

Bed Bug Epidemic: A Challenge to Public Health

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ABSTRACT

In recent years, reported cases of bed bug infestations in the U.S. and throughout the world have escalated dramatically, posing a global public health problem. Although bed bugs are not known to transmit disease to humans, they pose both direct and indirect public health challenges in terms of health effects, treatment, cost, and resource allocation and coordination. Education is an important component of prevention and treatment of infestations and health educators can play a key role in educating the public about this re-emerging problem and in organizing community-based responses. Therefore, the two goals of this paper were to: (1) provide an overview of the public health threat from bed bug infestations, and (2) provide prevention and treatment guidance for health educators to utilize in educating the public about this challenge.

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BACKGROUND

“Good night, sleep tight; don’t let the bed bugs bite.” Bed bugs were once such a common problem that they became part of popular culture. Although the saying continued, bed bug populations experienced dramatic decline during the mid-20th century with the use of dichlorodiphenyltrichloroethane (DDT) and other synthetic pesticides; they were essentially eradicated in the U.S. by the 1940-50s.¹ However, bed bugs developed resistance to DDT by the mid 1950s² and the U.S. began regulating DDT in the late 1950s; DDT was banned by the U.S. Environmental Protection Agency (EPA) in 1972.³ Further restrictions of pesticides oc-

curred in 1996 when the EPA re-evaluated numerous chemicals.^{1,4}

Bed bugs continued to pose a problem in less developed nations.⁵ One study found that 37.5% of children’s beds in rural Gambia were infested.⁶ More recently, the U.S. has had a resurgence in reported bed bug infestations.^{1,2,4,7-9} A survey conducted by the National Pest Management Association (NPMA) and the University of Kentucky found that 95% of survey respondents reported encountering bed bug infestations within the past year, up from 25% in 2000.⁹ The problem is not limited to the U.S. but is becoming a global public health problem, with reported cases escalating in Canada,

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Australia, Europe and Africa.^{2,7,10,11} A study found that reports of bed bugs in Toronto, Canada increased from 2002 to 2003 and that infestations were widespread.¹²

Factors contributing to the re-emergence of this pest include documented resistance to DDT, malathion, carbamate and pyrethoid insecticides and restrictions on indoor use of other pesticides due to health concerns.^{4,6,8} Other potential factors that may be contributing to the re-emergence of bed bugs in the U.S. and globally include increased mobility of populations (international travel), immigrant populations and transient workers, lack of bed bug control knowledge, reduced use of pesticides for control of other pests, and the decline or elimination of state and local public health agencies' vector/pest control programs.^{1,2,10,13}

Bed Bug Biology

Bed bugs are external parasites, similar to lice, which feed on blood.² Although they prefer human hosts, they will also feed on

birds, rodents, bats, and pets such as cats and dogs.^{5,7,14,15} Bed bugs are six-legged "true" bugs with a wingless, oval-shaped body and beak-like mouthparts used to penetrate the skin to suck blood from hosts.^{2,5,6,14,15} They range in color from colorless nymphs to brown or red in color as adults and have a flat shape from top to bottom that swells during feeding.^{5,7,12,13,15} Figure 1 (photo courtesy of Illinois Department of Public Health) shows an adult bed bug.¹⁶

Bed bugs have no formal nesting site but they do congregate—clusters of bugs may be found in cracks and crevices during the day, usually near sleeping areas.^{5,7,15} Bed bugs hide in a variety of places, including box springs and mattresses; bed frames; between carpet tack strips; along baseboards; ceiling moldings; window or door frames; behind electrical outlets or switch plates; in smoke alarms; behind wall hangings; in drapery pleats; behind peeling wallpaper, etc.^{2,5,10,14,15} They can also be found on furniture, cloth-

ing, and clutter or objects around the sleeping area.^{14,15} They travel easily through wall voids, thus spreading easily in multi-unit facilities.^{2,7,8}

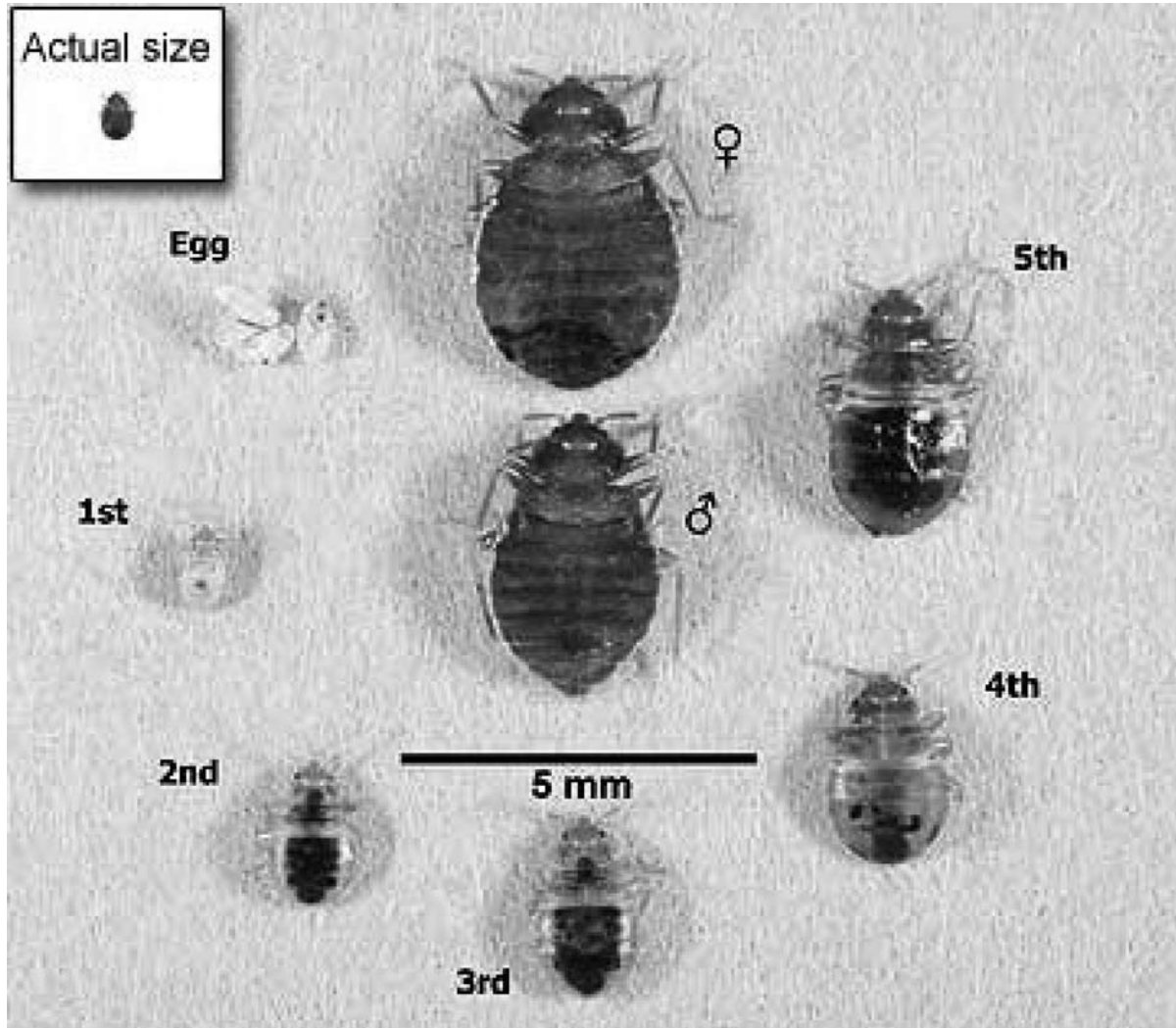
Eggs are glued to rough surfaces in areas where the bugs hide.^{5,7,14,15} Eggs are cream or white in color and hard to see with the naked eye (1 mm long).⁷ A female may lay 200-500 eggs during her lifetime,⁷ in groups of three to five per day.¹⁴ Eggs hatch in approximately 4-12 days¹⁷ and can mature to full adults in 4-5 weeks under ideal conditions (75-80% relative humidity with temperatures ranging from 83-90°F).⁷ Adults live 12-18 months and can remain fully active at temperatures down to 45°F if acclimated for 24 hours at temperatures below 60°F.^{7,13,15}

Figure 2 (provided by the EPA)¹⁸ shows the bed bug life cycle. Before reaching adult size, bed bugs go through five nymphal instar (molting) stages and need one or more blood meals before molting.^{5,15,17} Nymphs can live at least three months without feed-

Figure 1. Adult Bed Bug¹⁶



¹⁶Photo courtesy of Illinois Department of Public Health

Figure 2. Life Cycle of the Bed Bug¹⁸

Life cycle of the bed bug, starting from the top left, moving counterclockwise: eggs (1 mm), 1st stage nymph (1.5 mm), 2nd stage nymph (2 mm), 3rd stage nymph (2.5 mm), 4th stage nymph (3 mm), 5th stage nymph (1.5 mm), unfed adult (5.5 mm), and fed adult. ¹⁸Photo Courtesy of Stephen Doggett, Department of Medical Entomology, Westmead Hospital, Sydney, Australia

ing,⁷ and adults can survive up to a year without feeding,^{7,13,14} although incomplete blood meals and starvation will prolong development.^{5,15} They can feed to repletion in 3-10 minutes and will feed every few days if a host remains available.^{7,13}

Bed bugs spend most of their time hiding, coming out primarily at night to feed.^{5,6,10,15} They can travel 5-20 feet⁷ (maximum range is approximately 100 feet)¹⁷ nightly, each

direction, to reach a host and are attracted by the host's body temperature and carbon dioxide.^{10,14} They often void part of their previous meal while feeding, leading to blood-like spotting on mattresses and other surfaces.^{5,7,14,15} Following a meal, they quickly return to hiding.^{5,15} In addition to finding live bugs and eggs, other signs of an infestation include blood from squished bugs, dark fecal spots, eggs shell casings, and molted or casts

of bed bugs.^{5,7,14,15,17} In heavy infestations, there may be a sweet or musty odor compared to raspberries or stink bugs.^{7,13-15,17}

EPIDEMIOLOGY AND HEALTH EFFECTS

Bed bugs are opportunistic creatures. They can easily hitchhike on clothing, luggage, purses, backpacks, books, furniture and bedding.^{7,14,17} As such, infestations can occur nearly anywhere that humans travel



and/or sleep, such as in hotels or motels, dormitories, shelters, hospitals and care facilities, apartment complexes, in private homes, and on public transportation such as buses, planes, trains and ships.^{2,10,12,14,15,17} Infestations are not limited to particular socioeconomic status, so anyone can become a host.^{11,17} Because bed bugs can be carried in and on a variety of objects, an infestation is not an indication of poor hygiene or lack of cleanliness.^{4,5,8,12,15}

Although there is no conclusive evidence of disease transmission to humans,^{2,5,7,8,14} bed bugs have been found to naturally carry at least 30 human pathogens.⁷ However, there has been limited research in this area for several years.² The initial bite from a bed bug is painless and reactions to the salivary proteins differ from person to person.² According to the Armed Forces Pest Management Board, reactions can be classified into 5 stages: (1) no reaction; (2) delayed reaction (symptoms usually appear 1-3 days after bite and may last 2-5 days); (3) both immediate (symptoms usually appear 1-24 hours after bite and last 1-2 days) and delayed reaction; (4) immediate reaction only; and (5) no visible reaction.⁶ Individuals may develop a "sensitivity" to salivary proteins following repeated bites by a large number of bugs. Allergic reaction may include swelling, welts, and severe itching (lasting hours to days).⁷ Scratching bite sites increases inflammation, which can lead to secondary bacterial infection.^{7,8} In rare cases, anaphylaxis may occur.^{7,8} Bed bugs and their fecal droppings could pose a potential allergy and asthma trigger.⁷ Hwang et al reported that homeless individuals "with bed bug bites suffer a substantial degree of emotional distress."¹² Indirect health effects can include sleeplessness, agitation, and anxiety, as well as social stigma associated with having an infestation.^{2,7,8} The aftermath of an infestation can also lead to significant stress, especially if legal action is taken.¹¹

CHALLENGES TO PUBLIC HEALTH

The challenges to public health which professionals face include the fact that treatment options for bed bugs are lim-

ited and costly,^{8,12} making it difficult for certain populations to obtain treatment. Beyond the direct cost of treatment, bed bug infestations have additional financial impact through costs for clinical diagnosis and symptomatic medical treatment of bites.^{7,8} Indirect costs include legal fees and awards for damages¹¹ as well as decreased productivity and lost wages.^{2,8} Reporting of infestations is largely voluntary,⁷ so the true extent of the problem may be difficult to ascertain. Because bed bugs are not known to transmit human disease, local public health departments do not see them as a priority when allocating limited funding.^{2,8,12} The low priority level of bed bugs as a public health concern leads further to a lack of coordination between federal and state officials, although the CDC and EPA have begun coordinating efforts, including issuing a joint statement and allocating funding for research and outreach.^{2,8} Bed bug treatment has remained largely a local response in communities that view bed bugs as a serious issue, but municipalities struggle to identify landlord and tenant responsibilities for the costs of control and treatment.^{2,8}

Another concern is the misuse of pesticides not intended for indoor use or the application of indoor pesticides at levels higher than necessary.^{2,4} The EPA has expressed concern about individuals using illegal and unregistered pesticides to treat infestations, as well as misapplication of chemicals (using too much or use of outdoor pesticides indoors).^{1,2,4,7,13} Doing so may be dangerous, cause illness, and/or scatter pests rather than killing them.^{2,13} The EPA stresses following labeling directions carefully. In an effort to promote the safe use of pesticides for bed bug infestations as part of Integrated Pest Management (IPM), the EPA has developed a web-based search tool (see <http://cfpub.epa.gov/oppref/bedbug/>). In addition, the EPA cautions against using home remedies that have not been researched for effectiveness and safety because they can be dangerous or ineffective and may promote pesticide resistance.²

INCREASING PUBLIC AWARENESS AND TREATING INFESTATION

"An ounce of prevention is worth a pound of cure" has significant application when it comes to bed bug infestations. Bed bugs can be difficult to treat once they become an established population, so preventing their introduction to a new setting is an important component of bed bug education and outreach. Table 1 presents a few simple tips for travelers, based in part on suggestions by the EPA¹³ and Potter.⁵ Traveler awareness and precaution can reduce the chances of bringing hitchhiking bed bugs into new areas.

IPM relies on a variety of intervention strategies based on knowledge of pest life cycles to provide an economical means to control infestations while minimizing potential hazards to people, property and the environment.² IPM relies on identification and monitoring, sanitation methods, non-chemical measures, and targeted application of insecticides.^{2,7,13-15} The first step in IPM is to correctly identify the pest. When evidence is found, contacting a professional, licensed pest control company with experience using IPM to treat bed bug infestations is suggested.^{10,13,15}

Sanitation methods include de-cluttering, laundering, steam treating and vacuuming.¹⁵ Clutter provides hiding places for bed bugs, making detection and treatment more difficult. Therefore, removing clutter is a necessary step toward eliminating the pests.¹³ Laundering clothing and bedding will eliminate bed bugs on individual items, but will not provide residual protection, meaning that they are prone to re-infestation if eggs and insects are not eliminated from their hiding places.^{5,7,14} Similarly, vacuuming with a high efficiency particulate air (HEPA) filtered vacuum (which removes >99% of particles >0.3 micron diameter)⁶ will remove adults, nymphs, and debris that may block applied pesticides, but it will not collect all the eggs.^{5,7,14,15} Care must be taken when disposing of the vacuum bag so that bed bugs are not inadvertently spread to new areas.^{5,14,15} Professional-strength HEPA filter vacuums are available from a variety of



Table 1. Tips for Travelers: Bed Bug Awareness

When	Area of Concern	Strategy
Checking in	Bed and Room	Check for bed bugs in hotel/motel or hostel rooms by looking for dark fecal spots and live bugs. Pull back the bedding to check the mattress and box springs, especially along the seams. Also look at the underside of the bed skirt, along bed frame and base boards, and in and around furniture drawers.
During your stay	Clothing	Keep clothing in your zipped suitcase, in sealed plastic bags, or hanging in the closet. DO NOT put your clothing directly in hotel drawers.
	Luggage	Inspect the luggage rack. If there are no signs of bed bugs, store your bags on the luggage rack rather than placing them on the bed, floor, or upholstered furniture. Placing bags in the bathtub is also an alternative.
Upon return home	Clothing	Unpack directly into the washing machine and immediately wash clothing in hot water ($\geq 120^{\circ}\text{F}$) and dry on high heat (≥ 15 minutes) or dry clean items.
	Luggage	Inspect suitcases and bags for signs of bed bugs. An additional precaution is to store bags in sealed plastic bags and/or away from living spaces, such as in a garage.

janitorial supply companies. Steam cleaning or heating ($\geq 120^{\circ}\text{C}$) upholstered furniture, curtains, carpets and bedding will kill bed bugs and their eggs, but the process is slow and labor intensive.⁷ In addition, the steam head must be sufficiently large and care must be taken because the upholstery and bedding can disperse the treatment;⁷ excess moisture can cause additional problems such as mold, mildew and dust mites.^{7,15}

Non-chemical measures focus on eliminating bed bug access to hiding places. Mattress encasements for the mattress and box springs trap bed bugs and eggs and provide a bite-proof, escape-proof barrier.^{5,7,13-15} Another step is to seal cracks and crevices, preferably with a silicon-based sealant, and to seal electrical boxes and switch plates.^{7,13,15}

IPM also includes the limited application of chemical treatments. Residuals work better than highly repellent materials which may only scatter the bed bugs.^{14,15} At least two pesticides applications are usually needed, followed by very thorough re-inspections to ensure that isolated females are killed.^{5,7,14} Caution must be exercised with use of chemical treatments and must be used according to labeling directions.^{13,14}

Effective control of bed bugs requires

an integrated approach such as IPM as well as educating occupants.^{2,7} Because bed bugs travel easily through cracks and within walls, inspection and treatment in multi-unit facilities should be concurrent and coordinated with educational efforts to ensure occupant cooperation.^{2,7} Ongoing vigilance is also important throughout and following treatment.

WHAT HEALTH EDUCATORS CAN DO

Recommendations from the EPA's National Bed Bug Summit held in April 2009 included consumer education and communication to "develop targeted bed bug education curriculum (i.e., children in schools, nursing homes, health care, hotel industry...)" focusing on "identification, biology, prevention, safe treatment options...myths, sanitary guidelines [and] best practices."¹⁹ Additional recommendations called for fact sheets and training for tenants and landlords about the problem, including awareness of IPM practices.¹⁹ Education and communication play a very important part in any bed bug control program, particularly in multi-unit facilities. Education should explain what bed bugs are, how infestations are established and the control measures

used to eliminate them. In addition, education can encourage individuals to report infestations to government agencies, thereby improving tracking¹⁰ and possibly stimulating government agencies to increase the public's resources to deal with these pests. It is essential that health educators are available to answer questions and provide direction to those who are concerned but may not know where to get factual information. Prevention tips, such as the tips for travelers, are also an important component of public education. Although there are numerous resources online, such as through government agencies and university extension offices, it is important that messages be tailored to specific populations in clear language. Table 2 was developed from information provided on the EPA website,²⁰ and some state departments of health are beginning to post bed bug information on their websites.

These recommendations coincide with the health education profession's areas of responsibility as defined by the National Commission for Health Education Credentialing, Inc., especially with two particular areas – serve as a resource person (Responsibility VI) and communicate and advocate for health (Responsibility VII).²¹ Although

**Table 2. Top Ten Bed Bug Tips²⁰**

Bed bug Tip	Detailed Information
Be sure it is a bed bug infestation	To verify that you have a bed bugs and not another infestation such as fleas or ticks, visit: http://www.epa.gov/pesticides/bedbugs/index.html for identification tips.
Don't panic	It is possible to get rid of bed bugs, and you don't have to throw out all of your belongings to do it.
Explore treatment options before using pesticides	IPM** techniques may help you reduce bed bug populations without having to resort to pesticides. Visit: http://www.healthyhometraining.org/ipm/ and http://www.entomology.cornell.edu/cals/entomology/extension/idl/upload/Bed-Bugs.pdf . for more information. If pesticides do become necessary, contact a professional.
Reduce hiding places	Clean up clutter and encase your mattress and box springs with a protective cover (no tears) for a year.
Wash and heat-dry your bedding	Wash your bedding regularly in hot water ($\geq 120^{\circ}\text{F}$) and dry on high heat (≥ 15 minutes).
Freezing doesn't usually work	Home freezers usually aren't cold enough to kill bed bugs. To be effective it can take several days at 0°F or a week at 20°F to freeze bed bugs.
High temperatures usually work	Special, high-heat equipment is needed to treat a structure, but it may work to heat small items in black plastic bags under the sun at 110°F for at least three hours.
Don't spread bed bugs	If you decide to throw out some of your infested household items, make sure you destroy them so that others don't inadvertently spread bed bugs to new areas.
Reduce bed bugs	Vacuum floors, rugs, cracks, crevices, and all around the bed. When you are done, place the vacuum bag or contents in a plastic bag, seal it, and throw it out.
If necessary, contact a professional	Hiring a reputable pest control professional may be an effective way to quickly rid your environment of bed bugs, but be sure to talk to them about IPM** approaches. Visit: http://www.epa.gov/oppfead1/Publications/Cit_Guide/citguide.pdf and http://npic.orst.edu/state1.htm for more information.
*The information in Table 1 came from http://www.epa.gov/pesticides/factsheets/bed-bugs-faq-fs.html . **IPM stands for Integrated Pest Management	

bed bugs affect individuals, they have become a community concern due to the ease with which they spread and the direct and indirect impacts they have. Health educators can work as part of an interdisciplinary team to educate the public about this global health concern by serving as a resource and by developing resource materials about bed bug identification, biology, prevention, safe treatment options, myths and best practices including IPM. Beyond these two areas of responsibility, health educators can plan and implement community-based bed bug prevention programs in order to provide the public with the knowledge and skills necessary to prevent bed bug infestations, take appropriate precautions when travelling, and to treat bed bug infestations with best practice methods.

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