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Review of Field Tests on Bed Bug Control Technologies

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Key Messages

- There are numerous bed bug control technologies but few published studies that evaluate or demonstrate effectiveness in the field.
- Education and cooperation between affected residents, landlords, and pest control professionals are important for successful long-term bed bug management strategies.
- There are a limited number of insecticides available, so non-chemical methods to treat and monitor bed bug populations will be essential to future bed bug treatment regimens.
- Several technologies have been postulated, some which have laboratory evidence to support their efficacy, but no published field studies were identified in this paper.

Introduction

Economic, environmental, and health concerns with bed bug control technologies and management options are of interest to public health and pest management agencies, who often receive and need to respond to inquiries regarding bed bugs (Hemiptera: Cimex). However, control technologies are constantly changing as evidence emerges for evaluating their efficacy/feasibility and acceptance by regulators.

Potter (2011) provides a detailed history of technologies and products that have been used to control bed bugs over the millennia.[1] The movement went from oils, fire, and gunpowders to the creation of the first residual chemicals that decimated bed bug populations in the 1940s to the 1970s. The last effective residual products (e.g., chlorpyrifos, propoxur) were removed from indoor use in 1999 and, since that time, bed bug populations resurged to epidemic levels across the world. This document reviews the bed bug control technologies that have been evaluated in the field from 2005 to 2014 and will also comment on emerging technologies and pesticides.

Methodology

Key words based on the article on bed bug control methods by Koganemaru and Miller (2013) were used for the search (see Appendix A).[2] Databases searched include BIOSIS Preview; CAB Abstracts; Web of Science Core Collection (includes Science Citation Index Expanded, Book Citation Index – Science, and Current Chemical Reactions); MEDLINE; Current Contents – Agricultural, Biological, and Environmental Sciences; Current Contents – Physical, Chemical, and Earth Sciences; Academic Search Complete; and Zoological Record. These databases were selected to include three journals: the *Journal of Economic Entomology*, *Journal of Medical Entomology*, and *Journal of Vector Ecology*. Searches were refined to journal articles and titles, and abstracts were scanned for articles discussing bed bug control methods.

Searches focused on articles published in 2005 to 2014, and the following search limits were used:

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- Only English-language articles were considered for inclusion.
- Trade publications (e.g., *Pest Control Technology* and *International Pest Control*) were not considered, although researchers appear to publish in both peer-reviewed journals and trade publications.
- Journals that were not readily available through the University of Manitoba library system could not be considered and were not included.
- Experiments where field components did not directly test control methods or where bed bug control was reported as a collateral benefit were excluded.
- Articles that field tested monitoring for detection purposes were excluded.
- Experiments where the primary purpose of which was not testing bed bug control methods were excluded.

Results

Field tests

Six articles that described field tests were found; most offered a basic comparative analysis of bed bug counts or reduction between treatment groups. Articles generally covered non-chemical treatments or Integrated Pest Management (IPM) regimens. The lack of field tests on insecticides has been noted by at least one researcher (Wang et al. 2009), who also noted that more studies of this nature would be useful.[3] Despite the potential utility of future field tests of insecticides, Moore and Miller (2009) conclude from their study that the current arsenal of pyrethroid-based chemicals as they are currently allowed to be used are insufficient to eliminate bed bug infestations.[4] Articles summarized in Appendix B describe field tests for various bed bug management strategies.

Resistance to insecticides has prompted the development of IPM systems. Most of the studies included in the literature review feature non-chemical control methods implemented exclusively or in combination with chemical control methods because it is recognized that insecticide treatments alone will not eliminate infestations. IPMs were evaluated not only for their efficacy, but also for their cost effectiveness. Unfortunately, due to small sample sizes and large variances, no meaningful comparisons between traditional chemical-only treatments and IPMs were made in the articles reviewed. Treatment cost may be reduced by early detection. This suggests benefits for individuals who are aware of the signs of a bed bug infestation.

Emerging technologies under investigation

Described below are additional control methods that were encountered during the literature search, but did not meet the inclusion criteria; note this is not an exhaustive list. Most of the technologies below have not been shown to be effective. However, use of canine units, Neem and Cedar Oil, and heat and cold treatments are more promising.

Alarm Pheromones

Alarm pheromones ((E)-2-hexenal, (E)-2-octenal, and a (E)-2-hexenal:(E)-2-octenal blend) are an emerging tool which attempt to influence bed bugs from their hiding place in walls, cracks, and crevasses.[5-8] The primary purpose of the alarm pheromones is to promote the exposure of insecticides to bed bugs during treatment. The addition of these pheromones causes bed bugs to move out from their hiding spots and allow for more insecticide product to reach the insects and increase the overall efficacy. This research shows promise for increasing the overall effectiveness of chemical and non-chemical treatments in an IPM program.

Nymphal Bed Bug Pheromones

Nymphal pheromone research (4-oxo-($\boldsymbol{E}$)-2-hexenal and 4-oxo-($\boldsymbol{E}$)-2-octenal) has shown promise in the laboratory that prevents males from attempting copulation with adult females.[9-11] This would decrease reproduction in adult bed bugs and eliminate whole populations after approximately a year or more depending on living conditions of the bed bug. It could be a part of an IPM in combination of chemical and non-chemical control options.

Bean Leaves (Phaseolus vulgarius)

Natural bean leaves of *Phaseolus vulgarius* have shown to be effective in capturing all stages of bed bugs. These specific genus of bean leaves have micro hairs on them that when crawled over become attached to the exoskeleton of the bed bug. If there is a barrier of these bean leaves, it prevents the bed bug from proceeding any further and they consequently will die. Researchers are attempting to synthetically create the same natural capturing effect of the bean leaves, but have not been able to duplicate the effectiveness.[12] If they can synthesize a comparable leaf, it could be an effective biological alternative tool that can be used in combination with other techniques within an IPM program.

Alternatives/Biologicals

There is a great deal of research occurring in this area. Many researchers are attempting to provide solid, effective plant and alternative biological options.[13-15] All of these methods and products are in the research phase and are unlikely practical in the field. The only possible options are Neem and Cedar Oil, where they are finding fair to good results.[16,17] Although these products are not currently registered through the PMRA and EPA, they are available to the public and pest control professionals; no published field data has been produced.

Fungus (Beauveria bassiana)

The fungus, *Beauveria bassiana*, has shown in the laboratory to be a very effective alternative to infect a location that has bed bugs and the fungus transferring from the environment to the bed bugs.[18] There is almost complete mortality in laboratory situations. Field trials are in progress but the issue of introducing a fungus into the environment with concerns with allergenicity may hinder the progress of this technique. If the researchers determine a technique that will minimize the potential side effects, this fungus may add another biological alternative to controlling bed bugs.

Ivermectin (Mectizan)

The oral drug Ivermectin has coincidentally demonstrated effectiveness in controlling bed bugs for a few days after a patient had ingested it. Bed bugs that feed on individuals that have taken Ivermectin die from the blood meal ingestion of the drug.[19] Even though it is a unique way to control bed bugs the expectation would be that this method would not be approved for controlling bed bugs as most human trials like this would likely not be approved for alternative drug bed bug control.

Canine

Since approximately 2005, there has been an increase of specially trained, bed bug detection dogs. A certified handler with a certified dog may improve the chances of finding small infestations in locations like hotels, apartments, and hostels where there is usually a high rate or reasonable amount of occupant turnover. Dogs are generally accepted to be over 90 percent accurate in bed bug detections, whereas a trained Pest Management Professional is approximately 30-35% accurate in detecting small infestations. The dogs can alert to a small infestation well before an established bed bug problem occurs. Trained bed bug-detection dogs and their handlers are a benefit to increasing the success of an IPM program in a building and dogs are being used in many companies as another tool in the control of bed bugs.[20]

Bed Bug Bombs

Bed bug bombs have shown to be generally ineffective as a control option for bed bugs but if the product does directly hit a bed bug, there can be a certain level of control.[21] There are registered versions of this product available in the United States but not in Canada. There are currently no pending registrations of bed bug bombs in Canada. It is not likely a good option in an IPM program at this time as more work should be done in this area to increase the effectiveness of this technique.

Heat and Cold Treatments

Heat and cold treatments can be effective treatment options if the killing temperatures are reached for long enough time periods. Total home or building treatments with heat are very popular and are being touted as the “silver bullet.” These treatments are successful if the killing temperature of 120ºF is reached for more than four hours, but there is still a requirement of a chemical treatment after a heat treatment to completely decimate a bed bug population and their eggs.[22-26] This treatment regimen increases the overall effectiveness. For Canada, heat or direct contact cold treatments are currently the only control option for bed bug eggs. This is an area that needs further research for products that will control eggs. Cold treatments with Cryonite (-75ºF) are limited in their use and successful application depends on direct contact with the bed bug or egg. These methods are an option in an IPM program but its usefulness is limited.

End-use products and pesticides available in Canada

Appendix C summarizes end-use pesticides available in Canada as of November 10, 2013.[27] This list excludes one commercial end-use product containing the active ingredient bendiocarb and one domestic end-use product containing d-phenothrin and tetramethrin. These products are discontinued and expired on December 31, 2013.

The list was created by the Pest Management Regulatory Agency (PMRA) to provide an indication of the scale and magnitude of chemical products available in Canada in the Domestic and Commercial categories. It reveals only three chemical groups— with the third class as unclassifiable—that are available in Canada at this time. It would be beneficial to discover, test, and publish additional chemical classes or alternatives.

Discussion

Resident engagement and compliance is important to the success of any pest control regimen. For example, successful use of interceptor traps requires cooperative residents.[28,29] If bridges exist between beds, furniture and the walls, bed bugs can bypass the traps and crawl onto furniture in search of human hosts. The same was true of the willingness to regularly launder items or remove clutter prior to treatment. Several articles mentioned resident/tenant education as part of the treatment processes but they did not comment on the role, if any, education played on tenant compliance with instructions although additional education is recommended.[28]

The need for education of residents appeared particularly important in light of bed bug insecticide resistance and results that show chemical-only treatments are insufficient to eradicate infestations. Moore and Miller (2009) tested different chemical regimens and noted that neither the pyrethroid-based (traditional) nor non-pyrethrioid-based (novel) regimens tested were completely effective.[4] While authors never explicitly attributed failure to lack of resident compliance, some actions, such as not allowing full access to researchers and pest management professionals and frequent tenant movement among units, hinder bed bug control strategies. Another article noted that some residents in infested buildings are not concerned about infestations.[3]

The number of studies included in review is relatively small compared to the number of studies available on bed bug control methods because the majority of tests are conducted in laboratory settings. The lack of studies with field-tested control methods may be a result of several factors, including difficulty of finding study sites, securing funding, difficulty involving pest control companies for research purposes, and ethical considerations. Additionally, the studies included here tended to overlap in terms of control methods tested and researchers, relying on pitfall traps (including interceptors) and IPM. It would be useful to expand the scope of field testing to include more control methods. It will also be useful to have larger-scale studies conducted in a wider variety of environments.

Conclusion

Bed bugs have been increasingly resistant to chemical control methods such as permethrin and pyrethrin/pyrethroid insecticides. The number of available chemical classes has also reduced, increasing the chance of resistance occurring. Further alternatives or chemical classes need to be found before a wide-scale resistance to certain chemical classes occurs.

Non-chemical treatments including box spring or mattress encasements, use of hot steam, heat treatment, and manual removal contribute to effective IPM regimens. Interceptor (moat-style) traps were commonly used in many of the studies. These studies have demonstrated immediate, consistent and effective reduction to bed bug numbers. This type of trap offers the advantage of being able to assess bed bug populations more accurately than by visual inspection.

While studies exploring the use of chemical lures and CO_2 reveal promising results in directing bed bugs to traps, thus potentially reducing the numbers that migrate to hosts, complete elimination of bed bug infestations is very difficult even after repeated treatments over several weeks or months. However, significant reductions in bed bugs (e.g., >90%) can be achieved through proper use of non-chemical and chemical treatments. Educating affected housing managers and tenants, positive identification of bed bugs, and follow-up monitoring to ensure bed bug management strategies are long-lasting as an integrated pest management program is key in reducing and eliminating bed bugs.

Emerging technologies are the future products and techniques for pest management professionals. Some of the emerging technologies may become practical tools (Neem, Cedar Oil as examples) and others may be viable options or side effects of another treatment (Ivermectin as an example). However, these technologies will need further investigation, and their use should be added or removed from best practices pending their performance in field tests.

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Appendix A:

Search Keywords

- nymph* pheromone and bed bug
- bean lea* and bed bug
- insect-plant interaction and bed bug
- biomimetic and bed bug
- neem and bed bug
- botanical and bed bug
- enzyme and bed bug
- biopesticide and bed bug
- fungus and bed bug
- Ivermectin and bed bug
- canine and bed bug
- heat and bed bug
- cold and bed bug
- integrated pest management and bed bug
- insecticide and bed bug

Appendix B

Summary of Field Tests Reviewed

Article	Description	Results	Conclusion
Anderson et al. (2009)[30]	Using various configurations of a self-designed bed bug trap (cat-feeding dish baited with various attractant cues/options), a series of field tests and laboratory experiments were performed. Bait traps were placed in various locations of three bed bug-infested apartments used as field sites.	Laboratory experiments demonstrated that release of compressed CO_2 (400 mL/min) attracted significantly more bed bugs than compressed air alone. In two field sites (unoccupied apartments), traps baited with CO_2 significantly captured more bed bugs in all developmental stages than traps without CO_2; in one apartment, the number of bed bugs captured was 5898 over 9 days with CO_2 compared to 656 over 29 days without CO_2.	Baited traps may be useful for reducing host-seeking bed bugs. Across all the tests conducted in unoccupied apartments, traps baited with CO_2 were more effective for attracting and capturing bed bugs, regardless of whether heat or chemical lure (e.g., proprionic acid, butyric acid, valeric acid, octenol, lactic acid) were added. These types of traps may be useful for identifying bed bug infestations before tenants notice or report.
Moore and Miller (2009)[4]	Field tests were used to evaluate the efficacy of two insecticide regimens; one pyrethroid-based ('traditional') and one non-pyrethroid based ('novel'). Fifteen bed bug-infested apartments from the same housing facility were selected and randomly assigned to treatment groups (5 traditional, 5 novel regimen) and control group. The traditional pyrethroid-based treatment was comprised primarily of insecticides that have had bed bugs listed on the product label for many years (*β*-cyfluthrin, deltamethrin, hydroprene). The novel non-pyrethroid treatment consisted primarily of products where bed bug was added recently to the label, were EPA exempt, or had a label for crawling insect pests (chlorfenapyr, Steri-Fab, NIC 325, hydroprene).	After 8 weeks of bi-weekly treatments, the traditional treatment significantly reduced bed bugs from 39.8 ± 10.1 per unit to 2.2 ± 1.0 (95% reduction), whereas the novel treatment significantly reduced bed bugs from 71.4 ± 25.3 bed bugs per unit to 10.2 ± 4.4 (86% reduction). Neither treatment completely eliminated bed bugs during the duration of the field tests. A natural decline in bed bug numbers was seen in control units, but both treatment groups reduced bed bug numbers significantly more than control units.	Both traditional and novel treatment regimens were effective at reducing bed bug populations, but it is extremely difficult to completely eliminate bed bugs using currently available pesticides in the approved manner (i.e., amount and location). If pyrethroid products are not allowed to be used at higher concentrations and on more surfaces, IPM would likely be necessary to eliminate bed bugs in an infested multi-unit building.

Article	Description	Results	Conclusion
Singh et al. (2012)[31]	Field studies were designed to test the effectiveness of a new pitfall trap design (modified dog bowl); if chemical lures (nonanal, 1-octen-3-ol, spearmint oil, coriander Egyptian oil) help capture bed bugs; and to determine the effect of different CO_2 sources (compressed CO_2, sugar and yeast mixture) and release rates (100, 200, 400, and 800 mL/min) in attracting bed bugs. The field sites were occupied one-bedroom and studio apartments.	Over a 28-day period, the new pitfall trap design (77.2 ± 2.1% probability of trapping) captured on average 2.8 fold more bed bugs than interceptor traps (22.8 ± 2.1% probability of trapping); results were statistically significant. Over a period of 8 days, interceptor traps baited with a chemical lure mixture caught on average 2.2 (days 0-2) and 2.3 (days 3-8) fold more bed bugs than non-baited traps; results were statistically significant. CO_2-baited traps caught more bed bugs with increasing release rate. For example, release rate of 400 mL/min was more effective than the release rates of 100 and 200 mL/min. A significant difference was detected when comparing release rate of 800 mL/min with 400 mL/min and between 400 mL/min and 100 mL/min. The probability of trapping bed bugs for sugar-yeast generated sources of CO_2 and compressed CO_2 was 91.0 ± 1.3% and 90.0 ± 1.4%, respectively (no significant difference).	Interceptor traps may be modified to increase probability of trapping by increasing the depth of the wells. Lures such as CO_2 and chemical mixtures can also be added to increase effectiveness of traps. Using sugar-yeast mixtures or compressed gas as sources of CO_2 were similarly effective at trapping bed bugs; sugar-yeast mixtures are less expensive, but may require a larger container. A sugar-yeast CO_2 source, chemical lure, and pitfall trap could be used as an affordable alternative to detect bed bugs in vacant rooms and non-traditional locations (e.g., schools and office buildings). Researchers postulate that higher release rates may be needed to compensate for other factors, such as human odours, larger spaces, air movement, and physical obstacles.
Wang et al. (2009)[3]	This study examined the cost and effectiveness of two IPM programs over 10 weeks in a 15-story, 225-unit apartment building. The two treatment groups were diatomaceous earth dust-based IPM (D-IPM) and chlorfenapyr spray-based IPM (S-IPM). Each treatment group was randomly assigned eight apartment units with at least 10 bed bugs.	Before treatment, initial bed bug counts in apartment units were not significantly different from each other. After 10 weeks, the mean reduction in bed bugs in apartments treated with D-IPM or S-IPM were 97.6 ± 1.6 and 89.7 ± 7.3%, respectively; 50% of treated apartments remained infested. Interceptor traps and visual inspections after 10 weeks produced mean bed bug counts of 219 ± 135 and 39 ± 22, respectively. There was no significant difference in the average costs (labour, hot steam, chemical applications) of D-IPM ($463) and S-IPM ($482).	Results indicate that IPM programs may reduce exposure of insecticides but that residual activity is needed for complete elimination. Visual inspections can be aided by using interceptor traps, which were demonstrated to be more accurate for assessing bed bug populations and may reduce bed bug bites. One important factor in the treatment regimen success is resident attitude. They note that not all residents were worried about bed bug infestations and that not all residents were willing and/or able to comply with instructions for, as an example, washing linens and reducing clutter. Follow-up monitoring is required, as are follow-up treatments. Additionally, apartment complexes need to consider communal spaces when implementing bed bug control measures.

Article	Description	Results	Conclusion
Wang et al. (2012)[28]	Over 10 weeks, this study compared three bed bug management strategies of a 223-unit low-income housing building. The non-chemical treatment group, insecticide-only treatment group, and IPM treatment group, were assigned 9, 6, and 9 bedbug-infested apartment units, respectively. For ethical reasons, only lightly infested units were assigned to the non-chemical treatment group. Non-chemical treatment includes use of mattress/box spring encasements, hot steam, and manual removal. Insecticide-only treatment utilized Temprid spray (applied by pest control contractor), and either Tempo (1% cyfluthrin) or Mother Earth D dust (applied by researchers). The IPM treatment included the use of Temprid spray and either Tempo dust or Mother Earth D, in addition to methods in the non-chemical treatment group. Interceptor traps in all treatment groups were used to monitor bed bug populations.	After the initial treatments, researchers inspected the interceptors biweekly to monthly either until November 30, 2010 or until no bed bugs were found after two consecutive checks. The researchers also conducted interviews in January of the following year asking residents if their apartments were still infested, their evaluation of bed bug control in the building, and steps they had taken to control bed bugs. Initially, the median (min, max) bed bug counts in the non-chemical, insecticide-only, and IPM treatment were as follows: 4 (1, 57), 19 (1, 250), and 14 (1, 219), respectively. After ten weeks, the median (min, max) bed bug counts in the non-chemical, insecticide-only, and IPM treatment were as follows: 0 (0, 134), 11.5 (0, 58), and 1 (0, 38), respectively. By the end of the study, bed bugs were eliminated from 67%, 33%, and 44% of the apartments in the three treatment groups, respectively. A couple of months later, in January 2011, the researchers examined the 12 apartments to which they could gain access (three non-chemical methods only, six insecticides only, and three IPM treatment) again to discern the long-term effectiveness of each treatment regimen. Five of the apartments (two in non-chemical methods only, two in the insecticide-only group, and one in the IPM group) were still infested. These apartments had been infested between the initial treatment date and the close of the study ten weeks later.	Non-chemical techniques and regular monitoring can eradicate light bed bug infestations if residents are educated about the treatment. Results did not show a difference between IPM and non-chemical or insecticide-only treatment groups (i.e., they were equally effective). Bed bug management in low-income communities is difficult. Success requires a building-wide strategy dependent on resident motivation and cooperation, assistance from building management staff, and competency from pest control providers.

Article	Description	Results	Conclusion
Wang et al. (2013)[29]	Researchers evaluated the use of insecticide-treated (1% cyfluthrin) cloth bands attached to furniture legs compared to an IPM treatment. Insecticide-treated cloth bands were hypothesized to increase the likelihood that bed bugs not trapped in interceptors would be killed. The IPM treatment used the insecticide-treated dust bands in addition to 1% cyfluthrin dust applied to room perimeters, hot steam applied to infested furniture, installing mattress encasements, and installing interceptor traps. Both treatment groups included application of Alpine aerosol (0.5% dinotefuran) to live bed bugs during biweekly inspections. In the first field test, the control group included the use of interceptor traps and may have received monthly minimal insecticide sprays by existing pest control professional. In the second field test, the control group did not include any interceptor traps or insecticide treatment (i.e., untreated).	Laboratory tests showed that 99% of bed bugs who crossed dust bands were killed within 5 days. In the first field test, after 12 weeks of treatment, bed bug counts in the dust band, IPM, and control group reduced by 95, 92, and 85%, respectively; the mean counts were 4.0 ± 2.3, 4.2 ± 1.8, and 16.6 ± 7.4, respectively. Compared to control group, a significant difference in reduction was seen for dust band and IPM treatment groups. In the second field test, mean bed bug count in apartment units of the control group increased 381% (8.3 ± 2.3 to 39.8 ± 22.4), whereas mean bed bug count decreased 16% (4.3 ± 1.3 to 3.6 ± 1.9).	Installation of interceptor traps at the beginning of the first field test may explain the rapid decrease in bed bug counts 2 weeks into the study. Dust band treatment may render perimeter dusting unnecessary thereby reducing the amount of insecticide needed in treatment regimens. Dust bands and interceptors can keep populations low but will not eradicate infestations, which means that multiple treatment methods are needed.

Appendix C

Number of end-use products, by class, with the listed combination of active ingredients and/or synergists registered for use against bed bugs, as of November 10, 2013.

Product Class	Insect Resistance Action Committee Group: Active Ingredients	# Products
Domestic	**3A**: D-Phenothrin, Tetramethrin	22*
	3A: Permethrin	14
	3A: D-Phenothrin, Prallethrin **Synergist**: N-Octyl bicycloheptene dicarboximide, Piperonyl butoxide	3
	3A: D-Trans allethrin **Synergist**: N-Octyl bicycloheptene dicarboximide, Piperonyl butoxide	2
	3A: Pyrethrins, Tetramethrin **Synergist**: N-Octyl bicycloheptene dicarboximide, Piperonyl butoxide	1
	3A: D-Trans allethrin **Synergist**: Piperonyl butoxide	17
	3A: D-Trans allethrin, Pyrethrins **Synergist**: Piperonyl butoxide	1
	3A: D-Trans allethrin, Tetramethrin **Synergist**: Piperonyl butoxide	1
	3A: Permethrin, Pyrethrins **Synergist**: Piperonyl butoxide	8
	3A: Pyrethrins **Synergist**: Piperonyl butoxide	56
	3A: Pyrethrins, Tetramethrin **Synergist**: Piperonyl butoxide	2
	3A: Pyrethrins **Unassigned**: Silicon dioxide **Synergist**: Piperonyl butoxide	2
	Unassigned: D-Limonene	1
	Unassigned: Silicon dioxide	18

Product Class	Insect Resistance Action Committee Group: Active Ingredients	# Products
Commercial	**1A**: Carbaryl†	6
	3A: Cyfluthrin	1
	3A: Lambda-cyhalothrin	1
	3A: Permethrin	6
	3A: D-Phenothrin **Synergist**: N-Octyl bicycloheptene dicarboximide	1
	3A: Pyrethrins **Synergist**: N-Octyl bicycloheptene dicarboximide, Piperonyl butoxide	3
	3A: D-Trans allethrin **Synergist**: Piperonyl butoxide	2
	3A: Pyrethrins **Synergist**: Piperonyl butoxide	34
	3A: Pyrethrins **Unassigned**: Silicon dioxide **Synergist**: Piperonyl butoxide	2
	Unassigned: Boric acid†	1
	Unassigned: D-Limonene	1
	Unassigned: Liquid carbon dioxide	1**
	Unassigned: Silicon dioxide	5

*One end-use product is discontinued with an expiry date of 2015-03-01
**The end-use product is discontinued with an expiry date of 2016-09-04
†All registered bed bug uses for products containing these active ingredients are proposed for phase-out as a result of re-evaluation (see PRVD-2009-14, Carbaryl and PRVD 2012-03, Boric Acid and its Salts (Boron)). Boric Acid is still registered as of Feb 1, 2014.

1A- Acetylcholinesterase inhibitors; inhibition of the enzyme acetylcholinesterase, interrupting the transmission of nerve impulses.

3A- Sodium channel modulators; acts as an axonic poison by interfering with the sodium channels of both the peripheral and central nervous system stimulating repetitive nervous discharges, leading to paralysis.

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