



Bed Bugs: For Pest Control Professionals

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What You Should Know

- Bed bugs are one of the most difficult indoor pests to eradicate; standard insect control tactics will not eliminate an infestation.
- Bed bug control is intensive, and a minimum of two visits 10 to 14 days apart is mandatory.
- Bed-bug specific training should be administered to all pest control technicians.
- Even experienced pest control companies may not successfully eliminate bed bugs on the first series of treatments.
- Create a bed bug management plan in advance, keeping in mind all aspects of bed bug biology.
- Chemical treatments should always be supplemented with other, non-chemical control tactics (see Integrated Pest Management (IPM) Tactics for Bed Bug Control on page 6).
- Take precautions to avoid bringing bed bugs back to your home, business, or vehicle when leaving a job site.
- Provide and explain educational materials to all clients before treatments begin (see Extension fact sheet "Bed bugs: For Homeowners").
- Tell clients their responsibilities up-front.

History

Over the past decade reports of bed bug infestations (*Cimicidae: Cimex lectularius*) throughout North America and abroad have been on the rise. Accordingly, bed bug submissions to the Utah Plant Pest Diagnostic Lab have also been increasing.

This fact sheet is designed to inform pest control professionals of the complexities involved in eradicating bed bugs.

While some people believe that bed bugs switched from feeding on bats to "cavemen" over 12,000 ago, it



Fig. 1. Adult bed bug.¹

cannot be substantiated. We do know, however, from ancient accounts, that people were afflicted by bed bugs as early as 3,000 BC. Throughout time bed bugs moved north from the Middle East into Europe (circa 1500 AD), and farther north.

Early settlers likely brought bed bugs to North America from Europe. As the colonists' populations grew, so did the bed bugs. By the late 1800s into the early 1900s, Americans were plagued by bed bugs. An estimated one out of three homes was infested. People could pick up unwanted bugs on busses, taxis, in the movie theater—just about anywhere.

However, in the early 1950's something happened—bed bugs disappeared from the developed worlds' radar. Where did they go? A few things led to the decline of bed bug populations, most notably the invention of new insecticides like DDT and chlordane, and improved living standards and cleanliness. The insecticide DDT had a lasting killing effect (residual) of months to over a year. Homes, hotels, transportation vehicles, health care facilities, military facilities, etc., were doused with these new chemicals, and bed bugs quickly succumbed. By the end of the 1950's finding a bed bug in the U.S. was a rare occurrence. Improved cleanliness standards and the increased use of vacuums, and automatic clothes washers/driers also helped to keep bed bugs out of homes.

Beginning in the 1990s, the frequency of bed reports and calls for treatment began to increase, especially over the past few years. Pest companies that had not received a bed bug call in over 40 years started accepting bed bug jobs. Since then, the frequency of bed bug calls has drastically increased every year. There are many factors playing a role in the bed bug resurgence, but the most notable are the elimination of long-residual insecticides from the market and indoor use, and the increase in world travel.

Today's insecticides are not up to the challenge of effectively controlling bed bugs, largely because chemical companies haven't created products to battle these pests, and because of resistance in wild bed bug populations to pyrethroid-based insecticides, the ones most commonly used to battle bed bugs. And, because of increasing world travel, people are unknowingly transporting bed bugs all over the world, and even into their own homes.

Description and Life Cycle

Human bed bugs are oval insects that are flattened top to bottom, and are visible to the unaided human eye. Adults are always wingless and may resemble aphids, ticks, or other immature true bugs (Fig. 1). Bed bugs are normally brown in color, but become red and bloated after feeding (Fig. 2).



Fig. 2. Bed bug nymph engorged with blood.²

All stages are very flat in shape which allows them to hide in spaces as narrow as a business card, or in the holes of staples. Nymphs look similar to adults except smaller, and are nearly colorless or pale yellow. Newly hatched bed bugs are about 1mm long, while adults reach 6mm. All life stages have a short, 3-segmented straw-like mouthpart, and 4-segmented antennae. Like mosquitoes, the "straw" is made of two tubes, one for injecting a numbing agent and blood thinner, and another for sucking the blood out of your body. Both sexes can pierce animal tissue and remove blood with a pain-free bite. Bed bugs mostly feed at night and early morning, but can occasionally feed during the day. Hosts of the common bed bug include humans, mice,

rats, rabbits, guinea pigs, horses, cattle, and poultry.

On average, bed bugs complete a generation (egg to egg) in 1.5 to 2 months, but can range from 1 to 4 months depending on temperature and accessibility to blood meals (Fig. 3).

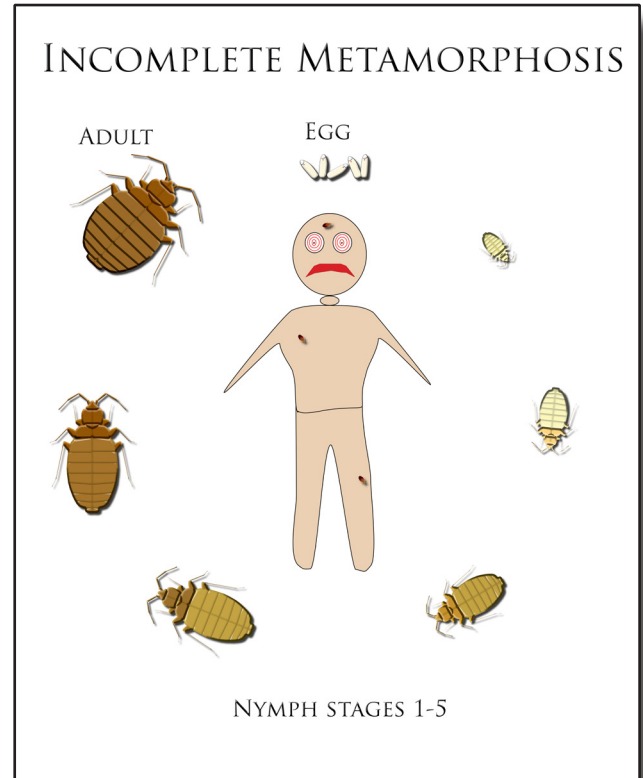


Fig. 3. Bed bug (*C. lectularius*) life cycle: egg, 5 instars (immature stages), and adults. Bed bugs must feed in order to molt to the next developmental stage, and for reproduction.

Bed bugs go through 5 immature stages called instars. Every stage must feed in order to molt to the next stage of development. Adults must feed to produce eggs and sperm. Later instars and adult bed bugs can survive for well over a year without feeding if conditions are favorable (Table 1).

Survival of Bed Bugs in Days After Feeding		
Stage	50°F	80°F
1st Instar	275	28
2nd Instar	399	46
3rd Instar	413	71
4th Instar	433	73
5th Instar	485	40
Adult Female	425	87
Adult Male	402	43

Table 1. Bed bug survival between blood meals in days after feeding (data adapted from Pinto, 2007³).

Bed bugs reproduce via "traumatic insemination." Unlike traditional fertilization, male bed bugs will pierce the females body cavity with its copulatory organ and deposit sperm into the body cavity. Females have a specialized organ (mesospermalege) under their hard outer shell that accepts sperm and translocates it to the ovaries. Mated females begin laying eggs 3 to 6 days after fertilization, and can lay 200-500 eggs over a life span of 6 to 18 months. On average, bed bugs lay 5 eggs per week. Eggs are oval-shaped and white, and are about 1mm long--visible to the unaided human eye (Fig. 4). Eggs take 7 to 10 days to hatch, and can be resistant to insecticide treatment. At the least, bed bug egg biology makes a second insecticide treatment necessary 2 weeks after the first. Because



Fig. 4. Bed bug (*C. lectularius*) eggs (~ 1mm long)¹.

of the number of eggs laid per week, populations can grow into the thousands in just one month!

As with some other insects, all life stages can be found living in large groups (Fig. 5), but bed bugs may live solitarily, too. In addition to cast skins from molting, "blood" droplets can be an indication of a bed bug infestation (Fig. 6). After each blood meal, bed bugs excrete reddish-brown/purple-blue fecal spots on or near the host, or in their daytime hiding places. There are several species in Utah within the order Hemiptera and family Cimicidae that can be mistaken for bed bugs, including: 1) bat bug (*Cimex pilosellus*), 2) barn swallow bug (*Oeviacus vicarius*), and 3) poultry bug (*Haematosiphon inodorus*). The treatment of these species is different than for bed bugs, so have the specimen identified before planning a control strategy.

Bed Bug Behavior

Bed bugs are secretive, nocturnal insects that emerge from hiding places at night to feed on nearby hosts. Although bed bugs are wingless, they can travel over 4 feet per minute, and travel an average of 20 feet in search of food. In extreme cases, bed bugs have been



Fig. 5. Immature and adult bed bugs often huddle together.¹

recorded traveling over 60 feet in search of food. Host searching occurs in three stages: 1) random searching, where bugs walk around searching for a host or chemical/physical host cues, 2) CO₂ gradients allow bed bugs to find their way toward a carbon dioxide-exhaling host, and 3) host body temperature will attract bed bugs once in close proximity. The bed bugs will test the host until a suitable blood vessel is found, which may lead to multiple bites from the same bug. In the absence of human hosts, bed bugs can survive on blood meals from household pets or rodent pests.

Bed bugs prefer to feed on exposed bare skin (face, neck, shoulders, arms, hands, etc.). If left undisturbed, a bed bug can obtain a full blood meal in 3 to 5 minutes, but averages about 15 minutes. After feeding they will quickly retreat into hiding. They are sensitive to movement, and will withdraw their mouthparts if disrupted,



Fig. 6. Bed bug fecal spot.¹

and feed in a new location once the disruption has stopped, which also leads to multiple bites. Individual bed bugs do not feed every night, but must feed before each molt. Typically, nymphs and adults feed every 5 to 7 days if blood is available. Optimal feeding temperature is 80°F, but they can feed when temperatures are below 50°F. Bed bugs can live a long time without feeding, so vacating a residence to "wait them out" is usually not an option (Table. 1).

During the night, bed bugs are likely hiding in enclosed places such as along furniture seams, headboards, night stands, even under wall paper or in wall cracks. Because bed bugs are relatively flat and small, they can fit into almost any space, going undetected without careful inspection. They can infest all rooms in a house, not just a bedroom. Recent data from 16 infested one-bedroom apartments shows where bed bugs prefer to hide⁴:

- 60% in box springs
- 22% in mattresses
- 13% in sofas and chairs
- 4% in bed frames
- 1% in other areas

Given the bed bugs' small size they can be easily transported on clothing, luggage, cleaning/maid carts, furniture, etc. Within a home, they can be easily transported around in clothes, blankets, etc. If you decide to move to the couch or recliner to take nightly refuge, they will follow you! They can move from room to room, or between apartments or hotel rooms via wiring and pipes in wall voids, especially if repelled by a pyrethroid application, or if seeking food in the absence of their primary host (you).

Bed bugs are also unknowingly being spread. In particular, refurbished mattress sales, second hand stores/garage sales, furniture rental companies, and moving van rentals are all places to pick up an infestation of bed bugs. Always inspect second hand or refurbished furniture/beds, and rental furniture for bed bugs.

Medical Importance

Bed bugs are parasites that generally do not kill the host; however, heavy infestations can weaken small animals, such as pets. Bed bugs can carry a number of human pathogens, fortunately, there is no evidence that bed bugs transmit diseases. Typically, humans do not notice bed bug feeding at first because it happens during the night. Over 2-7 days, the bite area may itch, swell, burn, become inflamed, or form a welt. Effects of a bite vary with the individual, but may persist for a week or more in susceptible persons. Symptoms may worsen with multiple bites, although some people have no adverse reaction to bed bug bites.

Often bed bug bites are attributed to other insects or

spiders and may go unnoticed for a long time. As a result, populations can get quite large before they are detected. It is important to recognize not all bites are caused by bed bugs. An infestation is confirmed by finding actual bed bugs, which may take a professional. The chances of encountering bed bugs increases with travel, staying in hotels or buying used furniture. Bed bugs should be suspected if you wake up with red, swollen bites you did not have when you went to sleep, or notice itchy bumps on skin that are exposed at night.

Control

As an owner of a pest control company you should never guarantee the elimination of bed bugs. On average, only 50% of control programs will eradicate bed bugs. Bed bugs are probably the most difficult household pests to eradicate because of their unique biology, and because the only acceptable treatment level is 100%. This is not the case with most pests, where some level of tolerance is usually acceptable.

Successful control begins with education for both the client, the pest control operator (PCO), and the pest control company owners. At the least, this fact sheet should be carefully studied by all parties and distributed/interpreted to clients during your first meeting. For a more thorough discussion on all aspects of bed bugs and their management, purchase a copy of "The Bed Bug Handbook", and keep up with new information in Pest Control Technology (PCT) and other journals. One of the biggest barriers to successful control is lack of knowledge of bed bug biology, and the intense techniques that must be employed for a successful program. Education will help break down that barrier.

Steps to a successful bed bug control program include:

- 1) verbal or written education for you and your client
- 2) work with the client to develop a management plan; you must have understanding and cooperation from the client and all involved parties (tenants, etc.)
- 3) thorough inspections before every treatment and at least 2 weeks after the final treatment
- 4) combining traditional insecticides and Integrated Pest Management (IPM) tactics
- 5) one follow-up visit about 2 weeks after the initial treatment, more may be necessary for eradication
- 6) thorough documentation/record keeping
- 7) develop a plan to eliminate reintroductions

Inspections

Control begins with inspections. With a thorough inspection you can locate bed bug populations in advance and know where to treat, decreasing treatment times. A proper inspection should include thorough note-taking and documentation. Taking photos of inspected areas can also be beneficial. See Table 2 for a list of items that should be carried in your bed bug inspection tool kit.

Inspection Toolkit
- pliers
- screwdrivers (flat and phillips)
- latex gloves
- one-piece jump suit will minimize the likelihood of bed bugs getting into your clothes
- flash light/head lamp
- magnifying glass, or hand lens
- collection jars (collect specimens and send the UPPDL for identification)
- a partner for lifting heavy furniture
- knife
- crowbar
- camera
- notebook and pen, or pre-made inspection worksheet
- electricity/outlet tester
- ladder
- pressurized air can for spraying in small cracks

Table 2. Items a pest control operator should carry for conducting thorough inspections.

To start an inspection, talk to the residents and see if they can direct you to populations of bed bugs, etc. This can save time. Once inside, inspections involve more than removing bed linens and looking at the mattress seams (see the common hiding places of bed bugs in the "Bed Bug Behavior" section). You must search everywhere! From a "popcorn" ceiling, to under paint or wallpaper chips, beneath the dust screen on the underside of box springs, staple holes on the box springs, all furniture, electrical outlets, behind baseboards, picture frames, stereo equipment, and even the tack strip under the carpet--this is not an exhaustive list! When inspecting, look closely for adults, immatures, eggs, shed skins, and fecal spotting. High populations of bed bugs can have a coriander-like aroma.

Bed bugs are very difficult to detect. Even a thorough inspection that yields no visual counts can be grossly incorrect. Table 3 shows how misleading a thorough visual inspection can be. In the table, visual counts are compared to counts taken from "interceptors" created by the

authors of a recent publication⁴. In addition to greatly improving detection rates during inspections, they also help in your control program by catching bed bugs that your treatments miss.

# of bed bug traps	Furniture type	# of bed bugs in traps	# of bed bugs in visual inspection
10	Bed, sofa	411	102
8	Bed, sofa	41	2
4	Bed	21	1
4	Bed	38	6
4	Bed	8	3
4	Bed	90	22
8	Bed, chair	43	7
6	Sofa	1103	166

Table 3. Comparison of bed bug visual and interceptor bed bug counts. (Data adapted from Wang et. al, 2009⁴.)

Remember to not bring bed bugs home with you or in into your vehicle. Put work clothes in a sealed plastic bag after the inspection and launder/dry clothing on the hot cycle ASAP. Repeat the inspections every 2 weeks or monthly. Provide a final inspection 2 weeks after the final treatment. Just because you don't see anything doesn't mean you have eradicated every bug. Even thorough inspections by trained professionals and bed bug scent hounds can miss bed bugs.

Insecticide Considerations

Most of today's insecticides are not effective for killing bed bugs. The long-residual chemicals of the past are either off the market, or are not registered for indoor use. Unfortunately, most bed bug populations are already showing resistance to pyrethroid (group 3A) products (i.e., cyfluthrin, cypermethrin, deltamethrin, fenvalerate, permethrin, pyrethrins, etc.), largely because their mode of action is closely related to that of DDT (group 3B), which was heavily used for bed bug control. Both groups are known as sodium channel modulators (group 3).

The problem today is that the majority of the insecticides available for indoor use and on mattresses are pyrethroid based (group 3A). These are contact insecticides that generally lose effectiveness once they dry. In Utah there are about 360 products with bed bugs on the label; about 240 of those are labeled for use on bed bugs AND mattresses. Most of those products are pyrethrin based, and not very effective killers of bed bugs. In fact, evidence is showing that pyrethroid insecticides may actually be repelling, or spreading bed bugs into new areas.

There isn't much data on the efficacy of individual products for bed bug control, e.g., one insecticide is better than another. One active ingredient being used with moderate success (33%-50% effectiveness) is chlorfenapyr. It is a good idea to use multiple formulations of insecticides. Use aerosols to get into small hiding places like behind baseboards; use pyrethroid, or non-pyrethroid dusts in difficult-to-reach spots such as behind electrical outlet plate covers (turn off electricity before making this application); use liquid sprays on baseboards, mattresses, box springs, and other easily accessible areas.

The use of "bug bombs" or fogs is NOT recommended. These products do not get into cracks and crevices to kill bed bugs, and may actually repel bugs into adjacent living spaces. The only insecticidal treatment proven 100% effective at eliminating bed bugs with one treatment is whole structure fumigation. The most commonly used gas for this is Vikane. This gas is different from that in "bug bombs." It easily penetrates into wall voids, small cracks, furniture, clothing (everything), for total kill. The gas concentration and temperature are monitored to ensure that all adults, immatures, and eggs are exposed to a lethal dose. The drawback to this method is expense, and difficulty applying to large structures.

Low-hazard materials such as diatomaceous earth, silica gel, and ground limestone can be effective supplements (or replacements) for pyrethroid insecticides. These products are useful because bugs can not develop resistance to them. They act mechanically on insects by "cutting" the waxy cuticle layer on the outside of their body. A bed bug that walks through the dust will die within 2 weeks. A recent study compared two bed bug control methods: IPM tactics plus diatomaceous earth (DE) and bed bug traps, versus IPM tactics and chlorfenapyr. IPM tactics for both treatments were the same: mattress and box spring encasements, hot steam treatments, and textile laundering. The IPM plus DE and traps was more effective than using IPM plus chlorfenapyr spray. The use of diatomaceous earth is highly recommended as a primary or additional product in any bed bug program. Other materials including botanically derived sprays and oils may also be used, however their efficacy has not been tested.

Using only chemical sprays will not likely eradicate bed bugs. Practicing Integrated Pest Management (IPM) will lead to a higher percentage of successful programs. See Table 4 for a list of IPM-based management techniques.

IPM Tactics for Bed Bug Control
- client and PCO education
- inform clients and involved parties of their responsibilities up-front
- clients must launder all textiles weekly, especially before inspections and treatments and store in garbage bags or air-tight containers
- residences should be prepared for inspection/treatment in advance, which includes laundering textiles, emptying drawers, cabinets, and cleaning clutter that may obstruct successful inspection or treatment
- use bed bug-proof mattress and box spring covers after first treatment (make sure covers are tested and approved for bed bugs--not all covers are effective--Protect-A-Bed is one approved brand)
- vacuum carpets, furniture, drapes, etc. before treatment; make sure not to transport bedbugs in vacuum
- minimize clutter, especially items stored under the bed
- repair the house to minimize harborage sites for bed bugs and eggs
- create a management plan to stop the reintroduction of bed bugs after a successful treatment
- purchase or construct monitoring traps to obtain a more accurate estimate of densities
- heat and cold treatments are also somewhat effective
- inspect before and after every treatment
- insecticide treatments using multiple formulations: liquid, dusts/gels, and aerosols

Table. 4. Integrated Pest Management (IPM) tactics for bed bug control.

Bed Bug Monitoring

There aren't many effective devices for monitoring bed bugs. One device, however, is fairly inexpensive and will allow you to monitor for bed bugs before and after treatments, as well as supplement personal and professional control efforts. Climb-up bed bug interceptors can help isolate your bed or furniture from bed bugs remaining in your house (Fig. 7). Furniture legs can be placed in the middle of the interceptor, in addition to a layer of diatomaceous earth for insecticidal action.

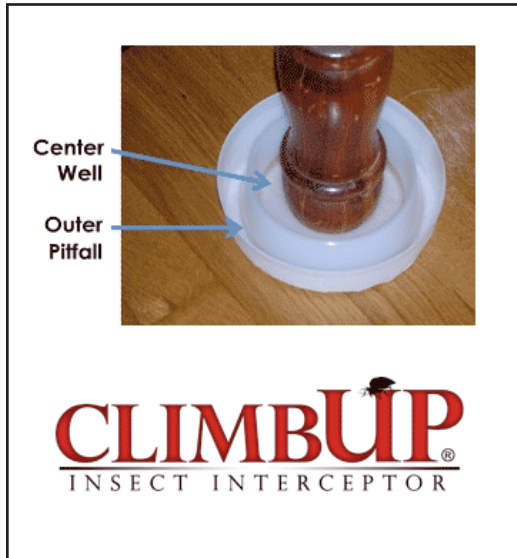


Figure 7. Bed bug traps can be a beneficial addition to your bed bug management strategy⁶.

Bugs trying to crawl up or down the bed will be caught in the slick-sided device. You can check the devices daily to monitor bed bug activity. If you do not want to purchase these, you can make one on your own. Please read Wang et. al, 2009 a³, b⁴ for directions on constructing this device.

Conclusions

Bed bugs are one of the most difficult structural pests to eliminate, and cannot be eliminated by traditional, insecticide-based methods alone. Education for pest control company owners, technicians, and clients is necessary for successful treatment. Additionally, cooperation between the pest control company, the client, and all involved parties is critical for success. Bed bugs are designed to survive. Their ability to hide, find hosts, survive insecticide treatments, and live long periods between feeding make them especially difficult to control. A minimum of two treatments, 14 days apart is mandatory for bed bug control, but more are usually needed. Inspect before every treatment and 2 weeks after the final treatment. Use multiple formulations of registered insecticides in conjunction with the IPM tactics listed above, and the interceptors described above for maximum effectiveness.

If you have questions, contact the Utah Plant Pest Diagnostic Lab by phone: 435-797-2435, or visit our website at: www.utahpests.usu.edu.

Further Reading

- ³Pinto, L.J., Cooper, R., and Kraft, S.K., 2007. Bed bug handbook: the complete guide to bed bugs and their control. Pinto and Associates, Mechanicsville, MD.
- ⁴Wang, C., Gibb, T., and Bennett, G.W., 2009. Evaluation of Two Least Toxic Integrated Pest Management Programs for Managing Bed Bugs (Heteroptera: Cimicidae) With Discussion of a Bed Bug Intercepting Device. *Journal of Medical Entomology*, 46(3):566-571. Entomological Society of America.
- ⁵Wang, C., Gibb, T., and Bennett, G.W., 2009. New interceptors assist in bed bug monitoring: New research examines the effectiveness of interceptors. *Pest Control Technology*, April, pg. 118
- ⁶http://www.bedbugsupply.com/Climbupamprtrade-Insect-Interceptors_p_22.html#. Accessed January 8, 2009.

Picture Citations

- ¹ Images courtesy of Gary Alpert, Harvard University, Bugwood.org.
- ² Images courtesy of Joelle Olson, Ecolab, St. Paul, Minnesota.

Precautionary Statement: All pesticides have benefits and risks, however following the label will maximize the benefits and reduce risks. Pay attention to the directions for use and follow precautionary statements. Pesticide labels are considered legal documents containing instructions and limitations. Inconsistent use of the product or disregarding the label is a violation of both federal and state laws. The pesticide applicator is legally responsible for proper use.

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