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Bed Bugs – Importance, Biology, and Control Strategies

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Foreword. The common bed bug, *Cimex lectularius* L., the tropical bed bug, *C. hemipterus* (Fabricius), and a few closely related species of blood-feeding true bugs (Hemiptera: Cimicidae) have been persistent pests of humans throughout recorded history. They may have evolved as cave-dwelling nest ectoparasites of mammals (probably bats), with at least one species later switching to feed mainly on cave-dwelling humans. As humans moved from caves to tents and, ultimately, houses, bed bugs, especially the common bed bug, were probably brought along. Bed bugs appear in the literature and folklore of many cultures and countries, from the Egyptians, Greeks and Romans to early Jewish and Christian writings, and in the records of colonial Americans (Usinger 1966). After World War II, widespread use of synthetic insecticides led to sharp declines in bed bug populations in most industrialized countries. By 1997, they were so scarce in the U.S., Canada and Europe that it was difficult to find fresh specimens to use in teaching college entomology classes (Snetsinger 1997). Some contemporary Pest Management Professionals (PMPs) with years of experience have still never seen an active bed bug infestation. By the early 2000's, a resurgence of bed bugs began in the U.S., Canada, European countries, Australia and parts of Africa. Infestations have occurred in homes, hotels, hostels, cruise ships, submarines, airplanes, trains, schools, and long-term care facilities (Cooper and Harlan 2004, Doggett *et al*. 2004, Hwang *et al.* 2005, Johnson 2005). This Technical Guide was developed to meet the need for current information and guidance regarding bed bugs and their control.

Contents

Acknowledgements

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Disclaimer

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Introduction

In recent years, bed bugs have become much more common worldwide, especially in developed countries. The purpose of this TG is to provide general information about the main pest species of bed bugs, including their importance, key aspects of their biology and behavior that can affect control efforts, and strategies and techniques that pest management professionals (PMPs) and others may wish to implement to achieve desired levels of control. Management strategies and techniques chosen will usually be dependent on important details of the local situation, such as physical conditions (especially temperatures), living conditions of the affected human population, military activity, and available control resources and expertise. Unless otherwise stated, the focus of this TG is the common bed bug, *Cimex lectularius* L. ***Bolded and italicized sections in this TG represent main points and/or new information since the last edition in 2012***.

Corrections or suggestions to improve this TG should be sent to: Editor, TG # 44, Bed Bugs – Importance, Biology, and Control Strategies, Information Services Division (ISD), Armed Forces Pest Management Board (AFPMB), US Army Garrison - Forest Glen, 2460 Linden Lane, Building 172, Silver Spring, MD 20910-7500, Phone: (301) 295-7476, FAX: (301) 295-7473; or DSN: 295-7476. Email: http://www.acq.osd.mil/eie/afpmb/contactUs.html

Purpose

To provide background information on the importance, biology and behavior of bed bugs that can impact control efforts against them and to suggest a range of current control strategies and techniques that are known to usually be effective. Emphasis must be placed on integrated methods, timely resolution of the pest problem, and maximum education of, and involvement by, members of the affected human population. This TG is also intended to provide additional references to assist decision makers and local PMPs in resolving and preventing bed bug infestations.

Importance

Blood feeders. Bed bugs consume only blood, usually feeding on a mammal (*e.g.*, bat, human) or bird. They need at least one blood meal of adequate volume in each active life stage (instar) to develop to the next stage and to reproduce. There are five nymphal stages, and each one may feed multiple times if hosts are readily available. Fig. 1 shows the egg and nymph stages; Fig. 2 shows an adult.

Fig. 1. Bed bug eggs and nymphs. Photograph by H. J. Harlan.

Fig. 2. Adult female bed bug feeding. Photograph by G. D. Alpert.

Adult bed bugs may feed every three to five days throughout their estimated six to 12 month adult life span. The act of biting a host can cause both physical and psychological discomfort, and can result in local allergic skin reactions to injected salivary proteins (Feingold *et al.* 1968, Reinhardt and Siva-Jothy 2007, Goddard and deShazo 2009).

Potential to transmit human pathogens. Bed bugs have been found naturally infected with at least 40 human pathogens but have never been proven to biologically or routinely mechanically transmit any of them (Usinger 1966, Cooper and Harlan 2004, Goddard and DeShazo 2009, Cooper 2011, Doggett *et al*. 2012). There is no evidence that human pathogens are capable of multiplying within bed bugs, which may explain why there are no documented cases of disease transmission through bed bug bites. However; human pathogens may remain viable in freshly fed bed bugs. Bed bugs inoculated with concentrated HIV retained the virus for up to 8 days (Webb et. al, 1989) and artificially fed bed bugs retained hepatitis B surface antigen (HBsAG) for at least 7.5 weeks. (Jupp et. al. 1978, 1979). Shedding of viral DNA fragments in bed bug feces and retention of hepatitis B virus through a normal molt seem to support the possibility of mechanical transmission, as when bugs are crushed onto abraded human skin (Jupp *et al.* 1991, Blow *et al.* 2001). During pest control work, the blood from crushed bed bugs that gets on gloves and application equipment should be treated like any other infectious disease inoculum. The possibility of all routes of disease transmission related to bed bugs has yet to be thoroughly investigated.

Bites and health effects. Bed bug bites are often almost undetectable on some people, but their saliva contains biologically and enzymatically active proteins that may cause a progressive, visibly detectable allergenic skin reaction to repeated bites. Depending on bite intensity and frequency, on persons who do show reactions there are typically five post-bite effect stages: no reaction (no, or too few, antibodies developed), immediate reaction only, delayed reaction, immediate plus delayed reaction, and no visible reaction (due to circulating IgG antibodies). Typical symptoms include a raised, inflamed, reddish wheal at each bite site, which may intermittently itch intensely for several days

(Fig. 3). "Immediate" reactions may appear from one to 24 hours after a bite and last 1-2 days (Fig. 4) (Feingold *et al.* 1968, Goddard and deShazo 2009).

Fig. 3. Reaction from bed bug bites, 30 minutes after feeding. Photo by H. J. Harlan.

Fig. 4. Reaction from bed bug bites, 48 hours after feeding. Photo by H. J. Harlan.

"Delayed" immune reactions usually first appear one to three (up to >14) days after a bite, and redness and periodic intense itching may last 2-5 days (Reinhardt and Siva-Jothy 2007). Humans who are frequently bitten by bed bugs may develop a sensitivity "syndrome" that can include nervousness, almost constant agitation ("jumpiness"), and sleeplessness. In such cases, either removing the bed bugs (physically or chemically) or relocating the person can cause the syndrome to disappear over time. Several additional cimicid species are known to bite humans, including tropical bed bugs, poultry bugs, various species of bat bugs, and swallow bugs. A social stigma may be associated with bed bug infestations (Usinger 1966), but at present, there is rarely an expectation, or requirement, to report infestations to any public health or government agency.

Bed bugs have recently been reported to produce large amounts of histamine as a component of their aggregation pheromone (Gries *et al.* 2015). In large infestations histamine may be an indoor contaminant that could have health implications for residents in such situations because histamine in bed bug feces is thought to be an environmental risk factor in bronchial and dermal allergic diseases (DeVries *et al.* 2018). Additional health effects reported in medical literature have included: facilitated secondary infections from scratching bites (Goddard and deShazo 2009), causing and worsening asthma (Abou Gamra *et al.* 1991), blister-like skin eruptions (Liebold *et al.* 2003, Doggett *et al.* 2012), true anaphylactic reactions (Parsons 1955), and anemia (Pritchard and Hwang 2009).

Importance as pests. Because they are nocturnal, use cryptic harborages, are very small and elusive, and can detect and avoid many chemicals, including cleaning agents, bed bugs are often difficult to control. Complete elimination of an established bed bug population is nearly impossible to accomplish in a single service visit by most PMPs. They are easily transported on or in luggage, furniture, boxes, and clothes. Except after a blood meal, they are very thin and can fit through, or hide in, very narrow cracks.

Unfed adults can live for several months, sometimes >1 year under certain conditions, while 2nd through 5th stage nymphs can survive for 3-4 months without feeding (Polanco *et al*. 2011). Cooper *et al.* (2015) showed in a mark-release-recapture study that large nymphs (3rd- 5th instar), adult females, and adult males were recovered up to 1.9, 3.8, and 4.5 months after host absence, respectively.

The numbers, geographic distribution, and severity of bed bug infestations are still increasing in Europe, North America, Australia and other parts of the world. The public's fear of bed bugs, the effects of their bites, the stigma of having an infestation, and the characteristic, "musty-sweetish" smell of large or long-standing infestations magnify their importance as pests. Bed bug infestations can affect mental health as well, causing emotional and psychological problems such as sleep disturbances, anxiety, depression, delusional parasitosis and paranoia (Susser *et al*. 2012, Goddard and deShazo. 2012).

Because the general public is not very knowledgeable about bed bugs, their bites nearly always lead to visits to a clinical medical facility or expert (often a primary care physician). There are usually additional costs for diagnosis, or for symptomatic treatments. In 2004 alone, 17 of 65 homeless shelters in Toronto spent a mean of $US 3,085 each to address bed bug problems (Hwang *et al.* 2005). Lawsuits have produced awards of $US 20,000 to 382,000 plus expenses (Gooch 2005, Johnson 2005).

Because of their ability to adapt and survive in any environment suitable for their human hosts, bed bugs can become established and develop significant populations even in long-term deployment sites involving only tents as troop shelters. In more permanent military housing, they can quickly become established wherever they are introduced.

Biology and Behavior

Common bed bugs may be found in all temperate areas of the Northern and Southern Hemispheres, almost anywhere that humans have established homes. They thrive at temperatures and humidities that are considered comfortable by most people, who usually afford them ample blood meals and plenty of good harborage nearby. The tropical bed bug, *Cimex hemipterus* (Fab.), requires a higher average temperature than does the common bed bug. It is widespread at tropical and subtropical latitudes worldwide. In continental Europe, established infestations of this species are rare. In the Western Hemisphere, they are seldom found north of Mexico or Puerto Rico, or south of Peru or Brazil. Only occasional limited populations of this species have been found in Florida and Chile. Several species of bat bugs, swallow bugs, and other bird-feeding bugs occur in various north and south temperate regions where they may also bite humans (Usinger 1966, Gold and Jones 2000, Krinsky 2009, Harlan *et al*. 2008, Doggett *et al*. 2012, Bowles *et al.*, 2013). Figure 5 illustrates the key distinguishing characteristics to identify bed bugs and other important bugs that bite humans. Figures 6 and 7 illustrate the differences between bed bugs, bat bugs and tropical bed bugs.

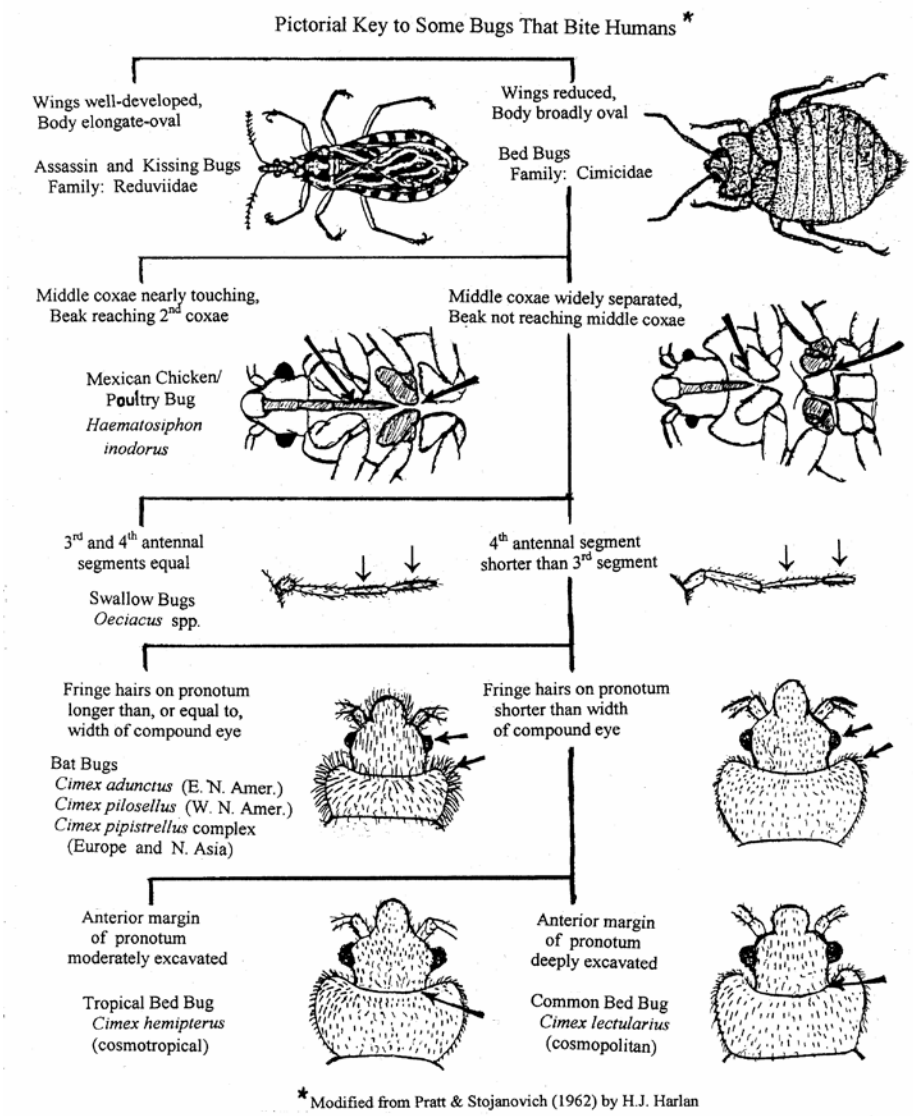


Fig. 5. Pictorial key of bed bugs and other biting bugs of public health importance.

A B C

Fig. 6. A: Common Bed Bug (*C. lectularius* L.) B: Eastern Bat Bug (*C. adjunctus* Barber) C: Tropical Bed Bug (*C. hemipterus* Fabricius) (Persson 2017)

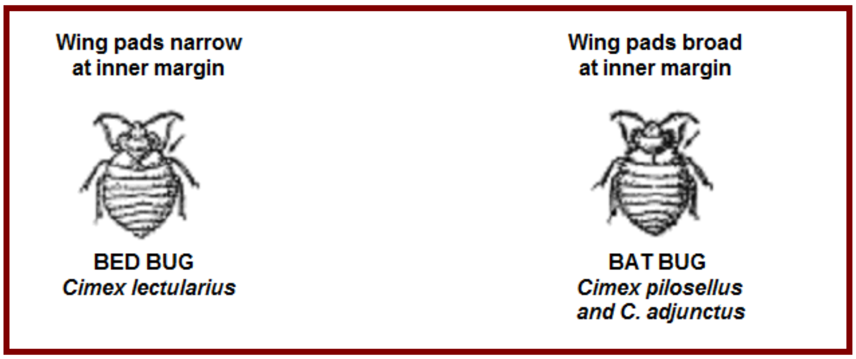


Fig. 7. Illustration of the wing pad inner margin difference a diagnostic character between bat bugs and bed bugs (Cranshaw *et al*. 1994).

Adult bed bugs are about 5-7 mm (3/16-1/4 inch) long, broadly oval, flat, brown to reddish-brown true bugs, with a 3-segmented beak, 4-segmented antennae, and vestigial wings. They have very thin, vertically-flattened bodies covered with short, golden-colored hairs. They give off a distinctive “musty-sweetish” odor, due to certain “alarm” chemicals that are produced by glands in their ventral thorax. Abdomen tips of males’ are usually pointed and those of females are more broadly rounded.

Bed bugs feed only on blood, usually of mammals or birds, and mate by “traumatic insemination.” It may take 3-12 minutes for one bug to fully engorge. About 20% of the time, adult bed bugs and large nymphs will void remains of earlier blood meals while still feeding. This produces the typical rusty or tarry spots seen on bed sheets or in bug hiding places (Fig. 8). They may feed repeatedly, but every nymphal stage must have at least one blood meal before it can develop to the next stage. Both males and females must feed at least once every 14 days in order to keep mating and producing eggs (Usinger 1966).

Fig. 8. Bed bug adult on sheet, showing typical fecal spots. Photo by H. J. Harlan.

Although bed bugs seem to prefer humans, they readily feed on birds, rodents, or other mammals. Their life cycle from egg-to-egg may take four to five weeks under favorable conditions [*e.g.*, 75-80% RH; 28-32°C (83-90°F)]. They can survive and remain active at temperatures as low as 7°C (46°F), if they are held at an intermediate temperature for a few hours, but their upper thermal death point is 45°C (113°F). Bed bugs are nocturnal but will seek hosts and feed in full daylight if hungry. Females attach their 1 mm-long, cylindrical (about four times as long as their diameter), pearly-white eggs to any nearby surfaces, usually in crevices (harborages), where the active bugs hide in groups or clusters. Each female may lay 1-3 eggs/day and 200-500 eggs during her adult lifetime (often 6-12 months or longer). Cast bed bug "skins" usually accumulate in harborages.

Movement and Dispersal. Bed bugs will readily travel 5-20 ft. from an established harborage to feed on a host. Dispersal of bed bugs from one structure or infestation site to another is usually passive – the bugs or their eggs are unknowingly carried in or on pieces of furniture, bedding, luggage, clothing, electronic devices or cardboard boxes. Hentley *et al.* (2017) showed that bed bugs are attracted to dirty laundry, which stresses that leaving worn clothing near sleeping areas can be exploited by bed bugs and facilitates passive dispersal by travelers or visitors. Used furniture purchases or rentals are rather common, especially in poor communities, and this may also help spread bed bugs to new sites.

Large multi-unit buildings can be difficult to rid of bed bugs. Once bed bugs become established, any control effort that does not include nearly concurrent inspection of all units, and a coordinated program of treatment and occupant education, will usually fail (Pfiester *et al.* 2009). ***Bed bugs often disperse to adjacent rooms or floors from partially-treated units, or from areas treated with repellent insecticides. Bed bugs will also move to adjacent rooms regardless of treatment, in order to find new hosts in different areas.***

They readily move through wall voids, utility lines, heating ducts, hallways, and laundry or mail chutes (Wang *et al.* 2010). In a mark-release-recapture study in New Jersey, without the use of repellent insecticides, 5% of the population naturally moved between apartments over a 14 day period, traversing to apartments to the left, right, across the hall, and one level below the original infested apartment (Cooper *et al.* 2015).

Detection and Surveillance

A bed bug infestation is usually revealed through finding live bugs or signs (e.g., dark fecal deposits or lighter rusty spots) on bed linens or in harborages (Fig. 8), detecting eggs or cast skins in harborages or near feeding sites, noting where and when alleged victims have been bitten, or smelling the bugs' characteristic odor. Eggs are not easily seen but are often located very close to fecal spots (which are more easily recognized).

Any combination of two or more of these signs can help verify an infestation and help determine the bugs' population size and distribution. Monitoring may be augmented by using pitfall or sticky traps (possibly augmented by chemical or CO_2 attractants). Pitfall traps (interceptor monitors) on bed legs or chair legs near beds are reliable in detecting even low level infestations over a period of 2-4 weeks.

For cimicid species that mainly feed on bats or birds, detecting and locating their usual hosts' roosts or nests is important. When the host animals are removed, excluded, exterminated or when they migrate, the bugs frequently enter human living areas as they search for new hosts.

Inspection and Detection. Detection of bed bug infestations is essential for early interventions, locating and targeting the infestation, and confirmation of elimination. Detailed inspection by a qualified person is the essential first component of any effective bed bug control program. If present, the bugs must be detected, accurately identified, and their harborage sites and a rough estimate of the population size determined as quickly as possible. Even with the use of detection dogs or attractant-baited traps, a visual inspection must still be done to determine exact locations and extent of the main infested sites before any control action can be done. Certain pyrethrin-based flushing agents may help stimulate the bugs to move around, making them easier to detect where populations are limited. However, ***repellent pyrethroids may cause more harm than good when used as flushing agents, by dispersing bed bugs to previously uninfested areas such as adjacent rooms or apartments.*** Cimicids that feed chiefly on bats or birds can often be located by finding and examining their hosts' nests nearby.

Fig. 8. Bed bug-infested mattress showing typical signs of infestation. Photo by B. Pannkuk.

Bed bug detection and monitoring techniques. Several techniques have been developed and marketed for detecting and monitoring bed bug infestations. Scent dogs have been specially trained to detect even small numbers of live bed bugs and possibly their viable eggs as well, with a reported accuracy of up to 95% (Pfiester *et al.* 2008).

Pheromones and alarm scents produced by the bugs themselves have been characterized and are being developed for possible use to attract the bugs or facilitate other control techniques or products (Siljander *et al*. 2008, Benoit *et al*. 2009, Feldlaufer *et al.* 2010).

Simple pitfall, barrier, or harborage-mimicking devices can intercept and trap bed bugs with or without augmentation by any of the attractants just mentioned (e.g., see Wang *et al.* 2010). Pitfall interceptor traps (Fig. 9) placed beneath bed legs or chair legs near beds are reliable in detecting even low level infestations. Recent research indicates that 2 monitors/room, one on a bed leg and another on chair leg near the bed have detected 92% of infestations within 3-4 weeks, and using four detectors/room reduced detection time to 2 weeks (Vail and Chandler 2017). Interceptors are not as effective when bed or sofa legs are too wide to fit into them. In these cases, pitfall traps (Fig. 10) such as the ScenSci Volcano, with or without lures, can be placed next to the legs (Dae-Yun Kim *et al.* 2017).

Fig. 9. Interceptor pitfall trap.

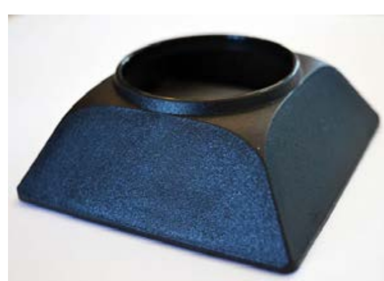


Fig. 10. Volcano trap.

Special high-technology devices (*e.g.,* see Anderson *et al*. 2009) combine various elements like CO_2, proprietary chemical lures, and heat to attract and catch bed bugs seeking their next meal. A new remote bed bug monitor called the Delta Five Bed Bug Monitoring System is connected to a Wi-Fi network for constant pest monitoring. Each monitor uses a combination of heat and a lure to attract bed bugs into its chambers, and when a bug enters, the system captures it, takes a full-color photo, and sends an email alert for further follow-up. Its current cost is between $50-$100 per device, plus $30 per lure that lasts several months.

Surveillance Limitations. Each of these techniques or devices offers promise as an additional tool, but none of them appears, so far, to be a "stand alone" method for detecting and characterizing bed bug infestations, regardless of the physical setting. Further, none of them can exert much of a direct effect upon control of any given bed bug infestation. Even after one of these detects (or narrows down the general locations of) an infesting bed bug population, someone must still confirm those infested sites, correctly ID the bugs, and go on to effect some form of control.

Sticky traps are a simple way to monitor many crawling pests, and have been used to augment other techniques for control of spiders and cockroaches. Although bed bugs will often get caught on such monitors, many recent reports from PMPs in North America have indicated that ***sticky traps are not very effective at detecting small to moderate populations of bed bugs***. Sticky traps often fail to catch a bed bug even when infestation signs are obvious, bugs are easily observed, and people are being bitten routinely nearby.

Canine scent detection. ***Trained and "certified" dogs are not accurate all the time*** (they may have their "bad days," as might their respective handlers). For example, Cooper *et al.* (2014) evaluated four canine detection teams on multiple days and found them to be inconsistent in their ability to detect bed bugs on different days, with no significant relationship seen between the team's experience or certification status and their detection rates. Mean detection rate was only 44% (range: 10-100) with a mean false-positive rate of 15% (range: 0-57).

Any detection device may be avoided by a few bugs in any given population due to certain quirks in the bugs' own biology and behavior. Particularly after chemical control interventions have been initiated, bugs normally found on or near the bed may be repelled to locations far from their normal and ideal locations. Cooper *et al.* (2015a) showed that 61% of infestations could be detected near the bed by interceptor monitors before treatment, but only 40% in the same location after treatment. Furthermore, interceptors that were placed away from the sleeping area in the treated apartments detected over 90% of remaining bed bug activity. Such bed bug movement and activity patterns following treatment prompted Cooper *et al.* (2015b) to promote an "***elimination protocol***" requiring:

1) Three consecutive 14-day follow-up visits without bed bug activity in interceptors placed throughout apartments
2) No observed activity during visual inspection
3) No new bugs or bites reported by residents

Integrated Control Strategies and Techniques

Integrated Management

An integrated approach to bed bug management is essential in eliminating a bed bug infestation. Insecticide resistance is often very high in bed bug populations, therefore the use of a variety of pest control strategies and techniques, including the use of physical prevention and treatment methods, non-chemical and chemical control methods, and biological control methods are paramount to eliminating modern bed bug infestations. Education and training of homeowners and/or building managers to identify and report any bed bug signs are critical to detecting and preventing further spread of an infestation to other rooms or apartments within a building. Documentation of all reporting, surveillance and control activities is particularly important where property owner liability comes into play or where bed bug control methods fail. Property owners, pest control companies and residents all rely on working together using an integrated strategy for bed bug elimination.

Education

Various economic factors can influence control decisions, and the human occupants' (victims') understanding and cooperation are still essential for optimum success in any situation. Educating the occupants of any living space infested by bed bugs is essential to ensure that they actively cooperate in the control program. Occupants must understand that they will be expected to improve and maintain sanitation, minimize clutter, and perhaps also seal harborages to exclude or restrict the movements of the bed bug population. It will help if occupants know some basics of bed bug biology and behavior, as well as the proposed control strategies and techniques. Education may include verbal explanations, answering questions, posting notices, broadcasting notices, postings on web sites, or distributing handouts. Educational tools must be made available in the local language (multiple languages, in some cases). Throughout a control program, continuous communication should be maintained between occupants, building managers, PMPs, any government agencies, and any local non-government organizations (NGOs) involved.

Physical Removal and Exclusion

Vacuuming. Removal by vacuuming bugs, shed skins and eggs is very important because nymphs often hide in older instar's shed skins resulting in protection from insecticides. Bed bugs can be vacuumed from exposed harborages or resting sites, such as box spring edges or mattress seams, but their eggs are stuck tightly to harborage surfaces and are usually hard to remove. Using a high efficiency particulate air (HEPA) filtered vacuum, which filters out >99% of all particles taken up that are >0.3 micron in diameter, will ensure that many allergens associated with bed bugs and their debris are also removed. A nylon sleeve placed over the vacuum pipe end is recommended when removing BED BUGs for counting. Once complete, the nylon can be inverted, bed bugs counted, the sleeve tied again and discarded.

Vacuuming, especially during inspections, will immediately remove a sizable portion of the pest population and will usually kill some of the bugs in the process. Vacuuming will also indicate new activity at future inspections. The used vacuum bag should be removed immediately afterward, sealed tightly inside a larger plastic bag, and that bag incinerated or placed in the next normal trash collection. Bed bugs may also be removed from exposed resting sites by pressing down on them with the sticky side of any commercially available tape or lint-roller, hand-picking them, or brushing them directly into a container of over-the-counter (OTC) rubbing alcohol or soapy water (Potter 2004, Gooch 2005, Harlan *et al*. 2008, Cooper 2011, Doggett 2011).

For bed bug species that feed mainly on bat or bird hosts (e.g., bat bugs, swallow bugs and tropical bed bugs), removing those hosts and all their nesting materials is an essential first step. Next, all access routes between those hosts' nesting or roosting sites and nearby human living areas must be sealed shut. Finally, treating their hosts' roosting or nesting areas with a properly EPA-labeled insecticide to kill all, or most, of the remaining bug populations may be necessary, and should facilitate their elimination. For bat bugs and swallow bugs, insecticidal treatment of living areas can usually be minimized, as they do not reproduce well on human blood.

Exclusion. Bed bugs have weak, flexible, piercing-sucking mouthparts, and weak, simple feet (tarsi) and claws. They cannot chew or claw through even a very thin coating of sealant or an unbroken layer of paper or cloth. Sealing a layer of almost any material in place, to completely cover a harborage opening, can halt bed bugs' passage. If they are sealed inside a void or harborage, living bugs are effectively removed from the pest population and will eventually die in place. Sealing most of the openings between a harborage and bed bugs' usual host access site(s) will at least restrict the bugs' movements and help temporarily reduce the intensity of their feeding. Storing clothes and other items in Ziploc® plastic bags or tightly-sealed containers can greatly reduce potential harborage sites.

Mattress covers. Commercially available plastic covers (>0.08 mm thick, usually with a zippered edge) as well as fabric covers can completely enclose a mattress or box spring and prevent any bed bugs harboring in them from accessing hosts. Originally developed to reduce human exposure to allergens in mattresses infested with house dust mites, such covers can both seal in and exclude bed bugs. They may also be homemade, using plastic sheeting (>3 mil thickness) that is sealed shut with durable, flexible tape (*e.g.,* nylon fiber tape, duct tape) (Cooper and Harlan 2004). An EPA-labeled pyrethroid insecticide has been incorporated into at least one new mattress liner that is commercially available (ActiveGuard®, 1.64% permethrin).

Temperature Killing Techniques

Heat. Since at least the early 1900s, bed bugs have been controlled by heating infested rooms or whole buildings to temperatures > 45°C (113°F), the thermal death point for the common bed bug. Although 45°C has been demonstrated as the thermal death point for bed bugs, many researchers and pest control companies recommend achieving 48°C (120°F) to reduce the time for bed bugs to succumb to potentially under one minute. For heat treatment to be effective, it is critical that high temperature and low relative humidity be maintained for a minimum length of time. Depending upon equipment, most heat companies attempt to keep temperatures under 63˚C (145˚F) to limit the amount of damage experienced in the home. Propane powered heat treatment equipment can achieve temperatures above 63˚C (145˚F) but damage can be an increased concern and needs to managed appropriately. Regardless of equipment, furniture should be flipped over after critical temperature is reached for immediate exposure of bed bugs to the heat. Electronic temperature sensors and control devices are used to regulate and monitor the heating process. Measuring ambient temperatures using temperature sensors is critical because many aspects of building/room construction absorb heat or are resistant to rising ambient air temperatures. Utility closets and wall/floor interfaces are usually cold spots and should be carefully monitored. Failed heat treatments are the result of bed bugs finding these cold spots and surviving.

Laundering infested linens or cloth items in hot water with detergent, followed by at least 20 minutes in a clothes dryer heated to at least 63˚C (145˚F), should kill all life stages of bed bugs (heat below 49˚C (120˚F) will not kill all eggs) (Potter 2004, Harlan *et al.* 2008, Pereira *et al.* 2009, Cooper 2011, Kells and Goblirsch 2011, Doggett 2011). Note: laundering in cold water, even with soap, will not kill bed bugs. Commercial dry cleaning of suitable items kills all stages of bed bugs.

Commercially available portable heat chambers now offer an alternative to hot laundering of both cloth and non-wettable items (*e.g*., picture frames, books, shoes). These chambers are constructed of insulated material, shaped generally like a box or a hanging clothes wardrobe (bag), and most are electrically heated. For heat-treating individual items, Pereira *et al.* (2009) discussed several aspects of heat treatment for furniture and similar items in a room while other actions and control techniques could be pursued concurrently. Some heat chamber examples include Bug Stop Hot House, Bed Bug Baker, and ZappBug Oven.

Heat Treatment Cautionary Notes. ***Heat treatment provides no residual effect, and bed bugs can re-occupy any site so treated immediately after temperatures return to suitable levels.*** Potential physical distortion of structures or their contents, as well as flammability risks associated with some kinds of heat sources, may be a concern in particular situations (Usinger 1966). ***Many items may be damaged by heat treatment*** (e.g., pressurized cans, printer cartridges, foods that melt, medicines, anything made from wax, oil paintings, vinyl records, video tapes, photo negatives, house plants, laminated furniture and all flammable materials like lighters, ammunition, etc.), therefore these items must be removed before treatment (Doggett *et al.* 2018). Heat treatments and sprinkler systems within buildings are different in the various states, therefore it is essential that operators be familiar with their specific systems and state laws.

Steam. Steam treatments have been used effectively by PMPs to quickly kill live bugs and their eggs in the seams of mattresses and other cloth items, as well as in cracks and crevices (Wang *et al.* 2018). ***Steam is less effective through fabrics and does not penetrate leather. This technique requires practice and care, and it is a slow process because it requires a speed of 3 cm/sec.*** The steam emission tip must be about 2.5-3.8 cm from the surface being steamed. If the tip is too far away, the steam may not be hot enough to kill bed bugs or eggs. If the tip is too close, bugs may be blown to the floor, and excess moisture may be injected into the treated material, which may lead to other problems (e.g., facilitating dust mite population survival and increase; growth of surface molds). If high pressure steam blows bed bugs and their eggs off of surfaces and into other areas of the room, the bugs may recover and spread to other areas of the house. Therefore, the carpet and floor below and around steamed items must also be steamed or treated. Wang *et al.* (2018) also found that various kinds of steamers (i.e., consumer vs. professional) work equally well in killing bed bugs, but professional steamers are usually larger, hold more water, and thus require less time to refill and reheat.

Cold. Exposure to low temperatures can kill bed bugs if they are kept cold enough long enough. Bed bugs can tolerate -15˚C (5˚F) for short periods and, if acclimated, they can survive at or below 0˚C (32˚F) continuously for several days (Usinger 1966, Harlan 1997-personal observations). Cold treatments of rooms or whole buildings to control bed bugs have not been well studied, nor often employed, but freezing furniture or other items within containers or chambers [*e.g*., below 0˚F (-19˚C)] for at least four days may be a practical alternative for limited infestations or to augment other control measures.

The use of CO_2 "snow" from pressurized cylinders, sprayed onto bed bugs and into their harborages, kills them by rapid freezing. As with steaming, care must be taken not to blow bed bugs and their eggs into other areas of the room without treating these as well. In addition, the safety of releasing moderate to large amounts of CO_2 into certain types of human living spaces may need to be evaluated (*e.g*. basement apartments, and similarly enclosed or partially sunken spaces may allow a build-up of harmful concentrations at their floor level).

Pesticides

Currently, non-chemical products and techniques are incapable of efficiently or quickly controlling or eliminating established bed bug populations. Although pesticide resistance has been noted to be common within bed bug populations, precise placement of a suitably-labeled, EPA-registered and formulated residual chemical insecticide is still an integral part of an effective integrated pest management program for bed bugs. Populations can be reduced and perhaps controlled by applying interior sprays or dusts to surfaces that the bed bugs contact and to cracks and crevices where they rest and hide. Many currently-labeled chemical insecticides still can provide some residual control of even slightly-resistant bed bugs, if they are properly and precisely applied.

When using residual insecticides, you should choose the least toxic active ingredients and formulations. Microencapsulated and dust formulations will have a longer residual effect than others. Retreatment, when needed, should be carried out after the shortest interval permitted by the label until the pest bug population has been eliminated. The choice of products and specific application techniques can depend on many factors, like the physical location and structural details of the bugs' harborages, product labels (which can vary by political jurisdiction), the immediate environment, cost factors, and local or national laws.

Several newer active ingredients and products with multiple classes of active ingredients (*e.g*., a neonicotinoid plus a pyrethroid) have added bed bugs to their labels. Some of these products have been reported by some PMPs to be fairly effective against field populations of bed bugs, but they may act much more slowly than pyrethroids. ***Diatomaceous earth, silica gel, and insecticidal dust formulations are becoming more***

popular because they are long lasting and more effective than sprays. The following list is a sample of popular insecticides and combinations labeled for bed bug control (only those with an asterisk are currently NSN approved:

- Alpine dust (dinotefuran 0.25%, diatomaceous earth/silicon dioxide 95%)
- CimeXa (amorphous silica gel)
- Drione (amorphous silica gel, pyrethrin)
- Syloid 244 (silica gel)
- Crossfire (clothianidin 4%, metofluthrin 0,1%), PBO 10% aerosol or concentrate mix for seams and matresses
- *Temprid (imidacloprid and β-cyfluthrin)
- Transport GHP (acetamiprid, bifenthrin)
- Bedlam Plus (sumithrin, MGK 264, imidicloprid)
- Tandem (lambda-cyhalothrin+thiamethoxam)
- Phantom (chlorfenapyr)
- *Nuvan Prostrips and aerosol (dichlorvos)
- Home Defense (bifenthrin, cypermethrin)
- *Deltadust, (deltamethrin)
- Suspend (deltamethrin)
- Dragnet (permethrin)
- Proof Bed Bug & Dust Mite Spray (neem oil)
- Sterifab to treat furniture (ethanol and d-Phenothrin)
- Zenprox (etofenprox and PBO)

The United States Environmental Protection Agency has developed a search tool that can help you select an EPA-registered bed bug product that meets your needs, based on the specific site needed to treat. Specific sites include mattresses, cracks/surfaces/voids (e.g. open spaces inside structures such as walls or floors), entire rooms, or the whole house. Specific products, active ingredients, companies, and EPA registration numbers can also be used to find bed bug insecticides. The products listed in this search tool are those that can be purchased by any consumer and can be found here: https://www.epa.gov/bedbugs/find-bed-bug-pesticide-product

Insecticide Resistance. This TG is intended mainly as a background information source and will not detail the nature, prevalence, distribution, or history of insecticide resistance in bed bugs. Resistance may have been a major contributing factor to their past and continuing spread, and can make controlling them very difficult. Resistance has been well documented by many investigators, in many geographically widespread populations of common bed bugs (Potter 2004, Moore and Miller 2006, Romero *et al*. 2007, Harlan *et al*. 2008, Cooper 2011, and Doggett *et al*. 2012). For more details about the nature and distribution of insecticide resistance in bed bugs, see: Adelman *et al.* 2011, Mamidala *et al.* 2011, Romero *et al.* 2007, WHO 1982, WHO 2006, Yoon *et al.* 2008, and Zhu *et al.* 2010.

Insecticide applications alone seldom eliminate bed bugs, therefore single active ingredient pesticides should never be the sole method of controlling bed bugs! Expect bed bug insecticide resistance to be high, even to products with combinations of active ingredients. Even using the newest active ingredient combination products, common examples of low mortality of field populations include 55-85% mortality after 5 days, and

7-60% mortality after 8 days! Combinations of different control methods (IPM) are therefore paramount to success.

New pesticide efficacy test kit. To help choose suitable products to use against bed bugs, particularly if resistance is strongly suspected, a new pesticide efficacy test kit may be helpful. To gain information about possible insecticide resistance in field populations, the Lab-In-A-Bag Pesticide Efficacy Kit from Protect-A-Bed can be used to test bed bugs collected from the infestation site. Any available pesticide can be used in the test assay, to determine which pesticide active ingredients and formulations are most effective against that particular bed bug population. The kit includes modular evaluation dishes and interchangeable substrate inserts such as furniture fabric, bedding fabric and wood to test pesticides normally applied to these different surfaces. A how-to-tutorial of the product is available online at http://www.lightsoutbedbug.com.

Dusts. Sprayable residuals containing pyrethroids have reduced residual toxicity as they age, with reported mortality against lambda-cyhalothrin of only 50% after 4 days (Anderson and Cowles 2012). Desiccant dusts on the other hand, with their physical mode of action and long residual activity, are superior to sprayable pyrethroid products for killing bed bugs.

Diatomaceous earth, silica gel, or other properly-labeled dust formulations can also be used to treat certain sites, like cracks and crevices. *Note however that* ***boric acid, which is effectively used as a desiccant dust against cockroaches and other insects, is NOT effective against bed bugs*** (Sierras *et al.* 2018). Singh *et al.* (2018) evaluated the efficacy of eight other insecticide dust products using three exposure methods: 1) brief exposure—bed bugs crossed a 2.54-cm-wide dust-treated band, 2) forced exposure—bed bugs were continuously exposed to a dust-treated substrate, and 3) choice exposure—bed bugs were given a choice to stay on either dust-treated or untreated substrate. The brief exposure method was the most sensitive in detecting the differences among the insecticides, and only CimeXa (silica gel) dust caused 100% mortality from all three exposure methods. Other tested dusts (1% cyfluthrin, 0.05% deltamethrin, 0.075% zetacypermethrin+0.15% piperonyl butoxide, 1% pyrethrins, 1% 2-phenethyl propionate+0.4% pyrethrin, 0.25% dinotefuran+95% diatomaceous earth, 100% diatomaceous earth) caused ≤ 65% mortality in the brief exposure assay. Silica gel dust-exposed bed bugs also transferred CimeXa dust horizontally to unexposed bed bugs resulting in 100% mortality at 4:6 donor: recipient ratio. These results suggest that ***silica gel is one of the most promising insecticide dusts for controlling bed bugs.*** Retreatment using dusts should be done after the shortest interval permitted by the product label until the bug population has been eliminated.

Crack-and-crevice applications. Because of their habit of hiding clustered together in cracks and narrow harborages, precisely applied crack-and-crevice treatments are among the most effective control techniques against bed bugs. Active ingredients change over time, and several are currently available, as well as some products that contain multiple ingredients labeled for use against bed bugs. Various formulations and devices are also available for applying insecticides to bed bug-infested areas. For example, dust formulations should be used in electrical outlet boxes and in other places where it is desirable to employ low-risk (low volatility and toxicity), long-lasting products.

Insect growth regulators (IGRs). Insect growth regulators are harmless to vertebrates because of their unique mode of action and low application rates. Juvenile hormone analogs (JHAs) such as methoprene and hydroprene have been proven effective against many urban insect pests, however, control of bed bugs with some IGRs may not be quite as effective. Goodman *et al.* (2012) tested two IGR products, Precor® and Gentrol® (methoprene and hydroprene, respectively) for efficacy against various bed bug stages as a direct spray and as dry residue, using three bed bug strains. At 1X and 2X of the label rate, these IGRs had no significant effects on bed bug eggs or nymphs. Only residues at 3X and 10X label rates caused a reduction in fecundity and impaired development, and at the time of this revision, the 2017 Gentrol label rate had not changed since 2001, therefore label rates would be ineffective against bed bugs. Moore and Miller (2008) confirmed this by conducting field evaluations of insecticides for controlling bed bugs in low-income housing and found no evidence after eight weeks that hydroprene contributed to reducing bed bug populations. Therefore, ***while IGRs are attractive add-ons to chemical treatments for longer lasting household pest management, methoprene and hydroprene in particular would have little impact on bed bug populations without at least tripling the label rates. Applications made at these elevated rates are a violation of Federal Law and must not be done.***

“Natural or Botanical” Essential Oils and EPA-exempt (25-b) Insecticides. The idea of “green pest management” focusing on the use of natural and low-toxicity materials instead of conventional synthetic insecticides has become more and more popular, and with it have come many more “natural” or “safe” products, including those for use against bed bugs. Many natural essential oils are by-products of plant-based refinery operations and some have insecticidal properties. Many of these qualify for EPA exemption under section 25(b) of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), where manufacturers are not required to provide efficacy data for registration. With lowered regulation and lower cost of development, many more of these types of products are on the market for bed bug control. Efficacy trials for these products are rarely published, however, leaving little scientific data supporting efficacy claims. Meanwhile, manufacturers still make strong efficacy and safety claims.

The testing of some commercially available natural products has revealed that most of them are not effective at all, and the few that are better are slow at killing bed bugs, particularly compared to normal insecticides. Researchers at Rutgers University tested eleven commonly available “green insecticides,” along with two synthetic insecticides using direct spray applications to bed bug adults and nymphs from field strains (Singh *et al.* 2014). Results were not surprising, as most of the tested natural pesticides performed poorly. Only two products (EcoRaider™ and Bed Bug Patrol™) provided high mortality, but only 10 days after the direct spray. More recently, Zha *et al.* (2018) screened 18 essential oils, three silicone oils, and paraffin oil for their toxicities against bed bugs. Results showed that toxicities varied significantly in topical assays, and all of the evaluated essential oils were less effective than silicone oils and paraffin oil (the most effective essential oil was blood orange). Direct spray of 1% water solution of 3-[hydroxy (polyethyleneoxy) propyl] heptamethyltrisiloxane, the only silicone oil that mixes well with water, resulted in 92% bed bug mortality after 1 d.

The speed of control of natural pesticides is generally slower than that of synthetic insecticides and so population reductions will likely take longer. However, Szumlas (2002) showed that a 3% dishwashing detergent (e.g., Dawn™) diluted in water and sprayed directly onto German cockroaches (*Blattella germanica*) at a normal pump-spray application rate (20 $\mu l/cm^2$, or 1 gal spray/200 ft^2) knocked down and killed 100% of all cockroach adults and nymphs, within 3 minutes. It is unclear, however, if the same 3% Dawn dishwashing detergent spray would have this effect on bed bugs. Additionally, pesticides containing Dawn's active ingredients (sodium lauryl sulfate, among others) would require EPA registration before legal use.

Biopesticides. ***There is one biological pesticide currently on the market to control bed bugs. Aprehend® is an oil formulation of fungal spores produced by the fungus Beauveria bassiana.*** When bed bugs come into contact with the spores, the spores germinate within 24 hours, penetrate the cuticle, grow inside the bug and eventually kill it within 4-10 days. Bed bugs may carry spores to harborages as well, helping target hard-to-find aggregations (Aak *et al.* 2018). This biopesticide is popular because it adds a new mode of action to the arsenal of pesticides, without the specter of resistance that often closely follows chemical active ingredients. However, being a biological entity, care must be used in handling and applying the spores. Spores are very temperature sensitive and die at >27˚C (82˚F), so PMPs must be careful not to leave them in a hot environment. Cold temps on the other hand do not affect the spores. Spores are very susceptible to water and high humidity. Water kills the spores because they germinate away from the bed bugs and quickly die without a host. Residual treatments are reported to be effective for up to 3 months, therefore quarterly treatments may be necessary.
Preliminary field trials on Aprehend have demonstrated the product to be effective and in one heavy infestation provided an 85-95% reduction in population after only one treatment with Aprehend, bed encasements, interception devices and physical removal of active bed bugs. Subsequent trials have demonstrated similar results in other infestations but inconsistency in performance of the product has been documented in a smaller percentage of infestations. Greater bed bug activity and movement have been observed by some PMPs after application, including observations of many more bed bugs in non-traditional locations such as kitchens, bathrooms, etc. The effects of progressing fungal infection on the central nervous system of bed bugs is likely the cause, but these effects are yet to be described. Since the product's launch in 2017, concerns have been raised about potential health issues associated with the product (although little to no issues have been documented to date), relative humidity and its impact on the spores as well as other mechanical issues with the application of the product. More trials need to be conducted to understand how to manage limitations of the product.

Excitation, Irritation and Activation Synergy with Residual Treatments

Bed bugs move around as part of their normal biorhythm patterns, sometimes to surrounding rooms or apartment units. The use of flushing agents, carbon dioxide and heat have been shown to increase bed bug activity significantly.

Synergized pyrethrins are often lethal to bed bugs, and some may cause a flushing effect. The use of pyrethrins at 0.1-0.2% after application of residual insecticide formulations may increase pesticide efficacy by irritating the bugs, initiating an excitatory effect, and causing them to leave their hiding places and causing increased exposure to the residual insecticide.

Hentley *et al.* (2017) showed that CO_2 elevation to a level that simulates human occupancy stimulates bed bugs to initiate host searching behavior but does not necessarily direct them to the host. Aak *et al.* (2017) utilized this aspect of bed bug host seeking behavior to enhance the effects of residual treatments. Bed bugs were lured from their harborages and forced to make contact with residual treatments through the use of CO_2 gas at a level to stimulate bed bug host seeking behavior. Once per day for seven days, CO_2 gas from 600 g (1.3 lb.) of dry ice was placed at the location of the bed to stimulate bed bug activity and make contact with desiccant dusts (diatomaceous earth or synthetic amorphous silica powder) placed in and near harborages. Using this one-week protocol and then allowing students to move back into the rooms, all 5 bed bug-infested dormitories that had the combined treatment of desiccant dust and CO_2 were freed of bed bugs within 10-12 weeks, whereas bed bugs persisted in all 6 dormitories with only desiccant dust treatment. An additional note is that if rooms can be vacated for 7-14 days prior to treatment to allow eggs to hatch and to starve adults and nymphs, then bed bug activation using CO_2 may be even more effective in improving the efficacy of residual treatment.

In addition to the use of flushing agents or CO_2 to stimulate bed bug movement into residually-treated areas, the use of moderate heat may also be helpful. Raising the ambient 32-35°C (90-95°F), combined with an application of desiccant dust, increases the egg hatching rate, raises bed bug metabolism and increases their movement in search of hosts. This technique has proven to completely eliminate infestations from vacant apartments and mobile homes in as little as two or three weeks.

The use of any method that increases bed bug movement has good potential to work synergistically with residual pesticide applications by stimulating bed bugs to move from their protected harborages into treated areas where they are exposed. A note of caution, however, is that bed bug control techniques that increase bed bug activity may result in bed bug movement to and infestation of a nearby unit. Legal action could then be taken by a management company or tenant in the newly infested apartment. Good bed bug IPM practices should therefore always consider adjacent rooms and apartments as well as those above, below and across from the infested room (for additional monitoring and control).

Fumigation. Fumigation of furniture, clothing, or other personal items can kill all bed bug stages present. However, fumigation is expensive and hazardous and therefore should be considered an absolute last resort effort for controlling a bed bug infestation. In addition, fumigation treatment will not prevent reinfestation immediately after the fumigant dissipates. Fumigation of an entire building is seldom necessary, practical, or affordable (WHO 1982, Snetsinger 1997, Gooch 2005, Harlan *et al.* 2008, Cooper 2011). Wang *et al.* (2012) reported that CO_2 was an efficient fumigant for smaller treatments. Carbon dioxide fumigation in sealed 158 liter (42 gallon) heavy duty garbage bags filled 90% full with fabric materials and/or boxes and 1,350 g dry ice per bag is sufficient to kill all stages of bed bugs hidden in the materials after 24 h at room temperature (23-24°C (73-75°F). On the other hand, high concentrations of nitrogen gas (N_2), are NOT effective under the same conditions (Herrmann *et al.* 2001).

Impregnated fabrics and bednets. Fabrics and bednets, factory- or self-impregnated with formulations of residual chemical insecticides, can help deny bed bugs access to hosts, and may kill some of the bugs that crawl on them. This can be economical because spraying, dipping, or coating formulations of products containing permethrin will often remain effective through many launderings, some for the life of the fabric (Lindsay *et al.* 1989). However, one West African population of tropical bed bugs, *Cimex hemipterus* (Fab.), has been reported to be resistant to both permethrin and alpha-cypermethrin used to treat bed nets for protection against malaria vector mosquitoes (Myamba *et al.* 2002).

Ultra Low Volume (ULV), aerosols, and foggers. ***Insecticides currently labeled for application by ULV, aerosols and foggers have little or no residual effects on bed bugs***. When used exactly according to their own product label directions, most of these applications (and products) will seldom penetrate into typical, cryptic bed bug harborages. If directly injected into such harborages, these products may stimulate some of the bed bugs to become active and move out into the open, allowing them to be seen by inspectors. Otherwise, bed bugs are seldom killed by such products, even with prolonged or repeated exposure to them, when applied according to their own labels.

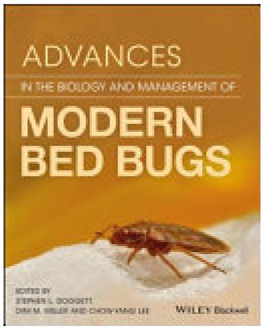
Follow-up. At least one follow-up inspection of infested sites should be conducted at a suitable interval (*e.g.*, 10-21 days) after each control effort or treatment, to detect any of the typical signs of continued infestation, such as live bugs, cast skins (after those present earlier had been removed), fecal spots on bed linens or harborages, or unhatched eggs. Note: Timing of the follow-up should be based on the approximate temperature of the premises to best detect recently hatched nymphs and bed bugs that may have survived through the treatment. When an apartment has been kept cool (tenants and apartment managers frequently think that cool temperatures, 15-21˚C (60-70˚F), will control them), 3-4 weeks is best for the follow-up. Poor tenants in the summer oftentimes do not have air conditioning, so the apartments are regularly found to be kept at 24-30˚C (75-85˚F); in that scenario follow-up is best done after 10 days to two weeks.

Additional Bed Bug Information and Web Sites

Please note that web sites may sometimes contain incorrect information. Government and university web sites are usually more unbiased and reliable than sites created by commercial or private interests.

Books, Manuals and Guides

The book entitled Advances in the Biology and Management of Modern Bed Bugs is a valuable resource for additional information on bed bugs (Doggett *et al.* 2018).



Stephen L. Doggett, Dini M. Miller, Chow-Yang Lee
John Wiley & Sons, 2018. ISBN 1119171539, 9781119171539, Length 439 pages

The book contains 48 Chapters from over 60 Authors and offers new information on basic and applied science. Major sections include bed bugs in society throughout history, their global resurgence, impacts on health and economics, biology, chemical ecology, population genetics, and management. Of particular note, the sections on management cover industry standards, pest control company perspectives, prevention, detection and monitoring, non-chemical control, insecticide resistance, chemical control, education, and bed bug control in specific situations like low-income and multi-unit housing, shelters, healthcare facilities, aircraft, and ships. Legal issues and the law is another section that includes important factors to consider as property owners and owners of pest control companies.

Doggett, S. (*ed*.). 2011. *A Code of Practice for the control of bed bug infestations in Australia*. 4th ed., Bed Bug Code of Practice Working Party, Australian Environmental Pest Managers Association, New South Wales, Australia. 91 p. (Sept.) ISBN: 1-74080-135-0: http://medent.usyd.edu.au/bedbug/cop_ed4.pdf
Latest PDF version available on-line at: www.bedbug.org.au.

Michigan Manual for the Prevention and Control of Bed Bugs, prepared by Michigan's bed bug working group:
https://www.michigan.gov/documents/emergingdiseases/Bed_Bug_Manual_v1_full_reduce_326605_7.pdf

What's Working for Bed Bug Control in Multifamily Housing: National Center for Healthy Housing: Reconciling best practices with research and the realities of implementation:
https://nchh.org/resource-library/report_what's-working-for-bed-bug-control-in-multifamily-housing.pdf

Websites:

EPA's bed bug web page: https://www.epa.gov/bedbugs. EPA's Spanish-language website: http://www.epa.gov/espanol/

CDC Bed Bugs website: https://www.cdc.gov/parasites/bedbugs/

Connecticut Coalition Against Bed Bugs:
http://www.ct.gov/caes/cwp/view.asp?a=2826&q=437580&caesNav=|

Michigan bed bug information site:
www.michigan.gov/emergingdiseases/0,1607,7-186--147759--,00.html"

New York State IPM Program under Cornell Univ.: www.nysipm.cornell.edu

Virginia Department of Agriculture Bed Bug Fact Sheets:
http://www.vdacs.virginia.gov/pesticide-bed-bug-outreach-and-education-program.shtml

National Center for Healthy Homes: www.nchh.org (and search)

Bed Bug Foundation (an international NGO): http://www.bedbugfoundation.org/

University of Kentucky Extension Entomology:
www.uky.edu/Ag/Entomology/entfacts/struct/ef636.htm

University of Minnesota: www.ipmctoc.umn.edu (then search)

National Pest Management Association (NPMA, www.pestworld.org):
Best Management Practices for Bed Bugs 2016 at:
https://www.pestworld.org/media/562243/npma-bed-bug-bmps-approved-20160728-1.pdf

PCT Magazine: www.pctonline.com (and search)

Pest Management Professional Magazine (formerly Pest Control Magazine):
http://www.mypmp.net (and search)

Bed Bug Central (part of Cooper Pest Solutions, Lawrenceville, NJ):
www.bedbugcentral.com or www.cooperpest.com

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Appendix 1. Sample Bed Bug IPM Template

This template outlines IPM strategies for controlling bed bug infestations in many military (or other) housing situations. Additional or alternative strategies and techniques are discussed elsewhere in this TG. The following sequence of steps should facilitate control of bed bugs in troop or family housing.

1. Inspection. Prompt, careful, thorough inspection by a qualified individual of sites reported or suspected to be infested by bed bugs. Even if detection dogs or multi-element (or other) devices have detected bed bugs, do an inspection to pinpoint the main infested sites. Start at the site where biting was reported and work outward for a 5-20 ft. radius.

2. Correct identification (ID) of any pest species found. A sample of the pests present should be collected and identified by a qualified person using suitable keys or other ID aids.

3. Education of occupants(s) and manager(s) of the infested structure(s). Occupants and managers should be provided concise, clear information about the ID, biology, and general behavior of any pest bugs found. They should be informed of the need for their cooperation and of any self-help steps they might take to reduce or limit the infestation, or that would help prevent re-infestation. Information can be provided by direct explanation, fact sheets (handouts), reference to a web site, or a combination of these.

4. Physical control measures. Vacuuming bugs, shed skins and eggs is very important, particularly with large infestations because nymphs often hide in older instar's shed skins resulting in protection from insecticides. Using a vacuum cleaner (preferably HEPA-filtered), remove the bugs and their cast skins from all observed and suspected harborage sites during the initial inspection, and periodically afterward (e.g., once weekly as a self-help action). The vacuum bag should be removed immediately afterward, sealed tightly inside a larger plastic bag, and that bag incinerated or placed in the next normal trash collection.

b. Launder all infested cloth items in hot water [>120°F (49°C)] for >10 min., with soap or detergent, then dry in a warm or hot dryer [>140°F (60°C)] for >20 min., or dry clean to kill all bed bug life stages present.

c. Consider enclosing each mattress and box spring in a sealable plastic cover, such as those sold to limit exposure to house dust mites.

d. Place and seal all recently laundered cloth items (*e.g.*, bed linens, clothing) inside large plastic bags or tightly-closed bins to prevent any bed bugs from reinfesting them.

e. Seal shut all cracks, crevices, and entry points to wall voids, using a high-quality silicone-based sealant, especially within a 20-ft. radius of any spot where bed bug bites have occurred.

f. Additional physical control measures against bed bugs may include: heat, cold, steam, controlled atmospheres, physical removal/mashing, or sticky insect monitors.

5. Chemical control measures.

a. A residual insecticide should be applied (by a properly qualified and certified, when called for on any given product's label), according to label directions, to each infested site and preferably to a small area around each site. This will often involve treating cracks and crevices. When planning and conducting any such treatments, consider examining, if not treating, the opposite side of any involved wall, floor, or ceiling.

b. Electrical outlet boxes, and similar voids that cannot be readily and effectively sealed, should be opened and treated with an appropriate insecticide dust.

c. Limited use of an aerosol or ULV pyrethroid may facilitate the detection of hidden bed bugs by causing them to move around more, and may also potentially increase their exposure to any previously applied residual insecticide. DO NOT use any over-the-counter (OTC) total-release "foggers." They are simply NOT effective, may cause bed bugs to scatter, and could also pose a fire hazard.

d. Fumigation or heat (or cold) treatment of batches of furniture, clothing or other items within chambers or smaller, portable heat-treatment devices (or similar-sized freezing units) may be warranted and affordable in specific cases, but whole-structure fumigation to control bed bugs is very seldom practical or economically feasible. Any of these types of treatments provide no residual effects at all.

6. Follow-up. Re-inspection of infested structures and sites should be done about 10-21 days after any initial treatment, and (if needed) again about 10-21 days later, to detect, and to precisely target any subsequent re-treatment of, any continued infestation site(s).