

BED BUGS

Integrated Pest Management in and around the Home

Bed bugs are blood-sucking insects in the family Cimicidae. Both nymphs and adults feed on sleeping or sedentary humans, mostly at night, a time when this pest's stealthy habits are difficult to observe.

Bed bugs are found worldwide in association with human habitations. The common bed bug, *Cimex lectularius*, is a widely distributed species most frequently found in the northern temperate climates of North America, Europe, and Central Asia. It occurs more sporadically in southern temperate regions. In tropical regions *C. hemipterus*, the tropical bed bug, is the dominant species. The most common species found in California is *C. lectularius*.

The growth and development of *C. lectularius* is optimal when it feeds on humans; however, this insect also feeds on other species of mammals and on birds found near the home including chickens, mice, rats, and rabbits. Bat bugs and swallow bugs, close relatives of bed bugs, may also be found in and around human dwellings and may sometimes bite humans, although their preferred hosts are bats and birds, respectively.

Until recently, bed bug infestations were thought to be associated primarily with crowded and dilapidated housing. However, bed bugs have undergone a resurgence in pest status and can now be found even in the finest hotel and living accommodations. The reasons for this resurgence aren't totally understood but appear to involve increased global travel and commerce, ease of movement of infested items, widespread insecticide resistance, and changes in pesticides available to control this pest.

IDENTIFICATION AND LIFE CYCLE

Adult bed bugs (Figure 1) are oval, wingless, about 1/5 inch long, and rusty red or mahogany. Their bodies are flattened, they have well-developed antennae, their compound eyes are small, and the area behind the head (the pronotum) expands forward on either side of the head, bearing many small hairs. The immatures (Figure 1), called nymphs, appear identical to the adults except for their smaller size (1/20–1/5 inch), thinner outer skeleton (cuticle), and lighter yellowish-white color.

Bed bugs are readily distinguished from another common blood-sucking species, conenose bugs (also known as kissing bugs), by their smaller size, more rounded shape, and lack of wings as adults. Conenose bugs may be up to 3/4 inch long. (See *Pest Notes: Conenose Bugs* in References.)

Bed bugs can be distinguished from their close relatives bat bugs and swallow bugs by comparing the length of the hairs on the pronotum to the diameter of the eye; this requires a hand lens or microscope. These hairs are shorter than the diameter of the eye on a bed bug and longer than the diameter of the eye on bat bugs and swallow bugs. This distinction is sometimes important to make, since managing these bed bug relatives involves managing their vertebrate hosts (i.e., bats and swallows) nesting in, on, or near homes.

Female bed bugs lay 200 to 500 tiny (1/20 inch) white eggs during their lifetimes, usually two to five eggs per day, on rough surfaces such as wood or paper near their hosts' sleeping places, resting places, or both (Figure 2). Gluelike material covers the eggs, which hatch in about 10 to 15 days at room temperature. After hatching occurs, the eggshells frequently remain stuck in place.



Figure 1. Bed bugs adults and nymphs. Scale bar represents 5 millimeters.



Figure 2. Bed bug eggs on paper. Eyespots are visible as red dots on the developing bed bug embryos.



Figure 3. Life stages of a bed bug. The five nymphal stages each require a blood meal before molting to the next stage. The increments on the ruler are millimeters.

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There are five progressively larger nymphal stages, each requiring at least one blood meal before molting to the next stage (Figure 3). The entire life cycle from egg to adult requires anywhere from five weeks to four months, depending on temperature and availability of food (blood). Development occurs most rapidly when temperatures are between 70° and 82°F.

Both nymphs and adults generally feed at night and hide in dark cracks and crevices during the day, although hungry bugs may feed any time hosts are nearby and sedentary. Common hiding places are typically located within 6 or fewer feet from areas where humans sleep or rest and include: along mattress seams and tufts; beneath covers; in wood joints of box springs; in cracks and joints of bed frames; behind baseboards and headboards; under loose wallpaper; behind picture frames; and inside furniture, appliances, electronics and upholstery. Bed bugs are more likely to harbor in or on materials made of wood, paper, or fabric as compared to those made of metal or plastic.

Occasionally, people may pick up bed bugs in theaters or on buses and trains. People can also bring bed bugs into their home on infested clothing, bedding, furniture, and luggage.

Bed bugs can go without feeding for 20 to 400 days, depending on temperature and humidity. Older stages of nymphs can survive longer without feeding than younger ones, and adults have survived without food for more than 400 days in the laboratory at low temperatures. Adults may live up to one year or more, and there can be up to four successive generations per year.

DAMAGE

Bed bugs feed on humans, usually at night when they are resting. This insect feeds by piercing the skin with its elongated mouthpart, which consists of four stylets that normally fold under its body when at rest but fully extend during blood feeding. Two maxillary stylets form canals, a small salivary canal that carries saliva into the wound and

a relatively large food canal through which body fluids from the host are taken in.

A bed bug can take up to six times its weight in blood during one feeding event, which takes between 3 and 10 minutes. Usually people aren't aware they have been bitten until afterward; bites occur while people sleep, and bed bugs are known to inject a natural anesthetic while feeding. However, saliva injected during the feeding can later produce allergic dermal reactions such as large itchy swellings on the skin. These may become irritated and infected when scratched (Figure 4). Swelling may not develop until a day or more after feeding, and some people show no symptoms at all. Bed bugs have never been shown to transmit human disease.

Distinguishing bed bug bites from the bites of other arthropods such as mosquitoes, fleas, and spiders is difficult to impossible. People often confuse itching bed bug welts with mosquito bites. The only way you can really confirm bed bugs as the cause is to find the bugs or their signs in your bed or bedroom. Often people are bitten when traveling and may be unable to produce a specimen, making diagnosis even more difficult.

In addition to direct injury to humans, bed bugs leave odors and unsightly fecal spots on bed sheets and around the insects' hiding places. These spots are usually reddish brown or dark brown to black, sometimes yellowish, roughly round (although sometimes they appear as streaks), and can be very small (Figure 5).

MANAGEMENT

Confirmed bed bug infestations should be managed by trained professionals. Managing a bed bug infestation is a difficult task that requires removing or treating all infested material and follow-up monitoring to ensure the infestation has been eliminated. Management will require employing several nonchemical methods such as vacuuming, washing bedding at a high



Figure 4. Bed bug bites cause swellings that become red and irritated when scratched. Some people, however, exhibit no visible symptoms after being bitten.



Figure 5. Fecal spots of bed bugs. Eggs and cast skin (exuviae) are visible in the upper left-hand corner. Scale bar represents 5 millimeters.

temperature, using steam or heat treatment, and sealing up hiding places.

Insecticides may be required to eliminate serious infestations. Several active ingredients are federally registered for bed bugs for over-the-counter use, but few have been demonstrated as effective. Pest management professionals (PMPs) have access to a wide range of effective registered products; however, insecticide resistance among bed bug populations is increasingly common. The best approach is to combine chemical and nonchemical tactics with increased sanitation and habitat modification practices. Prevention and monitoring of bed bug infestations are paramount and should be ongoing.

Monitoring and Detection

The presence of raised wheals, blisters, rashes, or any other dermal symptom associated with arthropod bites should never be used for diagnosis, since several household pests are known to bite humans, and since reactions vary

widely between individuals. You can confirm a bed bug infestation only by detecting the pests themselves or their signs, which include fecal spots, blood spots, egg cases, and shed skins (exuviae) (Figure 5).

Current research indicates 85% of bed bugs are found in or near the bed, so inspections for infestations should initially focus on the mattress, box spring, bed frame, and headboard. Lift the mattress and inspect all its seams and surfaces as well as those of the box spring. You may need to dismantle the bed. Keeping in mind bed bugs can utilize cracks and crevices as small as the width of a credit card, make sure to thoroughly inspect all potential harborage sites. Use a flashlight and a small mirror to aid in the inspection process. It can take a good deal of time, patience, and perseverance to detect low-level infestations.

Remember, these nocturnal insects are small. Although you can see adults and aggregations of nymphs with the unaided eye, seeing the eggs requires a hand-magnifying lens. Make sure to look for dark spots of dried bed bug excrement, blood spots where engorged bugs were inadvertently crushed, or the insects' light-colored shed skins. A foul, rotting, bloody meat, or acrid "buggy" smell might be present in heavily infested areas.

The remaining 15% of infestations usually are in upholstered furniture other than beds; in bedroom cabinets; along baseboards; under wallpaper; and in carpets, wall hangings, and similar hiding spots. Bed bugs prefer fabric or wood surfaces to metal or plastic. When there are heavy infestations, keep in mind that adjoining rooms, filing areas, and clutter can be out-of-the-way shelters.

Recent research has shown that canine detection utilizing dogs conditioned to the scent of bed bugs can be an effective tool for detecting bed bug infestations. Laboratory and simulated field studies have shown this method can be very accurate; under actual field conditions, however, canine detection

accuracy has been highly variable. Therefore, third-party certification and ongoing training of any canine team should be verified before hire, and any canine detection alert should be confirmed with a detailed inspection by a trained PMP.

Other recent research indicates monitors that attract or intercept bed bugs moving between a hiding place and a host can aid in bed bug detection, particularly when using several monitors near beds or suspect locations. Pest management professionals are already widely using these monitors. Although quite diverse in terms of size, appearance, and price, monitors generally fall within one of two categories: active monitors or passive monitors. All monitors have the benefit of ease of inspection as compared to potentially having to disassemble furniture and other household items to find bed bugs.

Active monitors employ an attractant—usually heat, carbon dioxide, host odors (kairomones), pheromones, or a combination of these—to lure bed bugs out of their harborage areas and into a pitfall or sticky trap within the monitor. These devices have the potential, especially in the absence of a host, to detect bed bugs that would normally remain hidden. Airborne aggregation pheromones and other behavior-modifying chemicals might someday help detect low-density infestations.

Passive monitors either exploit a bed bug's affinity for dark crevices or rely on chance encounters with pitfalls or sticky traps.

Interceptor monitors (Figure 6) are a hybrid between active and passive (pitfall) monitors in that they rely on the presence of a host (a sleeping human) to attract hungry bugs and then trap the parasites on route to their meal. These small double-cupped monitors are easily installed under the legs of beds and other furniture items. Research has demonstrated that such interceptors trapped six times more bed bugs than were found from human visual searches alone.

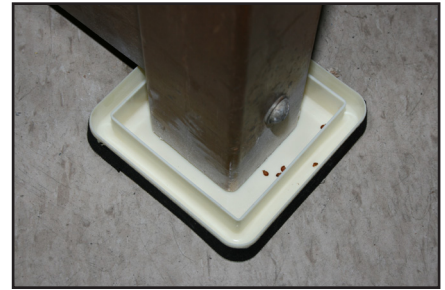


Figure 6. Interceptor monitors can be used under legs of furniture to trap bed bugs as they travel between harborage and host.

Prevention

People may bring bed bugs into their homes in luggage or on clothes after visiting an infested dwelling or hotel. If you travel frequently, look for signs of bed bugs in your hotel room by checking behind headboards and under sheets and by inspecting mattress seams and tufts, especially if you have been bitten. If you suspect bed bugs are present, change rooms or hotels. Inspect your luggage before leaving, and as soon as you get home, wash and dry all your clothes at the hottest settings the fabric will permit. Frequent travelers may want to store luggage away from the bedroom, such as in the garage or a hall closet.

You may also inadvertently bring bed bugs into your home on infested bedding or furniture. If you purchase second-hand furniture, especially beds or mattresses, thoroughly inspect the item before bringing it into your home. If you remove infested mattresses or furniture from your home, don't leave them on the curb or porch. Take such items immediately to the dump or clearly mark them as infested by bed bugs so others won't unknowingly bring the items into their homes.

Managers of hotels, furnished apartments, dormitories, homeless shelters, and other facilities that house transient populations need to train staff to recognize signs of bed bug activity and take action as soon as they find an infestation. One proactive step a manager can take is to regularly replace beds, mattress, and bedding materials. Frequent-

ly laundering bedding and placing potentially infested items into walk-in freezers or heat units during tenant turnover can help prevent the spread and establishment of bed bugs. Keep clutter down, so it is easier to inspect and so bed bugs have fewer hiding places. Also, seal up cracks, crevices, and holes in bedding, furniture, and other potential hiding sites. It is much easier to manage a bed bug infestation when the population is small.

Nonchemical Management

A number of nonchemical control methods can be used to manage bed bugs. These methods are directed at killing or removing bugs or restricting their access to beds or bedding material.

You can remove bed bugs and eggs with the suction wand of a strong vacuum; however, you must target the seams of mattresses and box springs, along perimeters of carpets, under baseboards, and in other areas where bed bugs live. A single vacuuming rarely gets all bugs and eggs and should, therefore, be repeated. Portable steam cleaners and other steam delivery devices can kill all bed bug life stages, so these items can also be used to clean mattresses and furniture. Care must be taken, however, to ensure steam penetrates into the areas harboring bed bugs and their eggs.

Commercial heating services are available to treat entire rooms in homes for bed bug infestations. The current recommendation for effective commercial heating services calls for a temperature of at least 140°F for two hours or 130°F for three hours (the minimum lethal temperature is 113°F), which will kill most bed bugs and eggs. In California, providers of heat services must be licensed and bonded by the Structural Pest Control Board. Chilling to a temperature of 32°F or lower and maintaining this temperature for several days will also kill bed bugs.

For suspected infestations in clothing or bedding, a home laundry drier at the hottest setting can be effectively used to deliver the necessary heat. At least

10 to 15 minutes exposure will be needed. Before using this method, consider whether heat will damage the fabric.

Mattress encasements specifically designed to prevent bed bugs from establishing harborages on mattresses are commercially available and have been shown to be effective through laboratory research. Encasements are particularly useful for hotels or other facilities with many beds. Encasements can also be used to contain bed bugs within mattresses when they can't be discarded or when control tactics such as steam or insecticide application are unavailable or undesirable. Bugs trapped inside encasements will eventually die due to starvation.

Other management practices include sealing up hiding places where bed bugs can hide such as cracks and crevices in walls and around windows and doors. As a temporary measure, you can sometimes exclude bed bugs by using commercially available double-cupped monitors that are easily installed under bed legs.

Insecticides

Insecticide applications alone won't control bed bug infestations. Insecticides must be combined with infestation prevention measures—a program of removing and cleaning infested beds, bedding, and other harborage sites—as well as nonchemical tactics such as steam or heat delivery and an ongoing evaluation and detection program to ensure treatment was effective and to manage future infestations early on.

The most effective bed bug pesticides are available to commercial pesticide applicators only. Professionals also have the equipment and expertise that allow for a more effective and precise application of insecticides. In addition, professionals have the training to detect and isolate infestations, which often allows for more effective long-term management.

Insecticides may be applied as liquids directly to cracks, crevices, bed frames, baseboards, and other similar sites, or they may be applied as dusts in cracks

and crevices. Pesticides aren't generally applied to mattresses or bedding because of potential risk to people. Using over-the-counter total-release aerosol foggers has been shown to be ineffective for bed bug control and potentially harmful to residents; therefore, they aren't recommended.

Liquid insecticide formulations, many of which are available for use only by PMPs, include:

- Products containing the botanical insecticide pyrethrin, which gives quick knockdown but little long-term control
- Various synthetic pyrethroid products (e.g., cyhalothrin, bifenthrin, deltamethrin, and permethrin)
- Mixtures of pyrethroids and neonicotinoids (e.g., Temprid and Transport)
- Various botanical oils
- Newer types of products including the pyrrole insecticide chlorfenapyr (Phantom) and the insect growth regulator (IGR) hydro-pyrene (Gentrol)

Fumigation using the active ingredient sulfuryl fluoride is commercially available for bed bug control in California and can be highly effective. However, this is a highly specialized and regulated treatment method, best for remedial control only. Since fumigants have no residual effects, other methods or a combination of methods will be needed to prevent reinfestations.

Some bed bug populations have developed resistance to pyrethroid insecticides and no longer can be effectively controlled by them. Therefore, there is growing interest in alternatives such as the mixtures, botanicals, and IGR listed above. Some studies, however, suggest that mixtures containing pyrethroids continue to drive resistance, that oils have little to no residual action, and that chlorfenapyr and hydro-pyrene may take many days to kill bed bugs.

Insecticides applied as dusts cling to the pest's cuticle, wearing away the insect's protective wax covering or poisoning the insect when it grooms

itself. Several dust products used in bed bug management include borates, diatomaceous earth, silica gel, and formulations containing pyrethrin or pyrethroids. These materials can provide long-term control as part of an integrated program if they are placed in out-of-the-way places, such as under baseboards or in wall voids, that don't get wet. Bed bugs may not groom themselves to the same degree as other pests, such as cockroaches, so insecticide dusts requiring consumption, including borates, may be less effective than anticipated.

Do-it-yourself Treatments

Although over-the-counter pesticide products that have bed bug control written on the label can be found on store shelves, they aren't generally recommended. Performance of these products under actual field conditions isn't known. If you need to use a pesticide, you are better off hiring a licensed professional pesticide applicator with experience in treating bed bugs; see *Pest Notes: Hiring A Pest Control Company* listed in References.

Residents do have an important role to play when their homes are infested with bed bugs. Once professional treatment has occurred, you should continue to monitor for bed bugs daily. Also, keep down clutter, and vacuum previously infested areas regularly.

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SUGGESTED READING

- Bed Bugs*. 2013. UC Riverside Center for Invasive Species Research. Available online, http://cirs.ucr.edu/bed_bugs.html.
- Bed Bug Information*. 2013. U.S. Environmental Protection Agency. Available online, http://www.epa.gov/bedbugs_ ❖

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WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in the original, labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Pesticides applied in your home and landscape can move and contaminate creeks, rivers, and oceans. Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits or vegetables ready to be picked.

Do not place containers containing pesticide in the trash or pour pesticides down the sink or toilet. Either use the pesticide according to the label, or take unwanted pesticides to a Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Household Hazardous Waste Collection site nearest you. Dispose of empty containers by following label directions. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.

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