

## **BED BUGS (HEMIPTERA: CIMICIDAE): AN EVIDENCE-BASED ANALYSIS OF THE CURRENT SITUATION**

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**Abstract** Records show that the bed bug, *Cimex lectularius* (L.), was common in the early years of the 20<sup>th</sup> century, but in developed countries declined steadily from the 1930s onwards, and remained at a relatively low level through the 1970's — 1990's. However, in developed countries, there were nonetheless significant reservoirs of infestation remaining in inner-city areas through this period. The current bed bug upsurge appears to have started almost synchronously in the late 1990's in Europe, the United States, and in Australia. In London, the number of bed bug treatments is growing at about 25% per year. A wide range of explanations have been proposed for the increase, including climate change, increased human movement, changes in insecticide use patterns, and reduced insecticide susceptibility of the bed bugs. Studies of bed bug infestations in premises providing hospitality services suggest that persistence of infestation is related to failure to achieve full eradication. Where bed bug infestation are completely eradicated, then even very busy premises may then remain completely free of infestation for extended periods. Addressing the current bed bug upsurge is of key international public health importance. Correct identification of the factor(s) responsible for the bed bug increase is critical in developing effective management strategies. As such, strategies need to be based wherever possible on firm evidence.

**Key Words** Pest control, insecticide application indoors, control strategy

### **INTRODUCTION**

After several decades when bed bugs, *Cimex lectularius*, in developed countries were relatively uncommon, there is a resurgence currently underway. This resurgence is evident from an examination of the Proceedings of the International Conference on Urban Pests. None of the Proceedings covering the 1993, 1996, 1999, 2002 and 2005 conferences contained any presentations on bed bugs. However the Proceedings from the current 2008 conference, contains at least eight bed bug presentations.

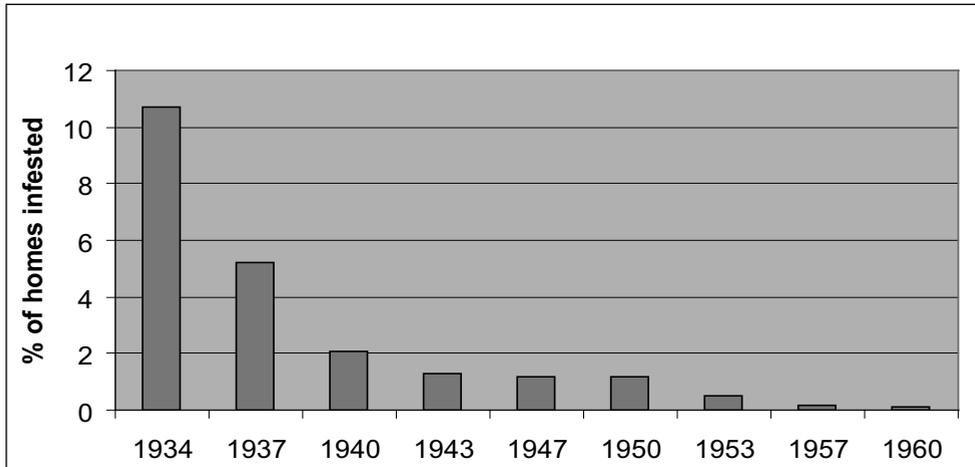
There has been extensive recent media coverage of the resurgence in many countries, with a wide range of explanations proposed. This presentation reviews the limited data on bed bug trends, in an attempt to understand the mechanisms that may have influenced the decline and rise of the bed bug over the last eight decades. The intention is to identify strategies that may assist in combating the resurgence.

### **BED BUGS: THE EARLY YEARS**

Data on bed bug prevalence in the early 20<sup>th</sup> century is limited, but all points to bed bugs being very common at that time. In the UK, bed bugs were of sufficient concern in the early 1930s for a Royal Commission on Bed Bugs to be established. The Commission reported that in London, UK... 'in many areas all the houses are to a greater or lesser degree infested with bed bugs' (Ministry of Health, 1933).

Partly as a result of findings of the Royal Commission, the Public Health Act was passed in 1936, which gave local authorities powers and responsibilities for dealing with 'verminous premises'. The treatments at that time consisted primarily of fumigation with either sulphur dioxide or hydrogen cyanide. Such treatments were applied to entire homes, although were only really effective where the homes were sufficiently airtight to allow effective concentrations of fumigant to be maintained. In addition, hydrogen cyanide was used in mobile fumigation vehicles to treat furniture and personal possessions of those moving from infested properties into new houses (Busvine, 1957). Although Busvine (1957) reported that the insecticide DDT is responsible for the successes of early bed bug control efforts, his data clearly show that at least in the

town on which he reports in detail, bed bug infestations fell by at least 80% before the introduction of DDT in about 1945 (Busvine, 1964). This suggests that very substantial bed bug reductions can nonetheless be achieved even in the absence of effective conventional insecticides.



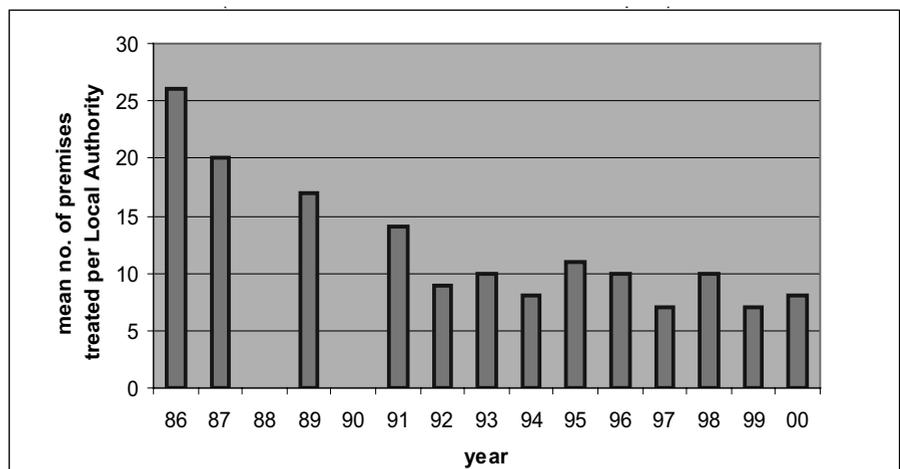
**Figure 1.** Bed bug infestation trends in a English (UK) town (Busvine, 1964).

Despite the success of the early interventions, DDT did nonetheless have a dramatic impact on bed bug incidence internationally, once introduced. Data from Denmark shows a dramatic reduction after 1945 (Busvine, 1957). In the US it was reported that “this method of treatment has been widely adopted and is so effectively done in large towns in the US, that pest control operators are apparently losing this source of business” (Busvine, 1957).

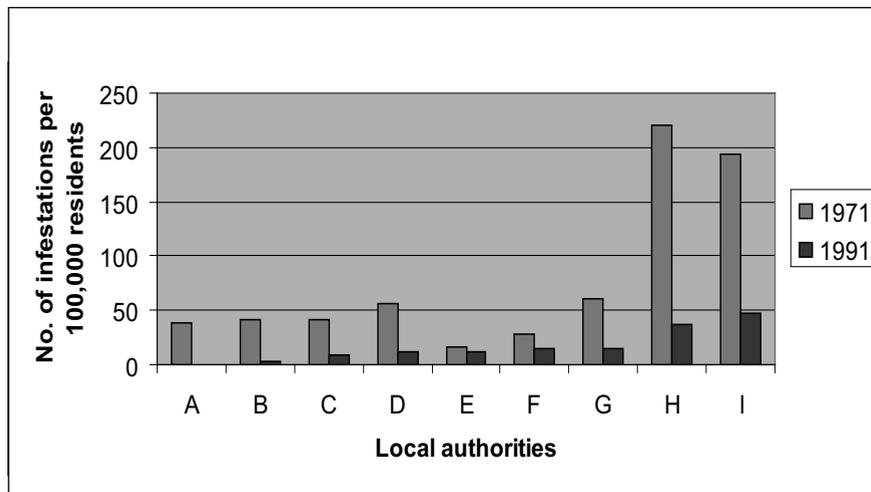
### BED BUGS IN RECESSION

Reviews of the status of bed bug infestations in developed countries in the 1950-1990 period tend to assume that bed bugs were at a very low level. Doggett (2005) reviews the bed bug recession period under the heading ‘How bed bugs were defeated’. However examination of the limited data over this period shows that nonetheless bed bugs were still present, albeit at low levels. For example the UK Chartered Institute of Environmental Health (CIEH) collected data on the numbers of treatments for various pests carried out annually by local authorities (Chartered Institute of Environmental Health, 1986 - 2000). Their data show that although the number of bed bug treatments did decline through the 1980s, there were, even during the early 1990s, around 10 bed bug treatments being applied per local authority per year. However, the CIEH data is pooled for England and Wales, and it is not possible to determine whether the bed bug problems were uniformly distributed, or whether they were particularly associated with any particular areas.

**Figure 2.** Trend in number of premises treated for bed bugs in England and Wales (Source: Ann. Environ. Health Rpt.)



In north western England there are local authority records of the number of confirmed bed bug infestations reported in 1971 and in 1991 (Boase, 2007). Each local authority was responsible for an area containing between 200 and 400 thousand residents. A number of interesting points emerge from this data. Firstly, the number of bed bug treatments per 100 thousand residents is very unevenly distributed, with some areas showing >60 times more bed bug infestations than others. Over this 20 year period the data show that the number of bed bug infestations fell in all local authorities, showing a median reduction of about 78%. There was some stability in the relative infestation levels, with the same two authorities having the highest infestation levels in both years. Compared to the other areas in this survey, these two authorities with persistent bed bug problems may be characterised as being congested, densely inhabited, inner-city areas.



**Figure 3.** Bed bug prevalence in north western England (Source: Boase, 2007); grey bars = 1971; black bars = 1991.

Another contemporary account of the presence of bed bug infestation in the recession period is provided by Cornwell (1974). He reports that in the period 1967-73, about 61% of infestations were found in domestic residential property, while about 25% were in institutional hostels, hotels, and hospitals (Cornwell, 1974). In the US, Pinto (1999) stated that in the 1950s, during the bed bug recession period, infestations were mainly found not in domestic property but in homeless shelters, and prisons. If the data from the UK are representative of elsewhere, it indicates that despite the overall substantial decline in bed bug infestations over the second half of the 20<sup>th</sup> century, there were significant reservoirs of bed bug infestation that persisted through this period, particularly in inner-city areas. It is possible that it was bed bugs from such inner city reservoirs that subsequently fuelled the resurgence.

### BED BUGS IN RESURGENCE

Probably the first indication that bed bug resurgence was underway was an article about bed bugs by Birchard (1998) in a medical journal. This report was followed by two more publications relating to the UK: Paul and Bates (2000), and Boase (2001). The latter publication reported that the increase may have commenced in the mid 1990s. In the US, reports of an increase were first published in 1999 (Pinto, 1999). In Australia, Coghlan (2002) also reported an increase, and Doggett (2003) presented data showing that the increase had been underway from the mid 1990s. Although these authors tend to agree that the increase first became apparent in the last few years of the 20<sup>th</sup> century, it is possible that the increase may have started some years earlier but not have been detected.

Estimates of the extent of the increase vary considerably. One detailed study (Richards, cited in Anon, 2007) involved examination of the records of requests for bed bug treatment received by the pest control sections of eight London local authorities, over the period 2000-2005. These London data show an annual increase of 24.7%, with some individual London local authorities now carrying out >2000 treatments per year. This high infestation level is by no means universal across the UK, and anecdotal information indicates

that in some other parts of the UK the infestation level is much less. In Australia, data from a survey of pest control companies indicated a 4500% increase over seven years (Doggett and Russell, 2007).

### EXPLANATIONS FOR THE RESURGENCE

The bed bug resurgence has attracted much attention. A wide range of explanations have been proposed by various sources, which are summarised in Table 1, together with some comment.

Establishing the cause of the bed bug upsurge is crucial, if effective strategies are to be put in place. If the main cause of the upsurge is poor awareness and slow reporting of infestation by the public, then public awareness campaigns would be important. However, if the cause is a high level of importation of infestation, then dedicating more pest control technicians to bed bug control would be appropriate. If the cause is reduced insecticide susceptibility, then a suitable resistance management strategy would be more appropriate (Rust, 1996).

**Table 1.** Potential explanations for the bed bug resurgence

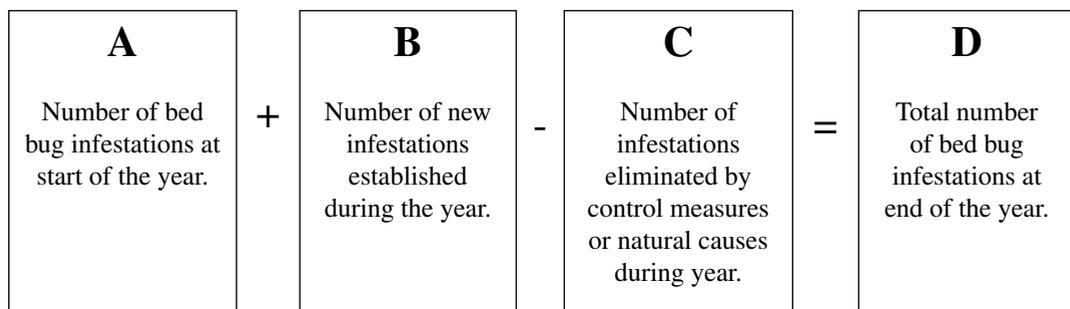
Issue	Explanation	Comment
<b>Social and human issues</b>	Increased sales of second hand items.	Bed bugs can be dispersed on infested second-hand items, but there is no evidence that sales of such items have increased substantially over the last 15 years. This does not address the increased occurrence of bed bugs in modern hotels.
	Decline in public awareness of bed bugs.	There are no data on public awareness. Epidemiologically, a community that is slow to recognise and report bed bug infestations would facilitate a bed bug increase through allowing more time for entrenchment and dispersion.
	Increased overcrowding in residential properties.	Congested domestic premises make bed bug control difficult. However, bed bug problems have increased in hotels, where congestion is seldom an issue.
	Increased human migration, as a result of EU expansion and conflict (Balkans, Middle East).	Bed bugs are dispersed in the course of the travel. Although metapopulation dynamics might allow an upsurge to be driven by increased movement rates alone, the importation hypothesis typically assumes that there are large reservoirs of bed bugs in some countries, which are being exported to those countries experiencing an increase. There is no evidence for large reservoirs of <i>C. lectularius</i> , from which those found in recipient countries are being steadily imported. If export of bed bugs from tropical countries was driving the increase, then there would be a large increase in <i>C. hemipterus</i> in recipient countries. Tropical bed bugs have been found in southern Australia (Doggett et al, 2003), and in the UK, but they are not responsible for the overall increase.
	Increased human movement for business and leisure.	
<b>Environmental issues</b>	More central heating and double glazing.	If indoor temperature increases have been sufficient to accelerate bed bug reproduction, then other indoor invertebrate pests might also show increases; there is no indication of such an increase. Some indoor pests, such as fleas, are in decline.
	Global warming.	

**Table 1 (Continued).** Potential explanations for the bed bug resurgence.

Issue	Explanation	Comment
<b>Pest control issues</b>	Inadequate training of pest control technicians.	Pest control practices have changed in response to the resurgence, which has required some re-training. There is no evidence that an initial decline in competence actually caused the increase.
	Changes in the pattern of insecticide use.	Starting in the late 1980s, there has been a decline in use of broad spectrum, residual sprays for ant and cockroach control--that may also have collaterally killed some bed bugs, to species specific bait products. This change has been linked to increasing bed bug infestations (Simon, 2004). It is questionable whether sprays applied for cockroach and ant control will have had much impact on bed bugs concealed on beds and mattresses. Now, it would be unlikely that a cockroach spray treatment would eliminate bed bugs, since there are frequent call-backs even where sprays are specifically targeted at bed bugs.
	Effective insecticides withdrawn from use.	Non-availability of DDT has been cited as a factor that allowed the current bed bug resurgence. However, DDT resistance was widely recognised decades ago, and even if it was available now, it is unlikely to be effective.
	Insecticide resistance.	The recent discovery that there is widespread and sometimes high levels of resistance to several currently used conventional insecticides, would explain both the current difficulty in controlling bed bugs, and as a result the increasing numbers of infestations (Boase et al., 2006; Romero et al., 2007; Kilpinen et al., 2008).

**BED BUG INFESTATIONS AS A METAPOPOPULATION**

In addition to viewing the bed bug upsurge as an increasing number of individual infestations, the individual infestations within a given city, area or country may be collectively viewed as a metapopulation (Stejskal, 2002). The status of the metapopulation results from the balance of a number of local processes including dispersion, establishment, detection and control activities, acting on each individual infestation. In very simple terms as shown in Figure 4 below, if the rate of establishment of new infestations (B) is greater than the rate of extinction of infestations (C), then the metapopulation continues to grow (Hanski, 1999). These dynamics will be very familiar to epidemiologists.



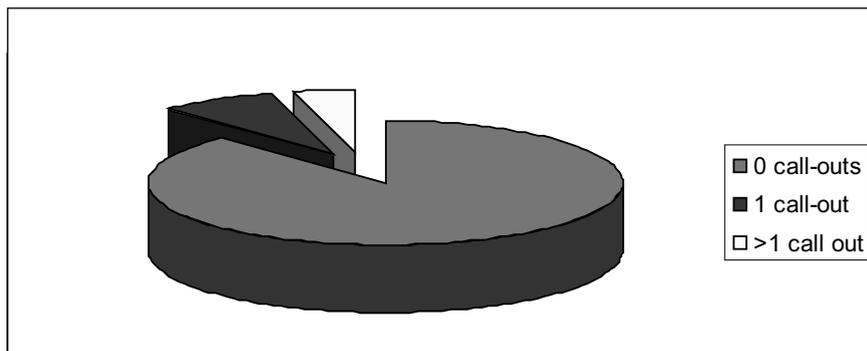
**Figure 4.** Diagrammatic representation of metapopulation dynamics of bed bug infestations.

Considering bed bug infestations in a particular area as one metapopulation, helps highlight key aspects of the control programme. It emphasises the necessity for timely eradication of infestation. Even if a bed bug treatment is 100% effective, a delay in identifying, reporting and treating the infestation may be nonetheless sufficient to maintain the bed bug upsurge, through allowing time for infestation to disperse to new sites before treatment. Alternatively, if treatments are not 100% effective, then even prompt treatment will not halt the upsurge, since the treatment would still allow recovery and then subsequent dispersal of the surviving infestation. Such an epidemiological approach can help in the development of effective bed bug management strategies.

### UNRAVELLING THE UPSURGE

Statistics on the annual number of bed bug treatments show the gross trends, but do not provide the fine detail that may enable the trends to be analysed. To attempt to clarify the nature of the bed bug increase, data on bed bug infestations were collected from several hundred premises in Europe providing hospitality services. The premises varied in size, but could each accommodate between about 100 and 1200 people. All premises had a broadly similar rate of turnover of people. Some premises were located in urban areas, while others were in out-of-town locations. There was a general concern among managers of premises participating in the survey that bed bug infestations were increasing, and that the infestation were being repeatedly introduced by those using the accommodation. All of the premises received professional pest control inputs if and when infestation was identified.

The data are deliberately presented anonymously to protect the identify of participating organisations. The data show that 8.3% of participating premises were affected by bed bugs in 2006, and 12.6% of premises in 2007, a conversion rate for 2006-2007 of 4.3%. This conversion rate may be compared with research by Newberry (1991) working in South Africa, who found that bed bug-free huts became infested at a rate of 11% per year when the nearest infested properties were distant. Clearly the majority of premises in the 2006-2007 study did not have a bed bug infestation. Those bed bug treatments that were required were concentrated in a small proportion of the premises, and these particular premises often experienced repeated call-outs for bed bug treatments, often to the same area within the building.



**Figure 5.** Bed bug infestation in accommodation blocks in Europe, 2007.

Had there been a high risk of invasion, as believed by many of those responsible for the accommodation, it is likely that a large proportion of premises would have been affected. Instead a low proportion (~12%) of premises were affected and of those affected premises, 33% required frequent visits by pest control organisations to treat infestation. This pattern of infestation and treatment suggested that the presence of infestation was less related to a high level of bed bug re-invasion, and more to a failure to achieve riddance.

To test this hypothesis, one of the most affected premises was selected for a riddance treatment. The particular building selected could accommodate up to about 1000 people. This building had had a worsening bed bug infestation over the preceding years, which had been attributed to repeated re-introduction of bed bugs. All rooms were carefully inspected, and a treatment pattern devised based on the inspection findings.

Given the current concerns over insecticide resistance, those rooms that were treated each received a series of 3 treatments over a 3 week period, comprising pyrethroid, carbamate, organophosphate and insect growth regulator active ingredients, together with desiccant dusts in voids, (Rust, 1996). All rooms were regularly inspected at 2 or 3 monthly intervals after treatment. The treatment achieved full eradication of bed bugs, with no more bed bugs found on inspection, or reported by those using the accommodation. In the 12 months following the treatment programme, despite the total number of people using the accommodation in the premises approaching 100,000, no new infestation of bed bugs has since been discovered.

This exercise has now been repeated on a smaller scale in other premises, with the same results, i.e. once complete riddance is achieved, then premises tend to stay free of infestation for extended periods. Although this work is still on a limited scale, it strongly suggests that the hypothesis that repeated re-introduction of bed bugs is the cause of heavily infested buildings (although of course bed bugs are carried from time to time on people's personal effects) is not universally true. Instead, failure to achieve complete eradication appears to be a better explanation for recurrent infestation. In addition, the work shows that even where insecticide resistance is a concern, careful selection and use of insecticides can still achieve complete eradication.

### **BED BUG CONTROL STRATEGIES AND CODES OF PRACTICE**

The recent increase in bed bug problems has focussed attention on the techniques and procedures used for bed bug control. There is a clearly a considerable diversity of thinking and understanding among those responsible for product development, and as a result, a diversity of techniques and strategies being used by practitioners. Identifying best practice has been somewhat hampered by the paucity of data and operational research that might enable effective practices to be selected on the basis of clear evidence. In the absence of a consensus on the reasons underlying the bed bug increase, there is a tendency for bed bug Codes and Regulations to attempt to standardise every aspect of bed bug management, rather than focussing on those issues which may be specifically responsible for the upsurge. It is hoped that as the reasons underlying the increase become clearer, then the Codes of Practice will become more targeted.

The Australian Code of Practice for Bed bug Control (Doggett, 2007) was the first national code to appear. The Code was assembled by a panel consisting of entomologists, representatives of the pest control servicing industry, and of insecticide manufacturers. Compliance with the document is not mandatory in Australia. This document runs to over 60 pages, and stresses the need for: 1) Training of pest control staff and those responsible for managing accommodation; 2) Preventative procedures such as use of metal bed frames; 3) Detailed pre-treatment inspection procedures, both in infested and adjoining rooms; 4) Use of both chemical and non-chemical control procedures; and 5) At least one follow up visit and treatment after 7-10 days.

In the US, the San Francisco Department of Public Health produced Regulations on how to control bed bug infestations (Ojo, 2006). These Regulations set out succinctly the responsibilities of residents, those responsible for managing residential properties, and pest control operatives. Key steps include the need for: Bed bug awareness training for those managing residential premises, a rapid response to bed bug complaints, inspection of premises and units adjoining the known infested property, proper pre-treatment preparation of premises, a sequence of 3 treatments at 2-weekly intervals, and a 45 day guarantee on all treated premises

### **CONCLUSION**

Bed bug infestations represent a significant public health risk, and well as having a major economic impact (Anon, 2004). It is important that strategies intended to combat the resurgence are based on clear evidence-based practice, and are monitored to ensure their effectiveness.

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