

Vacuuming Bed Bugs from Furniture as a Stand-alone Treatment?

K. M. Vail, J. G. Chandler, J. Glafenhein, and R. Harmon
University of Tennessee Urban IPM Lab
kvail@utk.edu

In my position as the UT Extension Urban Entomologist, I often receive inquiries from people unable to afford bed bug management treatments. If their infestation is causing health-related complications, for instance, they have diabetes and the bite wounds keep getting infected, I'll often seek local pest management professionals to provide treatment at a much-reduced price. But, I can't reach out to you for every request I receive from people unable to pay. So what options do these folks have to manage a bed bug infestation?

Most of the over-the-counter spray insecticides labeled for bed bugs contain pyrethroids and the majority of bed bug populations in the US are resistant to this class of insecticides. Residents would need to contact every bed bug with the insecticidal spray directly. And many attempt this but never eliminate the bugs. Evidence for this comment comes from the nearly 4000 apartments that Jennifer and I have inspected over that last seven years. Many apartments had bed bug spray next to the bed and still had bed bugs. Finding each and every bug would require a great deal of moving and flipping furniture and pulling off dust covers – not something the elderly or disabled could easily do.

Silica aerogel has a good record of killing bed bugs. Still, few residents have an electric applicator or another duster to apply a light coating for the dust to work. Instead, residents place the dust in piles along baseboards, causing an inhalation hazard when the mounds are disturbed and particles become airborne.

So what other options did they have? Nonchemical controls seem the obvious choice. We describe many "inexpensive" nonchemical options in our UT Extension publication, [SP761 Affordable Bed Bug Management](#). Mechanically removing bed bugs with forceps, lint rollers, and vacuums are a few options to reduce the biting populations. Steaming and putting clothing through the dryer take advantage of the bed bug's susceptibility to heat. Expose a bed bug to 122F, and no matter which stage is present, it will be dead within a minute. In 2018, research out of Rutgers University revealed that inexpensive steamers (about \$100 or less) such as Haan and Steamfast were just as effective as the commercial SteamMax, but working time was significantly reduced in the homeowner models. Steaming bed bug-infested furniture is a slow process, with directions commonly suggesting using a wide-headed hose attachment and moving about 1 inch per second. A few words of caution when using steamers: steam will not penetrate leather and easily damages surfaces such as microfiber, silk, and wood. Also, dusting works better after



Fig. 1. Steamer damage to a microfiber chair.

steam and not before. The lower the humidity, the longer and more effective silica aerogel will be. Other nonchemical options include encasing the mattress and box spring, and using passive pitfall traps under legs of the bed and upholstered furniture.

In the rest of this article, I'll share the results of a vacuuming experiment we conducted on heavily infested furniture. Vacuuming has many advantages. Besides immediately reducing the biting population, vacuuming can remove all visible bed bugs which makes new activity more obvious. Vacuuming removes shed skins and thereby eliminates harborage that protect first and second instars from insecticidal sprays. Residents could be more optimistic when bed bugs are removed because they aren't constantly reminded of the infestation. Vacuuming bed bugs and infested furniture can be empowering because it gives the resident a method to reduce biting populations while waiting for professional treatment. Vacuuming is an essential component of bed bug integrated pest management programs; however, the effect of vacuuming as a stand-alone treatment is unknown.



Fig. 2. Furniture used in vacuuming study, from left to right: black recliner, brown leather chair and ottoman.

We decided to determine if vacuuming naturally infested furniture could remove all bed bugs promptly when furniture is vacuumed twice a week. On November 5, 2015, a heavily infested black vinyl recliner, and a brown leather chair and ottoman set were removed from a high rise building and delivered to our lab by a pest control company. The furniture had been sprayed with Bedlam and Sterifab before it was wrapped in plastic wrap and delivered. Each piece of furniture was isolated in separate inflatable swimming pools and the pools' interior walls coated with corn starch to prevent bed bug escape. On November 6 we vacuumed as many bugs and eggs as possible. A small vacuum with a knee-hi stocking placed in the hose and kept in place by a crevice tool was used to collect bed bugs and eggs. One advantage of using the crevice tool was to scrape visible and accessible eggs from the chairs. The legs and dust cover were removed from the brown chair. In retrospect, this was not a good idea since the legs

could not be reattached. A small dust cover was removed from the black chair. Initially, the ottoman was not vacuumed to see how long it took the bed bugs to die with no vacuuming, but, because of the large population of bed bugs present, it was decided that we should also vacuum the ottoman to prevent escapes into the laboratory. This decision was made the following Monday, so there are no data for November 6 for the ottoman, although a visual estimate of bugs present was made. We purposefully did not scrape the eggs and kept the legs and dust cover in place on the ottoman to mimic the effort of residents who would not have the time or the desire to spend hours for the first vacuuming.



Fig. 3. Rachel demonstrating the vacuuming technique on a hospital bed from a previous study. Note the stocking under the crevice tool.

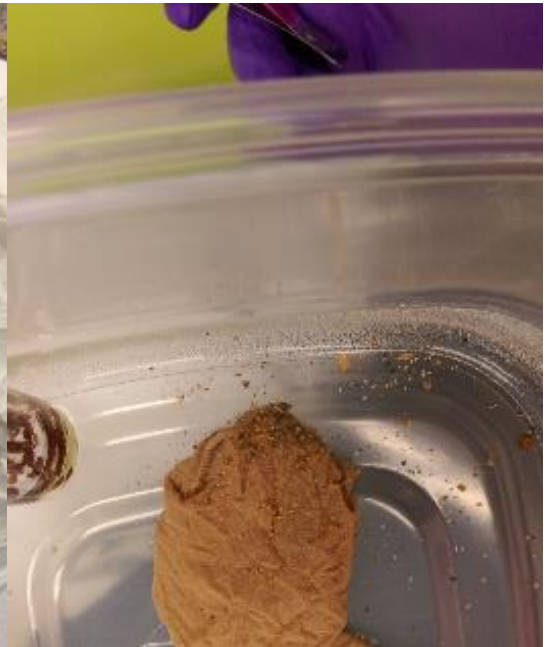


Fig. 4. The stocking's contents were emptied into a plastic container and the bed bugs counted and transferred to alcohol.

After the first day of vacuuming, all furniture was vacuumed twice a week (typically on Monday and Friday). A different stocking was used for each piece of furniture. The brown chair was flipped to vacuum underneath; this did not happen at first with the recliner since it sits on metal feet, and we did not know if it would be safe to flip over. All living and dead bugs collected were counted and sexed if an adult or classified as small nymphs (instars 1-3) or large nymphs (instars 4-5). Eggs were not counted. Bugs collected were put into a vial of 80% ethanol to preserve them for future analysis.



Carbon dioxide stimulates bed bug movement because it simulates the exhalation of a host. Dry ice traps, which release carbon dioxide as the dry ice sublimates, were placed in the pools on December 9 and 16, February 16, March 3, and finally, on March 31 and Apr 1 to ensure all bed bugs had been removed from the furniture.

Fig. 5. The dry ice trap consisted of dry ice placed in an insulated coffee cup, and the cup's tab pulled back to let the carbon dioxide slowly escape. The trap sits in a Bedbug Blackout Detector.

Results and Discussion

Interesting observations:

- The brown chair was also infested with German cockroaches, which would shelter with the bed bugs, but in the 1 1/8 inch screw holes in the legs, usually one screw hole was inhabited by roaches and the other with bed bugs.
- Bed bugs would start coming out of hiding if someone worked in the lab all day (such as feeding day).
- On December 10, we placed some females collected from the furniture into a cup to see if they laid any eggs- none ever did. We also decided to feed them to see if they could still lay eggs, but they had died when we checked about one week later.
- A few carpet beetle larvae were also found on the brown chair.
- Many unfed 1st instars and other bed bug stages were collected engorged from the brown chair during the first vacuuming. The eggs seen the 2nd time we vacuumed the brown chair could have been missed during the first vacuuming or were laid after vacuuming.



Fig. 6. An immature assassin bug was found eating a bed bug in the pool of the black recliner on Nov 10. A sympathetic graduate student occasionally fed lab-reared bed bugs to the assassin bug and released the assassin bug outdoors when the weather warmed and it had fully matured into an adult.

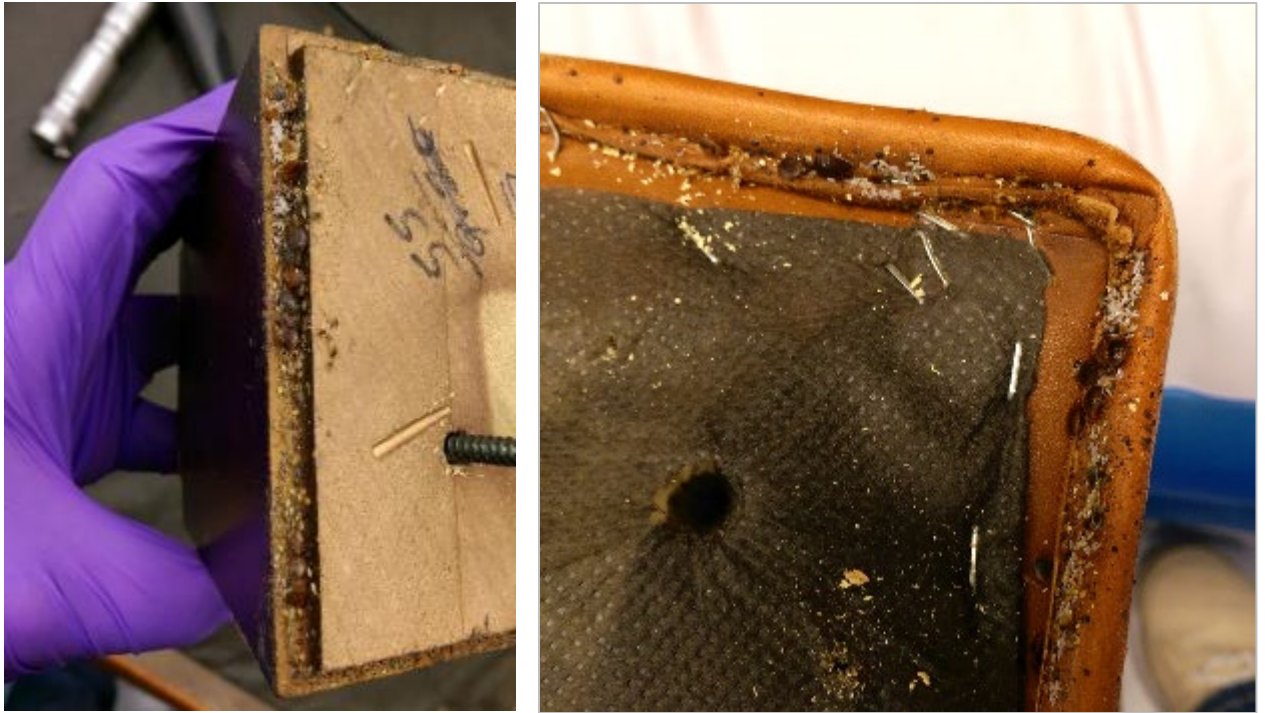


Figure 7. Bed bugs are found in tight cracks and crevices. Note the large number of bed bugs found between the chair leg and base. These would not have been easily collected with the vacuum if the leg had not been removed. The dust cover and legs were not removed from the ottoman and one leg was not removed from the brown chair.

Table 1. Cumulative number of bed bug stages removed from each piece of furniture.

Furniture type	# Small Nymphs	# Large Nymphs	Total # Nymphs	# Males	# Females	Total # Adults	Total # All Bed Bugs
Black Recliner	351	153	509	158	157	325*	834
Brown Chair	375	79	454	103	67	180	634
Ottoman	1126	137	1263	85	81	166	1429
Average	617.3	123	742	115.3	101.7	223.7	965.7

*Note: We were unable to determine sex in 10 of the adults removed from the black recliner.

Table 2. Nymph to adult, small nymph to large nymph and male to female ratios for bed bugs removed from each piece of furniture.

Furniture type	Nymph/Adult ratio	Small nymph/Large nymph ratio	Male/Female ratio
Black Recliner	1.57	2.29	1.01
Brown Chair	2.52	4.75	1.54
Ottoman	7.61	8.22	1.05
Average	3.90	5.09	1.20

Table 3. Cumulative vacuuming time to remove all bed bugs from each piece of furniture.

Furniture type	Cumulative vacuuming time (hours)
Black Recliner	6.4
Brown Chair	7.6
Ottoman	2.4
Average	5.5

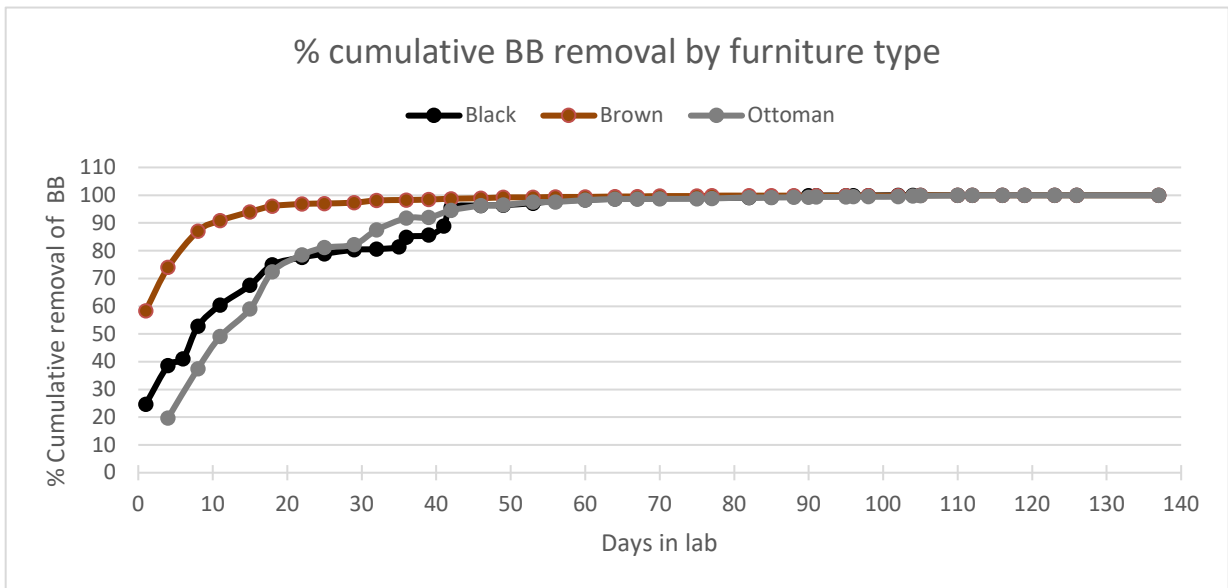


Fig. 8. Cumulative percentage of the bed bug population removed on each vacuuming day.

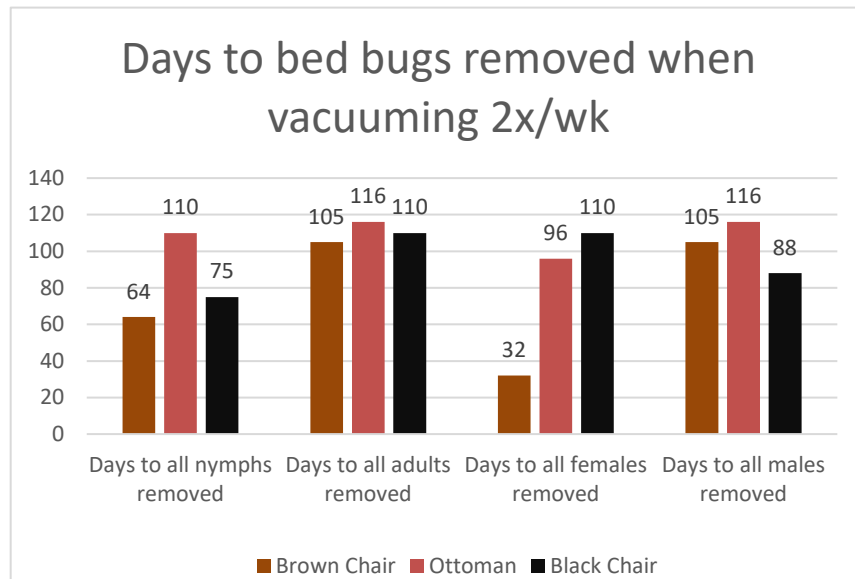


Fig. 9. The numbers days until all nymphs and adults (male and female) were removed from each piece of furniture.

An incredible number of bed bugs were found on each piece of furniture. Would you have guessed that we removed the most bed bugs (1429) from the smallest piece of furniture, the ottoman? Probably not. How could this occur? Well, maybe the pest management professional didn't service the ottoman because no one sat on it. Carbon dioxide acts as the longer distance lure, but heat and body odor help locate the host as the bug gets closer. Could stinky feet have attracted bed bugs to the ottoman? A study in Scientific Reports revealed dirty laundry was more attractive to bed bugs than clean laundry, which might have factored in. Take home message: Whether using chemical or nonchemical options, ensure all furniture that comes in contact with humans and their body odors is treated, even if humans don't sit in it - it could be harboring a thousand bed bugs.



Figure 10. Eggs were not counted, but were very abundant, especially on the ottoman.

The applications of Bedlam or Sterifab before delivery did little to impact these bed bug populations. Bedlam and Sterifab are contact or nonresidual insecticides, meaning they don't persist very long and must contact the bug to have any effect on it. Most of the bed bugs collected throughout the 116 days were alive; only 4.5% of the bed bugs were dead. Because of widespread bed bug resistance to sprayed insecticides, it's essential to locate as many bugs and treat them directly with a residual or nonresidual insecticide for the insecticide to have its most significant effect. Purdue University researchers discovered that a Knoxville bed bug strain is highly resistant, 292,000 times as resistant, to deltamethrin as the susceptible Harlan strain reared in the lab since the early 1970s. This same Knoxville strain had reduced susceptibility to chlorfenapyr and bifenthrin. These results further emphasize the need to rotate insecticides from different chemical classes, the importance of a thorough inspection to locate all bed bugs, and the need for desiccant dust applications of one of the few insecticides with demonstrated residual effects on field strains of bed bugs. For our next newsletter, I'll describe how you can determine if your bed bugs are resistant to an insecticide.

On average, we collected nearly a thousand (966) bed bugs from each piece of furniture and found 1.2 males per female, about four nymphs per adult, and five small nymphs per large nymph. Keep in mind that no host was available to these bugs unless they snuck a meal from Rachel while she vacuumed. From her photo above, you can tell that she discouraged this behavior by wearing a Tyvek suit, gloves, and had her hair tied back to prevent making a bridge from the furniture to her skin. Populations were not growing except possibly for the first week or two. A mated female bed bug can lay eggs for about 10 days after she feeds. So mated females engorged at the time of furniture removal could have laid eggs and first instar nymphs emerged 7 – 10 days later. Since none of the other nymphs could molt without a blood meal this could cause a higher ratio of small to large nymphs. And eggs were particularly abundant.



Figure 11. Removing a dust cover provides access to the interior of the furniture, but ensure it's not part of the chair's support system before doing so.

Throughout the study, we spent a little more than 8 minutes vacuuming per vacuuming day. On the first day of vacuuming, 34% of the bed bugs had been removed and by 34 days, ninety-five percent of the bed bugs had been removed. We removed the very last bed bug from the brown chair, black recliner and the ottoman at 105, 110 and 116 days, respectively. An average of 5.5 hours of vacuuming was needed to remove bed bugs from all furniture. If we had vacuumed once a day for 8 minutes and assuming we would have the same bug removal rates, we estimate it would still have required about 40 days.

It took less time to vacuum the ottoman each day because of its smaller size and lack of access to its interior, but longer to remove the last bug because of the same reason - lack of access to its interior. So removing dust covers can speed bed bug removal; just ensure the surface isn't a part of the chair's support system, or you may be buying a chair. Gaps in plywood interiors also provided hidden, difficult-to-reach harborages and could have prolonged the removal of bed bugs from the furniture. This brown chair was damaged in other ways too; we were unable to replace its legs. A less invasive treatment for the gap between the intact leg and chair might have been a light dusting of a silica gel or similar desiccant dust.

Very different results may have been obtained if a host had been present. Recall the bugs became active when someone entered the room. The dry ice traps were supposed to simulate a human's presence, but we didn't use this frequently enough to adequately mimic the time a human would typically be present in an apartment. Researchers have used a combination of nonchemical controls in inhabited apartments and eliminated bed bug infestations quicker than demonstrated in our study.

Conclusions

Vacuuming is a crucial tool in bed bug management and is especially useful to quickly remove visible bed bugs when found in large numbers. After treatment, vacuuming removes dead bugs, helps determine if bed bugs are still active and removes the larger nymphs' exoskeletons that provide smaller nymphs shelter from insecticidal sprays. In our study, one-third of the population was removed from isolated furniture on the first day of vacuuming, but to remove all bugs required an average of 110 days when vacuuming for about 8 minutes twice a week. Our interest in this study was to find an affordable way to remove bed bugs using equipment the resident already owned or could purchase for less than \$50, but results were less than satisfactory because it took too long. Also, we removed dust covers and flipped furniture which the elderly may be unable to do. This study should be repeated in inhabited apartments to determine if daily vacuuming of the exterior of furniture that's used regularly can eliminate bed bugs from an apartment more efficiently than seen in the current study.

Acknowledgements

This material is based upon work that was supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2013-34103-21213.