

Time and Cost Estimates of Building-wide Bed Bug Inspection Techniques in Multi-unit Housing

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Bed bugs feed on the blood of humans by probing through the skin on exposed areas of the body with their hypodermic needle-like mouthparts. The body often responds with a red, raised, itchy area, although allergic reactions are less likely in older victims. Severe reactions to, or other physical medical problems from, bed bug bites are rare; however, mental health complications are more common. Bed bug infestations cause anxiety, sleeplessness and stress.

Why are bed bug infestations more abundant and widespread in high-rise properties for elderly and disabled residents?

Multi-unit structures, such as apartments, have been hit the hardest with bed bug infestations. Results from a 2014 University of Tennessee survey of Tennessee and Alabama apartment managers indicated (1) low-income properties experienced a greater percentage of bed bug-infested properties (Figure 1), (2) mid- and high-rise properties had a significantly greater percentage of infested units (Figure 2), and (3) housing for elderly populations had significantly more infested units than other property types (Figure 3). Why is this the case? Budgets for low-income housing are stretched

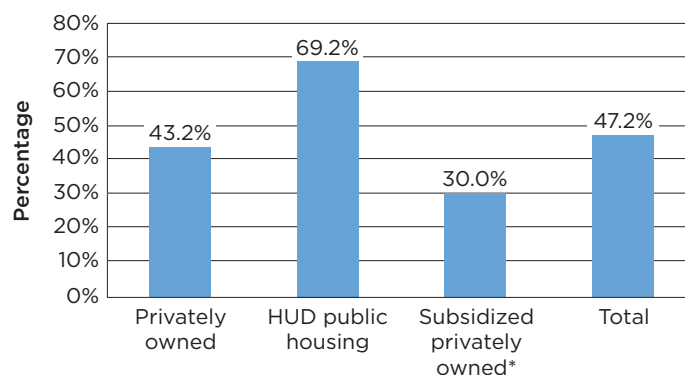


Figure 1. U.S. Department of Housing and Urban Development (HUD) public housing experienced the greatest percentage of properties infested with bed bugs. (Source: Tennessee and Alabama 2014 apartment manager survey results.)

and may be insufficient to support all needed methods of control. Typically elderly populations are not working, and thus a bed bug host is present all day and night. Having constant access to a host allows bed bug populations to build more rapidly. Bed bugs are excellent hitchhikers that move quickly and grasp rough surfaces with tarsal claws. Residents may socialize in individual rooms or recreational halls; thus, visitors transport and share their bed bugs within the building and elsewhere. Many elderly individuals moved from a house to a one-bedroom apartment and kept much

of their memorabilia, leading to an accumulation of clutter that provides numerous places for bed bugs to shelter. Bed bugs are challenging to locate in clutter, and often the clutter cannot be treated with chemicals. Many charitable organizations and rental companies fail to treat for bed bugs before delivering furniture or appliances. Furniture infested with bed bugs may be placed outdoors and other residents may move the infested furniture into their apartment. Elderly individuals are less likely to react to a bed bug bite and typically have poorer eyesight; thus, they often unknowingly live with bed bugs. Or they may know bed bugs are present but are concerned that they will lose their furniture or be required to extensively prepare for treatment. In this case, they may intentionally fail to report them. In-home services, such as housekeeping, social worker visits, meal deliveries and others may unintentionally move bed bugs from room to room. Equipment to assist movement (wheelchairs, walkers) may harbor bed bugs that are dislodged as the resident moves through the building or bed bugs may hitch a ride home when the resident rides in vans or public transportation.

In addition to the resident behaviors mentioned above, having multiple apartments in the same building allow bed bugs to actively transport themselves from one unit to the next through wires, conduit, pipes, ducts, floors, walls and hallways.

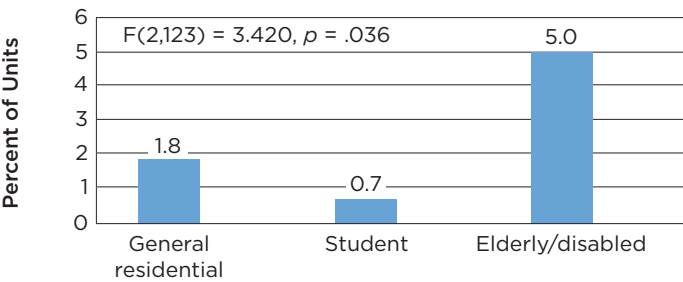


Figure 2. More properties with elderly and disabled residents were infested with bed bugs compared to general residential or student housing. (Source: Tennessee and Alabama 2014 apartment manager survey results.)

Bed bug management

Bed bugs are managed by following a plan that includes accurately identifying specimens; educating residents and managers in preventing and controlling bed bugs; determining the bed bug locations throughout the structure by inspecting, detecting, and monitoring; using nonchemical management methods (heat, steam, freezing, encasements and manual removal with vacuums,

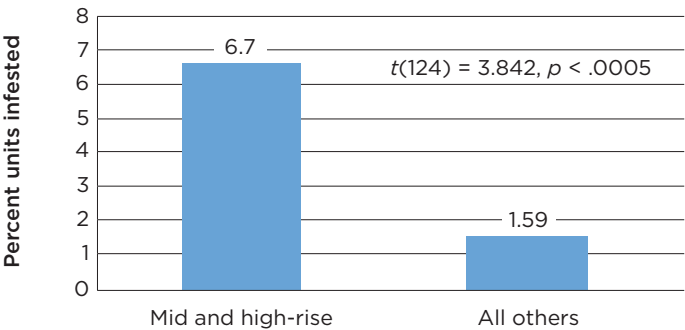


Figure 3. Results of the 2014 Tennessee and Alabama apartment manager survey indicate that a greater percentage of apartments were infested with bed bugs in mid- and high-rise properties than all other property types. (Source: Tennessee and Alabama 2014 apartment manager survey results.)

lint rollers and tweezers) and chemical controls (silica dust, combination products and rotation of insecticide classes). Follow-up evaluations determine if bed bugs are still present and additional control treatments are applied until the infestation is eliminated. See “[PB 1763 Bed Bugs: Management and Prevention](#) and [SP761 Affordable Bed Bug Management?](#)” for details of these control options.

Importance of early detection

When we were asked to help solve an East Tennessee housing authority’s bed bug problem, we thought about the options in a management plan. We decided early detection would have the most significant impact. A preliminary assessment of four of their buildings indicated 32 percent of apartments were infested with bed bugs. We needed to decrease the spread! If bed bugs had been detected earlier, the spread would have been reduced, and furniture could have been treated instead of thrown away. If less than 10 bed bugs were present in an apartment, then the infestation could have been successfully treated nonchemically. Residents would be more likely to report an infestation if they would not lose their furniture.

Many of our Tennessee apartment managers rely on residents to report bed bug infestations which can have disastrous results (Figure 4). This publication describes the bed bug detection research we have conducted in low-income housing for elderly and disabled residents and will focus on the time required to conduct the various techniques used in building-wide inspections. Here we expand on the techniques described in the UT Extension publication “[SP788 Detecting Low-Level Bed Bug Infestations in Multifamily Housing: Bed Bugs Sucking the Budget Out of Your Buildings?](#)”

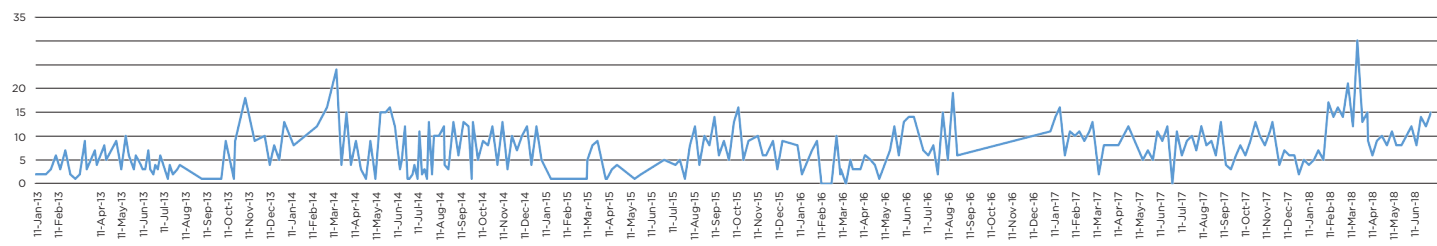


Figure 4. Five-year record of the number of units treated during each visit by a pest management professional in a Tennessee low-income high-rise for elderly and disabled residents. Most of this time, managers relied on resident reporting and pest management professionals' application of sprayed pesticides.

Building-wide inspections

Conducting a building-wide inspection is imperative to discover all infested units simultaneously and to treat them before they spread throughout the building. However, to perform a bed bug inspection for an entire building required some modifications from the typical extensive visual inspection of a single apartment. Basically, every accessible crack and crevice is inspected in a comprehensive apartment inspection which could require hours of effort (See SP788 for a description of an extensive visual inspection). For example, to check an entire building of 240 apartments using a comprehensive visual inspection for an hour per apartment would require 30 days, assuming an 8-hour workday could be devoted to this purpose. This is not practical. In the research presented below, we validate work conducted by Rutgers University researchers (Wang et al. 2016) and evaluate modifications of this technique using various combinations of quick visual inspections and passive pitfall monitors.

With a quick visual inspection (QI), only beds and upholstered furniture are inspected as these objects are the most likely to put the bed bug closest to an immobile viable host. In the bedroom, the bed covering is checked and then removed, as are the sheets. Next, the outer surfaces of the mattress and box spring, including the outer covering, tags, seams and handles, are inspected for bed bugs and signs of their presence, including shed skins and fecal specking. Neither the mattress, box spring or bed frame are lifted or turned over. The bed is remade following the inspection and is included in the inspection time. The outer surfaces of the living room upholstered furniture are also inspected. While cushions, including zippers and seams, are lifted and inspected on all sides, the furniture is not flipped. No dust covers are removed on the bed or furniture.

The passive pitfall trap, also called a monitor, is an effective tool for finding bed bugs when present in low numbers. Pitfall traps have a rough, often

angled, outside surface that allows bed bugs to climb into the monitor and a smooth, vertical interior surface that prevents the bugs from climbing out. Furniture or bed legs can be placed in the inner area of the larger pitfall monitors, or monitors can be placed on the floor against vertical surfaces such as floor-bound mattresses or box springs or the legs of the bed frame or upholstered furniture. When no artificial lure is added to enhance attractancy to bed bugs, these traps are called "passive." Because the traps are placed near humans, their natural attractants of carbon dioxide, body odor and heat help lure the bed bugs to the trap.

We used passive pitfall traps in our study of three building-wide inspection techniques (Table 1). Technique 1 utilizes a quick visual inspection first and places monitors in apartments where bed bugs are suspected but not found, at every accessible leg of beds and furniture. The second technique is the same as the first, except the number of monitors is decreased to two, four or eight. The first step in the third technique is to place 2-4 monitors in every apartment. A quick visual inspection is conducted if no bed bugs are found in the monitors.

In techniques 1 and 3, we used the BlackOut BedBug Detector or the SenSci Volcano Bed Bug Detector. The PROTECT-A-BED LightsOut BedBug Detector was used with the second technique. The BedBug Detectors were placed against or under the bed's legs and upholstered furniture or other vertical surfaces. The SenSci Volcano was used in about one-half (43-50 percent) of the 4-monitor high-rises studied with technique 3. No lure was used in the SenSci Volcano, so it was still considered a passive pitfall. The smaller, square Volcano was placed against the legs of beds or upholstered furniture or walls.

We inspected 19 multi-unit housing communities for bed bugs from April 2017 through March 2020 when the global COVID-19 pandemic brought

our work to a halt. During these three years, we evaluated three types of building-wide bed bug inspections. For the most part, the same two people conducted these inspections, with one inspecting the bedroom and the other the living room. A vast majority of the inspected apartments were one-bedroom or efficiency/studio apartments. Facility personnel accompanied us to unlock the doors if the resident wasn't home. Most buildings housed low-income elderly or disabled residents.

Upon completing an inspection, we requested the pest management protocol and the apartment number of the known infested units from the housing manager to determine which newly found infestations were previously unknown to management. Additional building-wide inspections had been conducted before 2017, but we did not record the times for those procedures. So while they aren't mentioned here, they can be found at Vail and Chandler (2017a).

Table 1. *Components of the three building-wide bed bug infestation techniques evaluated in these studies.*

1	X	X			One at every accessible leg of beds and upholstered furniture
2	X	X			2, 4 or 8
3			X	X	2 or 4

Technique 1: A quick visual inspection (QI) with monitors placed under easily accessible legs of the bed and upholstered furniture when bed bugs were suspected in an apartment but not found.

A quick visual inspection was conducted in all accessible apartments. As soon as any living bed bug stage was discovered, the assessment ceased, and the location and quantity of bed bugs were estimated and recorded. The time to enter the apartment included the time we left the previous apartment until we entered the next apartment. We also recorded the time needed to conduct inspections. If no living bed bugs were found but there were signs that bed bugs were present, then monitors were placed under or against the easily accessible legs of the bed and upholstered furniture. Signs of bed bugs included cast skins, fecal specking, bed bug control products visible in the apartment or indications from the residents that they had seen or had been bitten by bed bugs. We used seven high-rises (53-264 apartments), one mid-rise (34 apartments), and one two-story motel-like structure (24 apartments) to evaluate this technique. All buildings were U.S. Department of Housing and Urban Development (HUD) properties, except one privately-owned, project-based property whose residents received Public Housing and

Housing Choice Vouchers (Section 8). Monitors were checked for living bed bugs two to four weeks after placement. This technique is very similar to Wang et al. (2016), except that those researchers inspected monitors after two weeks. In addition to the time spent entering and inside each apartment on each visit, we recorded where monitors had been placed and the level of bed bugs in each apartment using low (1-10 bed bugs), medium (11-50 bed bugs), and high (more than 50 bed bugs). We then calculated the building infestation rates, the percentage of apartments receiving monitors, the mean number of monitors per apartment, and the percentage of the infestations detected with quick visual inspection and monitors. Once pest management records were obtained, we determined whether the housing manager was aware of each infestation.

We found that bed bug management ranged from poorly to well done. In the high-rise buildings averaging 133 apartments, we saw an average infestation rate of 17 percent, with building infestations ranging from 1.4 to 33 percent. Because by nature bed bugs are difficult to find, we can't be sure that all bed bug infestations were detected, but we did find that the managers were unaware of 58 percent of our detections. We placed an average

of 7.7 monitors in 6.6 percent of the apartments. Most (88 percent) of the bed bug infestations were detected with a quick visual inspection, but we would have missed 12 percent of the high-rise infestations if we hadn't used the monitors. We also noted that no heavy infestations were found in the high-rise buildings and other buildings with less than 10 percent infestation rates.

The time required to conduct a quick visual inspection in a high-rise property was fairly consistent. The mean inspection time was 3.4 minutes with a range of 2.2 to 4.0 minutes. The average time to inspect monitors on the follow-up was slightly less at 2.7 minutes. Assuming 6.6 percent of the apartments will require monitors to be placed and an average of 7.7 monitors will be placed in each apartment, managers can use the number of apartments in their building to estimate the time to conduct a building-wide inspection and cost of monitors for the assessment.

Although we lacked replication for the mid-rise and two-story buildings, the average time for quick inspections (3.6 min) of the mid-rise fell within the range for the high-rise properties. In addition, the lower number of apartments in the motel-like structure reduced the urgency to conduct the inspections because we were ensured to finish within a day which was reflected in the longer average time to complete a quick visual inspection (4.8 minutes).

Technique 2: A quick visual inspection with a set number of monitors placed when bed bugs were suspected but not found. Technique 2 is similar to that described above, except only two, four or eight monitors were placed under or against the legs of the bed and upholstered furniture when bed bugs were suspected to be present but were not found. Results from a previous bed bug monitoring study indicated that one, two or four monitors were equally effective in detecting bed bugs at low levels in 80-90 percent of the infested units but detection required about four weeks (Vail and Chandler 2017b). Apartment numbers ranged from 118-150 in these six high-rise properties used to evaluate technique 2. Two of the buildings were privately owned and project-based for residents receiving Public Housing and Housing Choice Vouchers (Section 8); all others were HUD public housing. In general, monitors were checked at two or 12 weeks to determine if quarterly monitor inspections, a standard routine inspection interval for the pest management professional, were effective. We checked one building at two and four weeks. The same data were collected as in Technique 1, except that we did not record the bed bug infestation level.

Calculating time and costs to use technique 1 for building-wide bed bug inspection.

A building with 200 apartments would require about 1.5 days for a building-wide inspection using technique 1.

$200 \text{ apartments} * 3.37 \text{ minutes per apartment} + (200 \text{ apartments} * 0.066 * 2.73 \text{ minutes per apartment}) = 710 \text{ minutes or } 11.8 \text{ hours.}$

This is a slight underestimate because it does not account for movement between floors, especially for tall buildings with small elevators, or waiting for personnel to return with the next floor's keys if they lack a master key.

To estimate the number of monitors required for a 200-apartment building:

- $200 \text{ apartments} * 0.066 \text{ apartments requiring monitors} * 7.7 \text{ monitors per apartment} = 102 \text{ monitors}$
- According to Amazon.com on April 30, 2021, a 4-pack of BlackOut Bed Bug Detectors from SenSci was \$18. Thus total cost for monitors would be \$459. Cost per unit would be \$2.30.
- However, if the BlackOuts are purchased in bulk, let's say for \$2.50 each, the total cost would be \$255 or \$1.28 per unit.

Because we only had two buildings per treatment (two, four or eight monitors placed when bed bugs suspected), we have combined the data. Bed bug infestation rates averaged 13.4 percent (1.7-28.7 percent) in these buildings with an average of 139 apartments. Managers were unaware of an average of 70 percent (18.2-100 percent) of the bed bug infestations in their property. Monitors were placed in an average of 8 percent of the apartments. Again, most (93 percent) of the bed bug infestations were found during the quick visual inspection. Increasing the number of monitors did not increase the percentage of bed bug infestations found.

Increasing the number of monitors placed when bed bugs were suspected to be present did not increase the initial visual quick inspection time. The time to place monitors is affected by many factors including the time it takes to enter the structure, the ease in accessing the furniture and whether the resident is home and speaking to the inspectors. The average time (3.2 minutes) to put two, four or eight monitors in these six high-rise properties was similar to the time (3.4 minutes) to place an average of eight monitors in the seven high-rise properties when monitors were placed under all accessible legs of the beds and upholstered furniture.

Technique 3. A set number of monitors were placed in all apartments followed by a quick visual inspection when no bed bugs were found in the monitors. With this technique, two or four monitors were placed in every accessible apartment in each building. At one or three months, the monitors were inspected. If no living bed bugs were detected in the monitors, a quick visual inspection was conducted. Two monitors were placed per apartment in a HUD high-rise property with 118 apartments, and four monitors were placed per apartment in another HUD high-rise property with 91 apartments. Monitors were checked at three months. Based on stakeholder feedback from an annual bed bug and cockroach management meeting held in Knoxville, we extended our research to buildings other than mid- and high-rise properties. In 2020, we alternately placed two or four monitors in accessible apartments of HUD six- or seven-plexes (six or seven apartments in a one-story building) and a duplex community. Three or five monitors were alternately placed in the six two-bedroom apartments of the duplex. Monitors were checked in these buildings one month after placement. In addition to the time entering and inside each apartment on each visit, we recorded the infested units and calculated the building infestation rates, the percentage of the infestations detected with QI visual inspection and monitors, and the percentage of the units where the housing manager was unaware of an infestation.

Two high-rise properties averaging 104.5 apartments had an average unit infestation rate of 9.8 percent. Using Technique 3, monitors were inspected first, and as expected, more bed bugs were detected in the monitors than with the quick visual inspection. More bed bugs were detected in monitors for apartments having four monitors compared to those receiving two monitors. But this trend did not hold up when comparing 2- and 4-monitor apartments in six- and seven-plex buildings with a total of 41 apartments. More bed bugs were detected in apartments receiving two monitors than those receiving four monitors in this case.

We did note that the 3-month interval between placing monitors and inspecting them led to some issues. In some cases, tiny spiders had spread webbing over the opening of the Volcano traps. Also, dead bed bugs were frequently found in the monitors. These were not counted as an active infestation because dead bugs may have been jostled from the bed frame into the monitor. Sometimes, bed bug exuvia or shed skins were found in the monitor, but no living bugs were present, which indicated that the bugs might have escaped during this long interval. A better technique may have been to inspect the monitors at one month.

Pest management records were unavailable for these two high-rise structures during the time we conducted our studies, so we are unsure if the manager was unaware of the infestations. The housing manager was unaware of 28.6 percent of the bed bug infestations in the six- and seven-plex buildings. No bed bugs were found in the 15 duplexes we inspected, regardless of if they were one or two bedrooms. These duplexes represented the first community where we did not find any bed bug infestations.

Placing two monitors per apartment was slightly faster (1.7 minutes) than placing four (2.8 minutes). However, the time to check monitors and complete a quick visual inspection did not differ meaningfully between the two techniques (3.8 minutes versus 4.2 minutes). And, of course, when comparing monitor costs alone, costs doubled when placing four monitors (\$10) compared to two (\$5).

The total cost to conduct building-wide inspections when placing monitors first in all apartments and checking the monitors followed by a QI was significantly more (\$5-10 per apartment) than conducting QI in all apartments and placing monitors when needed (\$1.28 per apartment) because of the extra cost of the monitors. In addition, the need to enter each apartment twice using technique 3 required more time when placing monitors in every apartment. Room entry averaged 33 seconds each time in the high-rise properties.

While it is more expensive to place monitors in every apartment, there is another advantage to having monitors in each unit (Figure 5). While conducting technique 2 in one building used for a previous study, no bed bugs were found with the quick visual inspection. Both inspectors had a sense that bed bugs were present but found no living bugs. When they remembered that this building had been used as part of a previous outreach project nearly four years ago, they began a search for monitors. Sure enough, a monitor was located under the bed against the wall and in the interior was a living adult bed bug. It's possible the monitor prevented the bed bugs from establishing. Monitors have other uses, too, as they can be used to determine if an infestation has been eliminated (SP788).

We determined a correlation between low-level infestations and low percentages of infested units when building-wide inspections and nonchemical controls were used.

The following discussion pertains to buildings with three or more floors. Across all techniques, bed



Figure 5. A monitor had been placed April 16, 2014, against a leg of the bed. During a quick inspection almost four years later, on February 8, 2018, the inspectors sensed bed bugs were present but could not find any living bugs. Upon searching the room for bugs, they found this one living adult in a monitor from a previous outreach project located under the bed against the wall. This was the only sign of bed bugs in the room. Did the monitor prevent bed bugs from establishing?

bug management was highly successful in only three buildings, as indicated by infestation levels below 5 percent. Building-wide inspections were conducted quarterly by pest control or a canine scent detection team in each of these buildings. In addition, nonchemical control was a part of all of the treatment strategies in these buildings. In two of the three buildings, monitors were used to detect bed bugs and isolate the bed. Then steam, vacuuming and encasements were used, as were chemical sprays and dust to manage the infestations. This was a truly integrated pest management system. In the third building, whole rooms were heat-treated by a contractor, dead bugs vacuumed by the resident and desiccant dust applied. All furniture and other belongings were inspected for bed bugs before residents could bring them into the building. No high-level infestations were recorded.

For the three buildings where bed bug management was moderately effective, 8-10 percent infestation, some nonchemical controls were used, but not as extensively as those with low level infestations. Treatments included some heat treatment. Either entire rooms were heat-treated with an electric or propane heater or a heat tent was used on books, toys, etc. Steam was a part of the program in one building. Pesticidal sprays and/or a dust were used in all three. Building-wide inspection strategies varied. Either a maintenance worker inspected at an unknown interval or visually inspected 2-4 times per year or a pest control technician flipped furniture while checking during regular services on three floors per week. Four other buildings had infestation rates between 10 and 15 percent.

Of the remaining six high-rise properties, infestation rates were greater and ranged from 15 to 33 percent. Building-wide inspections were not used regularly in any of these buildings – they all relied upon resident reporting. Three had started building-wide reviews the month before we inspected, but their inspection effects would not be evident until they finished treatment. None of these used any type of nonchemical control other than a bed encasement if the resident requested it. Four of these six buildings had high-level infestations (greater than 50 bed bugs per apartment).

Lessons Learned

All building-wide bed bug inspection techniques were considered satisfactory because we found bed bug infestations of which the housing manager was unaware. We could not calculate the accuracy of each method because we could not determine if we had missed any bed bugs. Time and funding for this study would not allow us to destructively sample to find bed bugs in walls and other inaccessible areas. Even if bed bugs were missed, building-wide inspections conducted two to four times per year would detect infestations before they could increase significantly.

One of the most significant advantages of conducting building-wide bed bug inspections is that every apartment is inspected and those hidden, high-level infestations detected. In heavy infestations, bed bugs are often seen crawling on residents. Although bed bugs can be highly mobile in any size infestation, dispersal is highly troublesome in heavy infestations. Therefore, finding and treating these infestations is crucial to reducing infestation rates in the building.

Take-Home Message

Building-wide bed bug inspections and an integrated pest management plan using nonchemical and chemical controls are essential to reduce bed bug infestations below 5 percent and maintain infestations at that level or lower. While all techniques investigated in this study were effective, we feel most confident using technique 1. A quick visual inspection of the bed and upholstered furniture and placement of effective bed bug monitors under or against the easily accessible legs of the beds and upholstered furniture when bed bugs are suspected but not found should require 3.5 minutes for two people and about \$1.28 for monitors per 1-bedroom or efficiency apartment.

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