From Detection through Protection: Solutions for Fighting Bed Bug Infestations

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Introduction: Bed Bug History and Resurgence

Sixty years ago, bed bugs were virtually eradicated from developed nations, due mainly to the use of DDT and other organochlorines and organophosphates— once-common insecticides used in the United States. In the 1990s bed bugs started to re-emerge, as more countries banned DDT (DDT was banned in the U.S. in 1972). 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 hitchhikers and are easily transferred via infested linen/clothing, used furniture, and other personal belongings, it is impossible to completely prevent their entry into facilities.

Bed bug populations have again begun to flourish due to lack of public awareness, increased travel (domestic and foreign), the discontinuation of traditional insecticides, and insecticide resistance. In a 2018 survey, The Professional Pest Management Alliance (PPMA) reported that in the prior year, 97% of U.S. pest control professionals treated for bed bugs, with a majority of respondents noting an increase in bed bug prevalence and service work from previous years[1]. Bed bug activity follows a seasonal pattern, with the highest rates of infestation occurring in the summer months and the lowest in winter; this is believed to be driven by both seasonal temperatures and rates of human travel.

In response to the resurgence of bed bugs, lawmakers have either passed laws or have pending legislation to address the issue. Although disease transmission has not been proven, 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[2]. 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 U.S. case, a federal judge upheld a $382,000 award to a brother and sister who were bitten by bed bugs in a Chicago motel[3]. In the UK, a prestigious London hotel settled a substantial bed bug claim out of court[4]. Proper treatment of bed bug issues will ultimately minimize property managers' liabilities and protect their image.

Objective: To Review the Various Detection and Treatment Methods

There are many products and treatment options available to combat bed bugs. The objective of this paper is to review current inspection and treatment practices as well as to provide expert recommendations on protocols and services. The paper will begin with a look at the unique biology of bed bugs, followed by a comparison of common inspection and traditional treatment methods, along with some of today's alternative options.

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 70% of humans display a response to bed bug bites[5]. The remaining portion of the population has no reaction to the bite, allowing the population of bed bugs to go unnoticed or unreported for long periods of time. Reactions to bites may be apparent in a few hours or days, potentially appearing up to two weeks after exposure. Severity of reaction to bed bug bites varies widely between individuals (ranging from minor inflammation to wheals that are painful, itchy, and may last for several weeks). In rare cases, bed bug bites may elicit a systemic allergic response[6]. Reactions to bed bug bites may resemble other arthropod bites or skin conditions. Therefore, diagnosing a bed bug infestation solely from supposed bite reactions is not possible.

After hatching out of the egg stage, bed bugs go through a series of five molts before reaching the adult stage. A blood meal (feeding) is required to molt from one stage to the next. Complete development from egg to adult takes approximately six to eight weeks but varies depending on environmental conditions and host availability. 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/22˚C), 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 can be difficult to inspect for and treat bed bug infestations.

1 https://pestworldmag.npmapestworld.org/2018/05/31/ppma-survey-highlights-bed-bug-prevalence-nationwide/
2 Business Week
3 Ihonline.com
4 dailymail.co.uk/news/article-429132/Lawyer-bitten-bed-bugs-sues-leading-London-hotel.html
5 http://www.pctonline.com/PCT1002_bedbugs.aspx
6. https://www.pctonline.com/article/pct1214-bed-bugs-bite-allergic-reactions/

Bed Bug Inspection and Detection Methods

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

A. Visual Inspections

Visual inspection continues to be the most practical and cost-effective way to detect bed bug activity. With adequate education provided by a Pest Management Provider (PMP), onsite 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 a guest complaint has been filed. However, when bed bug activity is suspected, a trained professional should be contacted to provide a thorough inspection and recommendation for treatment if necessary.

B. Canine Inspection Services

Canines can be trained to inspect potentially infested areas by detecting 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 (fewer than 10 bugs). 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 that certified canine detection services in the U.S. are working according to industry-driven standards. However, the accuracy rate of trained canines continues to vary significantly in the field (30% - 80%)[1], which is likely based on the level of training provided, the relationship between the canine and its handler, individual experience, location of the infestation and environmental conditions (airflow, temperature, humidity, etc.). Finally, 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 property staff.

C. Monitoring Devices

A wide variety of monitoring devices are commercially available which may detect and/or trap bed bugs. Active monitors use CO_2, heat, and/or chemical attractants to lure bed bugs to the device. Passive monitors use no attractants and instead rely only on the natural mobility of the bug by intercepting their pathways to and from the host. Some bed bug monitoring devices are connected and can collect data and send a digital alert when a bed bug has been detected. Other (unconnected) monitors require visual inspection to determine bed bug presence.

The recommended monitor design will depend on property- and situation-specific needs and considerations. For example, active monitors have the benefit of attracting bed bugs to them and may therefore be more effective in capturing bed bugs on a shorter timescale. However, they may require frequent lure replacement which can be costly and labor intensive. By contrast, passive monitors may require a longer timescale to capture bed bugs due to their lack of attractive lure, however they require less ongoing maintenance. Connected monitor designs have the benefit of minimizing the need for frequent device inspection, but may require a greater upfront and ongoing financial investment.

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 CO_2, 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. While bed bug monitors themselves cannot eliminate a bed bug infestation, they can aid in early identification of an infestation and/or provide assurance after treatment that an infestation has been eliminated.

D. DNA/Protein Analysis

Technology exists for identifying the presence of bed bug DNA or proteins in a specimen sample, or from the swabbing of a surface. After a surface swab or suspect insect/artifact is collected, results may either be available immediately or sample submission to an analytical laboratory may be required. It's important to note that while DNA/protein analysis can be bed bug specific, it cannot distinguish between an active versus a previous infestation. In addition, only samples that contain insect parts, cast skins or fecal material will be able to be positively identified.

Samples producing a negative result do not necessarily indicate a bed bug-free area. Therefore, bed bug DNA/protein analysis should not be used as a replacement for thorough visual inspections by a qualified, licensed professional.

1 Data presented at the 2014 Bed Bug Summit

Traditional Treatment Methods

Professional Application of Chemical Insecticides

In this section, we analyze traditional treatment methods (multi- vs. single-treatment protocols), the importance of inspecting and treating adjacent rooms, and potential for insecticide resistance.

■ Multi- vs. Single-Treatment Protocols

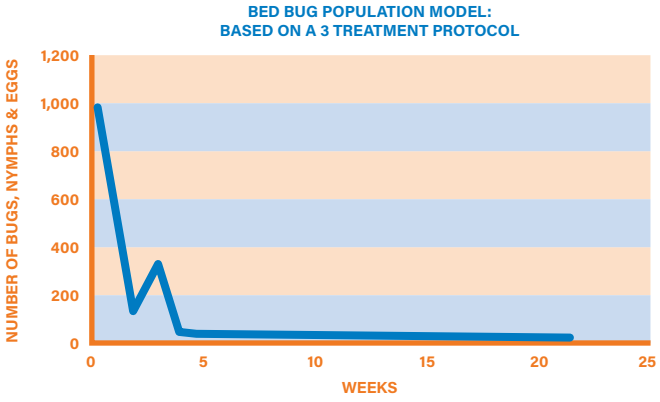
Due to the biology and behavior of this insect, most pest management providers and industry sources agree that multiple treatments are necessary to control active bed bug infestations[1]. Rationale to support a multi-treatment protocol includes:

- Direct contact of the product to the bed bug is ideal. However, bed bugs (adults and eggs) are often located in areas that are difficult to reach with chemical or non-chemical control measures. In addition, bed bugs can be tolerant of certain insecticides, particularly at low doses or short exposure times. 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 seven to ten 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 have a high risk of failure. A multi-treatment protocol performed by a licensed pest professional is critical to successful elimination.

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 or bed bug harborage area is missed:

THREE – TREATMENT PROTOCOL

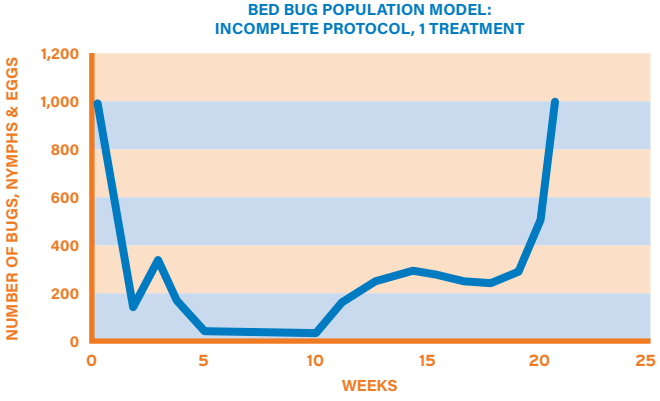


The **recommended, multi-treatment protocol** is modeled to be the most effective solution for controlling bed bug populations.

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)

SINGLE – TREATMENT PROTOCOL



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.

1 http://www.pestworld.org/all-things-bed-bugs/best-practices/guidelines/#bp1286

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 some stages of bed bugs may survive the initial treatments and continue laying eggs. A multi-service protocol, on the other hand, provides a thorough, consistent service, even in worst-case scenarios.

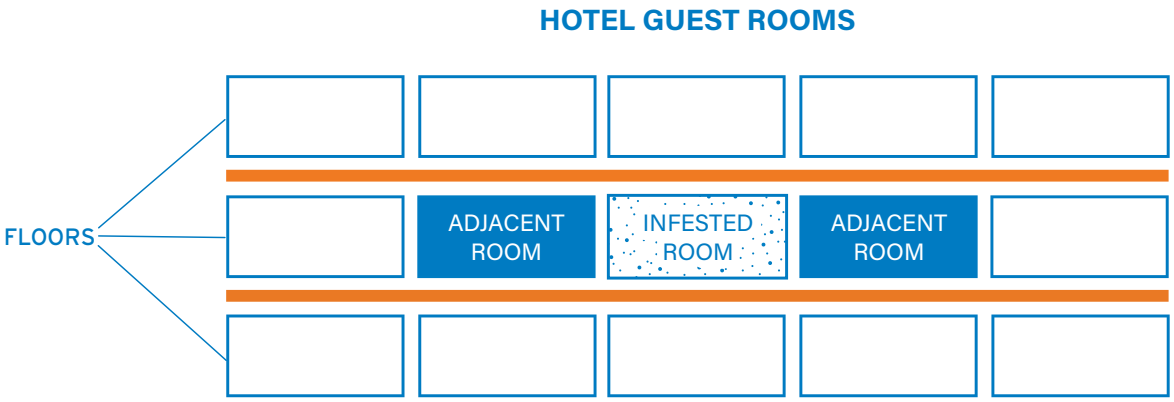
The condensed nature of single-treatment methods increases the risk that bed bug populations will rebound. A single service is likely to fail due to limited product efficacy (both chemical and non-chemical practices), likelihood of product degradation, and the potential to overlook critical areas.

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

- **Armed Forces Pest Management Board** — — "Re-inspection of infested structures and sites should be done about 10 to 21 days after any initial treatment, and (if needed) again about 10 to 21 days later, to detect and precisely target the treatment of any continued infestation."
- **National Pest Management Association** — "Multiple service visits may be required to eliminate bed bug infestations. The reasons include, but are not limited to:
  - Some bed bug harborage areas may be missed during initial service
  - Any eggs not destroyed may hatch and subsequent nymphs may not be controlled by residual material
  - Bed bugs may escape treatment inside protected harborages
  - Insecticide resistance
  - Insecticides with poor residual effects"[1]
- **Australia Code of Practice** — "Most of the insecticides registered for bed bug control in Australia have little proven ovicidal effect and thus do not kill the eggs. These products also provide poor residual control and thus to kill newly emerged nymphs, additional treatments must be undertaken after the initial application. This time will be dependent on the ambient temperature and at least one follow-up visit must be made with an insecticidal application. If the infestation is heavy, further inspection and treatments will be needed."[2]

Inspection & Treatment of Adjacent Rooms

Studies have shown[3] that rooms adjacent (on either side) to infested rooms are at an increased risk of infestation and should therefore be inspected and proactively treated in addition to the infested room (see figure below).



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

- **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."

1 NPMA Bed Bugs: Best Management Practices 2011 http://bedbugsbmps.org
2 A Code of Practice for the Control of Bed Bug Infestations in Australia, Stephen L. Doggett, p. 48, 4th Edition, September 2011
3 Data from internal Ecolab study

There are multiple reasons for inspecting and 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.

Actual size of an adult bed bug

Actual size of the space a first instar nymph can fit through — 1mm

- Housekeeping staff and their equipment may transfer bed bugs between infested and non-infested rooms.
- The repellent nature of some available treatment products may cause bed bugs to migrate.
- A proactive treatment to the adjacent rooms will provide an additional line of defense against the potential spread of bed bug activity. Properly treating a bed bug infestation will help reduce liability risk with guests.

Pesticide Resistance

Bed bugs have developed a variety of physiological defense mechanisms (resistance) to certain pesticide products. This generally results from repeated exposures to sublethal doses of chemicals over time. Resistance is especially likely to develop when a single product, or single active ingredient and single mode of action is used repeatedly and even more so when it is used exclusively. To overcome resistance, pest control operators must continually evaluate new and existing products against both lab and field strains of bed bugs to determine the level of resistance. In addition, a bed bug treatment should incorporate multiple active ingredients and product formulations for optimum control.

Alternative Treatment Methods

In addition to the traditional insecticide treatments, pest management providers are using a variety of alternative methods to combat the bed bug problem.

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 (46°C) must be held for at least four hours in order to effectively kill all bed bug life stages. (See table below.)

	< 100° F / 38° C	115° F / 46° C	> 130° F / 54° C
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 (46°C) 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:

Enclosed heat

Enclosed heat is a process by which furniture and other potentially infested items are placed inside an insulated enclosure and warmed to lethal temperatures. Warm air is circulated throughout the Enclosure and around the items placed within it by use of heating equipment and fans. Benefits of this type of treatment include eliminating the spread of bed bugs from infested items to new areas because the service is completed within the infested room(s). It also reduces the need to discard potentially infested furnishings.

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 by placing spacers or lifts between and under the objects that are heated. Bed bugs often harbor in areas within the room itself in addition to furniture items. For this reason, enclosed heat cannot be used as a stand-alone solution to control bed bug infestations. Traditional treatment methods must still be applied to areas outside of the system during the treatment process.

Smaller versions of the enclosed heat solution are available for treatment of infested luggage or other, heat-tolerant personal items. These versions utilize an internal heating element that reaches lethal temperatures over a period of several hours, as described above. Due to challenges associated with heat transfer, it is recommended to remove contents and treat empty luggage using this type of equipment. Treatment of clothing or linen within these devices should be avoided. Infested clothing and linen should instead be laundered at 140°F (60°C) or placed in a dryer for 30 minutes.

Off-site trailer heat

Trailer heat treatments require furniture to be removed from the infested room to an off-site location where the heat treatment is performed. The furniture is then returned to the rooms after treatment. Even if 100% mortality is achieved, this process can be inconvenient and labor intensive. It creates risk of spreading bed bugs to non-infested areas during transportation of the furnishings. After the furnishings and other items are relocated to the trailer, a traditional insecticide treatment of the infested room(s) would still be necessary.

Whole-room, structural heat

A whole-room or structural heat treatment entails bringing industrial-grade heaters into a room or structure and heating it for an extended period to eliminate bed bugs. This treatment method requires expertise and experience in handling specialized heating equipment, as well as a sound knowledge of bed bug biology and behavior. Steps must be taken to protect against potential damage to sensitive furniture items. The room must be prepped prior to treatment to ensure proper circulation of the heated air in order to achieve lethal temperatures. Fire and smoke systems should be suppressed, and insecticides should be applied to form a barrier in areas where bed bugs may migrate to escape the heat treatment. If not performed correctly by an experienced professional, structural heat treatment can result in spread of bed bugs to other areas, ineffective treatment, and damage to the treated room and its furnishings.

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. The "lethal zone" only extends 2 to 3 inches from the steam dispenser. Steam treatments alone are not practical, as thorough coverage and penetration of all bed bug harborages within box springs, mattresses and behind items with a fabric overlay is not possible. Bed bug eggs recessed deeply into cracks and crevices may survive. Applying steam is labor intensive and should be used in combination with traditional insecticide products or other means of control for long-term protection.

C. Cold

Placing items which cannot be laundered or heat-treated in a standard household freezer can be an effective means of killing bed bugs, including eggs. Holding bed bugs at -13°C (8.6°F) or colder for a minimum of 3.5 days is lethal to all life stages[1]. As with heat treatments, it is critical to ensure lethal cold temperatures are achieved and held in all areas within treated items. Densely packed items may take longer to reach lethal temperatures.

Extreme cold treatment via the use of frozen CO_2 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, this method will only kill bed bugs on direct contact, and the force required to push the frozen carbon dioxide through the nozzle can dislodge and displace bed bugs to other locations, spreading the infestation[2]. 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. Furthermore, it offers no residual protection in hard-to-treat areas, generally making it ineffective as a stand-alone solution.

D. Biopesticides

Increasing in popularity in recent years are pesticides which use a biological active ingredient and may be marketed as "green." Examples of biological active ingredients include fungal spores and plant-derived chemicals. These active ingredients may be non-toxic to vertebrates (people and pets) but are not necessarily so by default. This is a diverse category of pesticides and thus products vary significantly in their efficacy in treatment of bed bugs; each product/formulation must be considered individually. Biopesticides may be preferred in situations where conventional chemical treatments are unacceptable or undesirable, e.g. when resistance to conventional insecticides is suspected or as an alternative option for difficult-to-treat furniture items or personal belongings.

E. Fumigation

Fumigation is less common than traditional bed bug control practices but can be extremely effective. Fumigation involves covering an entire structure in a tent and pumping a fumigant gas such as sulfuryl fluoride into the tented structure to kill all life stages of bed bugs. Treatment time depends on the size of the structure being fumigated and the degree of infestation. Other factors impacting fumigation success include temperature and how adequately the structure is sealed. A successful fumigation treatment can potentially eliminate an infestation within one service visit. Fumigation is an extremely complex process and must only be performed by highly trained and certified professionals. Due to the specialized equipment and labor needs required for this process, it is typically significantly more costly than traditional methods. Fumigation may not be feasible in all situations, e.g. buildings which cannot be fully evacuated for the duration of the treatment.

1 Olson, J.F. et al, Cold Tolerance of Bed Bugs and Practical Recommendations for Control, Journal of Economic Entomology, Volume 106, Issue 6, 1 December 2013, Pages 2433–2441, https://doi.org/10.1603/EC13032

2 Bed Bug Foundation - European Code of Practice, page 27, May 2011, Version 1

F. Over-The-Counter Consumer Products

Many consumer products will kill bed bugs if applied directly to the pest. However, because bed bugs are often located in inaccessible cracks and crevices, application of these products is generally not cost-effective in eliminating an infestation of bed bugs. Additionally, many consumer products contain active ingredients or rely on mechanisms which are largely ineffective for bed bug control. Products marketed as "bug bombs" or foggers are particularly ineffective against bed bugs despite their popularity among consumers. An Ohio State University study concluded that a thin layer of cloth was enough to effectively shield bed bugs from the effects of common fogger products, and the low concentrations of pesticide released by foggers are not sufficient for killing bed bugs[1]. Furthermore, most consumer products offer no residual protection, thereby only offering temporary relief from bed bugs. If applied incorrectly, over-the-counter products may contribute to the spread of the infestation to other areas.

G. Bedding Solutions

Mattress 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 studies that took place outside of the laboratory.

It is important to note that mattress encasements are not intended to prevent or control an infestation, but to protect mattresses from needing to be discarded in the event of an infestation. At $25 to $80 each, protecting every mattress with an encasement can be a big investment for some properties. However, establishments with more frequent bed bug incidents may find that over time, mattress encasements are the more cost-effective option as opposed to discarding infested mattresses.

Box spring encasements

Although box spring encasements have also been proven effective in preventing an infestation from spreading into or out of the encasement, installation can be challenging. It's also important to protect the encasements from ripping or tearing by placing protective barriers between the bed frame and the box spring. 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 hotel properties[2]. 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.

Insecticide-impregnated fabrics

Insecticide impregnated fabrics are designed to fit around the mattress and box spring like a fitted sheet and should be placed under the linens to avoid direct contact with humans. The fabric is impregnated with an insecticide that reduces the likelihood of bed bugs harboring on these furnishings and kills bed bugs after a prolonged exposure. Similar to traditional encasements, this product will not prevent bed bugs from being introduced to a facility or from infesting other items in the room.

1 Jones, S.C. and Bryant, J. L., Ineffectiveness of Over-the-Counter Total-Release Foggers Against the Bed Bug (Heteroptera: Cimicidae), Journal of Economic Entomology, Volume 105, Issue 3, 1 June 2012, Pages 957–963, https://doi.org/10.1603/EC12037

2 Ecolab 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.

Summary and Recommendations for Action

Although once thought to be virtually extinct in developing countries, bed bugs are now recognized as one of the most troublesome pests and show up across a wide range of industries including hospitality, long term care, acute care, movie theatres, retail stores, offices, public transportation, and restaurants. 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 licensed and experienced pest management provider, education of staff is still the most critical aspect of an effective bed bug program.

Property staff should be trained by a pest management 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 identifying bed bug infestations before they spread to other areas.

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 management 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 pest management provider for an inspection and/or treatment service.
- Communicate regularly with your pest management provider. Strong communication ensures that potential concerns are addressed before they become a larger problem.

What Your Pest Management Provider Should Do

- Provide a science-based service protocol that uses a combination of traditional and non-traditional methods of control to ensure elimination of all life stages and prevent re-occurrence.
  - Provide visual inspections conducted by trained professionals — still the most practical and effective means of bed bug detection.
  - Provide information on how to prepare for inspection and treatment.
  - Direct property staff on what to do with infested items.
  - Recommend proper procedure for handling linens that have come in contact with bed bugs.
  - Treat infested and adjacent areas with effective products and protocols that maintain the safety of guests/occupants.
  - Inform staff on when it is appropriate to re-enter the treated areas.
  - Perform follow-up services 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.
  - Facilitate comprehensive on-site education sessions in team meetings or on an individual basis.
- Provide 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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Dr. Olson is a Director of RD&E for Ecolab's Pest Elimination Division. With over 20 years of service, she has been involved in a variety of vital projects, such as insect rearing, training, product/equipment testing and product development — including establishing new protocols and programs for urban pests. She currently manages the Pest Elimination innovation pipeline, patent portfolio, and team of individuals responsible for developing and commercializing new technologies. Dr. Olson received her B.S. degree in Biology and her M.S. and PhD in Entomology from the University of Minnesota, which included research on the chemical ecology and behavior of bed bugs. She has been a member of the Entomological Society of Minnesota since 2003.

Morgan Manderfield

Morgan Manderfield is a Senior Entomologist for Ecolab's Pest Elimination Division. Since joining the organization in 2017, she has contributed to insect rearing, product and equipment evaluation in the lab and field, test method development, training of service technicians and customers, and technical service in the form of pest identification and consultation. Morgan serves on a team of individuals responsible for developing and commercializing innovative devices and protocols for Ecolab's pest elimination programs. Morgan received her B.S. in Biological Sciences from Rowan University and M.S. in Entomology from the University of Nebraska-Lincoln. Morgan is a Board Certified Entomologist with the Entomological Society of America and is also a member of the National Pest Management Association, the Minnesota Pest Management Association, and Pi Chi Omega (a professional fraternity for urban pest control).

Dr. S. John Barcay

The late Dr. Barcay was an expert on pest elimination techniques for food and beverage processing, food service, hospitality, and related industries. Dr. Barcay served on the Ecolab Pest Elimination RD&E team from 1990 until his passing in 2019, when he held the position of Senior Staff Scientist. He specialized in developing effective integrated pest management programs with minimal use of insecticides and he led many of the division's insecticide evaluation and development projects. Dr. Barcay published many articles on pest management and was the co-holder of several patents for pest baits. He contributed the Cockroaches Chapter to the 9th edition of Mallis Handbook of Pest Control, published in February 2004. Dr. Barcay received both his M.S. and PhD in Urban Entomology from Purdue University. He was a member of the National Pest Management Association, Entomological Society of America, American Mosquito Control Association, Gamma Sigma Delta (the honor society of agriculture), Society for Vector Ecology, Pi Chi Omega (a professional fraternity for urban pest control) and the Independent Organic Inspectors Association. Dr. Barcay contributed significantly to earlier versions of this paper, and much of that work has been left unchanged this current revision

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