Mini-review

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Using research and education to implement practical bed bug control programs in multifamily housing

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Abstract

Multifamily housing facilities serving low-income populations have been at the forefront of bed bug outbreaks. Research conducted in the past 8 years has consistently proven that integrated pest management (IPM) is the best approach for successful suppression of bed bug infestations. Bed bug IPM in multifamily settings is especially dependent upon a collaborative community or building-wide effort involving residents, building staff and pest control technicians. Other components of a bed bug IPM program include regular monitoring to detect early-stage bed bug infestations and combined use of non-chemical and chemical interventions. Lastly, to reduce reinfestation rates and costs associated with bed bug control, it is critical to continue periodic monitoring and implement preventive control measures even after successful elimination of bed bugs has been achieved.

Keywords: *Cimex lectularius*; community-based IPM; non-chemical control; chemical interventions

1 INTRODUCTION

Over the past two decades, the common bed bug, *Cimex lectularius* L., has emerged as one of the most difficult to control urban pests in developed countries.[1] Of the various postulated reasons for this recent resurgence, insecticide resistance, increased travel, trade (including the transfer of second-hand furniture) and the decreased use of broad-spectrum insecticides within human residences appear to be the leading causes that have triggered the bed bug outbreak.[2−4] The difficulty associated with control of bed bugs partly stems from their ability to withstand exposure to certain pyrethroid insecticides.[4−8] Further, it appears that overreliance on other insecticide groups currently used for bed bug control will only aggravate the resistance problem. In addition to resistance-associated control issues, bed bugs are nearly an exclusive people pest.[9] They feed on people and have adapted to live in close association with humans. This and their cryptic behavior have allowed them to spread rapidly and invade all human transportation systems and lodging, recreation and workplace environments,[9] thus making our efforts to control bed bugs even more challenging. In summary, insecticide resistance, bed bug behavior and the dwindling list of effective management options have made the battle to control and prevent bed bugs a difficult undertaking.

Bed bugs impact on human health through their blood feeding and lesions from biting that often lead to itching, secondary infections from scratching and other allergic responses.[10,11] Perhaps more important are the emotional and financial control costs as well as medical expenses resulting from bed bug infestations.[10−13] Of recent concern is the finding that bed bugs can bidirectionally transmit pathogens responsible for Chagas disease to animals in controlled laboratory experiments specifically designed to test the disease transmission potential.[14]

Of the various sectors affected by bed bug outbreaks, housing entities serving low-income populations have been most severely affected.[11,15] Property managers and tenants in apartment complexes, shelters, dormitories and other housing facilities do not know how to get rid of bed bugs effectively, and infestations are difficult to manage where the necessary financial resources are not available. Research conducted in the past 8 years has shown that an integrated pest management (IPM) approach that utilizes a combination of chemical and non-chemical control options is the best strategy for bed bug management.[16,17] However, because integrated bed bug management can be costly,[16,18,19] pest management professionals (PMPs) hired on a lowest bid basis are not likely to implement a sustainable IPM program.[20] This situation is compounded when residents are unwilling to admit the presence of an infestation for social reasons or for fear of repercussions by the management. By comparison, bed bug management strategies in single-family housing lack the complexity of multiple-family housing, and they usually have more readily available financial and medical resources.[17]

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There is a huge reservoir of bed bugs in low-income, multifamily housing.[21] Those individuals who cannot receive bed bug treatment (including preventive measures) will continue to serve as a source of reinfestation for others. To break this cycle, it is imperative to effectively suppress or eliminate chronic bed bug infestations in low-income public housing.

In real-world situations, implementation of bed bug control programs using a non-IPM approach rarely yields total and immediate eradication. For example, the majority of apartments in certain public housing communities in Virginia and Indiana remained infested in spite of receiving regular in-house and/or professional bed bug treatments.[22,23] As mentioned earlier, sustainable bed bug IPM programs are required for eliminating persistent bed bug infestations that plague low-income, multifamily dwellings.[16,17] As per the definition, IPM is a promising and environmentally safe approach to pest management that includes: (i) proactive monitoring; (ii) combined use of multiple control strategies (chemical and non-chemical); (iii) implementation of follow-up preventive measures. Implementation of research-based bed bug IPM can aid in preventing as well as mitigating existing infestations.[16,17] The goal of this mini-review is to discuss the scientific literature directly related to educational and research efforts on different components of bed bug IPM in multifamily housing.

2 MANAGING THE PROBLEM

There is a consensus within the academic community that integrated control of bed bugs using non-chemical and chemical control techniques is the best management approach.[11,16–20,24–26] Multiple bed bug IPM programs implemented in certain infested apartments of high-rise buildings have shown that greater than 90% reduction in population numbers can be successfully achieved.[18,20,24,25] However, in these field studies, complete eradication of infestations from ca 30% of the treated apartments was not possible owing to several factors, including non-cooperation from residents and the short timeframe (10–12 weeks) available to implement IPM.

Lack of complete bed bug elimination, common in multifamily settings, raises the risk of bed bug dispersal to adjacent or nearby apartments within the building, resulting in the spread and establishment of infestations.[22,27] Because implementation of IPM in certain infested apartments of a building failed to achieve complete elimination of chronic bed bug infestations, a building-wide IPM approach was tested in two different field studies.[16,17] In the first study, conducted in Indianapolis, Indiana, the contractor- and researcher-led bed bug control program (phase I) reduced bed bug counts to zero (determined over 4 weeks) in 78% of the infested apartments. However, the researcher-led building-wide IPM program (phase II) eliminated bed bugs from 96% of the treated apartments.[17] Similarly, Cooper *et al.*[16] demonstrated that a complex-wide IPM program that included periodic monitoring and use of biweekly non-chemical and chemical treatments reduced the bed bug infestation rate from 15 to 2%.

Success of a community-based bed bug IPM program in multifamily dwellings is also improved when the following factors are included as a part of the program: (i) resident, building manager and PMP education, training and cooperation; (ii) proactive monitoring; (iii) use of non-chemical and chemical tools; (iv) follow-up preventive measures (Fig. 1). In the following subsections, we discuss the status of research on each of these four important elements of community-wide bed bug IPM.

Table 1. Responsibilities of housing administrators, residents and pest managers (professional or in-house) in bed bug IPM

Bed bug education and collaborative efforts between residents, administrators and pest managers are essential for success of housing-wide IPM

Administrators

- Facilitate the development and distribution of an agreed upon bed bug management plan
- Arrange for and conduct educational programs as needed so that all residents and staff members understand what bed bugs look like, where they come from and how to find them
- Ensure that a dedicated, in-house staff member is trained to inspect for, report and/or treat bed bug infestations
- Develop and implement a resident move-in inspection protocol to avoid new bed bug introductions
- Hire qualified PMPs or have in-house pest control technicians trained to implement housing-wide bed bug IPM strategies

Residents

- Immediately report any bed bug findings to building management
- Eliminate bed bug conducive conditions by reducing clutter, regularly launder bed linen and clothes, eliminate contact between furniture and walls and between bed linen and the floor (NB: housing staff should provide clutter removal and laundry assistance to disabled and elderly residents as necessary)
- Prevent bed bug introductions by:
  - not bringing infested items, clothing, mattresses, furniture, etc., into the building
  - being extra vigilant when visiting places with known bed bug infestations
  - fully cooperating with building staff and pest managers in implementing IPM procedures

Pest managers

- Perform regular inspections and implement chemical and non-chemical interventions as necessary
- Monitor closely and employ bed bug preventive strategies

2.1 The role of education and effective communication in bed bug control

In multifamily settings, a three-way collaborative approach involving the community of residents, building administrators and the PMPs is required for IPM to be successful.[16,17] Clearly defined roles and responsibilities of the residents, building managers and PMPs (or in-house technicians) that are crucial for sustainable community-based bed bug control are summarized in Table 1. In-depth discussion of these guidelines can be found in several extension articles and educational materials developed by different universities (e.g. Gibb TJ, http://extension.entm.purdue.edu/bedbugs/) and organizations.[28–31]

Dedicated bed bug IPM efforts from all community groups are dependent on training and education. To date, only the PMPs and building staff have received adequate training. Numerous websites offer bed bug identification and management tips for residents. Similarly, most universities have websites devoted to educating clients. However, on-site education seminars and demonstrations to assist residents in identifying infestations and eliminating conditions conducive to bed bug infestations lag behind. Cooper *et al.*[16] reported that training videos, brochures

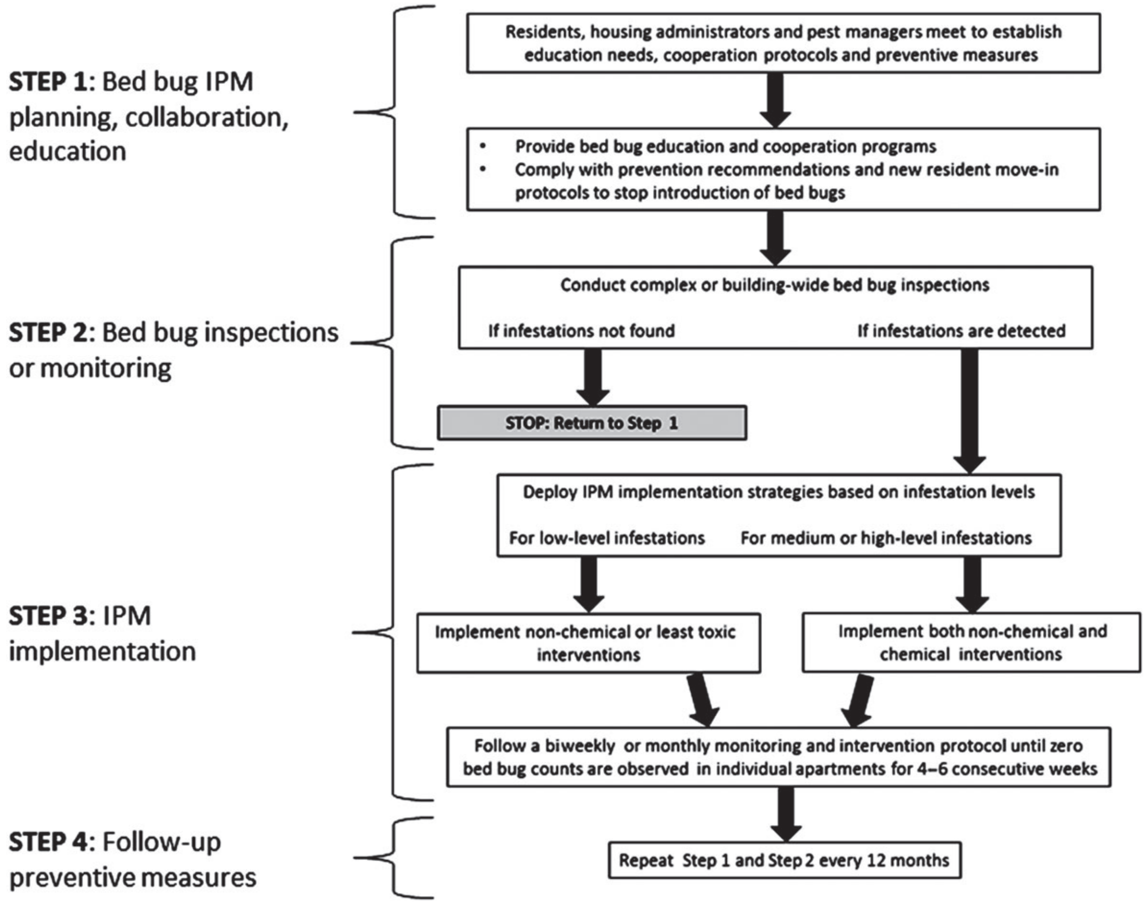

Figure 1. Flowchart for implementing bed bug IPM in multifamily housing.

and presentations, even when made available to the residents, resulted in a mixed outcome on the overall success of the IPM program. Training did not improve the ability of residents to reduce conducive conditions, but it did change their opinion about overall bed bug management and ways to deal with an infested mattress or box-spring.[16] These results and findings from other studies[17,25] imply that perhaps a more practical hands-on training approach is required to enable the residents to make meaningful contributions to a community-based bed bug IPM program. Moreover, it may also be important to help disabled or elderly residents in resolving clutter and other issues associated with bed bug infestations in a more aggressive manner.[16,32]

In addition to the direct benefits of improved training to the overall success of community-based bed bug IPM, comprehensive educational and training forums developed for residents from low-income, multifamily housing agencies may also have broader implications. Firstly, resident education and cooperation may significantly help to suppress the chronic infestations, which will further help to reduce the reservoir of bed bugs in these settings. Secondly, proper training is also likely to discourage the residents from using unproven do-it-yourself products or over-the-counter pesticides that may unintentionally expose residents to harmful chemical residues[33] and exacerbate issues associated with insecticide resistance.

2.2 Detecting the problems

Early identification of bed bug infestations is critical for the overall success of an IPM program. Population genetic studies using microsatellite markers have shown that most bed bug infestations originate from the introduction of a single mated female.[34–36] Thus, early identification of an introduction or low-level infestation is the first step in keeping bed bugs from becoming entrenched. Generally, a positive correlation exists between number of treatments required to eliminate an infestation and the initial bed bug count.[16] Newly introduced low-level infestations (a few bed bugs per apartment, based on monitor count or visual inspections) can be more easily eliminated using a completely non-chemical approach.[16,24] In contrast, eliminating established infestations with hundreds of live bed bugs may require a combined use of non-chemical and chemical interventions, which can be costly.[16,17,19,24,27] Several methods used for bed bug detection have been reviewed by Vidyanathan and Feldlaufer.[21] The broad categories of monitoring techniques used for bed bugs include: (i) active monitors; (ii) passive monitors; (iii) visual inspections; (iv) trained canines.

Active monitoring traps utilize chemical attractants, carbon dioxide (CO_2) or heat used alone or in some combination to capture bed bugs (e.g. the Verifi® bed bug detector; FMC, Philadelphia, PA). High cost is usually a concern with active monitors, but traps that use either dry ice or a sugar, yeast and water mixture as CO_2 source can be used as an inexpensive alternative.[37–39] Passive monitors do not contain an attractant, but are pitfall type (e.g. Climbup® interceptors; Susan McKnight Inc., Memphis, TN) or use an adhesive (sticky cards) to trap wandering bed bugs. Under lab and field conditions it has been shown that passive monitors baited with a chemical lure, CO_2 or heat trap significantly more bed bugs than non-baited monitors.[18,37–40] Nonetheless, passive interceptors without any lures can be very effective for monitoring when placed strategically throughout the apartment[16,18,37]

Visual inspections are another option for detecting bed bugs. Details on performing thorough visual inspections for bed bugs can be found in Pinto *et al.*[41] and Wang *et al.*[22] Visual inspection is the method most commonly used by PMPs. Even so, field studies have indicated that visual inspections alone do not consistently provide accurate quantitative information on bed bug infestations. In one comparative study, passive Climbup® interceptors were shown to reveal 6 times more bed bugs than those detected by visual inspections.[18] Although bed bug monitors are more effective than visual inspections for determining the presence or absence of bed bugs and estimating bed bug numbers, combined use of active or passive monitors and visual detection is recommended as the best practice.[16,18,24]

Canine detection of live bed bugs and eggs is another inspection method used by the pest management industry.[41–43] Pfiester *et al.*[42] showed that in artificially infested environments canines were able to accurately detect olfactory cues associated with live bed bugs and eggs. However, a more recent study that examined the bed bug detection efficiency of 11 canine teams in naturally infested apartments reported contradictory results.[43] Detection rates varied widely (10–100%), and false-positive alerts were as high as 57%. The accuracy of any particular canine team (handler and canine) evaluated on multiple days showed significant variance. The major conclusion from the Cooper *et al.*[43] study was that the ability of canines to detect bed bug infestations in natural environments differs greatly from controlled settings. This suggests that better training programs are required for both the handler and the canine to improve their detection efficiency in real-world settings. Cooper *et al.*[43] also concluded that the use of canines is more practical in larger, non-residential settings such as schools, office buildings, theaters, etc., where the use of other detection techniques may not be feasible.

2.3 Bed bug interventions

In response to the global bed bug resurgence, a flurry of untested bed bug control technologies and products have become available over the past decade, and this growth is expected to continue.[11,26] As expected, most of these products fail to achieve adequate bed bug control. However, a few control options have been successfully deployed within the IPM framework.[16–18,20,24,25,44] These useful technologies and/or products are broadly classified into two categories: (1) non-chemical methods and (2) chemical treatment options. Haynes and Potter[26] and Doggett *et al.*[11] have reviewed various control options available for bed bug management. Here we present a brief overview of non-chemical and chemical techniques that have been successfully utilized within the IPM strategy.

2.3.1 Non-chemical interventions

Non-chemical bed bug management includes the use of mechanical and physical control options that serve as effective and generally safe alternatives to the use of insecticides.[24,45,46] These can be used effectively as stand-alone treatments or in combination with chemical insecticides, depending on the level of bed bug infestation. Field studies in apartments with few live bed bugs (1 to ≤60) have reported successful reduction (>90%) in bed bug numbers using non-chemical control measures, i.e. mattress encasements, hot steam, hand or vacuum removal and Climbup® interceptors.[16,24]

Manual removal of bed bugs either by hand or by vacuum is the simplest mechanical control method that can be used in an IPM program.[24,25] Vacuum cleaners are particularly useful in reducing bed bug numbers in heavily infested apartments where bed bugs can be seen moving on the floor, beds or furniture.[17,47] Sealing and disposal of infested furniture or other belongings that cannot be effectively treated owing to logistic or cost limitations is another simple physical removal method.[11]

The use of mattress and box-spring encasements is an important IPM tactic.[16,17,30,48] Encasements serve a dual purpose in bed bug management. Firstly, they permanently confine bed bugs inside the mattress or box-spring. Secondly, encasements reduce hiding areas for bed bugs, making inspections and treatments easier and more effective. In addition to encasements, passive Climbup® interceptors properly placed under the legs of beds and other furniture can create a barrier for bed bugs that try to access beds or leave infested beds or furniture.[18,37] Interceptors also facilitate physical removal of trapped bed bugs, thus contributing to overall population reduction.[18,37] Recent observations indicate that Climbup® interceptors, placed away from the furniture (hallways, kitchen, bathrooms, etc.), can trap migrating bed bugs and indicate population hot spots that require treatment.[16]

The use of high temperatures (heat) to kill bed bugs is another popular non-chemical technique. Exposure to temperatures close to 50 °C is considered to be lethal to all stages of bed bugs, but if such temperatures cannot be achieved, longer exposure times (60–90 min) at temperatures between 45 and 48 °C are also effective.[49–52] The different methods of exposing bed bugs to heat include the use of: (i) a clothes dryer; (ii) hot steam applicators; (iii) portable heat chambers; (iv) portable whole-room heaters; (v) heating trucks. The first two have been successfully used as a part of bed bug control programs in multifamily apartment complexes.[16–18,20,24,25] Infested bed linen, blankets, window curtains, clothes and soft toys can be placed in a clothes dryer on a high heat setting to kill all bed bug stages.[26,53] To ensure that the temperature of the infested fabric or material surpasses the lethal level of 50 °C, it is recommended to dry clothes for a longer duration (30–50 min). Portable steam machines that are capable of delivering hot steam (70–85 °C) are excellent for instantly killing exposed bed bug eggs, nymphs and adults.[16,17,24,54] Applying steam slowly (10 cm s^{-1}) and maintaining the nozzle head in close contact with the treated surface is recommended to maximize its effectiveness and improve heat penetration.[54]

To kill hidden bed bugs and their eggs, the temperature of the infested items can be raised to lethal limits (~50 °C) by exposing them to high heat within portable heat chambers or by raising the temperature of the entire room or dwelling. Both of these techniques are used by PMPs in combination with other chemical and non-chemical control measures; however, peer-reviewed publications that report the utility of heat chambers or whole-room heaters in an IPM program are lacking. Moreover, difficulties associated with quickly raising the temperatures of all bed bug harborage areas to lethal levels,[55] and high cost, are major concerns associated with apartment and especially multiunit building heating.[26]

As with heat, bed bugs are incapable of surviving exposure to cold temperatures (−21 to −30.5 °C for different life stages).[49–51]

A comprehensive laboratory study by Olson *et al.*[56] demonstrated that temperatures ranging from −15 to −18 °C are capable of killing bed bugs with 3.5 days of continuous exposure, whereas temperatures below −20 °C require ca 2 days. Such lengthy requirements are likely not feasible in mutlifamily settings where resident cooperation and logistics are an issue. Nevertheless, it is a convenient technique for killing bed bugs hiding in small non-washable items. A relatively new device (Cryonite®) that delivers solid carbon dioxide (dry ice) through a nozzle at temperatures close to −78 °C is claimed to kill bed bugs upon contact. However, independent scientific studies proving the effectiveness of this device are lacking. Moreover, the Australian Code of Practice for bed bug control does not recommend the use of this method because it uses high pressure that may lead to unintended dispersal of bed bugs.[30]

2.3.2 *Chemical treatment options*

In spite of the fact that pyrethroid resistance is suspected to be a major factor in bed bug resurgence, insecticides are an important component of bed bug IPM. This is because non-chemical options are not effective as stand-alone methods for complete elimination of established bed bug infestations with hundreds of live bed bugs.[16,24] Widespread reports on pyrethroid resistance from different countries[4−8] have accelerated the development and registration of newer formulations and chemistries for effective bed bug management. As of 2015, major groups of insecticides available for bed bug management in the United States are: (i) various dust and spray formulations of pyrethroids; (ii) neonicotinoids (dinotefuran); (iii) pyrethroid + neonicotinoid mixtures; (iv) pyrroles (chlorfenapyr); (v) silicates (diatomaceous earth); (vi) essential oil and detergent products.

In addition, carbamate and organophosphate (OP) insecticides are also registered for bed bug control in parts of Asia and Africa. In general, resistance issues to OP and carbamates are not as severe as pyrethroid resistance.[7,8] Only one volatile OP, dichlorvos (DDVP), is registered for use against bed bugs in the United States. Fumes of DDVP are effective in killing all stages of bed bugs, including eggs.[57] However, owing to its known adverse effects on humans, its use is restricted to vacant dwellings. Sulfuryl fluoride is another fumigant registered for bed bugs, but it is not commonly used owing to the high cost associated with whole-building treatments. Phillips *et al.*[58] showed that lower rates of sulfuryl fluoride are effective against all stages of bed bugs. It is possible that lower label rates of sulfuryl fluoride for bed bug control can reduce the high costs associated with its use. Juvenile hormone mimics such as hydroprene and methoprene are not effective for bed bug control at the current label rates.[59]

Detailed molecular investigations with pyrethroid recalcitrant strains have shown that the majority of bed bug strains in the United States have developed multiple mechanisms of resistance.[6,60−62] Specifically, resistance-associated genes (cuticular proteins, ABC transporters and cytochrome P450s) that both interfere with penetration of pyrethroids into the insect body and enhance the detoxification process are highly expressed in the legs, head and integument of bed bugs.[6] In addition to resistance factors expressed in the integument,[62] most bed bug strains (96 of 110) were also shown to carry resistance-associated mutations in the target-site gene.[5,63]

Given the extent and multiple modes of pyrethroid resistance in bed bugs, judicious use of these insecticides within IPM programs is recommended. For example, dust formulations of pyrethroids applied either as crack and crevice or as impregnated dust bands around legs of beds/furniture are more effective and recommended over spray formulations.[24,25,64] Similarly, mixture products (pyrethroids + neonicotinoids) are more effective in bed bug management programs because they contain two insecticides with different modes of action.[17,24,44,65] A recent report by Jones *et al.*[66] showed that 10 min exposure of bed bug females to permethrin-impregnated *Active*Guard (Allergy Technologies LLC, Ambler, PA) mattress encasements negatively influenced their feeding behavior and reproductive ability. Thus, in spite of resistance problems, certain pyrethroid-containing products and formulations can be used for bed bug control in combination with other non-chemical and chemical tactics.

The US Environmental Protection Agency (EPA) has granted reduced-risk status to relatively newer non-repellent insecticides such as chlorfenapyr and dinotefuran. Various formulations of these products (spray, aerosol and dust), when used within the context of IPM, suppressed bed bug population numbers (89–96%) and reduced the overall pesticide use (62–96%) by comparison with the chemical-only approach.[18,20] Relative to pyrethroids and neonicotinoids, chlorfenapyr is a comparatively slow-acting insecticide.[67] Nonetheless, it has a longer residual life and, if faster mortality is expected, an aerosol formulation of chlorfenapyr can be used.[67] In addition to reduced-risk chemicals, low-toxicity products such as diatomaceous earth and essential-oil-based products (e.g. EcoRaider®; Reneotech Inc., North Bergen, NJ) were also shown to provide bed bug suppression that was comparable with the efficacy of neurotoxic and/or synthetic insecticides.[18,68]

3 FOLLOW-UP PREVENTIVE MEASURES

For community-wide bed bug IPM to be successful in the long term, periodic monitoring and implementation of preventive measures should continue even after bed bug elimination has been achieved. Population genetic studies with bed bugs indicate that a single fertilized female surviving IPM treatment is sufficient to initiate a reinfestation.[34−36] A number of organizations have published standard bed bug control guidelines that include steps for follow-up monitoring and preventive control.[28−31] However, only one peer-reviewed publication has reported the effectiveness of follow-up preventive measures on reinfestation rates in public housing.[16] In this study, complex-wide bed bug inspections in a majority of occupied apartments were not only done at the start of the study but also at 6 and 12 month intervals, which led to identification of reinfestations with <10 live bed bugs as well as new introductions. Proactive treatment of new infestations further prevented the bed bugs from becoming established. The authors also followed a specific post-elimination monitoring protocol in which monitoring was continued for 4–6 weeks after bed bug counts were reduced to zero. Post-elimination monitoring, which included resident interviews about bed bug bites and sightings as well as visual and interceptor trap inspections, avoided premature termination of interventions. Lastly, apartments where new residents had moved in were also inspected for bed bug activity on a regular basis. Together, these inspections led to high elimination rates, minimal reinfestation rates and an overall reduction in chronically infested apartments from 15 to 2%. Cooper *et al.*[16] concluded that post-elimination monitoring of all apartments in a multifamily setting should be conducted as a part of community-based bed bug IPM.

4 EMERGING TECHNOLOGIES FOR THE IPM TOOLBOX

Of the many bed bug control methods currently advertised, only a few methods based on in-depth scientific understanding have the potential for inclusion in bed bug IPM. The recent discovery of a blend of bed bug aggregation pheromones including five volatile components and one less volatile contact chemical (histamine) appears to hold promise for developing highly effective active bed bug traps with chemical lures.[69] Similarly, the finding that the chemical agonist VUAA1 of the bed bug odorant receptor coreceptor (Orco) changes the pheromone aggregation response of treated insects is likely to be important for the development of behavior-modifying chemistries.[70] Biological control of urban insects is not considered to be feasible, but the ubiquitous association of the mutualistic bacterium *Wolbachia* with bed bugs and the inability of insects lacking this symbiont to reproduce may be exploited for biocontrol.[71–73] Finally, modified-atmosphere technologies that use CO_2,[74] liquid nitrogen, chlorine dioxide[75] and ozone (Feston J *et al.*, unpublished data) show some promise for treatment of small bed bug-infested items in sealed chambers. However, their use for whole-room or dwelling treatments seems unpractical. It remains to be seen whether these technologies find utility in IPM programs.

5 SUMMARY AND CONCLUSIONS

Although it is agreed that integrated management of bed bugs will continue to be the best approach for managing bed bugs, the various IPM tools that are used may continue to evolve over the next few years. It is imperative that researchers recommend technologies that are proven to be successful through rigorous and independent scientific testing.[11,26] Of course, such research will require increased funding from public and private organizations. High costs associated with bed bug IPM[16,18,19,23] are currently a major limitation to its adoption by housing agencies and other affected sectors of society. Cooper *et al.*[16] reported an annual cost of $US 65 000 for community-wide IPM in a complex of 358 apartments. However, because the integrated approach is more likely to eliminate chronic bed bug infestations, the long-term costs associated with IPM will be equal to or less than a chemical-based control strategy.[16] It is also expected that newer IPM tools that are less labor intensive and more economical will be developed. Finally, as bed bug control in multifamily housing is dependent on collaboration and face-to-face communication between residents, housing administrators and PMPs, practical training and demonstration efforts directed towards these groups will continue to be critical for the complete adoption and sustainability of bed bug IPM.

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