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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 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 current Pest Management Professionals (PMPs) with years of experience have never seen an active bed bug infestation. During the past 12 years, a resurgence of bed bugs has been reported in the U.S., Canada, the Middle East, several European countries, Australia and parts of Africa. Infestations have occurred in homes, hotels, hostels, cruise ships, trains, and long-term care facilities (Cooper and Harlan 2004, Doggett *et al*. 2004, Harlan *et al*. 2008, Hwang *et al*. 2005, Johnson 2005). This Technical Guide was developed to help meet the need for current information and guidance regarding bed bug control.

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Acknowledgments

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Disclaimer

Trade names are used in this TG to provide specific information and do not imply endorsement of the products named or criticism of similar ones not mentioned. Mention of trade names does not constitute a guarantee or warranty of the products by the author, the AFPMB, the Military Services, or the Department of Defense.

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 some 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), the condition of the 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.

Corrections or suggestions to improve this TG should be addressed to: Editor, TG # 44, Bed Bugs – Importance, Biology, and Control Strategies, Information Services Division (ISD), Armed Forces Pest Management Board (AFPMB), Forest Glen Annex – WRAMC, Washington, DC 20307-5001, Phone: (301) 295-7476, FAX: (301) 295-7473; or e-mail: afpmb-webmaster@osd.mil.

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 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. Also, 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.*, human, bat) 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. Adults must continue to feed periodically to reproduce. Fig. 1 shows eggs and several nymphal stages; Fig. 2 shows an adult female.

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 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 30 human pathogens but have never been proven to transmit any of them biologically or mechanically (Usinger 1966, Cooper and Harlan 2004, Webb *et al*. 1989). Hepatitis B viral DNA fragments have been recovered from bed bug feces and this virus can be retained through one normal molt, but is lost after a second successive molt. This seems to support the possibility of mechanical transmission, if infected bugs were crushed onto abraded skin of a susceptible human (Jupp *et al.* 1991, Blow *et al.* 2001).

Bites and health effects. Bed bug bites are often almost undetected on some people, but their saliva contains biologically and enzymatically active proteins that may cause progressive, visibly detectable allergenic skin reactions to repeated bites. Depending on biting intensity and frequency, there are typically five post-bite effect stages: no reaction (no or too few antibodies developed), delayed reaction only, delayed plus immediate reaction, immediate reaction only, and no visible reaction (due to excess circulating antibodies). Typical symptoms include a raised, inflamed, reddish wheal at each bite site, which may itch intensely for several days (Fig. 3). "Immediate" reactions typically appear from one to 24 hours after a given bite and may 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" reactions usually first appear one to three (up to 14) days after a bite and resultant redness and itching may last another 2-5 days (Feingold *et al.* 1968). Humans who are frequently bitten by bed bugs may develop a sensitivity "syndrome" that can include nervousness, persistent agitation ("jumpiness"), and sleeplessness. In such cases, either removing the bed bugs (physically or chemically) or relocating the person can cause the symptoms to subside over time. Several additional cimicid species readily bite humans, including tropical bed bugs, poultry bugs, various species of bat bugs, and swallow bugs. A social stigma may be associated with "having" bed bugs (Usinger 1966), but at present, there is rarely any expectation or requirement to report infestations to any public health or other government agency.

Additional health effects reported in the medical literature have included: facilitated secondary infections from scratching bites (Goddard and deShazo 2009), causing or worsening asthma (Abou Gamra *et al*. 1991), blister-like skin eruptions (Liebold *et al*. 2003), true anaphylactic reaction (Parsons 1955), and anemia (Prichard 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. Bed bugs 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 longer than a year), while second through fifth stage nymphs can survive for at least three months without feeding. The numbers, geographic distribution, and severity of bed bug infestations are rapidly increasing in Europe, North America, Australia and other parts of the world. The public's fear of bed bugs, the effects of their bites, and their characteristic, "musty-sweetish" smell magnify their importance as pests.

Because the general public is still not very knowledgeable about bed bugs, their bites nearly always lead to visits to a clinical medical facility or expert (often a physician). There are usually additional costs for diagnosis, or for symptomatic medical treatments. In 2004 alone, at least 17 of 65 homeless shelters in Toronto, Canada 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).

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. Furniture rentals and purchases of used furniture are rather common, especially in poor communities, and this probably helps rapid and repeated spread of bed bugs to new sites and redistribution of them back into places from which they may have previously been eliminated.

Large multi-unit buildings can be very difficult to rid of bed bugs. Once they become established, any control effort that does not include concurrent inspection of all units,

together with a coordinated program of treatment and occupant education, is usually doomed to fail. The bugs will frequently move from any partially treated, potentially repellent active site to adjacent rooms or floors. They readily move through wall voids, along utility lines, heating ducts, elevator shafts, and laundry or mail chutes.

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 pests wherever they are introduced.

Biology and behavior

Adult bed bugs are about 6-7 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 chemicals that are produced by glands in their ventral thorax. The tips of their abdomens are usually pointed in males but rounded in females.

They feed only on blood, usually of mammals or birds, and mate by "traumatic insemination." It may take 3-15 minutes for one bug to completely engorge. About 20% of the time, adult bed bugs and large nymphs will void remains of earlier blood meals while feeding. This produces the typical rusty or tarry spots seen on bed sheets or in bug hiding places (Fig. 5). They feed repeatedly, but each of the five nymphal stages must have at least one blood meal before it can develop to the next stage. Both males and females must feed at least every 14 days in order to keep producing eggs.

Fig. 5. Bed bug adult on sheet, showing typical fecal spots. Photo by H. J. Harlan.

Bed bugs will travel 5-20 ft. from an established harborage to feed on a host 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, 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 when hungry. Females attach their small (1 mm long) cylindrical (about four times as long as wide) pearly-white eggs to any nearby surfaces, usually in crevices (harborages), where they hide in loose groups or clusters. Each female may lay 200-500 eggs during her lifetime, which may be 6-12 months or longer. Cast bed bug skins usually accumulate in harborages.

Common bed bugs can be found all over temperate areas of the Northern and Southern Hemispheres almost anywhere that humans have established houses and cities. 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* (Fabricius), is widespread at tropical and subtropical latitudes worldwide, and it accordingly requires a higher average temperature than does the common bed bug. In continental Europe, established infestations of this species are rare; in the Western Hemisphere, it is seldom found north of Mexico and Puerto Rico, or south of Peru and Brazil. Occasional limited populations 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 parts of the world and may occasionally bite humans (Usinger 1966, Gold and Jones 2000, Harlan *et al*. 2008).

Control Strategies and Techniques

Detection. A bed bug infestation is usually revealed through finding live bugs or, observing signs such as dark fecal deposits or lighter rusty spots on bed linens or in harborages, discovering eggs or cast skins in harborages or near reported feeding sites, or smelling the bugs' characteristic odor (Fig. 6). Any combination of two or more of these signs can help verify an infestation, and help determine the bugs' distribution and prevalence. Monitoring may be augmented by using sticky traps and insecticidal aerosols that produce a flushing or excitatory effect. For cimicid species that mainly feed on bats or birds, detecting and locating their usual hosts' roosts or nests is important. The presence of such hosts may signal a possibility that their removal or exclusion could trigger or hasten an infestation of nearby human living areas.

Inspection. Detailed inspection by a qualified person is the essential first component of any effective bed bug control program. If found, the bugs must be detected, accurately identified (IDed), and their harborage sites and a rough estimate of the population size must be determined as quickly as possible. Even with the use of detection dogs or the new devices for attracting or trapping bed bugs, visual inspections must still be done to determine the exact location and extent of each detected infestation before any control effort is undertaken. Certain pyrethrin-based flushing agents can help stimulate the bugs to move around, making them easier to detect where populations are limited. For cimicids that feed chiefly on bats or birds, their populations can usually be located by finding and examining their hosts' nests nearby.

New bed bug detection and monitoring techniques. Several new techniques recently have been developed and are being marketed for detecting and monitoring bed bug infestations. Dogs are being specially trained to detect even small numbers of live bed bugs, and possibly their viable eggs as well, with a reported accuracy of about 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). 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. Other, physically simpler barrier or harborage-mimicking devices can also intercept and trap bed bugs (*e.g*., see Wang *et al*. 2010).

Each of these has considerable promise as an additional tool, but none of them appears, so far, to be a "stand alone" method for controlling bed bug infestations, regardless of the physical setting. Even when one of these techniques detects (and even narrows down the general location of) any population (infestation) of bed bugs, someone still must confirm their precise sites, ID them, and then effect some kind of control. Additionally, not even the previously mentioned dogs are accurate all the time (they may have their "bad days," as might their handlers), and the devices can be avoided by a few bugs because of certain quirks in the bugs' own biology and appetitive behaviors. Further, various economic factors and the human occupants' understanding and cooperation are still essential for optimum success.

Fig. 6. A mattress showing typical signs of bed bug infestation. Photo by B. Pannkuk.

Education. 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 proposed control strategies and techniques. Education may include verbal explanations, answering questions, posting notices, broadcasting notices, postings on web sites or distributing handouts in the local language. Throughout a control program, continuous communication should be maintained between occupants, building managers, PMPs and any involved government agencies.

Physical removal. 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 removes >99% of all particles >0.3 micron diameter, will ensure that many allergens associated with bed bugs and their debris are also removed. Vacuuming, especially during inspections, will immediately remove a significant portion of the pest population and will usually kill some of the bugs. Bed bugs may also be removed from exposed resting sites by pressing down on them with the sticky side of any commercially available tape, hand-picking them, or brushing them directly into a container of rubbing alcohol or soapy water (Potter 2004, Gooch 2005). For cimicids that feed chiefly on bats or birds, it is essential to completely remove all host nest materials followed by thoroughly applying some appropriate control action (*e.g.*, heat) or product (*e.g.*, a properly labeled insecticide) at and immediately around every prior nest site.

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 bug passage. If 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 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), 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 both seal in and exclude bed bugs. They may also be homemade using plastic sheeting 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 cover product that is commercially available.

Physical killing techniques (heat, cold, controlled atmospheres, steam)

Heat. Since at least the early 1900s, bed bugs have been controlled by heating infested rooms or whole buildings to temperatures >45^{o}C, the individual thermal death point for common bed bugs. For heat treatment to be effective, it is critical that high temperature and low relative humidity be attained for a minimum length of time. Pereira *et al.* (2009) recently published a study that addressed several aspects of this technique for eliminating

bed bugs from furniture and similar items in the same room while other actions and control techniques are pursued concurrently.

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, Harlan *et al*. 2008). Laundering infested linens or other cloth items in hot water with detergent, followed by at least 20 minutes in a typical clothes dryer on low heat, should kill all life stages of bed bugs but would not prevent their reinfestation.

Cold. Exposure to low temperatures can kill bed bugs if they are kept cold enough long enough. Bed bugs can tolerate -15^{o}C (5^{o}F) for short periods and, if acclimated, they can survive at or below 0^{o}C (32^{o}F) continuously for several days (Usinger 1966). Cold treatments of rooms or buildings to control bed bugs have not been well studied or often employed, but freezing furniture or other items within containers or chambers, *e.g.*, below 0^{o}F (-19^{o}C) for at least four days, may be a practical alternative for limited infestations or to augment other control measures. A new commercial technology uses CO_2 from cylinders deposited as a "snow" to kill bed bugs and a variety of pests by rapid freezing, but further field evaluations are needed to verify the efficacy of this technique. The safety of releasing moderate to large volumes of CO_2 into certain living spaces, *e.g.*, basement apartments or similarly enclosed spaces, should also be further evaluated.

Controlled Atmospheres. In preliminary laboratory tests by the German Federal Environmental Agency, all life stages of common bed bugs were reportedly killed by constant exposure to very high concentrations of carbon dioxide (CO_2), at ambient atmospheric pressure, within 24 hours. However, high concentrations of nitrogen gas (N_2) were not very effective under the same conditions (Herrmann *et al.* 2001).

Steam. Steam treatments have been used effectively by some PMPs to quickly eliminate live bugs and their eggs from the seams of mattresses and other cloth items. However, this technique requires training, practice and care. Manufacturers' instructions must be followed concerning the steam generating devices' operation, maintenance and safety precautions. The steam emission tip must usually 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 all the bed bugs and eggs that it contacts. If the tip is too close, 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.

Sticky Monitors. Sticky traps are a simple way to monitor many crawling insects, 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 they are not very effective at detecting small to moderate populations of bed bugs, even when infestation signs are obvious, bugs are easily observed, and people are being bitten routinely.

Pesticide Applications

Residual applications. Currently, non-chemical products and techniques are incapable of efficiently or quickly controlling or eliminating extensive or well-established bed bug populations. Precise placement of a suitably labeled, registered and formulated residual chemical insecticide is still the most practically effective bed bug control. Effective control consists of applying interior sprays or dusts to surfaces that the bed bugs contact and to cracks and crevices where they rest and hide. When using residual insecticides, care should be taken to select the least-toxic active ingredients and formulations, following an IPM approach. Microencapsulated and dust formulations have a longer residual effect than others. Synergized pyrethrins are often lethal to bed bugs, and some may cause a flushing effect, allowing faster analysis of the infested area. If the product label permits, addition of pyrethrins at 0.1-0.2% to organophosphate, or carbamate (where these active ingredients are legal and labeled for this use), or other microencapsulated insecticide formulations may increase efficacy by irritating the bugs, exciting them, and causing them to leave their hiding places, thus increasing their potential exposure to the freshly deposited insecticide.

Diatomaceous earth, silica gel, or other properly labeled dust formulations can also be used to treat cracks and crevices. Retreatment, when needed, should be done after the shortest interval permitted by the label until the pest bug population has been eliminated. The choice of chemical products and specific application techniques can depend on many factors, like the physical location and structural details of the bugs' harborages, the products' labels (which can vary by political jurisdiction), the immediate environment, and local or national laws.

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 insecticides.

Insect Growth Regulators (IGRs). When properly applied,IGRs have essentially no effect on vertebrate metabolism because of their mode of action and low application rates, but they can have a significant impact on bed bug molting, fertility and egg hatching success (Takahashi and Ohtaki 1975, Moore and Miller 2006).

Fumigation. Fumigation of furniture, clothing, or other personal items can kill all bed bug stages present. However, such treatments will not prevent re-infestation immediately after the fumigant dissipates. Fumigation of an entire building would be equally effective but, again, would not prevent re-infestation, and would seldom be necessary, practical, or affordable (WHO 1982, Snetsinger 1997, Gooch 2005, Harlan *et al*. 2008).

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 spray, dipping or coating formulations of some permethrin products 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*, was recently reported to be resistant to both permethrin and alphacypermethrin that had been used to impregnate bed nets for protection against malaria vector mosquitoes (Myamba *et al.* 2002).

Ultra Low Volume (ULV), aerosols, and foggers. Insecticides currently labeled for ULV, aerosols and foggers have little or no residual effects on bed bugs. Most will seldom penetrate cryptic bed bug harborages. If directly injected into harborages, these products may stimulate some bed bugs to become active and move out into the open, allowing them to be more readily seen. Otherwise, bed bugs are seldom killed, even by prolonged or repeated exposure to such products as those currently EPA-labeled in the U.S.

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 so as to detect any signs of continued infestation, like live bugs, cast skins (after those present earlier had been removed), fecal spots on bed linens or harborages, or unhatched eggs.

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Web sites offering bed bug information. Please note that web sites may sometimes contain incorrect information. The contents of government and university web sites are more consistently based on peer-reviewed scientific sources than sites created by commercial or private interests.

EPA's Bed Bug Website http://www.epa.gov/pesticides/controlling/bedbugs.html
EPA Spanish Website: "http://www.epa.gov/espanol/"

National Pest Management Association, www.pestworld.org

Bed bug central, @ Cooper Pest Solutions, Lawrenceville, NJ, www.cooperpest.com

Techletter, by Pinto & associates, www.techletter.com

PCT Magazine, www.pctonline.com

Pest Management Professional Mag., formerly Pest Control Mag.,
http://www.mypmp.net/

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

Harvard School of Public Health, www.hsph.harvard.edu/bedbugs/

Australian Environmental Pest Managers Association, www.aepma.com.au

The Ohio State University, www.ohioline.osu.edu/hyg-fact/2000/pdf/2105.pdf

The University of Minnesota, www.ipmctoc.umn.edu

The New York State IPM Program under Cornell University, www.nysipm.cornell.edu

The National Center for Healthy Homes, www.nchh.org

Joint Statement (by CDC & EPA) that "bed bugs are a pest of public health importance"**:**
http://www.cdc.gov/nceh/ehs/Publications/Bed_Bugs_CDC-EPA_Statement.htm .

Michigan bed bug information site (including several useful downloadable files)**:**
www.michigan.gov/emergingdiseases/0,1607,7-186--147759--,00.html"

Appendix 1. Sample Bed Bug IPM Template

This template outlines IPM strategies for controlling bed bug infestations in many 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 bugs, an inspection is needed to pinpoint infested sites. Start at the site where biting was reported or bugs were found and work outward for at least a 20 ft. radius.

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

3. Education of occupants(s) and manager(s) of infested structure(s). The 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.

a. 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 (once weekly is a suggested 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^{o}F (49^{o}C)] for >10 min., with soap or detergent, then dry in a warm or hot dryer [>140^{o}F (60^{o}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 sealed plastic cover, like those sold commercially, to limit exposure to house dust mites or bed bugs.

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 re-infesting 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 been reported, or where the bugs have actually been collected.

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

5. Chemical control measures.

a. A residual insecticide should be applied, according to label directions, to each infested site and preferably to a small area around each site. Such applications 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 sealed, should be treated with an appropriately labeled insecticidal dust.

c. Consider including some type of insect growth regulator (IGR) as a concurrent or adjunctive treatment (*e.g.*, as a tank mix).

d. 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 "foggers." They are not very effective and may cause bed bugs to scatter.

e. Fumigation or heat (or cold) treatment of batches of furniture, clothing or other items within chambers may be warranted and affordable in specific cases, but whole-structure fumigation to control bed bugs is seldom practical or economically feasible. And such 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 the treatment (if needed) of any continued infestation.