

From Detection through Protection: Solutions for Fighting Bed Bug Infestations

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Introduction: Bed Bug History & Resurgence

Sixty years ago bed bugs were virtually eradicated from the U.S., due mainly to the use of DDT – a once-common insecticide. Following the United States ban of DDT in 1972 by the EPA, bed bugs started to re-emerge by the late 1990s. Feeding exclusively on blood, bed bugs are carried from one location to another in and on the luggage and other personal belongings of travelers. Because bed bugs are transferred via infested personal belongings, it is impossible to prevent their entry into facilities.

Bed bug populations have again begun to flourish due to lack of public awareness, increased travel (domestic and foreign) and the discontinuation of traditional insecticides. The National Pest Management Association reported a 71% increase in bed bug-related calls from 2000 to 2005. In response to the resurgence, lawmakers in Hawaii, Phoenix, Boston and San Francisco have either passed laws or have pending legislation to address the issue. While bed bugs have not been shown to transmit diseases, these tiny, nocturnal, bloodsucking insects can seriously harm businesses by upsetting customers, generating bad publicity or, worse, triggering legal issues.

When addressing bed bug issues, property managers need to be aware that avoidance or inaction can have an exponential effect on the harm done to their business. For example, some hotels have spent \$60,000 to treat advanced infestations.¹ This does not include the lost revenue while rooms were down for treatment. Bed bug infestations have also triggered a variety of high-profile lawsuits – some seeking high damages. In one case, a federal judge upheld a \$382,000 award to a brother and sister who were attacked by bed bugs in a Chicago motel.² Proper treatment of bed bug issues will ultimately minimize property managers' liabilities and protect their image.

Objective: To Study the Effectiveness of Various Detection and Treatment Methods

Many new products and treatment options are being explored to combat the bed bug resurgence. The objective of this paper is to compare and contrast current treatment programs and detection methods as well as to provide expert recommendations on protocols and services available to control bed bug populations. The paper will begin with a look at the unique biology of bed bugs, followed by a comparison of common inspection and treatment methods, along with some of today's alternative treatment methods available.

Biology and Behavior: Why Bed Bugs Are Hard to Eradicate

Bed bugs are nocturnal human parasites. They feed exclusively on blood and prefer humans to other potential hosts. Roughly 20% of humans display an allergic response (often described as a red, itchy bump or wheal) to bed bug bites. An allergic response may be apparent in a few hours or appear up to two weeks after exposure.

After hatching out of the egg stage, bed bugs go through a series of five molts before reaching adulthood. A blood meal (feeding) is required to molt from one stage to the next. Complete development from egg to adult takes approximately 6-8 weeks. Females produce an average of eight eggs per day and up to 500 in a lifetime.

Bed bugs avoid light and prefer to reside in tight cracks and crevices near a potential host. Feeding typically occurs between 3 a.m. and 5 a.m., when there is little disturbance or movement. At room temperature (~70 °F), bed bugs can live from four to six months without a blood meal – and even longer at cooler temperatures. Due to their reclusive nature, it is difficult to inspect for and treat bed bug infestations. And since bed bugs are transferred via infested personal belongings, it is not possible to prevent their entry into facilities.

Bed Bug Inspection and Detection Methods

There are three commonly used methods for identifying bed bug populations, each with unique costs, benefits and challenges.

A. Canine Inspection Services

Dogs can be trained to inspect potentially infested areas based on a characteristic scent emitted by bed bugs. Companies that market canine inspection services highlight the speed of service and their ability to detect light infestations (less than 10 bugs) that could possibly be overlooked by humans, or those located within wall voids or other inaccessible areas. There are several companies that offer canine inspection services; however, there are only a limited number of well-trained dogs and handlers available. NESDCA (National Entomology Scent Detection Canine Association) is a certified association that has been established by the University of Florida's Department of Entomology, to ensure canine detection services are working according to industry-driven standards.

Though using canine units can be somewhat efficient, there are practical limitations, too:

- ▲ Positive identification of bed bugs by dogs depends on air flow, temperature and humidity.
 - Air flow will often dilute scents emitted by the bed bugs and may cause active infestations to be overlooked.
 - Fluctuations in temperature and humidity can also affect the volatility of the scent, making it more difficult to detect.
- ▲ Dogs may or may not be able to confirm active versus old or inactive populations.
- ▲ Many canine services require the use of two trained dogs to account for the failure rate present when using only one dog – increasing costs.
- ▲ There is no evidence to show that routine canine inspections are more or less effective at identifying an infestation, compared to a trained, licensed professional or your property staff.
- ▲ Even if a trained canine detects bed bug activity, it may not be able to identify where the infestation is located.
- ▲ Canine inspections do not provide long-term protection against frequent or new introductions of bed bugs, and a traditional treatment schedule is still required to eliminate infestations once they are detected.

B. Visual Inspections

Due to the challenges and expense of canine services, visual inspection continues to be the most practical and cost-effective way to detect bed bug activity. With adequate education from a Pest Management Provider (PMP), onsite property staff members – due to their proximity and the frequency of their daily tasks – are the most effective line of defense against bed bugs. They can spot bed bug activity before customers notice it. However, when bed bug activity is identified, a trained professional from a PMP should be contacted to provide recommendations on treating the infestation. Certified professionals should also be called upon to conduct visual inspections when activity is suspected but has not been confirmed. By communicating frequently with a PMP, a facility can address concerns before they become larger problems.

C. In-Room Monitors

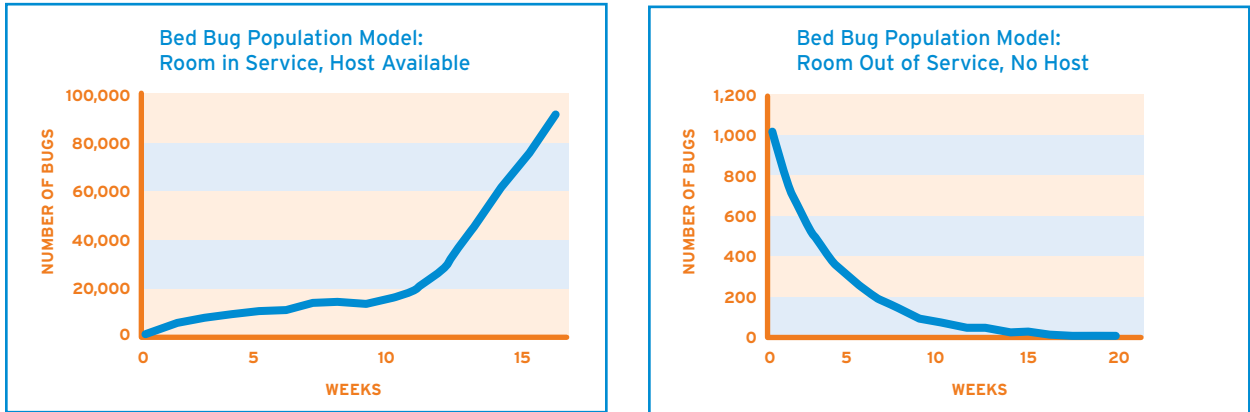
Bed bug monitors have been developed as in-room devices that are designed for detecting, monitoring and trapping bed bugs. The monitors use CO₂, heat and/or pheromones to attract bed bugs to the device, and glue or pitfall traps to catch the insects.

On their own, in-room bed bug monitors will not eradicate a bed bug infestation or even significantly reduce the population. In an independent study conducted at Purdue University, a bed bug monitor (utilizing CO₂, heat, pheromones and a pitfall trap) was left in a room with 1,000 bed bugs for 12 days. The unit trapped just 6% to 12% (0.5% to 1% daily catch rate) of the initial bug population – and this was without human interaction acting as a competing attractant.

Current monitors are designed to be placed under or next to a bed or near the headboard. Due to the infrequent feeding cycles and elusive nature of bed bugs, these monitors cannot guarantee 100% detection of a small infestation within a short period of time (see the following population model graphs). Because catch rates are low, even in heavily infested rooms, the monitors are intended to remain in the room at all times. Such devices may be alarming to guests and will not prevent them from being bitten.

Other independent industry research has shown that due to the slow-moving, cautious nature of bed bugs, pitfall traps and glue boards were not effective. The following models demonstrate the impact of a bed bug monitor trap on a bed bug population. When the room is left available for use and with a trap in place 24/7, the beginning population of 1,000 bed bugs can increase to 100,000 in 15 weeks. If the room is closed down and there is no host available for feeding, complete population control would take an estimated 20 weeks (assuming the unlikely event that all bed bugs are attracted and caught).

BED BUG MONITORS - EFFECT ON POPULATION



These models demonstrate how, even with a monitor trap in place 24/7, bed bug populations can explode – increasing from 1,000 to 100,000 in 15 weeks when a room is left available for use.

Model Assumptions:

- ▲ Initial population is ~1,000 bed bugs
- ▲ 5% daily catch rate (5 times higher than independent studies have shown)
- ▲ Room kept open (available for use) and trap in place 24/7
- ▲ Room closed (unavailable for use) and trap in place 24/7
- Assumes unlikely scenario that every bug is attracted and will be caught

In-room monitors can certainly alert facility personnel to the presence of bed bugs, but cannot identify how large the infestation is or where it may be located. Monitors pose other practical challenges as well. Daily service of the unit is required and live bed bugs are present in the device when caught – making handling the unit difficult for property staff and causing concern among room occupants and employees. Due to the sound generated by some of the units, their size, and the service required, most managers have stated that they would only allow the use of such a device if a room were unoccupied – eliminating any true effectiveness for proactive monitoring.

Traditional Treatment Methods

There is a lively debate in the pest control industry regarding the ideal bed bug treatment protocol. In this section, we analyze traditional treatment methods (multi- vs. single-treatment protocols), along with the importance of inspecting and treating adjacent rooms.

A. Multi- vs. Single-Treatment Protocols

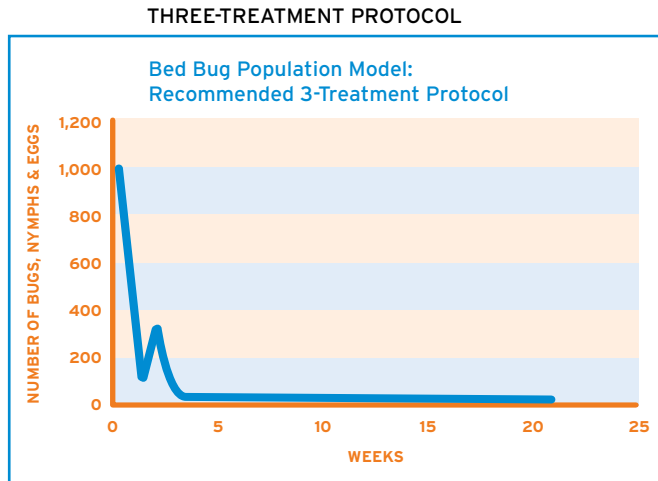
Due to the biology and behavior of this insect, most pest control professionals and industry sources agree that multiple treatments are necessary to control active bed bug infestations. Rationale to support a multi-treatment protocol includes:

- ▲ A direct treatment application to the bed bug is ideal. However, bed bugs (adults and eggs) are often located in areas that are difficult to reach with either chemical or non-chemical control measures. In addition, bed bugs are highly tolerant of insecticides. Multiple treatments will increase the likelihood that bed bugs will contact a treated surface and obtain a lethal dose.
- ▲ Some products currently labeled for bed bugs provide poor residual control and thus a treatment must be undertaken at a time after the initial application to directly treat the newly emerged nymphs. (Bed bug eggs hatch within 7-10 days at room temperature.)

When combining the challenges of product efficacy with reduced service visits and fewer opportunities to identify resurgence in activity, single-treatment protocols compromise the overall success of the program. A multi-treatment protocol is effective because it is designed to target both the reproductive life cycle and the behavior of bed bugs.

The following test models illustrate the rationale for adhering to a multi-treatment protocol. They compare a single-treatment protocol to the recommended multi-treatment protocol and reveal what could occur if a critical treatment step is skipped:

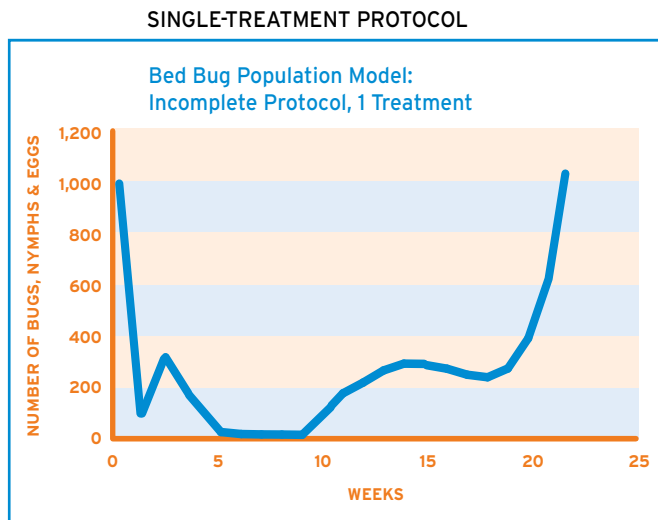
The **recommended, multi-treatment protocol** is modeled to be the most effective solution for controlling bed bug populations.



Model Assumptions

- ▲ Initial population is ~1,000 bed bugs (all life stages)
- ▲ Product is equally effective against all life stages
- ▲ Product efficacy degrades over time:
 - Day 0, 100% (effective)
 - Week 1, 90%
 - Week 2, 75%
 - Week 3, 50%
 - Week 4, 25%
- ▲ 90% coverage of residual treatments during service (allows for potential to miss spots)

The model for the **single-treatment protocol** demonstrates how the efficacy of the program can be jeopardized if critical treatment steps are eliminated. This graph shows the predicted effect on a bed bug population if only one treatment is completed.



Ecolab's conclusion: If one or more treatment steps are skipped, the efficacy of the bed bug treatment program may be jeopardized. The main reason why single-service protocols fail, is that any nymphs or adults that survive the initial treatments may continue laying eggs. A multi-service protocol, on the other hand, provides consistent efficacy, even in worst-case scenarios. It also allows for unknown variables such as inadequate coverage of product (missed spots), and bugs hiding deep within recesses.

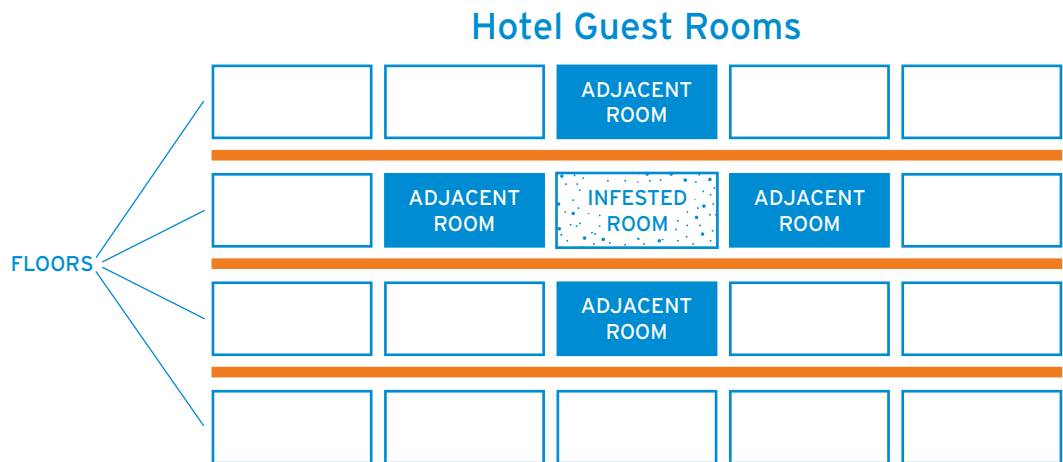
The condensed nature of single-treatment methods increases the risk that bed bug populations will rebound. A single service is likely to fail due to limited product efficacy (both chemical and non-chemical practices), likelihood of product degradation, and the potential to overlook critical areas.

Additional support from independent sources confirms that multiple treatments are needed:

- ▲ **North Carolina State** – “Many times the first application does not seem to give complete or immediate control. Additional treatments may be necessary in 1 to 2 weeks.”
- ▲ **University of Minnesota** – “Approximately two weeks post inspection, another inspection of the premises is required to confirm that all bed bugs were eliminated. This inspection must be as thorough as the preliminary inspection, and if bugs are found again, control procedures must be repeated.”
- ▲ **Armed Forces Pest Management Board** – “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 precisely target the treatment of any continued infestation.”

B. Inspection & Treatment of Adjacent Rooms

As recommended by the National Pest Management Association, all adjacent rooms (above, below, and to the sides) should be inspected and treated in addition to the infested room (see figure below).



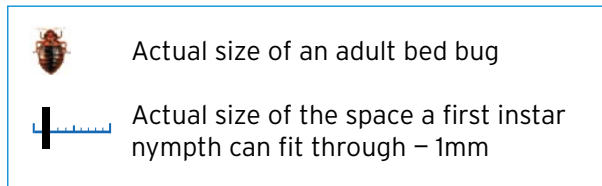
Health departments, research institutions, government organizations and pest experts around the globe recognize the need for adjacent room protocols as well:

- ▲ **State of Nevada** – “Bed bugs can wander between adjoining apartments through voids in walls and holes through which wires and pipes pass.”
- ▲ **San Francisco Department of Health** – “Owners and operators should instruct PMPs to inspect all rooms adjacent to bed bug infested rooms and treat the rooms for bed bugs.”
- ▲ **University of Kentucky** – “Since bed bugs can disperse throughout a building, it often will be necessary to inspect adjoining rooms and apartments.”
- ▲ **City of Boston** – “...must treat all horizontally and vertically adjacent units to the infested unit(s).”

- ▲ **Bed Bug Handbook** (Pinto, Cooper and Kraft) – “Bed bugs also wander into other rooms and even migrate to other floors by walking through wall and ceiling voids, or along pipe and wire chases...Expand the inspection to include the rooms or apartments adjacent to the infested site, and to those rooms directly above and below.”
- ▲ **Australian Environmental Pest Managers Association** (Doggett) – “A room site plan should be drawn showing the location of any activity. The room inspection should be as methodical as possible, noting all sites of bed bug activity on the site plan. The adjoining rooms should be listed. In any infestation, adjoining rooms and spaces, both either side and above and below, should be inspected.”

There are five principal reasons for treating adjacent rooms:

- ▲ The reclusive nature of bed bugs causes them to seek harborage in cracks and crevices – spaces as small as 1mm. This behavior allows them to easily migrate through wall and ceiling joints that may appear seamless.



- ▲ According to industry research presented at the 2007 Entomological Society of America annual meeting, there is up to a 25% chance that adjacent rooms will also harbor bed bug populations.
- ▲ Housekeeping staff and their equipment are “carriers” between infested and non-infested rooms.
- ▲ The repellent nature of some available treatment products may cause bed bugs to migrate.
- ▲ Properly treating a bed bug infestation will help reduce liability risk with guests.

Alternative Treatment Methods

In addition to the traditional insecticide treatments, pest control companies are using a variety of alternative methods to combat the bed bug problem – everything from extreme heat to mattress encasements. The results are mixed.

A. Heat

Exposure to extreme temperatures, including heat, is lethal to all life stages of bed bugs. Effective control is based on the temperature achieved and the length of exposure. According to a study conducted by Insect Control Research Laboratories in July 2004, temperatures of 115°F must be held for at least four hours in order to effectively kill all bed bug life stages. (See table below.) This lethal temperature is difficult to achieve due to concrete slabs, a common floor material, which typically absorb the heat.

	< 100° F	115° F	> 130° F
Bed Bug Adults	No mortality after 4 hours	> 4.0 hours for 100% kill	30 min. for 100% kill
Bed Bug Eggs	No mortality after 4 hours	> 4.0 hours for 100% kill	30 min. for 100% kill

Temperatures of 115°F must be maintained for at least four hours to kill all bed bugs – including eggs.

Source: Insect Control Research (July 2004)

Several methods which incorporate heat technology are currently available:

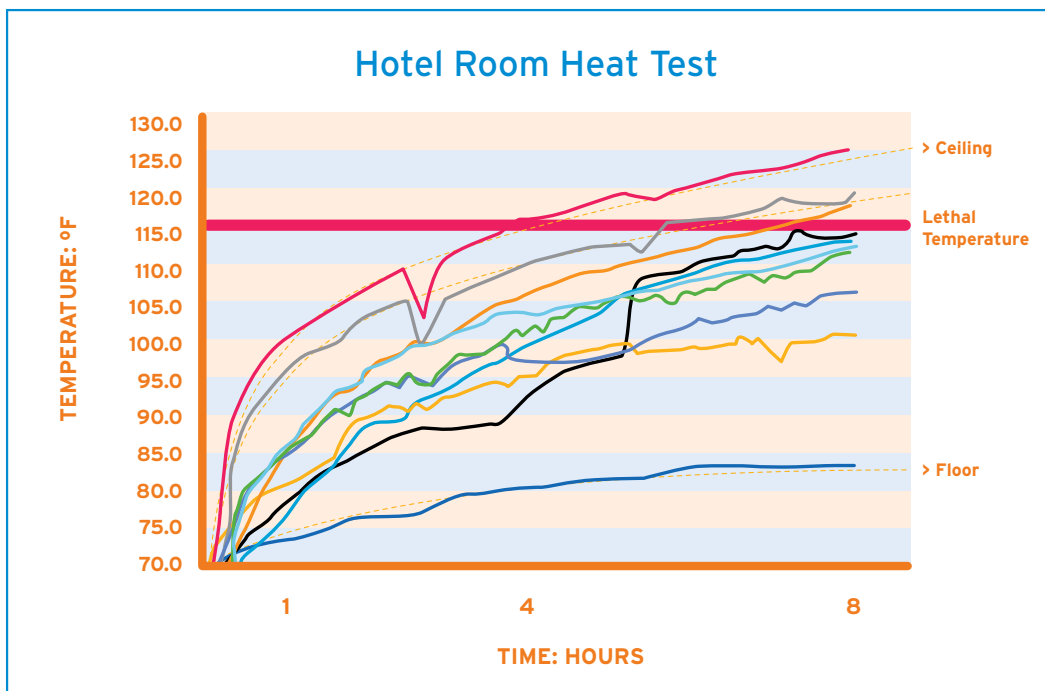
Off-site trailer heat

Trailer heat treatments require furniture to be removed from the infested rooms and transported to off-site trailers where the heat treatment is performed. The furniture is then returned to the rooms. Even if 100% mortality is achieved, this process can be inconvenient and labor intensive. It also poses the likelihood of spreading bed bugs to non-infested areas during transportation of the furnishings. In addition, evidence of an infestation on or in the furniture (dead bugs, fecal markings, etc.) may still be apparent after treatment – and the bed bug population in the room must still be eliminated by other means or the furnishings will become re-infested.

Whole-room, structural heat

Extensive industry research suggests that whole-room heat treatment is not a practical method for eradicating bed bugs in hotel rooms. Whole-room treatments are labor intensive and costly, due to the fact that heating an entire room to 115° for 4 hours demands tremendous amounts of energy. Field test research has also revealed hurdles such as protecting or removing sprinkler heads, potential damage to sensitive furniture items and overall ineffectiveness (see graph on next page). In addition, there is the possibility of forcing bed bugs to relocate to cooler locations – actually spreading the population to non-infested areas.¹ On top of all these difficulties, heat treatments alone offer no residual protection after service. If a single egg, nymph or adult survives, the room may become re-infested within a short time.

¹Potter, M., Romero, A., Haynes, K., and Jarzynka, T. "Bed bugs, heat, and hotel rooms" – Pest Control Technology, Oct. 2008



The temperatures of many critical harborage points in a hotel room did not achieve lethal levels after 8 hours of heating. Floor locations remained the coolest. These areas – under carpeting, behind baseboards, etc. – can be critical bed bug harborages.

Source: Ecolab Internal Test

In-room enclosed heat

Another method of heat application is an enclosed, in-room solution which circulates warm air throughout an insulated enclosure. Once set up in the room, the infested items are placed inside the enclosure and the unit is heated according to the lethal temperatures and times listed above. Clear benefits of this type of system include eliminating the transfer of infested items, possibility of reduced insecticide applications, and an opportunity to save infested furnishings from disposal. An effective enclosed heat system must be designed to minimize the opportunity for bed bugs to escape and allow for consistent heat distribution throughout the system. In-room enclosed heat technologies cannot be used as a stand-alone solution to controlling bed bug infestations. Traditional treatment methods must still be applied to areas outside of the system to account for the bed bug populations that may not be in the enclosure.

B. Steam

Steam treatment can be lethal to bed bugs. However, it must be applied directly to all life stages – including eggs – to be effective in eradicating a population. Plus, the “lethal zone” only extends 2 to 3 inches from the dispenser. Steam treatments alone are not practical in that thorough coverage and penetration of all bed bug harborages within box springs, mattresses and other soft good items is not possible. Bed bug eggs recessed deeply into cracks and crevices can survive. Another disadvantage of steam is the excessive wetting of mattresses or upholstery and the potential for damage to room furnishings. Applying steam is very labor intensive as well. And because it doesn't have long-term effectiveness, it should be combined with insecticides to provide residual protection in hard-to-treat areas.

C. Cold

Extreme cold treatment via the use of frozen CO₂ (Cryonite units) is lethal against all life stages of bed bugs. However, studies have shown that pests located beyond the 6-inch application distance can survive cold treatment. In addition, the force required to push the frozen carbon dioxide through the nozzle can actually dislodge and displace bed bugs to other locations, spreading the infestation. Similar to steam, cold treatment does not provide thorough coverage of bed bug harborage areas due to its small lethal temperature zone and inability to penetrate fabrics. And, it offers no residual protection in hard-to-treat areas, which could lead to a rebound in the bed bug population.

D. Over-The-Counter Consumer Products

Some consumer aerosol products can kill bed bugs if applied directly to the pests. However, most of these products provide temporary results only, with no residual protection. This makes them ineffective because the bugs are often only active and out of their harborage areas when searching for a host. Some may be completely ineffective, since suppliers are not required to provide efficacy data in order to label their products for bed bug usage. And, if applied incorrectly, these products may spread the infestation to other harborages within the room and may not interact well with products applied by a PMP.

E. “Proactive” Insecticide Treatments

In theory, preventative treatments for bed bugs would be ideal. However, due to the nature of how bed bugs are transported and the resilience of their life cycle, proactive services do not effectively reduce the risk of a bed bug infestation. Unlike treatments for other pests such as cockroaches and ants, there are no insecticidal treatments that will create an effective barrier against bed bugs. This is primarily because bed bugs don't crawl or fly in from the outside, but are carried into facilities on travelers and their belongings. Insecticide applications degrade quickly over time and would require routine product applications to be considered effective against bed bugs. For these reasons, many facility managers view these “proactive” treatments as expensive and unnecessary.

F. Bedding Solutions

Mattress & box spring encasements

Encasements can be custom-made to fit any mattress or box spring. Some brands have been laboratory tested and proven to prevent bed bug penetration into (or out of) the fabric and zipper end stop. Other brands have made similar claims, but – according to research presented at the 2007 Entomological Society of America meeting – have failed in outside laboratory studies.

Although encasements have been proven effective in preventing an infestation from spreading into or out of the encasement, installation is labor intensive. And it is possible to rip the encasements during installation or to have them tear over time, requiring costly replacement. Damage and wear to the box spring encasement is of particular concern. In fact, a 2009 study showed up to 85% failure (demonstrated by tears or holes) with the box spring encasement at one month post-installation at various hospitality facilities.¹ This creates liability concerns if a facility were to use the encasement to cover an infested mattress or box spring to avoid the cost of replacement, as even small rips or holes can allow bed bugs to escape back into the room, increasing risk to guests.

¹Ecolab installed 50 box spring encasements at various limited and full service hotels. There was an even mix of Kings, Queens, and Double bed sizes in the total sample.

At \$25 to \$80 each, protecting every mattress with an encasement can be a big investment. Many hotel operators don't believe they're worth the cost if used to protect the mattress from infestation. Though they may benefit locations with more frequent bed bug incidences, only the mattress will be protected, allowing the bed bugs to still infest other common harborage sites such as the box spring, headboards, carpeting, drapery and furniture.

Insecticide-impregnated fabrics

Some companies have developed bedding impregnated with insecticidal materials that they claim kill bugs on contact. Even if such products are 100% effective on contact, they will not control bed bug populations on their own. Traditional treatment protocols will still be required to combat bed bugs harboring in areas besides bedding. Additionally, such products will not prevent bed bugs from being introduced to a facility or infesting hard and soft goods (e.g. box springs, mattresses, headboards, night stands or seating). As with mattress encasements, insecticide-impregnated bedding is an expensive and impractical measure against preventing bed bug activity. Finally, there is additional concern regarding unnecessary occupant exposure to insecticide-impregnated materials.

Summary and Recommendations for Action

Although once thought to be virtually extinct in the U.S., bed bugs are now recognized as one of the most troublesome pests to the hospitality industry, and present risks to other industries where people reside for extended periods of time. There are increasingly more options to choose from with respect to bed bug treatments and detection. However, combined with good communication and a close partnership with a PMP, education of staff is still the most critical aspect of an effective bed bug program.

Property staff should be trained by a pest control provider to recognize bed bugs and signs of infestations and how to respond properly when bed bugs are suspected. Equipped with the knowledge of how to inspect for potential bed bug activity, a well-trained staff will serve as the most effective line of defense, by spotting bed bug activity before customers notice it.

The following is a detailed list of steps your organization should take in defending against bed bugs, as well as what should be expected of your pest control provider.

What You Should Do

- ▲ Thoroughly inspect incoming (used) furniture and wall hangings for bed bugs.
- ▲ Inspect rooms daily for bed bug activity.
- ▲ Repair any structural issues in rooms that may serve as bed bug harborages, such as loose wallpaper or cracks.
- ▲ If bed bug activity is discovered or suspected:
 - Immediately notify the supervisor on duty.
 - Leave the vacuum and linens in the room to prevent spreading bugs to other rooms.
 - Keep the room closed and do not allow occupancy.
- ▲ Contact your PMP for an inspection and/or treatment service.
- ▲ Communicate regularly with your pest management provider. Constant communication ensures that potential concerns are addressed before they become a larger problem.

What Your Pest Management Provider Should Do

- ▲ Provide a science-based, multiple inspection and treatment service to assure active infestations are identified and eliminated. One-time services are likely to fail because eggs may not completely be eliminated and critical areas may be missed.
 - Provide visual inspections conducted by trained professionals – still the most practical and effective means of bed bug detection.
 - Direct property staff on what to do with infested items.
 - Treat infested and adjacent areas with effective products and protocols that maintain the safety of guests/occupants.
 - Examine the room(s) and determine when occupancy is appropriate.
 - Continue to inspect and treat rooms during follow-up service to help ensure elimination is complete and that no eggs have hatched into live bed bugs. This step is critical to service success.
- ▲ Provide educational opportunities for property staff.
 - Comprehensive on-site education in team meetings or on an individual basis.
 - Laundry guidelines covering the proper procedure for handling linens that have come in contact with bed bugs.
 - Multi-lingual educational materials to ensure the property staff is informed on inspection procedures, warning signs and proper practices if bed bugs are found.

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Joelle F. Olson

Joelle Olson is a Senior Entomologist focusing on bed bugs for Ecolab's Pest Elimination Division. Since joining Ecolab in 2002, she has been involved in a variety of vital projects, such as insect rearing, training, product/equipment testing and project development – including protocol enhancements to the Ecolab Bed Bug Service. Joelle received her B.S. degree in Biology and her Master's degree in Entomology from the University of Minnesota – where she is currently working on her doctorate in Entomology, with a specific research focus on bed bugs. She has been a member of the Entomological Society of Minnesota since 2003.

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