



The History of Bed Bug Management— *With Lessons from the Past*

"A Strenuous Struggle, a vigorous campaign, is before any housewife who is called upon to dispute the occupancy of her home with that persistent pest unfavorably known as the bedbug, who, gorged with the blood of his victim, lieth up in his lair from daylight to candlelight, only to swoop down upon his helpless sleeping prey during the midnight watches."—C. L. Marlatt, The Bedbug, 1916.

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For much of recorded history, the common bed bug, *Cimex lectularius* L., was among the most hated of household insects. Infestations were rampant, extermination was difficult, and remedies were often as risky to people as they were to pests. During the second half of the 20th century, humanity received a reprieve from the sleep-depriving parasites, thanks mostly to the availability of potent residual pesticides. In recent years, however, bed bugs have made a comeback throughout the world (Boase 2001, Doggett et al. 2004, Potter 2005). In the United States, pest management firms in some cities are receiving dozens of requests for bed bug service per day, and the challenges of eradication have been likened to a proverbial "perfect storm" (Potter 2006). The past can offer many insights into the seriousness of this current resurgence. To help entomologists and society prepare for what lies ahead, this paper provides a historical review of the impacts of bed bugs and their management.

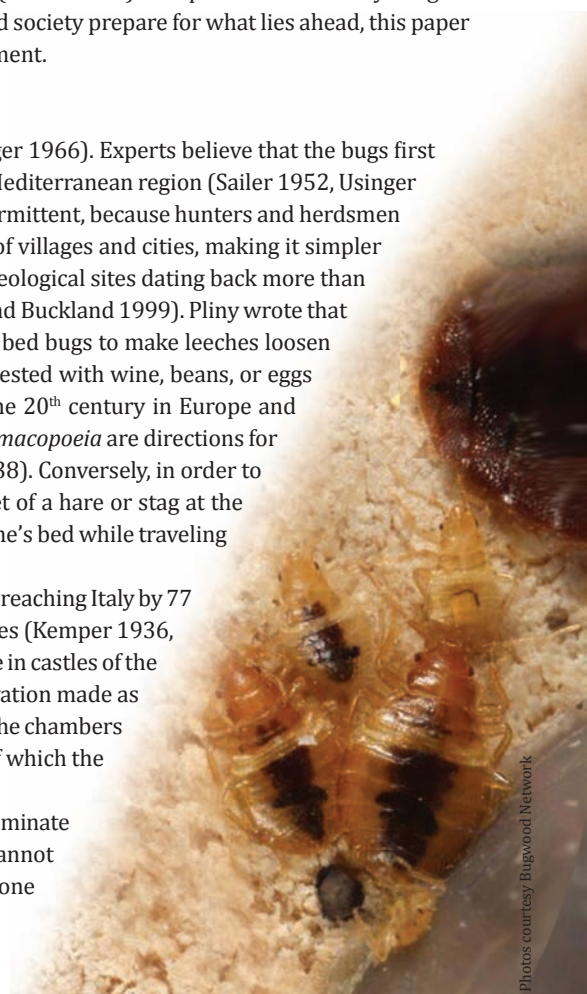
Pestiferous Origins

Bed bugs have been biting us since the beginning of recorded time (Usinger 1966). Experts believe that the bugs first parasitized bats and then moved to humans inhabiting the same caves in the Mediterranean region (Sailer 1952, Usinger and Povolny 1966). Relations between bed bugs and people were probably intermittent, because hunters and herdsman moved frequently. Life for host and parasite became easier with the formation of villages and cities, making it simpler for infestations to become established. Bed bugs have been unearthed from archeological sites dating back more than 3,500 years, when they were considered both pest and potion (Panagiotakopulu and Buckland 1999). Pliny wrote that a bed bug "cocktail" as a cure for snakebite, while the Greeks and Romans burned bed bugs to make leeches loosen their hold. The ancients also believed bed bugs could cure many diseases when ingested with wine, beans, or eggs (Busvine 1976). Bed bugs continued to be used for medicinal purposes well into the 20th century in Europe and North America. Included in the fifth (1896) edition of the *American Homeopathic Pharmacopoeia* are directions for making a tincture of *Cimex* to be used as a remedy for malaria (Riley and Johanssen 1938). Conversely, in order to deter bed bugs, the Greek philosopher Democritus (400 B.C.E.) advised hanging the feet of a hare or stag at the foot of the bed. Others suggested hanging a bear skin or setting a vessel of water under one's bed while traveling (Cowan 1865).

As civilization and commerce expanded, bed bugs spread throughout Europe and Asia, reaching Italy by 77 C.E., China by 600 C.E., and Germany and France, respectively, in the 11th and 13th centuries (Kemper 1936, Usinger 1966). Warmth produced by sleeping and cooking fires enabled the bugs to thrive in castles of the wealthy and huts of the working class. The poor, however, suffered the most—an observation made as far back as the 15th century and attributed to a lack of vigilant cleaning: "They infest both the chambers of rich and poor, but are more troublesome to the poor...For they do not breed in beds of which the linen and straw is frequently changed, as in the houses of the rich" (Aldrovandi 1603).

This pattern of infestation is recurring today. While it is true that bed bugs are non-discriminate in their feeding preferences, problems tend to be most acute for the poor, who often cannot afford professional extermination. The needy also depend more on secondhand items prone to harboring bed bugs (Potter et al. 2010).

Bed bugs were first reported in England in 1583 (Kemper 1936) and became common by the 17th and 18th centuries. They hitchhiked their way to the Americas aboard the ships



Photos courtesy Bugwood Network

of the first European explorers and settlers. Aided by commerce, infestations initially arose in seaport towns, appearing farther inland later on (Marlatt 1916). The latest resurgence of bed bugs in the U.S. has followed a similar pattern, with initial reports of infestation in the late 1990s appearing in such “gateway” cities as New York, San Francisco, and Miami.

The global distribution of bed bugs can also be traced to their naming. In ancient Rome, bed bugs were called *Cimex* (meaning “bug”), while the species designation *lectularius* referred to a bed or couch. The early Greek term for bed bug was *coris*, meaning “to bite,” from which the word coriander comes. One of civilization’s oldest spices, coriander (cilantro) was probably so named because when the leaves and unripe seeds are crushed, the pungent smell resembled that of bed bugs (*Encyclopedia of Spices* 2010). In England, bed bugs were simply referred to as “bugs.” The early Spanish word for bed bug was *chinche*, and Spanish-speaking people today often refer to them as *chinchas* or *chinche de cama*—literally, “bug of the bed.” Other descriptive names for bed bugs originating from Europe and North America include “bed louse,” “wall louse,” “wallpaper flounder,” “night rider,” “red coat,” “mahogany flat,” and “crimson rambler.” Bed bugs presumably did not occur in North America before the arrival of European settlers (Kalm 1748), thus there is no native word for them in the language of indigenous Americans.

Early Exterminators

Many of the methods used in managing bed bugs today can be traced to early European exterminators. Among the most famous were Tiffin and Son of London, who formed a business in 1690 to exterminate bed bugs for the nobility. The gas-lit sign over their shop read:

May The Destroyers Of Peace Be Destroyed By Us.
TIFFIN & SON,
Bug-Destroyers To Her Majesty.

Recognizing the ongoing threat of infestation, Tiffin noted: “We do the work by contract, examining the house every year. It’s a precaution to keep the place comfortable. You see, servants are apt to bring bugs in their boxes” (Cowan 1865). Tiffin mentioned finding the most bed bugs in beds, but cautioned, “if left alone they get numerous, climb about the corners of the ceiling, and colonize anywhere they can.” Centuries later, pest control firms are again advocating proactive

inspections for bed bugs. Presently, however, few clients are willing to pay for such services, preferring instead to take action only after an infestation has been discovered (Potter et al. 2008). As noted by Tiffin, the longer bed bugs go undetected, the more likely they will disperse outward from sleeping areas into other locations, making extermination more costly and difficult. In multi-occupancy dwellings such as hotels and apartments, the bugs also can spread to other locations before the source unit is discovered. Prevention has been a constant in the chronicles of bed bug management, and is one of the most important lessons to be learned from the past.

Another of England’s early exterminators was John Southall, who published the first work on bed bugs, *A Treatise of Buggs*, in 1730 (Fig. 1). The 44-page manual contained observations on bed bug behavior and advice for eliminating infestations. Southall was also an advocate of preventive inspections and repeatedly cautioned against bringing in infested belongings:

If you have occasion to change Servants, let their Boxes, Trunks, &c. be well examin’d before carried into your Rooms, lest their coming from infected Houses should prove dangerous to yours. In taking of Houses, new or old, and in buying Bedsteds, Furniture, &c. examine carefully if you can find Bugg-marks. If you find such, though you see not the Vermin, you may assure yourself they are nev’rtheless infected. If you put out your Linnen to wash, let no Washer-woman’s Basket be brought into your Houses; for they often prove as dangerous to those that have no Buggs...(Southall 1730)

To simplify inspection and treatment, Southall recommended that beds be plain, easy to disassemble, and as free from woodwork as possible. (The evolution of the bed as an object of modern society has been shaped by the bed bug. Additional influences with respect to design will be discussed later in this paper.)

Exterminator Southall also gained notoriety for his “Nonpareil Liquor,” a secret, supposedly sensational bed bug killer which he obtained from a native while traveling in Jamaica. The formula for the liquid has been lost, but it may have been derived from quassia wood, a tropical tree with insecticidal properties (Busvine 1976). A bottle of the stuff could be had for two shillings (about the cost of a nice dinner at the time) and contained enough to treat a typical bed. Many other “secret” bed bug formulas have been marketed over the millennia, a trend continuing to this day (Fig. 2). Tiffin had a pragmatic view of such remedies, however, noting that “secret bug poisons ain’t worth much, for all depends upon the application of them” (Cowan 1865). Some of the most extreme advice for killing bed bugs in the 18th century was published in *The Compleat Vermin-Killer* (1777), instructing readers to fill the cracks of the bed with gunpowder and set it on fire.

Bed Bugs in the 1800s

As mentioned earlier, bed bugs became plentiful in North America with the coming of European settlers. As a deterrent, beds were often made from sassafras wood (presumed to be repellent), and the crevices doused with boiling water, arsenic, and sulfur. According to Kalm (1748), this gave only temporary relief. Ships afforded ideal accommodation for bed bugs, and the railroad provided rapid transit to inland cities where the bugs had not been seen before. Hotels and boarding houses were especially buggy and travelers unwittingly carried them from place to place in their trunks and

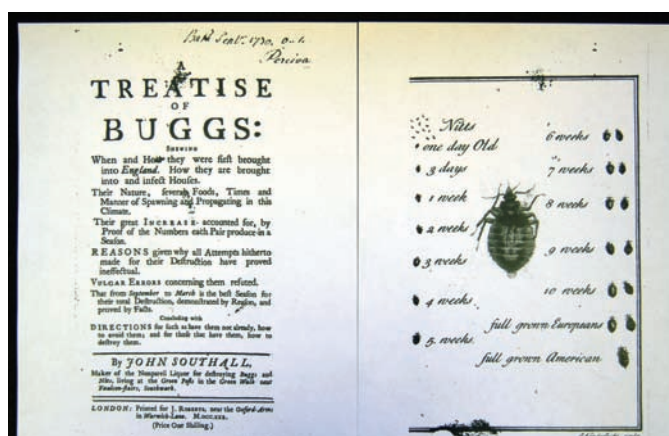


Fig. 1. Title and facing page from Southall’s 1730 treatise on the bed bug. The book sold for a shilling, while a bottle of his secret “Nonpareil Liquor” bed bug killer cost two.



Fig. 2. Many “secret” bed bug formulas have been marketed over the years, including these two from the early 1900s; A similar trend in the marketing of bed bug products is recurring today.

satchels. Vigilant travelers learned to pull beds away from walls and immerse the legs in pans of oil. Others relied on pyrethrum powder: “Dusted between the sheets of a bed, it will protect the sleeper from the most voracious hotel bug” (Osborne 1896) (Fig. 3). While such measures may have been helpful in eliminating the bugs, nowadays similar measures could lead to incarceration.

By the mid-1800s, bed bugs had become a particular problem in poor, overcrowded areas with low standards of hygiene. Wealthy households with an abundance of domestic help discovered that bed bugs could be kept in check with vigorous housecleaning, especially in respect to beds. Washing bedding, breaking down beds, and dousing the slats, springs, and crevices with boiling water or grease from salt pork or bacon proved helpful. Another benefit from such efforts was detection of infestations in their more manageable initial stages: “The greatest remedy is cleanliness, and a constant care and vigilance every few days to examine all the crevices and joints, to make sure that none of the pests are hidden away” (USDA 1875). Watchfulness and vigilance in hopes of preventing the establishment of bed bugs has been an oft-repeated mantra throughout the annals of bed bug management (Fig. 4). As bed bugs once again become plentiful, it will be interesting to see if society as a whole is capable of such vigilance again.

Bed Bugs in the 1900s

Bed bugs received a big reproductive boost in the early 1900s, when central heating of buildings became common. By the turn of the century, cast iron radiators were delivering warmth to every room in the house, a process made easier in the 1930s by electricity, fans, and forced air heating. Whereas bed bug populations had previously followed a more seasonal trend, increasing as the weather warmed, this enabled the bugs to thrive year-round (Johnson 1942, Trustees of the British Museum 1973).

In Europe in the 1930s and ‘40s, an estimated one-third of dwellings in major cities had bed bugs. Half the population of Greater London encountered them at some point during the year; and in some areas, nearly all households were affected to some extent (Ministry of Health 1934, Hartnack 1939, Harvey 1940). During this time, bed bugs became a community-wide problem, like rats. In some cases, infestation was so severe that the bugs were seen crawling from house to house, escaping through exterior windows and doors and

traveling along walls, pipes, and gutters (Matheson 1932, Ministry of Health 1934). A similar observation of bed bugs traveling outdoors between buildings was recently made by a pest control firm in Cincinnati, OH (E. Hardebeck, personal communication).

Although no social stratum was spared, the scourge was worse in poor, overcrowded neighborhoods. In England, the bugs became synonymous with slum living conditions, leading to the belief (even among some health officials) that bed bugs were one of the factors helping to create slums by attracting those who tolerated them and had acquired a degree of immunity (Ministry of Health 1934). The association of bed bugs with slum conditions was highlighted in a 1932 presidential address by C.K. Millard to the Society of Medical Officers of Health:

The most serious aspect of the slum problem, in my opinion, is overcrowding; and amongst those next in importance I am inclined to put that unsavoury feature of slum life—the (bed)bug-infested house... It is certainly not fair to put all the blame for the presence of bugs in a house upon the tenant. No doubt the tenant has his responsibility in the matter, and the tenants of bug-infested houses are not usually the cleanest of people; but often they are to be pitied as much as blamed...It must be remembered, however, before we judge others too harshly, that many of the class we are considering have been accustomed to the presence of bugs, more or less, all their lives, and familiarity has therefore bred indifference (Millard 1932).

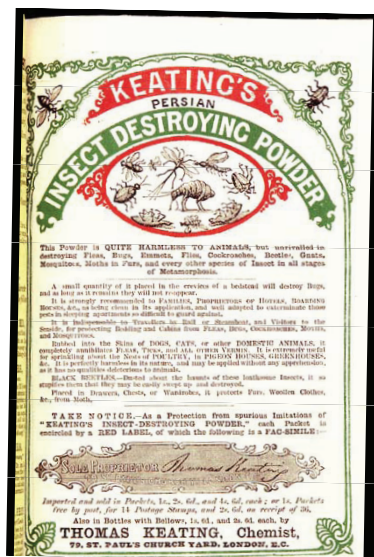


Fig. 3. (Top) One of the early effective bed bug killers was pyrethrum powder. One popular brand utilized in the mid-1800s was Keating's Persian Insect Destroying Powder; (Bottom) Travelers often puffed it between bed sheets using the same applicators to load gunpowder.



Consequently, slum clearance and the supervised transfer of tenants to new housing became an important means of combating the bed bug problem throughout much of Europe. According to Millard (1932), "Part of a complete campaign against the bed-bug must be to organize propaganda with a view to arousing an 'anti-bug conscience.'" Slum clearance campaigns were sometimes accompanied by fabrication and subsequent burning of large bed bug effigies as a means of consciousness-raising in the community (B. Campkin, R. Corea, personal communication). Such public displays are eerily similar to efforts to elevate awareness about bed bugs today.

Rigid disinfection protocols were instituted in Europe to minimize the chance of people transporting bed bugs from old to new housing. In England, families were taken to bed bug "cleansing stations," where their clothing and bedding were passed through a steam disinfector. Concurrently, furniture and other belongings were loaded into vans and fumigated with hydrogen cyanide (Ministry of Health 1934). In Sweden, citizens were housed in tents while their premises and belongings were being fumigated and several cities contemplated building hotels for this purpose. In Germany, some landlords required a written testimonial from an exterminator, stating that the apartment being vacated showed no signs of infestation (Hartnack 1939). Today, in similar fashion, some property managers are asking about bed bugs during pre-screening of prospective renters, although tenants' rights are better defended today than they were then. In New York City, for example, recent legislation was passed requiring leasers to provide bed bug infestation history for the prior year to any renter before the lease of the property (Buckley 2010).

A more comprehensive approach to preventing dissemination of bed bugs was taken by the Department of Health in Scotland. This approach, known as the Glasgow System, placed emphasis on educating newly relocated tenants on the importance of household cleanliness and the habits of vermin. Within a few days of occupancy, specialists within the Public Health Department trained in the detection of bed bugs inspected the dwelling and provided instruction on prevention and treatment. All tenants were visited at least monthly during the first three months to ensure that no bed bugs were introduced and preventive measures were proceeding satisfactorily. It is noteworthy that no such structured, community-wide programs were instituted concurrently in the United States (Ministry of Health 1934, Hartnack 1939).

During wartime, bed bugs were transported on bedding into many public air-raid shelters. They also fed on sleeping soldiers in barracks and battlefield trenches, and were spread on belts, backpacks, canteens, and helmets. Matheson (1950) reported one such

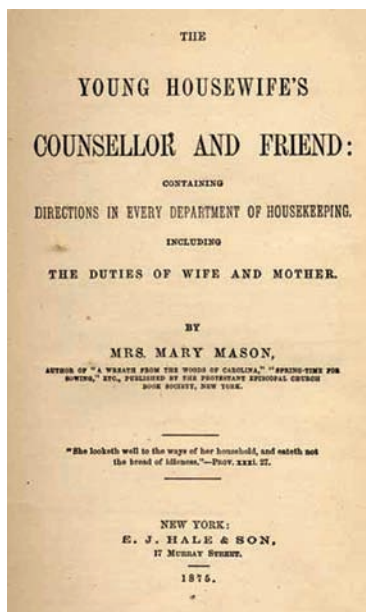


Fig. 4. Bed bug prevention and treatment were often mentioned in 19th-century guides on maintaining a clean and healthful home.

account from World War I: "In the East African campaign the bugs invaded the cork lining of the sun helmets of the soldiers. As the helmets were piled together at night, all soon became infested and the soldiers complained of bugs attacking their heads."

During World War II, bed bugs were so abundant they became a morale issue for the U.S. Army (Fig. 5). Families of the soldiers who were being feasted upon by bed bugs in their bunks pressed their representatives in Congress for a solution. Hearings were held, and as a stop-gap measure, hundreds of barracks were fumigated with hydrogen cyanide (Whitford 2006; E.J. Gerberg, personal communication). Soon thereafter, DDT was discovered to be a safer, more economical method of controlling infestations in military sleeping quarters. Bed bugs were also common on warships and even in the nooks and crannies of submarines.

In the first half of the 20th century, bed bugs also besieged all aspects of civilian life. Besides households and hotels, infestations were common in dressing rooms, restaurant seating areas, furniture upholstery shops, and especially laundries (Hartnack 1939, Mallis 1945). As noted by Herrick (1914):

One of the most prevalent ways by which bedbugs gain access to houses is on the laundry brought in by the washerwoman. The author has repeatedly seen bedbugs come in on the weekly laundry and has seen them hiding away among the crevices of the clothes basket. In several instances, the writer has seen these insects on the white spread of a bed on which the clean clothes have been laid by the laundress. This is a source of infestation that has to be constantly watched.

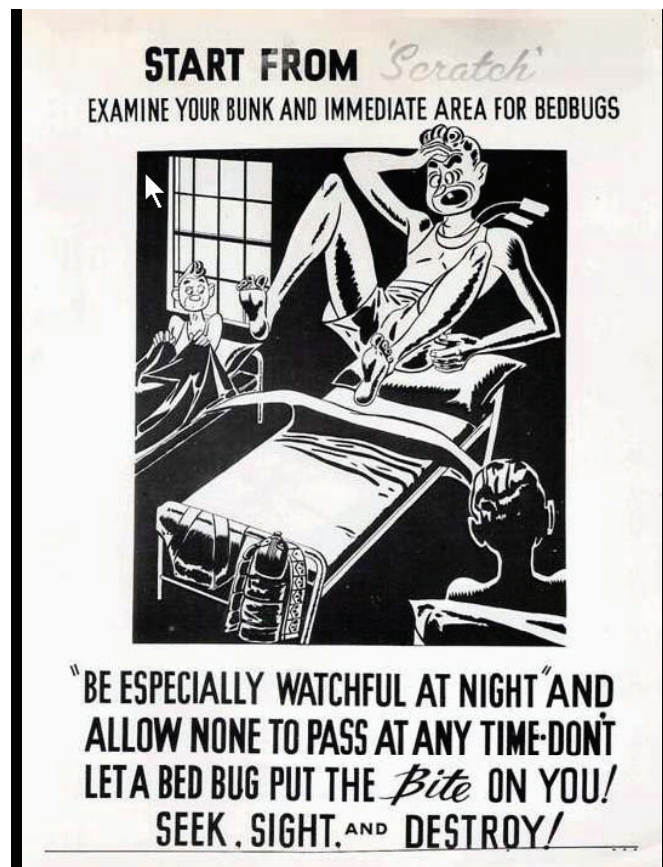


Fig. 5. Bed bugs were a continual problem for the military. This WWII poster instructed troops to keep a watchful eye for the bugs in their barracks (courtesy of E.J. Gerberg).

Theaters had big problems with bed bugs and sometimes had to tear out entire rows of seats and install new ones. Coat rooms and lockers in schools and businesses were also commonly infested. All modes of transport including trains, buses, taxicabs, and airplanes were carriers of bed bugs, and passengers unwittingly picked them up and transported them home or to work. In the 1930s, a survey of 3,000 moving vans in Stockholm, Sweden found bed bugs on 47% of the vans inspected, foretelling big concerns for moving and storage companies today. A subsequent survey in Finland showed that bed bugs were often found inside televisions and radios being serviced by appliance repair shops (Markkula and Thittanen 1970). Perhaps most disturbing is that bed bugs used to be very common in hospitals. Pest control firms throughout the world are once again encountering bed bugs in hospitals, nursing homes, doctor's offices, and dialysis clinics, as well as dormitories, schools, camps, day care centers, prisons, libraries, retail stores, office buildings, restaurants, fire and police stations, ambulances, funeral homes—and just about everywhere else they occurred in the past (Potter et al. 2010). Infestations are also arising again in poultry houses, from which the bugs can spread via the crates in which the birds are held en route to market (Steelman et al. 2008).

Efforts were made years ago to make habitations less favorable to bed bugs. Heavy, wooden beds laden with cracks and crevices were replaced with metal frames that were less preferred by the insects and easier to inspect. Bed bug-proof building construction was also stressed (see "Miscellaneous Control Methods"). Most importantly, people took measures to prevent bed bugs from entering the home. This involved constant watchfulness and attention to clothes sent to the laundress, blankets returning from summer camps and cottages, and suitcases after traveling. Frequent and careful examination of beds was advised to aid in finding the first bed bug. Nonetheless, it has long been recognized that the presence of bed bugs in the home was not necessarily an indication of neglect and carelessness: "for, little as the idea may be relished this insect may often gain access in spite of the best of care and the adoption of all reasonable precautions" (Blair 1911).

Because bed bugs were so difficult to keep out of the home, the housewife often battled them during spring cleaning (Fig. 6). An advantage of such timing back then was that in unheated homes, bed bug populations tended to be lower at the end of winter due to

the effects of cold temperatures. The excerpt below is one family's account of battling bed bugs in rural Arkansas in the early 1900s:

As I grew up on a farm the month of March turned our lifestyle into a bustle of activity. It came blustering in, bringing with it the first sunny, warm, springlike days we needed to get the year's work under way. So many chores needed attention it was hard to decide which had top priority on the list...

With all the soap for cleaning uppermost in our minds our thoughts turned to house cleaning. And in addition to getting rid of the accumulated dust and dirt we had to conquer the bed bugs (or chinchies). There were very few rent houses not infested with the pesky things. I don't know of any pests that multiplied faster or were more immune to all our efforts to get rid of them. Of course we had very little in the way of pesticides to use in those days, just Bee Brand insect dust that smelled awful but killed anything. And coal oil and boiling water that we could not get into all the places where bed bugs lived and laid their eggs.

To slow the bed bugs down and thin them out we took down and outside the beds and all the bedding, emptied the old straw ticks and burned the straw. We washed and boiled anything that was washable and scalded the bed slats and springs and poured boiling water in all the cracks and crevasses that the water would not ruin. We cleaned all other furniture and used a coal oil-soaked rag to get at places we could not pour water. We cleaned the walls as best we could, sometimes throwing boiling water on them then re-papering... We set the bedposts in cans of coal oil and kept beds and furniture away from the walls about two inches. We then could sleep in peace for a few weeks until another batch hatched out then we had the whole bit to do over. All this seems like such a lot of hard work (and it was) but having bed bugs was somewhat akin to having the itch or plague—embarrassing to have but impossible not to have, especially for people who moved a lot from house to house (Wood 2005).

The epidemic of bed bugs during the first half of the twentieth century prompted much research by universities and government agencies (Fig. 7). Seminal studies were conducted on behavioral ecology, potential for disease transmission, and pest management (Uisinger 1966, Reinhardt and Siva-Jothy 2007). Most recommendations relative to management centered on needing to be vigilant, and on the thorough application of insecticides (USDA 1953).

Bed Bug Insecticides

Insecticides used for bed bug control have a long and interesting history. All manner of concoctions were employed—gaseous, liquid, and dust—and some were as toxic to people as to pests.

Contact Sprays. Typical bed bug remedies during the 1800s and early 1900s included arsenic and mercury compounds prepared by the local druggist. The poisons were mixed with water, alcohol, or spirits of turpentine and applied with a brush, feather, syringe, eye-dropper, or oil can wherever the bugs were found. Mercury chloride (corrosive sublimate), popularly known as "Bed Bug Poison," was a common remedy used by both exterminators and the general public. One way to apply it was beaten together with the white of an egg,

Spring House Cleaning

SECURE the following material at our store when you begin to RENOVATE in a few days

FULL STRENGTH AMMONIA	BORAX
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BED BUG KILLERS IN LIQUID OR POWDER

These will help you to turn your labor into pleasure, just as sure as your house cleaning is a factor and necessity.

At Our Store in Plenty, Come and Get Them or telephone No. 9 and have them delivered

HOOD'S DRUG STORE
The Prescription Store

Fig. 6. Efforts to kill bed bugs often coincided with spring cleaning activities. Sulfur candles and other products were stocked and sold by druggists.



Fig. 7. Much of what is known about bed bugs today was published before 1950.

and then laid with a feather (Kinsley 1893) (Fig. 8). Unfortunately, a number of these products were also toxic to people, killing some accidentally, or perhaps by intent.

Pyrethrum, prepared from dried chrysanthemum flowers, is a much safer material that has been used since the mid-1800s to treat for bed bugs. An early brand was known as Persian Insect Powder, since the insecticidal effect was first discovered in Iran. Pyrethrum was included in many early bed bug preparations formulated as sprays and powders. During wartime, when pyrethrum quantities were in short supply, many other bed bug-killing compounds were



Fig. 8. Early bed bug insecticides often were dangerous: (Top) Mercury chloride, better known as "Bedbug Poison," was one of the most toxic; (Bottom) A feather was sometimes used to apply it and other liquids to cracks and crevices (reprinted from Clemson Agric. Bull. 101, 1941).

used, including rotenone, phenol, cresol, naphthalene, and Lethane 384, an organic thiocyanate which also had activity against eggs (Hockenyos 1940a, Doner and Thomssen 1943, Mallis 1945). Kerosene, turpentine, benzene, and gasoline were also widely used, as was alcohol, which is being sprayed onto bed bugs today. The effect of all these materials, however, was short-lived, seldom lasting beyond a day. Since the sprays lacked residual action and did not kill eggs, treatment had to be thorough enough to contact the bugs directly. Lacking effectiveness as a dry deposit, follow-up spraying one or two weeks later was necessary to kill emerging eggs and any adults or nymphs that were missed. Additional treatments were made thereafter until no more bugs were found.

A recurring mantra of bed bug management through the ages has been the need for thoroughness. According to Hockenyos (1940a):

The most important single factor in bedbug spraying is the degree of skill and competence of the operator applying the spray. Thoroughness is the key word and only experience will teach a man how to best find every possible place bed bugs may be harbored. Most operators take the beds completely apart and remove the casters from the bed legs. Dresser drawers are removed, rugs rolled back and pictures taken from the walls. Floor lamps are upturned, moldings pried loose in some cases and books and papers carefully examined. Each operator who does any considerable amount of this work will develop his own routine that becomes rather a matter of habit.

Mallis (1945) offered more succinct advice on treating for bed bugs: "It should be remembered that amateur efforts usually produce amateur results," which the pest management industry is finding to be just as true today.

Advertisements for early bed bug insecticides were often entertaining, and the names of the "potions" (e.g., "Bed Bug Poison," "Bed Bug Killer," "Bed Bug Murder") were intended to instill confidence in their performance (Fig. 9). Experts of the day, however, cautioned against putting too much confidence in the claims of the many so-called bed bug solutions:

It is foolish to place too much reliance on the very numerous preparations on the market which claim to get rid of bed bugs. The efficacy of some of these is doubtful since the chemicals they contain must come in actual contact with the bug in order to destroy it. This is extremely difficult to achieve on account of the bug's power of concealment... (Hunter 1938).



Fig. 9. Bed bug advertisements often were entertaining. The cartoonist for this 1928 ad was Theodore Geisel (Dr. Seuss).

Pest managers and the public would do well to heed such advice again, given that so many of our current bed bug insecticides also lack residual potency against infestations.

As can be imagined, many of the early bed bug preparations were smelly. Thus, perfuming the spray was recommended in such places as hotels, theaters, and coaches, and for “discriminating housewives,” whereas foul-smelling preparations were suitable for use on the farm for ridding poultry houses of bed bugs, and in “jails, cheap lodging houses and various other free, public institutions” (Doner and Thomssen 1943). Since many of the petroleum-based products also were highly flammable, buildings sometimes caught on fire if a match was struck too soon after treatment.

“Sometimes it is possible to destroy a light infestation by thorough soaking of the bed and other places with high-test gasoline.”

Lacking in residual action, the abovementioned sprays were most effective against light infestations discovered in the early stages. Spraying was more tedious and unreliable against heavy infestations that had dispersed beyond beds into other inaccessible areas. In these instances (and before DDT), fumigation was recommended.

Fumigants. Early bed bug fumigation often involved burning sulfur, sometimes called the “fire and brimstone” method. The burning of sulfur produces sulfur dioxide and lesser amounts of sulfur trioxide. A kettle or dish of powdered sulfur was placed in the center of the room, surrounded by a larger pan to keep the molten mass from spattering and setting fire to the floor (Hockenyos 1940b). Adding a teacupful of alcohol aided in complete burning of the sulfur. Ready-made sulfur candles could also be used but were more expensive (Fig. 10). Metal fixtures prone to tarnishing and corrosion were removed or coated with lard or Vaseline. The sulfur fumes also bleached and damaged wallpaper and fabrics, especially in the presence of moisture. In order to confine the fumes, cracks around windows and doors were sealed with strips of old newspapers coated with thin flour paste or soaked in water. Fireplaces and chimneys were sealed off with sacks or blankets, while the keyholes were stuffed with rags (Herrick 1914, Matheson 1950). Apart from the damage to household items and the stench from the burning sulfur, the procedure was comparatively simple and affordable, making it a viable control option for both householders and professionals. The sulfur fumes were lethal to all bed bug life stages, including eggs, but had poorer penetration than some other

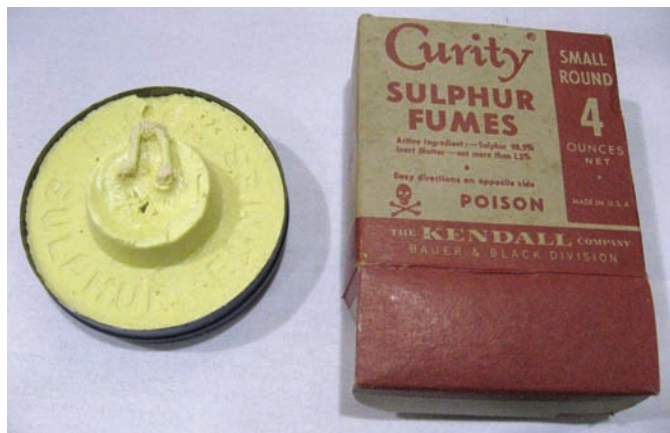


Fig. 10. Sulfur often was used as a fumigant for bed bugs. Ready-made candles were a convenient form for use by householders.



Fig. 11. Fumigating with hydrogen cyanide. The operator is opening a can of Zyklon discs in an army barracks infested with bed bugs during WWII (courtesy of E.J. Gerberg).

gases, and the process sometimes had to be repeated.

The gold standard for bed bug fumigation during the first half of the twentieth century was hydrocyanic acid (HCN, cyanide) gas. Fumigating with cyanide was highly effective, but costlier and more dangerous than previously mentioned methods. As with modern-day fumigations, the entire building had to be vacated, which was not essential when burning sulfur. Due to the danger, cyanide fumigations were best performed by professionals, but this was not always the case. In the 1920s and '30s, state agricultural experiment stations often provided instructions for using cyanide in their publications (Flint 1922, Strand 1924). Some mentioned that local druggists could supply materials and further advice—a risky proposition considering that breathing the gas caused unconsciousness within seconds and death within minutes (“Hydrocyanic acid gas is colorless and has a rather pleasant odor that reminds one of peach kernels” [McDaniel 1935]). Many people without the proper training and safety equipment were killed or seriously injured, and even professionals had mishaps using this effective but lethal material.

Various commercial preparations of hydrogen cyanide were available, including *Zyklon B* pellets and powder used in the gas chambers during the Holocaust. The most popular and convenient formulation used by pest control firms were “discoids,” consisting of fibrous absorbent discs saturated with liquid hydrocyanic acid gas. The discs were packed in gastight metal containers and opened with a special can opener (Mallis 1945) (Fig. 11). When exposed to air, the liquid cyanide quickly volatilized into toxic gas, necessitating the use of a gas mask. Applicators worked in teams with one person opening cans while the other scattered the discs onto layers of newspaper, cardboard, or dishpan-type wire containers:

With an assistant (both operator and assistant wearing gas masks) the operator starts the process of fumigating from the top floor, beginning with the cans farthest from the exit and working toward the exit. One man opens the cans, while the other follows along scattering the discs. They should work together and so time their action that the man opening the cans does not get too far ahead of the other one... Operators should *never* retrace their steps while scattering the Discoids, even though equipped with gas masks (American Cyanamid & Chemical Corp. 1938).

Special care was needed, post-fumigation, to adequately ventilate the building. Windows, doors, etc., had to be left open for at least 24 hours, and it was absolutely essential that all pillows, mattresses, bedding, clothing and rugs be taken outside and thoroughly aired and beaten (Mallis 1945).

Hydrocyanic acid gas could also be generated by sprinkling calcium cyanide dust onto strips of paper on the floor, or by placing water, sulfuric acid, and ounce-size sodium cyanide “eggs” into earthenware pots. These methods had their own inherent risks and were generally less convenient than using discoids.

Despite the dangers and other drawbacks (e.g., treatment was prohibited unless the entire building was vacated), HNC fumigation was long considered the most effective and efficient means of eliminating serious bed bug infestations. Railroad cars and ships were also fumigated; fumigation chambers and moving vans were widely used for disinfecting furniture and other belongings. But all that changed after the start of World War II when a new and more potent chemical spray became available: DDT.

DDT. The discovery and development of DDT for battling bed bugs and other pests is legendary. Dichloro-diphenyl trichloroethane (DDT)¹ was originally synthesized in 1874 by a young German chemistry student working on his thesis, but the compound stayed in obscurity until 1939 when Paul Muller, a Swiss scientist with the Geigy Company, discovered its remarkable insecticidal properties. (Muller was awarded the Nobel Prize for the discovery in 1948.) Initial quantities were under the sole allocation of the War Production Board to protect U.S. armed forces during World War II from disease-carrying lice, flies, and mosquitoes. Beginning in 1942, DDT was also evaluated against bed bugs in hopes of finding a more effective and economical method of control in military barracks. Test results by the USDA Bureau of Entomology and Plant Quarantine in Orlando, Fla., were deemed phenomenal and DDT was proclaimed “the perfect answer to the bed bug problem” (Bureau of Entomology 1945). By the end of 1945, chemical companies were also heralding the availability of DDT for civilian use, giving the public a potent new weapon in the war on bed bugs (Fig. 12).

What made DDT special was its long-lasting effectiveness as a dry deposit. No longer did bed bug sprays have to contact the insects directly, as was required with former materials. For the first time, bed bugs residing in hidden locations and nymphs hatching from eggs succumbed by resting or crawling on previously treated surfaces. While some studies reported a residual effect lasting at least six months (Madden et al. 1944, 1945), Mallis (1954) observed that samples of wallpaper sprayed with DDT continued killing bed bugs three years later, thereby eliminating the need for reapplication in the event of re-introduction. Experiments further showed that DDT had no repellency and did not disperse bed bugs throughout a room or building like pyrethrum and some other materials.

DDT applied as a 5% oil-base spray (typically blended with deodorized kerosene) or 10% powder was so effective that all the bed bugs in a room could eventually be killed by thoroughly treating the bed and nowhere else, since the bugs eventually had to come there to feed (Stenburg 1947). In practical use, most other locations in



Fig. 12. In 1945, suppliers began advertising the availability of DDT for civilian (non-military) uses, including control of bed bugs.

the room were also treated to hasten eradication. Thorough treatment of the entire bed, including both sides of the mattress, pillows, bed springs, and frame was recommended (Bureau of Entomology 1945, USDA 1953) (Fig. 13). One application usually did the job, in contrast to the recurring treatments previously needed (and being experienced today).

Interestingly, there was little mention of having to prepare for extermination by de-cluttering and washing bedding and clothing. This is quite different from current methods, which place great importance on such preparatory measures. Years ago, many households had fewer furnishings, knickknacks, clothing, toys, and clutter. Contaminating people’s belongings with pesticide was also less of a concern at the time.

Another factor that helped hasten the bed bugs’ demise was that DDT was relatively inexpensive and could be bought and used by anyone. DDT in various preparations could be purchased at most drug, hardware, and department stores, and at some food markets (USDA 1953). Unlike most fumigants, the material could be applied

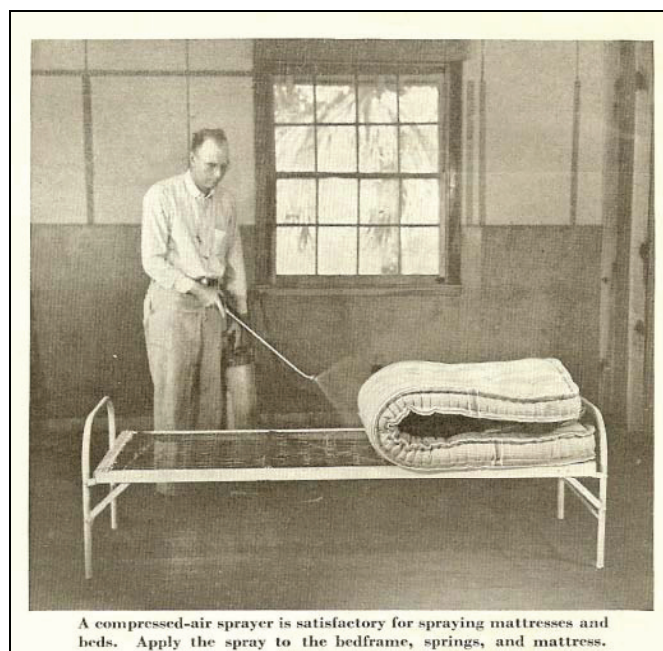


Fig. 13. When controlling bed bugs with DDT, treatment of the entire bed was recommended, including upper and lower surfaces of the mattress (reprinted from USDA 1953).

¹ The first insecticidal composition of DDT developed by J.R.Geigy, the Swiss parent company of modern-day Syngenta, carried the designation “Experiment No. G1750,” later named “Gesarol” for the spraying of agricultural pests. “Neocid” was the early designation for DDT compositions used to control lice, bed bugs, and other pests affecting humans and domestic animals. Much of the early testing was done by a team of 29 scientists working at the USDA Testing Station in Orlando, FL (The Geigy Company, 1944).

by householders and professionals alike with successful results. A few ounces of spray or an ounce of the powder was enough to treat a full-size bed and prevent re-infestation for at least a year. For added convenience, total-release DDT "bombs" (the same ones used in wartime by the military) were sold. The insecticide was also incorporated into paints and wallpaper. The all-out civilian assault with DDT was so effective and widespread that within about five years, it became difficult to find populations of bed bugs on which to do further research (J.V. Osmun, personal communication).

Resistance. As bed bugs were disappearing, reports began surfacing that some populations had become DDT-resistant. Failures were first noted in barracks of the Naval Receiving Station at Pearl Harbor in 1947, only a few years after the product was first used (Johnson and Hill 1948). During the next 10 years, other reports of bed bug resistance to DDT were confirmed, especially in tropical areas of the world (Busvine 1958). Spraying inside houses during malaria-eradication efforts probably contributed to the onset of resistance in bed bugs (Rafatjah 1971). While infestations worldwide were disappearing, Busvine (1976) astutely cautioned against complacency:

After the introduction of DDT bed bugs became a very minor problem...Yet there is still some danger of a recrudescence. In many hot countries, bugs have become virtually immune to DDT, because of resistance. If some of these resistant bugs are introduced, in the luggage of some immigrant, they could spread and provide a serious control problem.

With growing reports of DDT resistance, by the mid-1950s the National Pest Control Association began recommending malathion as an alternative. A 1% spray proved effective when applied thoroughly to the mattress, frame, baseboards, cracks, and other hiding places. To reduce odor, ventilation and masking agents were recommended. Other products used during the 1950s to 1970s to control occasional infestations of bed bugs included diazinon, lindane, chlordane, and dichlorvos. Mattresses were thoroughly sprayed and aired as part of the overall treatment. As with DDT, a single application usually did the job, provided spraying was thorough.

Although organophosphate and carbamate insecticides are no longer sold for bed bugs in the U.S., preliminary experiments suggest that some compounds (e.g., chlorpyrifos, propoxur) are still very effective (A. Romero, K. F. Haynes, and M. F. Potter, unpublished data). In countries where these materials are still being utilized, bed bugs are reportedly no harder to control than ants, termites, and cockroaches (Potter et al. 2010).

Nonetheless, history has shown that bed bugs can develop resistance to insecticides at a rapid rate. Widespread resistance to pyrethroids recently was confirmed in the U.S. (Romero et al. 2007, Zhu et al. 2010) and elsewhere in the world (Myamba et al. 2002, Boase et al. 2006, Kilpinen et al. 2008). What is especially worrisome is that today we have few effective alternatives, underscoring what can happen when pests resurface after entire insecticide classes are removed from the market.

Miscellaneous Control Methods

Insecticides have long been the principal means of controlling bed bug infestations. Other methods have been employed, however, and today many of the same techniques are again being tried or considered.

Bug proof design and construction. Through the ages, modifications were made to make beds and buildings less habitable to bed bugs. In the 16th and 17th centuries, mattresses were typically stuffed with straw and placed atop a latticework of ropes that needed regular tightening by twisting a wooden dowel (thus the expression "sleep tight..."). When the bugs became intolerable, the straw ticking was burned and replenished. Beds were long considered a status symbol for the wealthy. During the 14th through 18th centuries, they often were fashioned of ornately carved wooden timbers, which afforded countless places for the bugs to hide. Such beds also tended to be draped in fabric to keep out dust and drafts. Because of the bed bugs, exterminators began discouraging against such construction: "Beds especially... which I recommend should be plain, and as free from Wood-work as possible, and made to draw out, that the Wainscot and Walls may be better come at, to clear them from Buggs and Dirt" (Southall 1730).

By the mid-18th century, heavy crack-filled wooden beds were being replaced with cast iron, which was less attractive to bed bugs and easier to dismantle and inspect. Another advantage of metal over wood was that alcohol or kerosene could be poured over the joints and set on fire with a lighted match. The mid-18th century introduction of cotton mattresses also made it easier to de-infest bedding since the bugs "could be boiled to death without spoiling the fabric" (Wright 1962). Mattresses were also redesigned with fewer buttons, folds, and creases (Fig. 14).

Bed bug-deterrent design and construction was also encouraged elsewhere within dwellings. Cracks and crevices where bed bugs often reside were filled with soap, putty, or other sealants. In the 1930s and '40s, hospitals and hotels in Europe were being built with metal windows and doors and little or no woodwork. Floors were of cement or other tight composition with no baseboards. Walls were smoothly painted in lieu of peeling-prone wallpaper (Ministry of Health 1934, Hartnack 1939). Such bug-proofing measures have today been abandoned in favor of aesthetics and comfort. The coziness of the modern sleeping room is testament to how long it has been since bed bugs were top of mind. High-risk entities such as hotels, hospitals, and college dormitories may eventually need to re-think the way they design and furnish their rooms to make them less habitable to bed bugs.

Traps. Devices have long been used for trapping and removing bed bugs. For centuries, dishes, pans, and the like were placed under bed legs to discourage the vermin from scaling the bed and biting the sleeper. Oftentimes the dishes were filled with a liquid such as oil or kerosene. Similar pitfall traps are being marketed today (e.g., ClimbUp® Insect Interceptor, Susan McKnight, Inc.) to deter and monitor for bed bugs. In the 1700s, peasants also fashioned simple bed bug traps from planks of wood punched full of small holes. Placed under the mattress, the trap afforded convenient harborage for wandering bed bugs, which were removed and killed the following morning. Another trap for revealing bed bugs' presence utilized a wooden board and a flap of felt (Busvine 1976). More intricate "lobsterpot"-sized bed bug traps were constructed of wicker by 19th-century basket makers:

The trap was placed behind the bolster and between it and the head of the bed...the little anthropophagi after their

² Some refute this derivation, arguing there is no definitive proof that the saying originated from tightening the bed ropes. The *Oxford English Dictionary* states the phrase is fairly new, and many believe "sleep tight" refers instead to sleeping soundly or well, which dates back to the time of Shakespeare.

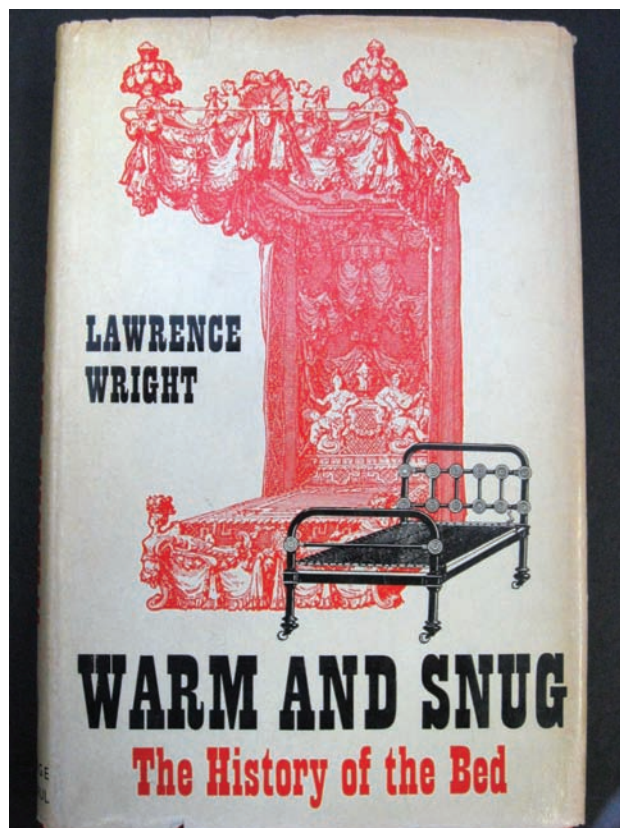


Fig. 14. Bed bugs have played an important role in the evolution of the bed. Today's comfort-oriented beds are once again prime real estate for bed bugs (cover from Wright 1962).

nightly meal would retire to digest between the interstices of the wicker trap. The housemaid in the morning would take the trap into the yard or garden and shake out the victims, who would meet a violent death under her feet (Wright 1962).

In the Balkan countries of southeastern Europe, common bean leaves were once used to entrap bed bugs. The leaves were spread on the floor of infested rooms, and the following morning, the leaves with the bugs on them were removed and burned (Bogdandy 1927). Subsequent studies found that bean leaves have no attractant effect on bed bugs, but the bugs became ensnared in the hooked hairs (trichomes) on the leaves while wandering at night (Richardson 1944). Glue traps, double-sided sticky tape, and other adhesives are modern-day versions being used against bed bugs, but their reliability is considered marginal.

Lethal temperatures. If bed bugs have a vulnerability, it is elevated temperature. Heat has been used to kill bed bugs for centuries. Boiling water was used to scald the bugs residing in bedding, bed slats, springs, and other locations. Candles were also deployed, as noted in this recollection by long-time pest controller H.L. Katz:

While my short term memory today is bad, I can still recall the acrid smell of roasting bedbugs in bedsprings with a candle, when I was a youngster in the 1920s. Candling bedsprings was what my mom learned when she lived in Russia at the turn of the century. We also put bottle caps filled with oil under the bed legs. (H.L. Katz, pers. communication via email to R. Kozlovich).

Others, including the U.S. military, used more drastic measures: "Flaming the cracks of steel cots with a blowtorch is quite effective" (War Department 1940).

C.L. Fewell received a patent in 1873 for the first portable steamer for the control of bed bugs, which was fashioned like a tea kettle with an underlying fire and ash box. "The manner of using the exterminator is by moving the spout along crevices in furniture or walls, as the case may be, when the jet of steam issuing from the spout penetrates to the lurking places of the vermin and carries with it instant destruction" (Fewell 1873). More sophisticated bed bug steamers powered by electricity are being used by the pest control industry today.

A more comprehensive way of controlling bed bugs with heat was adapted from methods developed in the early 1900s to de-infest granaries and flour mills. In an article entitled "Eradication of the Bedbug by Superheating," investigators in Canada showed that it was possible to de-infest a two-story house by stoking up the furnace and other stoves during summer to a temperature of 160° F (Ross 1916). Similar success was reported in another study where steam was used to heat a 350-room dormitory on a college campus in Mississippi (Harned and Allen, 1925). In this case, maximum temperatures in bed bug-infested rooms ranged from about 110 to 125° F, over a heating period lasting a few days. The authors concluded that very high mortality can be achieved at temperatures as low as 110° F when maintained for two days, and from a few hours exposure to 120° F. In the first edition of the Handbook of Pest Control (Mallis 1945), the author mentioned using superheating to mostly eradicate a severe infestation of bed bugs in an animal rearing laboratory. He reported that after eight hours of heating, "the mortality was so terrific, that a carpet of bedbugs covered the floor, and a slight draft through the room piled up windrows of the bugs against several objects on the floor."

Interest in using heat to control bed bugs all but vanished after the discovery of DDT. Today's renewed utilization of the approach reflects the lack of effective management options and greater concerns about pesticides (Potter et al. 2008).

Litigation

Seeking monetary compensation because of bed bugs is mostly a modern-day phenomenon, but not entirely. Bed bug bites have in fact triggered lawsuits for more than a century. In 1895, a Chicago jury ruled that "no man shall be required to pay rent for a house infested with bedbugs." Editorializing on the verdict, the news media noted that if the ruling held, "the great majority of Chicagoans would be relieved of their rent bills." In another early case involving a hotel (Bly vs. Sears), the court ruled that the presence of bed bugs did not furnish grounds for the recovery of damages because the plaintiff must have known that the hotel was previously "buggy" (Daily Iowa State Press 1902). Railroads were also defendants in bed bug lawsuits. In 1913, a Milwaukee man sued the St. Paul Railroad for \$10,000 (a lot of money in those days), claiming bed bug bites made him so ill that it interfered with his business trip. When the man returned home, he stepped off the train carrying one arm in a sling.

Past is Present

History has shown what to expect from the latest resurgence of bed bugs, and the forecast is troubling. All of society will be impacted as infestations appear in all the places they did years ago. Besides homes and hotels, bed bugs are materializing in schools, hospitals, theaters, offices, retail stores, libraries, day care centers, fire and

police stations, ambulances, moving vans, and funeral homes (Potter et al. 2010). Small cities and towns that had been spared for a while are now encountering the same type of infestations as larger metropolitan areas.

Perhaps the most unsettling aspect of 21st-century bed bugs is that we are in uncharted territory. There will be new challenges this time around, including unprecedented movement of people within towns and cities and around the globe; more clutter and belongings in which bed bugs can hide; less potent insecticides for both householder and professional use; more restrictions involving fumigation; greater apprehension about pesticides; and a mindset today that when someone is harmed, they should be compensated or sue for damages. The foundation of bed bug management still consists of hard work, public education, and constant vigilance to prevent or detect infestations in the early stages.



Bed bug extermination today is often done in much the same manner as in the 1940s.



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