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Bed Bugs Through History

Michael F. Potter

> *Among all the night enemies which often perturb our sweet quiet sleep, there is none more cruel than bedbugs.*
>
> Andrea Matthioli, 1557

1.1 Introduction

Bed bugs and humans have had long and interesting relations. Few pests throughout our history have been more detested, or inspired such innovation in pursuit of a solution. Much of humanity had a respite from bed bugs during the second half of the 20th century. Now that the reprieve is over, the past can provide insight as to what lies ahead.

1.2 Origins and Spread

Bed bugs have been biting us pretty much from the beginning. Evidence suggests the parasites first fed on bats, turning their attention to humans after we began inhabiting the same caves (Usinger and Povolny, 1966; Booth *et al.*, 2015). Relations between bed bugs and humans were probably intermittent back then, because hunters and herdsmen were wanderers. Life for the parasites became simpler with the formation of villages and cities, making it easier for infestations to become established. Bed bug remains have been unearthed from sites dating back to the Pharaohs (more than 3500 years ago), when they were considered both pest and potion (Panagiotakopulu and Buckland, 1999). The Roman scholar Pliny the Elder wrote that the Egyptians drank a bed bug "cocktail" as a cure for snakebite, while the Greeks and Romans burned the bugs to make leeches loosen their hold. Ingesting bed bugs was thought to cure maladies ranging from lethargy to urinary infections (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 bed bug" to be used as a remedy for malaria (Riley and Johanssen, 1938). The ancients also devised creative (if not entirely effective) measures to defeat them. The Greek philosopher Democritus (400 BCE), for example, recommended hanging the feet of a hare or stag at the foot of the bed, while others suggested suspending a bear skin (Cowan, 1865).

As civilization and trade expanded, bed bugs spread north and east through Europe and Asia, reaching Italy by 77 CE, China by 600 CE, and Germany and France, respectively, in the 11th and 13th centuries (Usinger, 1966). Warmth produced by sleeping and cooking fires enabled the bugs to thrive in castles of the

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wealthy and huts of the working class (Figure 1.1). However much like today, the poor and disadvantaged suffered the most: "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).

Bed bugs were first reported in England in 1583 and became common by the 17th and 18th centuries. They hitchhiked their way to the Americas aboard the ships of the first European explorers and settlers. Aided by commerce, infestations initially arose in seaport towns, appearing farther inland later on (Marlatt, 1916). The current resurgence of bed bugs in North America has followed a similar pattern, with initial reports of infestation in the late-1990s appearing in such "gateway" cities as New York, Chicago, Toronto, and San Francisco.

The global spread of bed bugs can also be traced to their naming. In ancient Rome, bed bugs were called *Cimex* (meaning "bug"). The species designation (*lectularius*), assigned centuries later by Linnaeus, 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 are crushed the pungent smell resembled that of bed bugs. Ancient Chinese who ground the bugs up to treat wounds called them *chòu chong,* or "stinky bug," and the obnoxious odor prompted a similar christening (*punaise,* "to stink") in medieval France. The Japanese once called bed bugs, *Nankin mushi,* or "insects from Nanjing (China)", an expression anecdotally said to have been coined during the Sino-Japanese war (1937–1945). However, this term is considered derogatory and now *Tokojirami* (bed louse) is more often

Figure 1.1 Bed bugs depicted in *Hortus Sanitatis* (Anonymous, 1536). This was the first ever encyclopedic compilation of natural history, originally published in Germany in 1485. Credit: Wellcome Images CC (https://www.diomedia.com/stock-photo-hortus-sanitatis-image19956256.html).

used. Another disparaging moniker, *venerschen* (little venereal), was used in Germany, presumably because of the pest's infectious disposition (Borel, 2015). In England, bed bugs were simply called "bugs." The early Spanish word for bed bug was *chinche,* and Spanish-speaking people today often refer to them as *chinches* or *chinche de cama*; literally, "bug of the bed." Other descriptive names originating from Europe and North America included "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, thus there is no definitive native word for them in the language of indigenous Americans (Usinger, 1966). Although the Hopi people of the southwestern USA do have a native word for bed bugs (*pesets'ola*), it is unclear if the word referred to the Common bed bug, *Cimex lectularius* L., or another Cimicid species perhaps associated with cliff-dwelling birds (Reinhardt, 2012).

1.3 Early Extermination Methods

People crushed, swatted, and hand-picked bed bugs long before they relied on pesticides (Figure 1.2). The close "hand-to-hand combat" could help explain the bugs' oft-reported loathsome smell: "This insect if it be crushed or bruised emits a most horrid and loathsome stench, so that those that are bitten by them are often in doubt whether it be better to endure the trouble of their bitings, or kill them and suffer their most odious and abominable stink" (Ray, 1673).

Figure 1.2 "Summer Amusement, Bugg Hunting" (Cruikshank, 1782). People hand-picked bed bugs long before the use of insecticides. Credit: Library of Congress, Washington, DC (https://www.loc.gov/item/00652100/).

Many of the modern methods for managing bed bugs today can be traced to early European exterminators. Among the most famous were Tiffin & Son of London, who formed a business in 1690 to exterminate bed bugs for the nobility. In the 17th and 18th centuries, the affluent became very concerned that the working classes would transport bed bugs into their homes. Recognizing the need for vigilance, 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" (Mayhew, 1861). Tiffin mentioned finding the most bed bugs in beds, but cautioned "if left unmolested they get numerous, climb to the tops of rooms, and about the corners of the ceilings, and colonize anywhere they can." Centuries later, pest management professionals are again advocating prevention for bed bugs, although the public is not always willing to pay for such services (Potter *et al.*, 2015).

Another of England's early exterminators, John Southall, published a treatise on the bug, which he referred to as "that nauseous venomous insect." Published in 1730, the 44-page manual contained observations on bed bug behavior and advice for eliminating infestations (Figure 1.3). Like Tiffin & Son, Southall advocated vigilance and cautioned against bringing in infested belongings: "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 nevertheless infected. If you put out your

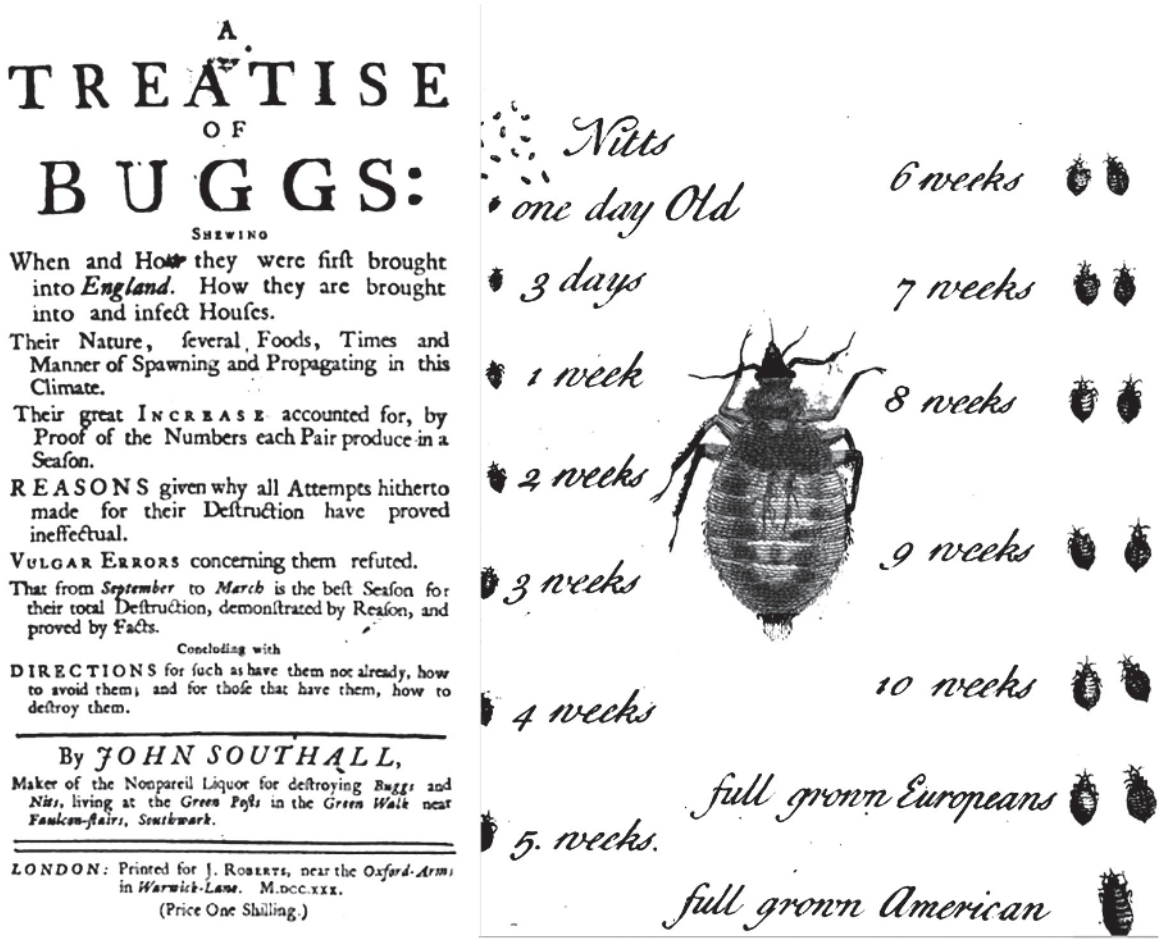
A
TREATISE
OF
BUGGS:
SHEWING
When and How they were first brought into *England*. How they are brought into and infect Houſes.
Their Nature, ſeveral Foods, Times and Manner of Spawning and Propagating in this Climate.
Their great INCREASE accounted for, by Proof of the Numbers each Pair produce in a Seaſon.
REASONS given why all Attempts hitherto made for their Deſtruction have proved ineffectual.
VULGAR ERRORS concerning them refuted.
That from *September* to *March* is the beſt Seaſon for their total Deſtruction, demonſtrated by Reaſon, and proved by Facts.
Concluding with
DIRECTIONS for ſuch as have them not already, how to avoid them; and for thoſe that have them, how to deſtroy them.
By JOHN SOUTHALL,
Maker of the Nompareil Liquor for deſtroying *Buggs* and *Nits*, living at the *Green Poſt* in the *Green Walk* near *Faulcon-ſtairs*, *Southwark*.
LONDON: Printed for J. ROBERTS, near the *Oxford-Arms* in *Warwick-Lane*. M.DCC.XXX.
(Price One Shilling.)
Nitts
one day Old
3 days
1 week
2 weeks
3 weeks
4 weeks
5. weeks.
6 weeks
7 weeks
8 weeks
9 weeks
10 weeks
full gronn Europeans
full gronn American

Figure 1.3 Title and facing page from John Southhall's "*A Treatise of Buggs*" (London, 1730).

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 treatment, Southall recommended that beds be plain, easy to disassemble, and as free from woodwork as possible. The evolution of the bed in modern society has been shaped by the bed bug. Additional influences on design will be discussed later in this chapter.

Exterminator Southall also gained notoriety for his "Nonpareil Liquor," a secret, supposedly sensational bed bug killer. The formula for the liquid has been lost, but 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). Many other "secret" bed bug formulas have been marketed throughout history, a trend continuing to this day. Tiffin had a pragmatic view of such remedies, noting that "secret bug poisons ain't worth much, for all depends upon the application of them" (Cowan, 1865). Some of the early advertisements for killing bed bugs were extreme. One recipe described in an English edition of the French *Dictionaire Oeconomique,* suggested mixing the drippings from a roasted cat with egg yolks and oil to form an ointment, which could then be rubbed onto infested furniture (Chomel, 1727). Other counsel, appearing in *The Compleat Vermin-Killer* (Anonymous, 1777), instructed the reader to boil a handful of wormwood and white hellebore, a poisonous flower, in "a proper quantity of urine" and wash the beds with it; or fill the cracks of the bed with gunpowder and set it on fire (the latter tome had similarly fervent advice for treating headaches — bleeding the person with leeches attached to one's temples.)

As noted 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 there are accounts of voyagers being fed upon during passage to the Americas, including on the *Mayflower*. Completion of the transcontinental railway system in the latter half of the 1800s afforded 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 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).

By the mid-1800s, bed bugs had become a particular problem in poor, overcrowded areas with low standards of hygiene. As in Europe, 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 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 were oft-repeated recommendations throughout the annals of bed bug management, a refrain being emphasized again today.

1.4 Propagation Within Cities (1880s–1950s)

Bed bugs received a big reproductive boost during the late 1800s and early 1900s. Cities in the USA and Europe grew at a frenetic pace due to expansion of industry and the pursuit of jobs. Mass influxes of people seeking a better life afforded the parasites easy access to sustenance. Builders and architects packed as many housing units as possible into available space, facilitating building-to-building movement of infestations. Propagation of bed bugs in the early 1900s was also aided by central heating of buildings. 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 1940s, 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 (UK Ministry of Health, 1934; Hartnack, 1939). George Orwell's *Down and Out in London and Paris* (1933) depicted bed bugs as enemy combatants: "near the ceiling long lines of the bugs marched all day like columns of soldiers, and at night came down ravenously hungry…" During this time, bed bugs became a community-wide problem like rats. In some cases, infestations were 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).

Infestations were similarly horrendous in cities within the USA. In 1939, the National Association of Housing Officials (NAHO) held an emergency meeting of housing managers from across the country. Opining on the bed bug menace, they lamented that: "If the furnishings of but one family moving into the new building are verminous – the percentage is usually much higher – there is every possibility that the woodwork, cupboards, and fixtures of the apartments will have become infested before the management can bring the condition under control (NAHO, 1939).

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 (UK Ministry of Health, 1934). 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.'" Articles were written to focus attention on especially dilapidated, bed-bug-ridden communities: "Here nearly every house is a haunted house. After dark there is no place more eerie, no torture more prolonged and blood-curdling than that enacted here year after year, no atrocity more revolting than the nightly human sacrifice. For there are vampires. I have seen them. I have smelt them" (England, 1931). 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 (Campkin, 2013). Such public displays are eerily similar to efforts to elevate awareness about bed bugs today.

Rigid disinfestation 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 (UK 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 an 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 greater today than they were back then. In New York City, for example, legislation was passed requiring lessors to provide bed bug infestation history for the prior year to any renter before the lease of such 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 preventative measures were proceeding satisfactorily (UK Ministry of Health, 1934; Hartnack, 1939).

Disinfestation protocols were also deployed by public housing authorities in the USA. Challenged by the bed bug's mobility (and restrictions on using cyanide in multi-occupancy buildings), communal initiatives were undertaken patterned after those being used concurrently in Europe. In such cities as Chicago and New

York, cooperating managers and tenants received federal and local funds to de-infest their communities. Paradoxically, the communal pest control programs disappeared soon after DDT (dichloro-diphenyl trichloroethane) became available for householder use in 1945. Exuberance over the sensational new pesticide caused housing managers to abandon the need for a community-wide approach, since each tenant could now slay their own bed bugs affordably and efficiently (Biehler, 2009). Unfortunately, the quick and easy "technological fix" proved unsustainable, and communities are facing the same bed bug challenges today.

During wartime, bed bugs were transported on bedding into many public air-raid shelters. They also fed on sleeping soldiers in barracks and battlefront trenches, and were spread on belts, backpacks, canteens, and helmets. Matheson (1950) reported one such 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 US Army. Families of 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). 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 infiltrated all aspects of civilian life. Besides households and hotels, infestations were common in dressing rooms, restaurant seating areas, furniture upholstery shops, and laundry services (Herrick, 1914; Mallis, 1945). 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 3000 moving vans in Stockholm, Sweden found bed bugs on 47% of the vans inspected. A subsequent survey in Finland showed that bed bugs were often found inside televisions and radios being serviced by appliance repair shops (Markkula and Tiittanen, 1970). Not surprisingly, infestations were also a persistent problem in hospitals. Professional pest managers today are battling bed bugs in virtually all the same places (Potter *et al.*, 2010, 2015).

Seeking monetary compensation because of bed bugs is not just a modern-day phenomenon. 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 (like so many others in the day) was previously "buggy" (Anonymous, 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 the 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 (Potter, 2011). Suits involving malevolent (intentional) introduction of bed bugs are not new either. In 1733, a porter was accused of purposefully seeding a London bathhouse with bed bugs. The same year another instance of a "Person whose Head had a very Mischievous Turn" was reported in Dublin (Sarasohn, 2013).

1.5 Determination – and a Silver Bullet

Humans have long sought to make their habitations less favorable to bed bugs. Heavy, wooden beds laden with cracks and crevices were replaced with metal frames that were less congenial to the pests and easier to inspect. Bed bug-proof building construction was also stressed (see Section 1.5.2). Most importantly, people took measures to prevent bed bugs from entering and establishing themselves within the home. This involved

Figure 1.4 Bed bug inspections used to be important in maintaining a clean and healthful home. Credit: Clemson Agricultural Bulletin 101 (1941).

checking such things as clothes sent to the laundress, blankets returning from summer camps, and suitcases after traveling. Frequent and careful examination of beds was advised to aid in finding the first bed bug (Figure 1.4).

Because bed bugs were so difficult to keep out of the home, the housewife often battled them during spring cleaning. 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. De-bugging the home was laborious; measures often included boiling anything that was washable, re-stuffing beds with new filling, scalding walls and floors with hot water, setting the bedposts in cans of oil, and setting off sulfur candles. Oftentimes such measures needed to be repeated since the effects were short-lived.

1.5.1 Bed Bug Insecticides

Insecticides used for bed bug control have a long and interesting history. All manners of concoctions were employed – gaseous, liquid, and dust – and some were as toxic to people as to pests. Typical bed bug remedies during the 1800s and early 1900s included arsenic and mercury compounds prepared by the local druggist. The poisons were often mixed with water, alcohol, or spirits of turpentine and applied with a brush, feather, syringe, eyedropper, or oil can, wherever the bugs were found. Mercury chloride, popularly known as "Bed Bug Poison" (Figure 1.5), was a common remedy used by both exterminators and the general public (the toxic compound was also used widely to treat syphilis). One way to apply it was with the whites of an egg, beaten together and then laid with a feather (Kinsley, 1893). Unfortunately, a number of these products were also toxic to people, killing some accidentally, or perhaps by intent. Many early bed bug sprays, such as kerosene and gasoline, were also highly flammable. Consequently, buildings sometimes caught on fire if a match was struck too soon after treatment.

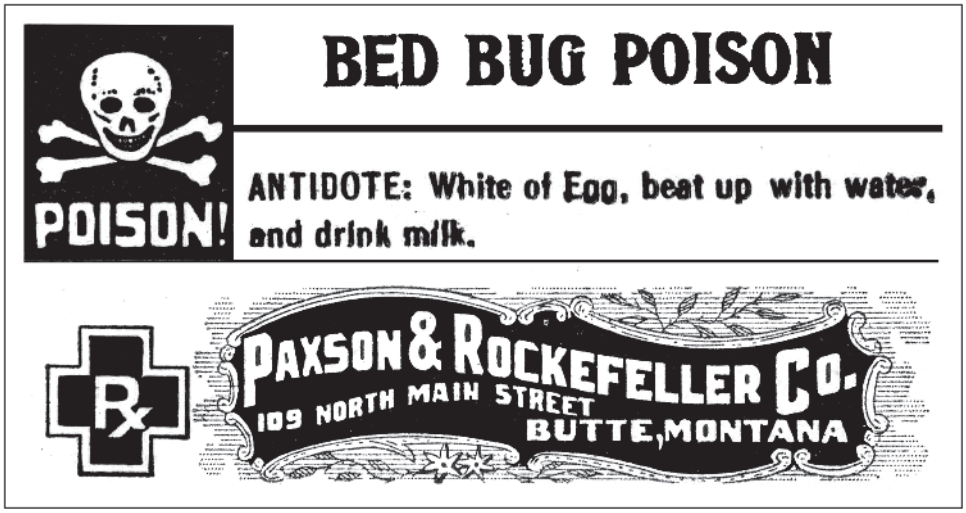

Figure 1.5 Mercury chloride, popularly known as "bed bug poison," was a common remedy for bed bugs. Many people died from accidentally or intentionally ingesting the poison.

Pyrethrum, prepared from dried chrysanthemum flowers, was a much safer material that was used from the mid-1800s to treat bed bug infestations. Pyrethrum was included in many early bed bug preparations formulated as sprays and powders. During wartime, when pyrethrum was in short supply, many other bed bug-killing compounds were used, including rotenone, cresol, and naphthalene. Kerosene, turpentine, benzene, and gasoline were also widely used, as was alcohol, which is still 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 bed bug eggs, treatment had to be thorough enough to contact the insects 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. A recurring theme of bed bug treatment has been the need for thoroughness (Hockenyos, 1940a). Mallis (1945) succinctly cautioned "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 (Figure 1.6). Despite having persuasive-sounding names like "Bed Bug Poison", "Bed Bug Killer", and "Bed Bug Murder", experts cautioned against putting too much confidence in their claims: "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). It would be prudent to heed such advice again since many products being marketed for bed bugs today have similar limitations.

Lacking in residual action, early bed bug sprays were most effective against smaller infestations. For heavy infestations (before availability of DDT) fumigation was recommended. Early bed bug fumigation often involved burning sulfur, sometimes called the "fire and brimstone" method (brimstone was the ancient word for sulfur). 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). Alcohol was often added to enhance ignition and burning. Ready-made sulfur candles could also be used but were more expensive. 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. 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

Figure 1.6 Promotions for bed bug products were common and often entertaining. The cartoonist for this 1928 advertisement was Theodore Geisel (Dr Suess). Credit: Standard Oil Company of New Jersey.

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 gases, and the process sometimes had to be repeated.

The gold standard for bed bug fumigation during the first half of the 20th century was hydrocyanic acid (HCN, cyanide) gas. Fumigating with cyanide was highly effective, but costlier and more dangerous than other 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. Many people without the proper training and safety equipment were killed or seriously injured, and even professionals had mishaps using the 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 cyanide, packed in gastight metal containers. 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 cardboard or newspaper. Special care was needed, post-fumigation, to adequately ventilate the building and its contents (Mallis, 1945).

Despite the dangers and other drawbacks, cyanide fumigation was long considered the most efficient means of eliminating serious bed bug infestations. Fumigation chambers and vans were widely used for disinfesting 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.

The discovery and development of DDT for battling bed bugs and other pests is legendary. DDT 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 sole allocation of the War Production Board, to protect US armed forces during World War II from disease-carrying lice, flies, and mosquitoes. Beginning in 1942, DDT was also evaluated against

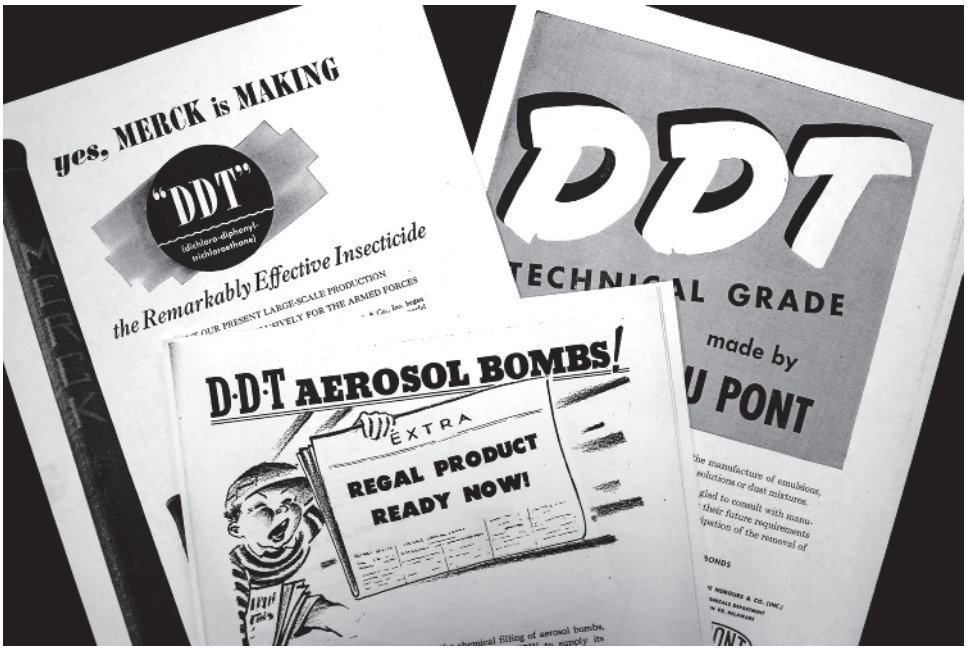

Figure 1.7 In 1945, suppliers began advertising the availability of DDT for civilian (non-military) uses, including control of bed bugs. Credit: M.F. Potter.

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, Florida, were deemed phenomenal and DDT was proclaimed "the perfect answer to the bed bug problem" (US 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 (Figure 1.7).

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 other 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) noted that samples of wallpaper sprayed with DDT continued killing bed bugs three years later, eliminating the need for reapplication in the event that some bugs were missed or reintroduced. 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 the room were also treated to hasten eradication. Thorough treatment of the entire mattress (Figure 1.8), pillows, bed springs, and frame was recommended (US Bureau of Entomology, 1945; USDA, 1953). 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, clothing, knickknacks, and clutter. Contaminating people's belongings with pesticide was also less of a concern at the time.

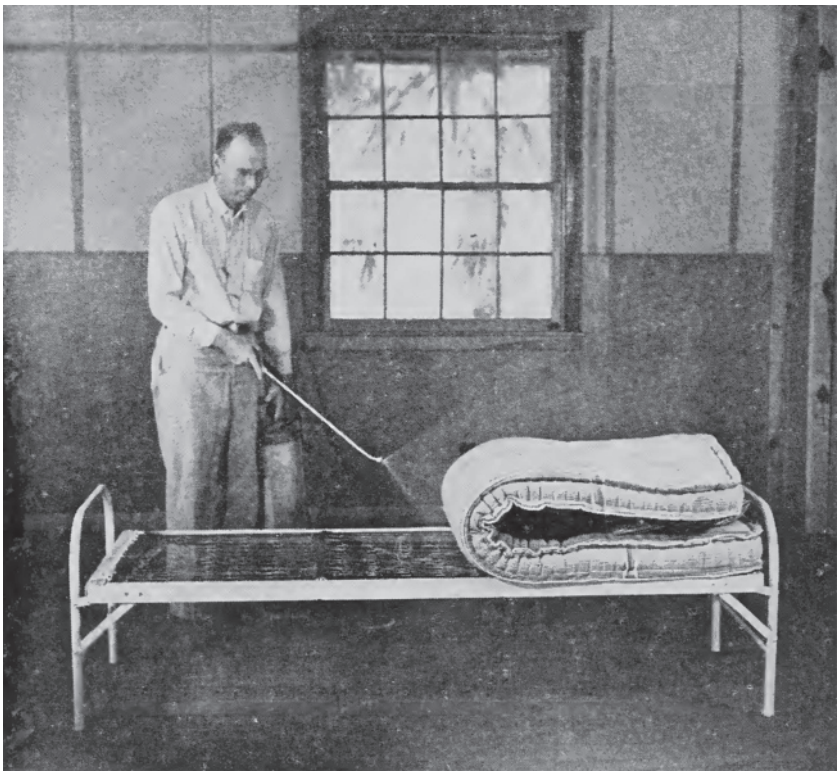

Figure 1.8 When controlling bed bugs with DDT, treatment of the entire bed was recommended, including the entire mattress. Credit: US Department of Agriculture (1953).

Another factor that helped hasten the bed bug's 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 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 five to seven years, it became difficult to find populations of bed bugs on which to do further research (J.V. Osmun, Purdue University, West Lafayette, unpublished results).

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 ten 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). With growing reports of DDT resistance, insecticides such as malathion, diazinon, and lindane were used as alternatives. As with DDT, a single application usually did the job, provided spraying was thorough. Pyrethroids were subsequently used as replacements, but resistance to these insecticides has also been documented in bed bugs throughout the world (Romero *et al.*, 2007; Zhu *et al.*, 2010; Davies *et al.*, 2012).

1.5.2 Bug Proof Design and Construction

Throughout history, 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. When the bed 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 such constructions.

By the mid-18th century, heavy crack-laden 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 ignited 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.

Bed bug deterrent construction was also encouraged in design of buildings. In the 1930s and 1940s, hospitals and hotels in Europe were being constructed 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, and cracks and crevices were filled with soap, putty, or other sealants (UK Ministry of Health, 1934; Hartnack, 1939). Today, such measures have been abandoned in favor of aesthetics and comfort. The coziness of the modern sleeping room is testament to how long it's been since bed bugs were top of mind. At-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.

1.5.3 Bed Bug Traps

Devices have long been used for trapping and removing bed bugs. Dishes, pans, and the like were placed under bed legs to discourage the vermin from scaling the bed and biting the sleeper. Oftentimes the saucers were filled with a liquid such as oil or kerosene. Similar pitfall traps are being marketed today 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 concocted 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 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 (*Phaseolus vulgaris* L.) were used for centuries 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). The bean leaves have no attractant effect on bed bugs, but the bugs become ensnared in the hooked hairs (trichomes) on the leaves while wandering at night (Richardson, 1943). Recent studies have attempted to fabricate synthetic versions of the tiny hooks so that the ancient approach might one day be used for management (Szyndler, *et al.* 2013).

1.5.4 Lethal Temperatures

Heat has been used to kill bed bugs for centuries. Boiling water was used to scald bugs residing in bedding, bed slats, springs, and other locations. Candles were also deployed: "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

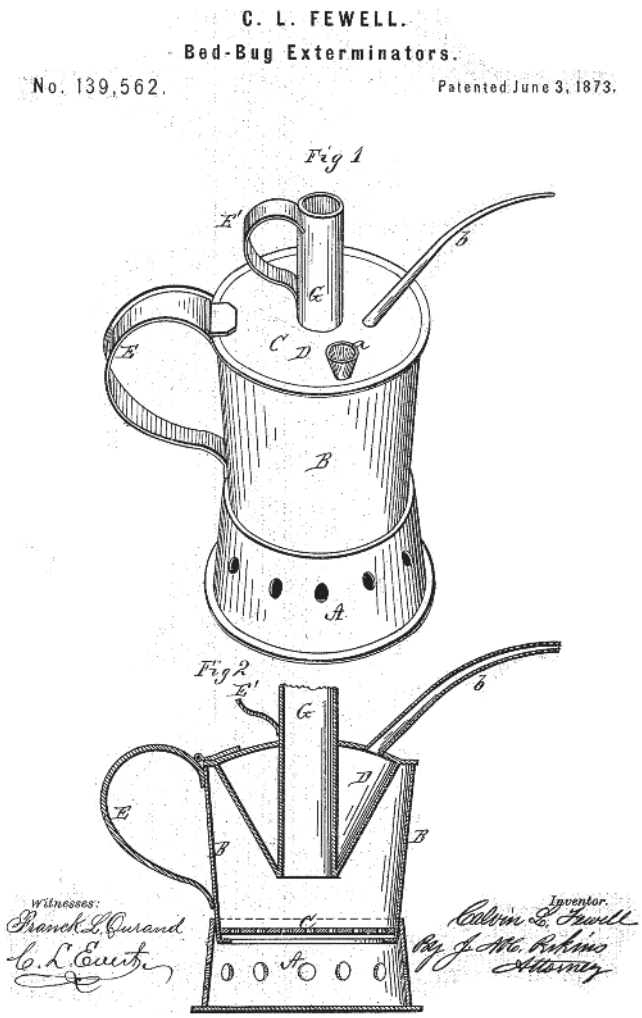

Figure 1.9 Early patent for a bed bug steamer, published in 1873. Credit: US Patent and Trademark Office.

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. comm. to R.D. Kozlovich, Safeway Pest Control, Cleveland). Others, including the US Military, used more drastic measures: "Flaming the cracks of steel cots with a blowtorch is quite effective" (US War Department, 1940).

C.L. Fewell received a patent in 1873 for the first portable bed bug steamer, which was fashioned like a tea kettle with an underlying fire and ash box (Figure 1.9). "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. Mallis (1945) mentioned using superheating to eliminate 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 reflects the lack of effective management options and greater concerns over pesticides.

1.6 Past is Present

History reveals both insights and concerns about bed bugs and their management. For much of the developed world, the modern-day resurgence of this pest serves as a reminder that it is not a birthright to live free of parasitic vermin. There will be new challenges this time around, including unprecedented movement of people locally and globally; more clutter and belongings in which the bugs can hide; less potent pesticides for home and professional use, and yet more restrictions on how liberally they can be used. Perhaps most challenging will be instilling again a mindset of societal vigilance. The foundation of bed bug management still consists of hard work, public education, and preventing or detecting infestations in the initial stages. It will be interesting to see if humanity is up to the challenge.

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