, $P = 0.049$) after treatment than the bait treatment (Table 4). The IPM and bait treatments resulted in 100.0 ± 0.0 and 94.6 ± 2.8% trap catch reduction, respectively, at 16 wk after initial intervention. Although all of the apartments in the IPM group did not have cockroaches based on trap catches at 16 wk, cockroaches were still found in some of the apartments based on visual inspection. Nonparametric analysis results were similar to that from ANOVA, except that the trap catch reduction in the IPM group was only marginally greater than the bait treatment at 4 wk ($\chi^2 = 2.9$, df = 1, $P = 0.091$).

At 29 wk, 16% of the IPM group ($n = 34$) had cockroaches. One apartment had high cockroach numbers. In contrast, 28% of the apartments in the bait

Table 4. Effect of IPM and bait treatments on field German cockroach populations

Treatment	% trap catch reduction (mean ± SE)[a]					
	2 wk	4 wk	8 wk	12 wk	16 wk	29 wk (7-mo)
IPM	65.3 ± 10.2a (12)	76.4 ± 11.1a (11)	90.2 ± 7.2a (12)	81.0 ± 14.0a (10)	100.0 ± 0.0a (11)	98.3 ± 0.0a (11)
Bait	48.2 ± 14.1a (11)	18.3 ± 23.5b (11)[b]	96.2 ± 2.0a (11)	94.0 ± 4.7a (9)	94.6 ± 2.8b (10)	85.8 ± 0.1a (11)

Those apartments with ≥12 cockroaches before treatments were included.

[a] Values in parentheses are numbers of apartments. Means within each column followed by different letters were significantly different ($P \leq 0.05$; ANOVA).

[b] Two apartments had large negative values.

Table 5. Total treatment cost per apartment over 29-wk period

Treatment group	No. apartments	Median (min.-max)			
		Time (min)	Bait (g)	No. traps	Cost/apartment ($)
IPM	12	49 (10–185)	45 (10–215)	40 (35–131)	65 (17–234)
Bait	11	22 (8–63)	50 (15–165)	0	35 (11–81)

Only those apartments with ≥12 cockroaches during initial survey were included.

treatment group (n = 32) had cockroaches. Five apartments had ≥12 cockroaches.

Effect of Education on Sanitation. The average sanitation rating in the IPM group changed from 3.8 to 2.4. The change from the beginning of the experiment to 29 wk was significant (t = 3.5, df = 10, P = 0.006). The sanitation level in the bait treatment group also improved (from 4.0 to 3.2), but the change was not statistically significant (t = 0.94, df = 8, P = 0.37). There was not a significant difference in the sanitation rating between IPM and bait treatments at 29 wk (F = 2.34; df = 1, 18; P = 0.14).

Effect of Nonchemical Tools on Reduction of Cockroach Numbers. Among the 12 heavily infested apartments, the median (minimum-maximum) number of cockroaches removed by trapping during the test period was 439 (15–5,783). Nine apartments received vacuuming which removed 300 (10–3,300) cockroaches. Among them, one apartment received two services, one apartment received three services, and the others received one service. For those apartments with ≥113 cockroaches in traps during the initial survey, at least 300 live cockroaches were removed by vacuuming. The effect of flushing and vacuuming was not obvious among those apartments with <113 cockroaches in traps. Less than 30 live cockroaches were removed by vacuuming from each of these apartments. The percentage of reduction by flushing and vacuuming was not clear because the total numbers of cockroaches in each apartment were unknown.

Besides cockroaches, the following animals also were found in the monitoring traps: mice, ants, small flies, spiders, millipedes, and beetles. During a visit on 14 December 2004, tenants from eight test apartments complained of mouse infestations. We placed six Trapper monitoring traps in each apartment. Mice were trapped in five of the mouse infested apartments after 24 h. Tenants were generally pleased to see both traps and baits were used to reduce cockroaches and other pests, especially mice.

Effect of IPM on Reduction of Insecticide Use. Similar amount of bait (log-transformed) materials were used in the two treatment groups during 7 mo (Table 5) (F = 0.1; df = 1, 21; P = 0.75). Most of the use occurred in the first month. For the 29 wk service, the IPM and bait treatment groups used 2.0 ± 1.1 and 6.5 ± 2.5 g per apartment, respectively. The difference was not significant (F = 1.5; df = 1, 20; P = 0.23).

Cost of Treatments. Because a good control program for cockroaches usually requires more than one visit, we used the cumulative cost during a 7-mo experimental period to compare the two treatment strategies. Education effort, necessary repairs, and sanitation effort were not factored into the cost because they were easily incorporated into the existing community service program offered by the housing authority. The median costs of the IPM and bait treatments were $64.8 (17.0–233.5) and $35.0 (10.7–81.0) per apartment, respectively (Table 5). The cost of IPM was significantly greater than that of the bait only treatment (F = 5.5; df = 1, 21; P = 0.03). This greater cost of IPM was mainly due to the additional time needed to perform flushing and vacuuming. Because flushing and vacuuming were only used 1–3 times at the early stage, the cost of IPM decreased significantly from 16 wk. The costs of IPM and bait treatments were $39.5 ± 7.8 and $15.6 ± 1.5 per apartment for the initial treatment, respectively. The costs reduced to $2.8 ± 1.3 and $5.7 ± 2.3 per apartment for the 29-wk service, respectively. The cost for the 29-wk service in the IPM group was similar to that in the bait treatment group.

Those apartments with one to 11 cockroaches during the initial survey were treated by trapping and baiting or baiting only. There were no significant differences in the costs between the two treatments (F = 0.06; df = 1, 13; P = 0.81). The mean cost per apartment during 7 mo was $13.4 ± 3.0 ($n$ = 7) and $14.4 ± 3.2 ($n$ = 8) for IPM and bait treatments, respectively. Those apartments did not have cockroach infestations or became vacant were excluded.

Discussion

The overall trap catch data during the 7-mo period demonstrated that IPM significantly improved the control of cockroach infestations than the bait alone treatment. The difference, however, was small. This was partly due to the high level of control by the Maxforce FC Select gel bait. The difference may persist beyond 29 wk due to the use of monitoring traps. Using monitoring traps not only assisted in removing the remaining cockroaches that were not killed by bait but also helped determine location and population levels of the remaining cockroaches. IPM may require significantly less bait beyond 29 wk because of the more precise placement of bait as a result of the use of monitoring traps.

It was not surprising to find that the cost of IPM was much greater than the bait treatment for the 7-mo period. The higher cost was largely due to the vacuuming procedure at the beginning of the experiment. The costs of IPM and bait only treatment for just the 29-wk service became similar. Despite the fact that IPM used more tools, its cost might continue to be similar to the bait treatment beyond 29 wk due to greater control and the need for less frequent treatments.

One of the objectives of IPM is to reduce the insecticide use. Although no significant differences in bait use were found between IPM and baiting in this study, we did see reduced amount of bait applied and fewer applications in the IPM group at the end (29 wk). More importantly, IPM achieved better control than baiting after 7 mo. The lower cockroach populations in the IPM group will make it less dependent on insecticides beyond 7 mo.

Miller and Meek (2004) found IPM was more effective and much more expensive than crack and crevice spray in controlling German cockroach infestations in public housing. The prescribed IPM treatment (baiting and vacuuming) resulted in 84% trap catch reduction after 5 mo. The IPM program in our study achieved 100% trap catch reduction after 4 mo. The main differences between the two IPM programs were that in this study, an improved bait (Maxforce FC Select) and traps were placed in the infested apartments to reduce cockroach numbers. The traps assisted in the placement of the bait. The greater efficacy of this IPM program indicates that sticky traps should be an integral part of a successful IPM program.

Vacuuming not only removes cockroaches but also has the potential to reduce cockroach allergens because vacuuming can remove large amount of cockroach products (e.g., dead cockroaches, cockroach feces, cast skins, egg cases). This benefit needs to be quantified and may be used to promote the adoption of IPM. Our laboratory studies indicated that white bread and beer baited sticky traps could increase the trap catches by 34-fold (unpublished data). Sticky traps are safe, nontoxic, and easy to use. The emergence of cockroach bait aversion and concerns about indoor pesticide overuse may prompt greater use of traps in future cockroach IPM programs.

Treatment with Maxforce FC Select gel bait alone resulted in a 96% population reduction at 8 wk, even with generally poor sanitation conditions. The bait treatment alone reduced cockroach population by an average of 95% during weeks 8–16. This demonstrates that when carefully applied and monitored, this gel bait was able to effectively reduce the cockroach infestations. However, 16 and 28% of the apartments in the IPM and bait treatment groups, respectively, still had cockroaches after 7 mo. Residents in public housing had various levels of knowledge and attitudes toward cockroach infestations. Some residents had fairly high levels of tolerance to cockroaches. They did not take action themselves to prevent or reduce cockroach infestations. Clutter and inaccessibility in some apartments were the main obstacles to cockroach elimination. For example, one apartment had a >30-cm deep pile of unwashed clothes in the utility room for ≈3 mo. Large numbers of cockroaches were found among the clothes. Flushing and vacuuming were conducted three times. In total, 215 g of bait and 185 min were required to properly treat this apartment. The cockroach counts reduced from 224 to 0 at 16 wk. However, a few cockroaches were still found by visual inspection.

Currently, the apartments managed by Gary Housing Authority receive treatment only when residents report cockroach infestations to the office. Persistent cockroach infestations in the apartments indicate the claim-based cockroach control practice does not effectively relieve the problem. Some residents did not report their cockroach infestations to the management office. The effectiveness of the insecticide applications were not documented or monitored. It is obvious that the current pest control contract terms need to be revised. Actions are needed to design, promote, and monitor self-sustaining IPM programs to effectively reduce cockroach population, reduce pesticide use, and lower cockroach allergen levels in multifamily housing. The goal of the pest management contract needs to be redefined with human health, especially children's health, in mind. Effectiveness of the program should have priority over the cost. Active monitoring and enforcement seem to be the key to the success of cockroach reduction. This requires coordination between the housing authority, pest management professionals, and tenants to set standards, goals, and commitments.

From our conversations with the tenants, there were misconceptions about the benefits and risks of various insecticides. Some residents only believed in "insecticide bombs" or baits in controlling cockroaches. Some preferred using sprays or dusts. Lack of proper use was evident based on the improper placement of insecticide baits or dusts. The tenants in the IPM group apartments were offered both education materials and person-to-person consulting during each visit whenever possible. They were willing to use simple education materials that help them understand the options available to prevent and control cockroach infestations. Continuous effort in delivering IPM information to the residents will help the adoption of community-wide IPM program.

There are a variety of effective cockroach management tools in the market. Our experience with Gary Housing Authority indicates that the management staff is fully aware of their chronic cockroach problems. However, they lack the proper funding, motivation, and coordination to implement more effective, and more expensive, IPM programs. This study provided new evidence on the severity of cockroach infestations, and on cost and effectiveness of IPM versus baiting for cockroach management. The findings stressed the need for building- and areawide IPM programs to protect the residents' health and the environment.

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