

Citation: Doggett S.L. (2007). **Bed Bugs – Latest Trends & Developments**. *Synopsis of The Australian Environmental Pest Managers Association National Conference, Pacific Bay Resort, Coffs Harbour, 4-6<sup>th</sup> July 2007*, pg 22-37.

## **Bed Bugs – Latest Trends and Developments.** **AEPMA National Conference 2007**

Stephen L. Doggett & Richard C. Russell

Department of Medical Entomology, ICPMR and University of Sydney,  
Westmead Hospital, WESTMEAD NSW 2145. Email:  
[stephend@icpmr.wsahs.nsw.gov.au](mailto:stephend@icpmr.wsahs.nsw.gov.au) Ph: 02 9845 7265 Fax: 02 9893 8659.

### **Aims**

The aim of this synopsis is to present the latest bed bug trends and to cover the recent developments in bed bug management technologies. Trends discussed include the findings of a recent bed bug survey of Australian Pest Managers, the financial impacts of bed bugs, bed bugs in the socially disadvantaged, and insecticide resistance. Recent developments include the use of bed bug sniffer dogs, mattress encasements, the Cryonite machine that employs CO<sub>2</sub> 'snow', and insecticide efficacy studies including control via Diatomaceous Earth. The various limitations and pitfalls of these developments are discussed along with the limitations of a range of management options – that the Pest Manager needs to be aware of.

Finally, predictions of future bed bug trends are made along with possible technological developments. The various factors that are needed to minimise the impacts of bed bugs over the long term are also discussed.

It is important to note that this synopsis is not a complete guide to bed bug management and control. For this, readers are referred to the '*Code of Practice for the Control of Bed Bug Infestations in Australia*' ([www.bedbug.org.au](http://www.bedbug.org.au)).

### **Latest Trends**

#### **Rates of Bed Bug Infestations**

With the release of the '*Code of Practice for the Control of Bed Bug Infestations in Australia*' in 2006, Australian Pest Managers were surveyed to in an attempt to more accurately gauge the extent of the bed bug resurgence and to advertise the Code of Practice. The survey sought to establish the number of treatments undertaken per year, the property types, what control methodologies were employed, time taken to eliminate an infestation, and information on the insecticides used. Full details of the survey follow, including questions asked (in italics) and responses recorded.

In summary, all states reported a dramatic rise in bed bug numbers with an average across Australia of 4,500% since 1999. State by state the following increases were noted and the graphs below indicate that bed bug infestations are growing in an exponential fashion:

- ACT – 495% since the year 2000.
- NSW – 8,434% since 2000.
- NT – 650% since 2004.
- Qld – 2,622% since 1999.
- SA – 6,450% since 2000.
- WA – 5,780% since 2000.
- Vic – 15,825% since 2000.

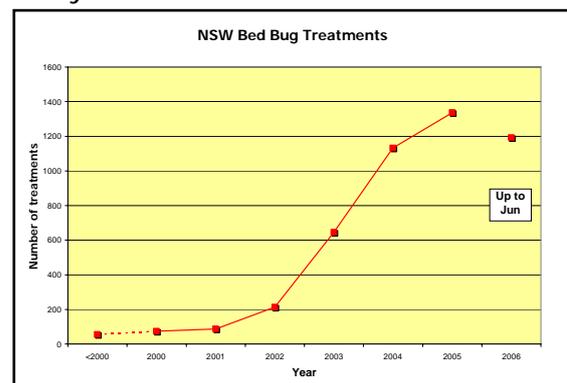
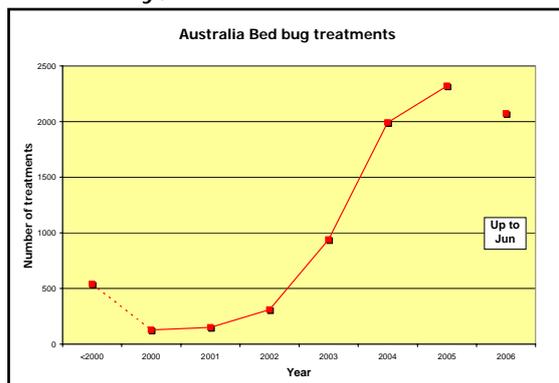
*Total survey responses = 121*

ACT (4), NSW (50), Qld (42), NT (2), SA (6), Tas (0), Vic (9), WA (8)

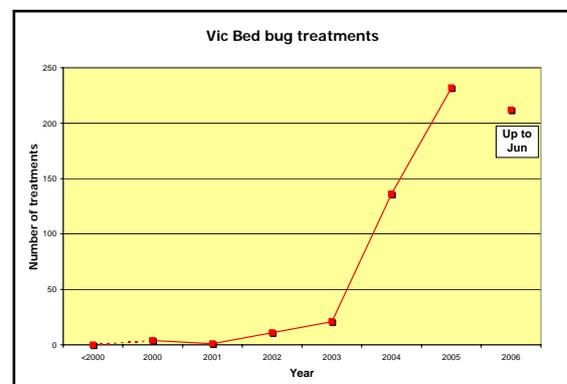
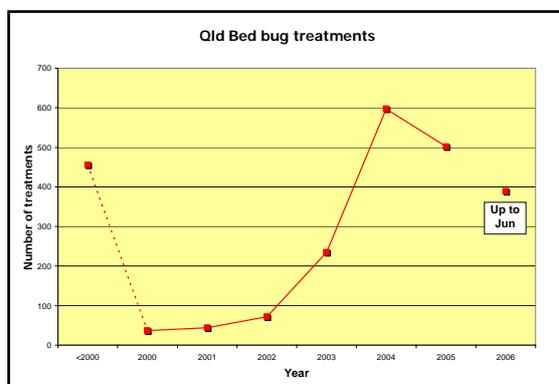
*Total number bed bug jobs reported/year \*Data not for complete 2006 calendar year*

<2000	2000	2001	2002	2003	2004	2005	2006*	Total
571	158	191	354	1004	2112	2464	2425	9279

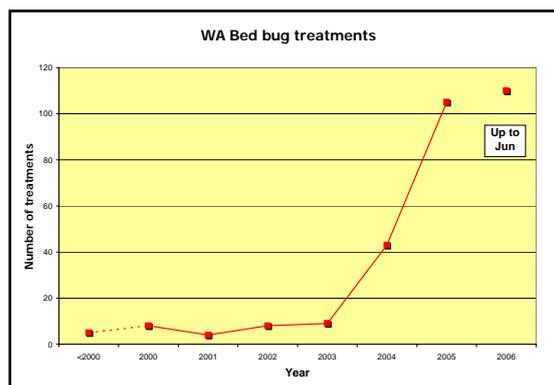
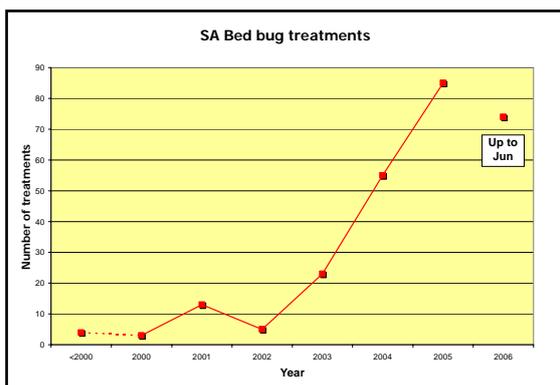
The following graphs plot the annual bed bug infestation rates as recorded by the survey, combined for Australia and state by state.



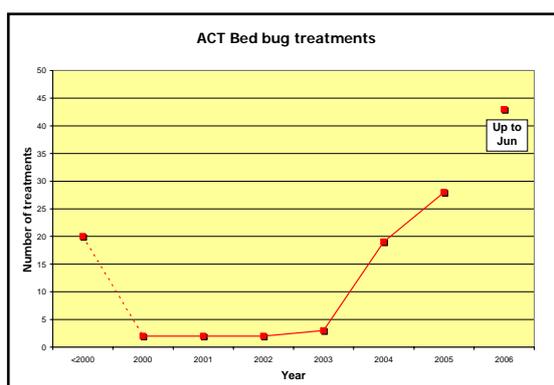
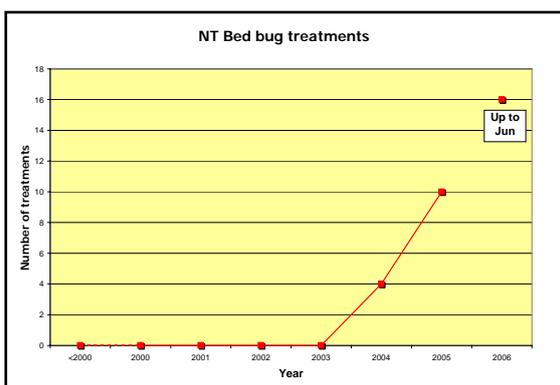
**Figures 1&2.** Annual bed bug infestation data as recorded by the 2006 Bed Bug Survey for pre and post the year 2000. Data combined for Australia (Fig. 1) and NSW (right graph).



**Figures 3&4.** Survey results for Queensland and Victoria.



Figures 5&6. Survey results for South Australia and Western Australia.



Figures 7&8. Survey results for Northern Territory and the ACT.

*List Property types treated*

Type	No.	%
Backpacker Lodges	1832	21.9
1-3 Star Motels	2069	24.7
4 Star Motels	874	10.5
5 Star Motels	445	5.3
Resorts	462	5.5
Homes	1062	12.7
Rented Properties	724	8.7
Caravan/Cabin Parks	86	1.0
Charter Boats	82	1.0
Trains	489	5.8

Trains	489	5.8
Staff Accommodation	153	1.8
Campervans/Motor homes	31	0.4
B&Bs	2	0.0
Farm Stay	2	0.0
Hospitals	2	0.0
Dormitories	2	0.0
Ships	12	0.2
Brothels	25	0.3
Boarding School	6	0.1
<b>Total</b>	<b>8360</b>	<b>100.0</b>

*What control methodologies do you use?* Vacuum: 29 (26% of respondents), Steam: 25 (23%), Insecticides: 110 (100%). Other, including: Physical removal (2), Black plastic (2), Heat via sunlight (1), Stiff bristle broom (1), Fogging (1), Sealing gaps (1), Heat, e.g. paint stripper heat guns (2), Squashing them (1), Freezing (1)

*Average number of treatments needed to eliminate infestations?*

No. Treatments	1	1-2	2	2-3	2-4	3	3-4	4	1-5
No. responses	16	14	38	12	3	13	2	2	1
%	15.8	13.9	37.6	11.9	3.0	12.9	2.0	2.0	1.0

Overall average: 2 treatments

*What is the average time spent per treatment?*

Time (hr)	0.5	0.75	1	1.25	1.5	1.75	2	2.5	3	3.25	4	5	6	8
No. responses	3	4	18	6	16	3	22	12	7	1	9	2	2	1
%	2.8	3.8	17.0	5.7	15.1	2.8	20.8	11.3	6.6	0.9	8.9	2.0	2.0	1.0

Overall average time: 2.1 hours

*Do you always reinspect the site after each treatment?*

Yes = 83 (79%) No = 23 (21%)

*Which insecticides do you find the most effective?*

<b>Insecticide</b>	Actellic	Bestox	Betacyfluthrin	Bifenthrin	Blattanex	Baytex	Cislin	Crackdown	Deltamethrin	Diazinon	Dursban	IGRs	Ficam	Permethrin	Pounce	Sumilary	Triflumuron	Botanical	Carbamates	SPs	Anything
<b>No.</b>	10	2	10	3	27	1	11	9	7	3	1	2	23	13	2	3	1	1	4	6	2
<b>%</b>	11.1	2.2	11.0	3.3	29.7	1.1	12.1	9.9	7.7	3.3	1.1	2.2	25.3	14.3	2.2	3.3	1.1	1.1	4.4	6.6	2.2

Shaded cells = unregistered products. 15 (16%) used unregistered products.

*Which insecticides have you found ineffective?*

<b>Insecticide</b>	Bifenthrin	Blattanex	Carbamates	Crackdown	Deltamethrin	Insectagas	Permethrin	Pestigas	Preclude	Responsar	SPs	Tempo
<b>No.</b>	3	1	1	3	17	1	8	1	1	2	11	2
<b>%</b>	6.5	2.2	2.2	6.5	37.0	2.2	17.4	2.2	2.2	4.3	23.9	4.3

*Have you read the Draft Bed Bug Code of Practice?*

Yes = 73 (69%) No = 33 (31%)

*Did you find the Code useful for your treatment methods?*

Yes = 61 (95%) No = 3 (5%)

*Would you be interested in attending a full day course on bed bug control?*

Yes = 84 (89%) No = 11 (14%)

*Comments on the Survey*

The total of 121 respondents meant that only a small part of the pest management industry was sampled; the number of registered Pest Managers is variously estimated to be somewhere around 4-6,000 within Australia. Thus the overall number of bed bug infestations reported by the survey represents a gross underestimate of the true figure. Even if the survey only captured 10% of those jobs undertaken by Pest Managers, then the number of infestations since the year 2000 comes to around 100,000. These figures also do not include complete data from the backpacking industry who often undertake the control themselves. For this reason, the property type is also

likely to be somewhat inaccurate as it has been this industry that has been hardest hit by bed bugs.

Another aspect that may have led to underreporting is that many Pest Managers equated 'Number of Bed Bug Jobs' in the survey with invoices per facility rather than actual jobs. For example with one company, one invoice equalled 48 separate treatments.

On initial examination, there appears to be some irregularities with the state by state data. For example, the high number of treatments pre-2000 in Qld was largely due to one Pest Manager undertaking 370 treatments in one staff accommodation facility in 1999. The Qld data also suggests a drop in treatments during 2005, however one Pest Manager who had undertaken 100 bed bug jobs in 2004 stopped due to the development of severe conjunctivitis resulting from the high amount of insecticides required to eradicate infestations. Another Pest Manager undertook training of housekeeping staff during 2004 and many of these clients stopped employing him for control. A third Pest Manager who undertook over 100 jobs in 2004 moved out of the state. Thus the apparent decline is artificial and there were relatively few survey respondents from some of the most severely bed bug impacted regions such as the tropical far north, the Sunshine and Gold Coasts.

It is a concern that such a high number of Pest Managers reported the use of unregistered insecticides. Perhaps this is a reflection of the poor performance of many of the currently available products due to insecticide resistance, as indicated by the number of products being reportedly ineffective. Interestingly, very few of the more experienced Pest Managers (namely those who recorded >100 jobs) reported product failure; perhaps this is an indication of the acquired wisdom in relation to bed bug control and the knowledge that diligence and perseverance are the essential keys to bed bug eradication.

It is also a concern that 21% of the respondents reported no follow up inspection. The insecticides used today are all non-ovicidal and thus will not kill the eggs. The eggs take around 7-10 days to hatch at normal room temperature and must be retreated as the residual may not be lethal. In all cases a reinspection must be undertaken and this cost should be incorporated in the initial quote.

For those Pest Managers who read the 'Code of Practice', 95% found the document beneficial. This endorsement should encourage all other Pest Managers to consult the Code, even if they have experience in bed bug management. The Code can be downloaded from [www.bedbug.org.au](http://www.bedbug.org.au), free of charge.

### **The Cost of Bed Bugs**

The actual costs associated with bed bug infestations to date have not been recorded. The lack of such information means that the overall economic impact to the Australian community can not be calculated. This information

is needed to prioritize much needed funding for research into better bed bug management strategies.

In order to calculate the economic burden due to bed bugs, the Department of Medical Entomology and Eagle Pest Control collaborated with two accommodation facilities that have experienced recurrent bed bug infestations (data unpublished). The first was a three star Sydney inner city motel. This particular motel has had 39 rooms infested out of a total of 110 rooms (i.e. 35.5% of rooms).

The costs included: loss of income with room closures during treatment (\$36,312.00), pest control (\$14,870.90), linen replacement (\$585.00), refurbishment costs (\$3,900.00), refunds (\$3,471.00) and miscellaneous (\$390.00). The total becomes \$59,528.90 or \$1,526.38 per room. This amount does not include the replacement of mattresses and furnishings nor the loss of patronage, and thus the real costs are likely to be substantially higher.

The second facility was a staff accommodation block attached to a tertiary health care facility where between 2003 and 2005, 68 of 352 rooms (19.3%) reported bed bugs. Costs in this instance included: replacement of bedding and linen (>\$7,220), pest control (approx. \$32,000), control equipment purchases (>\$1,000) and intellectual support (>\$2,000). The total of around \$42,000 equates to \$617/room, although many costs were not included such as the medical expenses for treating afflicted staff, loss of productivity with such staff, and various miscellaneous costs. In comparison to the previous facility where loss of income through room closure was the major economic loss, the rooms in the staff accommodation block are rented on a long term basis and thus in this instance there was no associated loss of income.

It is unlikely that these control costs would be representative across the entire accommodation industry or to the homeowner. For example, backpacker lodges regularly undertake the control themselves and often do not close rooms for treatments, thus the costs would be considerably less. In comparison, a five star motel loses more money when a room is closed and so costs are much greater. For the homeowner, mattresses and beds are often discarded, and so overall control costs are usually even greater. Thus to accurately determine the overall economic burden of bed bugs to the Australian community is virtually impossible from the figures above. However, if the average cost per infestation is around \$1,000 and the number of bed bug infestations in recent years is conservatively estimated at 100,000, then the economic loss to Australia becomes \$100million; a figure that may well be a gross underestimate. In light of the recent exponential growth in infestations, these costs are set to dramatically increase.

Most importantly these figures above do not include any litigation; in the advent of such action the above costs may seem insignificant to the individual accommodation provider. For example, a United States court awarded \$US385,000 against one motel, while more recently there have been claims lodged for \$20million.

## Bed Bugs in the Socially Disadvantaged

A disturbing recent trend is the increasing number of bed bug infestations that are occurring amongst socially disadvantaged groups. These infestations can be massive, involving thousands to even tens of thousands of bugs (Figs. 9 & 10). Usually the tenant does not have the economic capability to pay for control or sometimes even the cognitive awareness to know that bed bugs are present, as mental illnesses can be high amongst this group. In multistorey dwellings, these large infestations often only become evident after the adjoining units in turn become infested, which is almost inevitable. Units three stories above or below the prime source can become invaded, while the tenant in the main infestation can pass bed bugs to other units via their clothing.



**Figure 9.** The end of a metal bed in a massive bed bug infestation, this short segment approx. 12cm in length contained hundreds of bed bugs.

The prime infestation will have bed bugs virtually everywhere within the dwelling. Not only will the bed be heavily infested, but the bed bugs will be in books and CDs, pictures and wall hangings, clothing, cupboards and other furniture, lounges, whitegoods, under carpets, behind skirtings and in wall cavities. Compounding the challenge of controlling such a large infestation in these homes is that they tend to be heavily cluttered, and bed bugs will be scattered throughout these belongings. Control thus becomes impossible unless the clutter is removed and discarded, or taken off site for fumigation. For the tenant this clutter is their lifelong belongings and any suggestions of disposal of such property must be undertaken with due sensitivity and in conjunction with the manager of the facility, with the possible assistance of social workers.

For the Pest Manager these infestations can present an ethical dilemma; after all the infestation is likely to have been present for some time, even years. This may suggest that the manager of the facility or the carer has not been fulfilling their guardianship role of the tenant with due care. The socially

responsible act for the Pest Manager is to inform the relevant State Department of Health (such as the Public Health Unit) or an Environmental Health Officer within the local Council of the nature of the infestation and the need for appropriate action for the welfare of the tenant. By doing this however, the Pest Manager may feel that they could jeopardise their future employment with the facility, although this has not been the experience of the authors.

In heavy infestations, the Pest Manager will require considerable cooperation from a number of parties to achieve control. This may include the owner or manager of the facility (such as the state Department of Housing if Government owned, or charitable organisation), contract cleaners, community health nurses, social and/or charitable workers to help relocate the tenant and provide assistance in removing and replacement of clothing and belongings, and maintenance workers to assist the Pest Manager in gaining access to areas for treatment. It will be necessary that the tenant is relocated and that none of their belongings (including any clothing currently worn) should be permitted into the new premise.

It is advisable that the Pest Manager has a detailed Management Plan, which is provided to all parties. Not only does this appear highly professional but it also protects the Pest Manager in the advent that recommended procedures are not undertaken. If an Environmental Health Officer is called in to investigate the infestations, which is not an uncommon occurrence, then a Management Plan may well be requested.

The bed bug Management Plan must include recommendations on:

- The proper handling and disposal of infested items.
- The handling of infested items to be kept for treatment via fumigation.
- Advice on minimising the risk of the tenant passing bed bugs onto any other premise.
- The need to remove carpets, wall paper, floorings, skirtings and other fixtures to gain access to harbourage areas for treatment.
- The treatment process, including non-chemical methods and a list of the actual insecticides employed and how they are used.
- The need for follow up inspections and treatments.
- The necessity to keep the room unoccupied during the treatment period.
- The need to inspect, and if necessary, treat all adjoining units.
- Recommendations on reducing harbourage locations post treatment, e.g. sealing cracks and crevices.
- Other post treatment processes, such as housekeeping recommendations or other needed refurbishments.

Most importantly, the Management Plan must stress that bed bug eradication is a cooperative venture between the client and the Pest Manager.

A behaviour common amongst these tenants is the tendency to collect items off the street that are intended for disposal, such as old furniture. These items may well have been discarded for the very reason of being infested with bed bugs. It thus becomes important for the manager of these facilities to

attempt to change such behaviours and limit what can be brought into the dwelling, and this recommendation should be included in the Management Plan. If the tenant is under a carer or regularly visited by friends and family, then these people may have also inadvertently transported bed bugs to their own home. The Management Plan should recommend that the manager attempts to inform all of the tenant's contacts about the bed bug infestation and the possible need of undertaking an inspection in their respective homes.

The Pest Manager should be present when the contract cleaners arrive to discard belongings. The Pest Manager must then inform the cleaners on how the infested belongings are best handled, including any OH&S recommendations (such as the wearing of overalls and the use of gloves), to minimise the risk of spreading the bugs further.

Regarding the control process itself, vacuuming should supplement the discarding of infested items as the preferred forms of non-chemical control (although note the limitations of vacuuming further in the text). As steam is extremely time consuming, in these infestations it becomes impractical to use. This means that insecticides (and lots of insecticides) will be the main control tool, preferably using at least two products from different insecticide groups.



**Figure 10.** Close-up of a CD rack (inset) showing large numbers of bed bugs and eggs. Every item in this room was heavily infested.

Such large infestations represent a high risk to the Pest Manager as control equipment items brought into the dwelling can easily become infested. Likewise, the bugs can get onto clothing and so the Pest Manager should be wary of their procedures, such as leaning against objects.

The difficult task with these infestations is establishing when eradication is finally achieved. Only through repeated treatments and follow up inspections, including one at least some months after the initial course of treatments, can the Pest Manager be certain of success. Not surprisingly, such jobs are time consuming, involving numerous consultations, inspections, treatments and follow up visits. Thus the overall price must be commensurate with the labour

input and will come to many thousands. In New South Wales, if the tenant is within either Government or charitable housing, then these groups have been paying the eradication bill. The problem is if the tenant is outside of these groups; who then pays the control costs? This is something that society is yet to determine.

### **Insecticide Resistance**

There have been a number of contributing factors postulated as the reason for the bed bug resurgence including the development of insecticide resistance. Many Pest Managers in Australia have suspected this for some time as they often find bed bugs walking over previously treated surfaces in follow up inspections. Our Department even has a strain of bed bugs that were collected on *permethrin* dust.

Resistance to DDT and other organochlorines was well described during the 1950's (Busvine 1958). As DDT belongs to the same chemical group as the synthetic pyrethroids (namely sodium channel modulators or 'Group 3' insecticides), it is perhaps not surprising that recent investigations have shown high levels of resistance in the current crop of bed bugs to the latter insecticide group. A study from the United Kingdom (Boase *et al.* 2006) found that field strains of the Common bed bug, *Cimex lectularius*, demonstrated a high degree of resistance to both the synthetic pyrethroid *alphacypermethrin* and the carbamate *bendiocarb*. Investigations from the United States revealed similar information, recording that field collected Common bed bugs were several thousand times more resistant to *deltamethrin* and *lambda-cyhalothrin* (both synthetic pyrethroids) than susceptible strains (Romero *et al.* 2007)

So what does this mean for the Australian Pest Manager? Currently in this country most of the insecticides registered for bed bug control belong to the synthetic pyrethroids, with a small number of carbamates available, namely *bendiocarb* and *propoxur*, and the organophosphates *pirimiphos-methyl* and *diazinon*. Thus most of the insecticides registered here belong to those groups that overseas have demonstrated resistance. While such susceptibility testing has yet to be undertaken in this country, field observations such as that mentioned above, suggests that resistance is occurring here as well. This means that the Pest Manager must hit the insect with large doses of insecticide by applying directly at the pest; the remaining residual may not produce a kill. As all of the insecticides are non-ovicidal, repeated applications must be undertaken to kill emerging nymphs and any other stages missed in the initial application (which is highly likely).

## **Developments**

### **Bed Bug Detection: Sniffer Dogs**

The only advance in recent years in relation to the detection of bed bug infestations is the use of sniffer dogs. Sniffer dogs have been used for many years for termite detection, where they have shown their value in conjunction

with other technologies. Claims from the United States state that sniffer dogs can check a room in 1.5 minutes, which is certainly much quicker than any human Pest Manager. They are especially useful for detecting small infestations (large infestations are easy to spot) and can be employed in a proactive system of bed bug detection. If an infestation is detected early, treatment success will be greater, while for the accommodation industry this means there is less chance of guests being bitten (and undertaking possible litigation!) and room closure will be reduced. Sniffer dogs can also be used to check the success of the treatment.

Of course not just any dog can be used, they must be trained by an accredited facility and undergo regular retraining. Bed bug 'controls' (i.e. bed bugs placed in containers, which are then hidden in random rooms) must be used as part of the process of regular assessing the accuracy of detection of the sniffer dog. Currently there are no standard operating procedures in place for bed bug sniffer dogs, however a Code of Practice for termite sniffer dogs is in development, which should have relevance for bed bug detection.

It should be noted that there have been no formalised independent scientific investigations assessing the worth of bed bug sniffer dogs (for example are they sensitive enough to detect one first instar nymph?), however such investigations are underway in the United States (see the first web site listed under sniffer dogs in the references for details of the study).

The only negative with sniffer dogs is that many hoteliers are concerned that they present a possible image problem; some in the accommodation industry believe that the public could believe that the sniffer dogs are in the facility to detect drugs or even bombs. In fact one of the largest motel chains in Australia refuses the use of sniffer dogs in their premises for these very reasons. Having sniffer dogs brought into a motel almost advertises that bed bugs are a problem and thus some accommodation managers are reluctant to have them used. Only with repeated infestations and spiralling control costs, do such attitudes change.

### **Non-Chemical Control: Black Plastic**

In parallel with the re-emergence of bed bugs are all sorts of old control methodologies. One of these is the suggestion that bed bugs can be eradicated by wrapping infested mattresses in black plastic and placing them outside in the sun; the theory being that the heat generated will kill the insects.

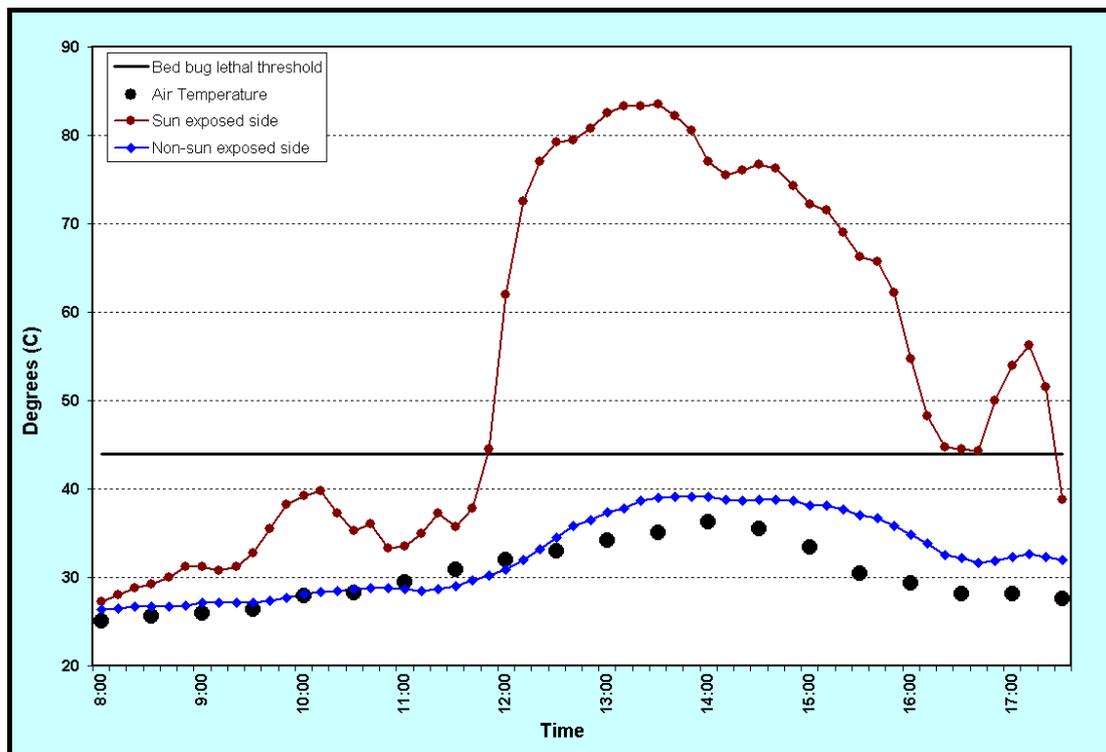
But will this actually work or is the idea just an 'old pesties' tale? The concern is that all items have an inherent thermal inertia; i.e. an ability to withstand temperature changes. As mattresses are reasonably large, the thermal inertia might prevent the temperature rising to the point that is lethal for bed bugs, i.e. 60°C to achieve instantaneous death and 44°C for at least one hour.

To examine the black plastic theory, staff from the Department of Medical Entomology tested two mattresses; a basic 8cm thick foam rubber mattress, and a 32cm thick multilayered inner spring mattress that had a padded layer on both the top and bottom (Doggett *et al.* 2006). Data loggers were placed on both sides to accurately record the temperature changes over time and the mattresses were then wrapped in black plastic and placed outside on a sunny hot Sydney summer day.

On the day of the experiment, the air temperature peaked at 36°C and remained above 30°C from 11:00am until 3:30pm. The temperature on the sun exposed side of both mattresses reached 85°C; however, the underneath did not reach 44°C; the highest reading was 41.5°C for the foam mattress (Fig. 11) and less than 35°C for the thicker mattress.

The thermal inertia of the mattresses ensured that they were not heated through sufficiently. It is also likely that the use of black plastic cannot be relied upon to treat even smaller items. The problem is that bed bugs respond rapidly to heat and a slow rise in temperature will cause them to move to cooler areas. This means that when heat is employed for bed bug control, the temperature rise has to be very rapid. Currently the only effective method of using heat for bed bug control is via steam, or for clothing and infested linen, hot water followed by treatment in a hot clothes dryer.

Clearly the 'old pesties' tale is nothing more than an 'old pesties' tale and black plastic should not be relied on in any integrated bed bug control program. Also to be pragmatic, why would anyone want to do this procedure other than to remove the item from an infested site for disposal? If an infested mattress is wrapped without treating, it is highly probable that bed bugs and eggs will



**Figure 11.** Results of the 'Black Plastic' investigations with the thin mattress (see text for an explanation).

be knocked off in the process, thereby potentially spreading the infestation further. In all cases the mattress should be treated before leaving a room to minimize infection risk. This can be done with vacuuming, steam and/or insecticides.

Pest management also needs to be practical; for example wrapping an infested mattress in a unit will be very difficult as the mattress will probably be a Queen size and there may be very little room. The mattress can not be dragged outside to be wrapped as a trail of bugs will be left behind. Even if there is plenty of room, many of the new multilayered mattresses are over 20kg and thus heavy and very awkward to move, which presents obvious OH&S issues. Thus not only should control methodologies be efficacious, they need to be practically achievable as well.

### **Non-Chemical Control: Pitfalls in the use of Vacuum & Steam**

Vacuuming can be used as part of an integrated pest management approach for the eradication of bed bugs. This should be undertaken prior to insecticide application in order to reduce the overall biomass of an infestation and to remove dirt from areas to allow for better insecticide penetration.

As in all control options, the Pest Manager needs to be aware of any techniques limitations. All previously vacuumed areas need to be treated with insecticides as bed bugs within crevices can hold on against the suction forces, and the eggs are glued into place and resist removal via vacuum (Figure 12).

It is important that the vacuum does not become the source for further infestations and must be properly 'disinfected' following use. Units such as the Karcher models have the base and all hoses composed of solid plastic; these can be completely removed and sterilised in hot water.

The main pitfall with steam is that the flow rate must be kept to a minimum and heads with multiple jets should be used. If not, bed bugs can be blown about without killing the insects.

### **Non-Chemical Control: Mattress Encasements**

Seamless mattress covers provide fewer potential harbourage areas than mattresses, thus making the mattress less susceptible to an infestation. The covers can also be readily removed for laundering thereby making control easier. An extension to the benefits



© 2007 Department of Medical Entomology, ICPMR

**Figure 12.** The egg of the Common bed bug, *Cimex lectularius*, note the glue holding the egg to the substrate. The dot is the eye of the developing nymph.

provided by mattress covers comes with the recent development of mattress encasements produced by the company 'Protect-A-Bed', available through Residex in the United States (<http://www.residex.com/bedbugs/index.html>). These covers have incorporated an inbuilt membrane that is impervious to bed bugs; not only can bed bugs not escape from these covers, they are unable to bite through the material. This means that an infested mattress and ensemble base can be encased with 'Protect-A-Bed' and in due course all the bugs will die of starvation. A great deal of attention has been made in reducing seams and places where bed bugs can hide on the encasement. If an infestation ensues, then the encasement can be sterilised via hot wash and dry cycles without affecting the integrity of the membrane.

The obvious advantages of this system are that insecticide use is minimised and there are cost savings as the infested mattress does not need to be discarded, even with heavy infestations. As bed bugs can live for up to six months at 22°C, or even longer in cooler climates, this means that the encasement must be kept on the mattress for a long time. Removal prior to this represents an infection risk and there are no locking mechanisms to prevent accidental removal. Currently there are no published independently verified scientific studies which have assessed the effectiveness of 'Protect-A-Bed'. This product is now available in Australia and distributed through Garrards.

### **Non-Chemical Control: Cryonite**

The Cryonite is a machine that employs carbon dioxide (CO<sub>2</sub>) 'snow', which is essentially a powdered form of solid CO<sub>2</sub>. Carbon dioxide snow is not a new technology; entomologists have been using the snow for decades as an attractant for blood sucking insect pests such as mosquitoes. What is new is that the snow is being used to kill pests rather than attracting them, and it kills via the freezing action of the CO<sub>2</sub> snow.

The Cryonite basically consists of a gas cylinder, a high pressure hose, a wand that delivers the snow and a trolley to carry all the above. The cylinder is switched on and the wand applies the snow directly at the bed bugs. As the mode of action is via freezing, the product is lethal to both free living stages and the eggs (compare this with insecticides which are non-ovidical). The control is immediate with no residual action, which means that insecticides must be used as an adjunct.

The dry ice snow forms better in cooler rooms, although in high humidity the nozzle can freeze stopping the dry ice flow. One 10kg bottle of CO<sub>2</sub> will last for around 20mins and in a small infestation 1.5 bottles will be used.

The Cryonite may be seen as an alternative to steam for bed bug control and a comparison of these two technologies are listed in the table below.

### *Steam vs Cryonite – a comparison*

<b>Feature</b>	<b>Steam</b>	<b>Cryonite</b>
Mode of action	Heat via steam	Freezing via CO <sub>2</sub> 'snow'
Likelihood of blowing bed bugs about	Moderate to Low*	High
Treatment width in a single pass	Depends on attachment, up to 30cm wide	3-4cm wide
Treatment speed	Slow	Fast
Initial Cost	\$1-3K, depending on machine	\$500 initial training, \$295/month or \$3,540/year, for machine hire
Recurrent costs	Nil	The CO <sub>2</sub> bottles: ~\$50/bottle, a minimum of two will be needed per infestation, more for heavy infestations
Use on electrical items	No	Yes (but note safety instructions such as ensuring device is properly earthed)
Health Risks	Minimal	Possible anoxia if room is poorly ventilated
Other uses	Steam cleaning	Food industry pest control

\*The steam machine must be set on minimum flow rate and a multiple head jet should be used to minimise risk of blowing bed bugs.

Note that the Cryonite swath width (the area which is being treated) is moderately narrow. While the device can be passed over an area more quickly than a steam head, wide steam heads can be used to treat large areas in a single pass and thus the Cryonite may offer no advantage in terms of time saving. There is a high CO<sub>2</sub> flow rate, which is a concern as even the lowest flow rate may blow bugs about. Also, there could be safety issues in relation to the development of possible anoxia (loss of oxygen through high CO<sub>2</sub> levels) and the machine should be used with the recommended safety precautions. For example, in heavy infestations, many bottles would be required and there are no safety devices supplied with the machine to warn the operator when dangerous levels of CO<sub>2</sub> in the atmosphere have been reached.

Currently, the Cryonite is only leased to Pest Managers who are accredited by Insectomatic, the importer of the technology. The accreditation involves a written and practical test and costs \$500/company. At present, there is no capacity to train the trainers.

It must be noted that currently there are also no published independently verified scientific studies which have assessed the efficacy of the Cryonite. A list of contacts for the Cryonite is provided in the reference list.

### **Chemical Control: Insecticide Efficacy Studies**

Over the last two years insecticide efficacy studies have begun to be published (Todd 2006, Moore & Miller 2006), however these have been largely conducted on susceptible bed bug strains and thus much of the data probably has little relevance to the current situation in light of the recent reports of resistance. The study by Todd however, included Gentrol, an insect growth regulator (juvenile hormone analogue) with the active ingredient, *hydroprene*. Despite resistance having not been reported with this insecticide group, the product failed to prevent treated nymphs from moulting into adults, although there was considerable adult mortality. Some of the surviving adults were then able to produce viable young.

Another insect growth regulator, the chitin synthesis inhibitor, *triflumuron*, was tested against the Common bed bug by the Department of Medical Entomology (unpublished data). First instar nymphs were placed on filter paper treated at the doses equivalent to 1ml and 2ml product/L water (these are the doses currently registered for other insects), plus there was an untreated control. The bugs were offered a blood meal weekly and blood feeding, moulting and mortality were recorded. In the controls and both test doses, the bugs developed into the adult stage with no significant difference in mortality. This trial and the work by Todd suggest that these particular insect growth regulators may have limited value in an integrated bed bug control program unless they are synergistic with insecticides.

### **Chemical Control: Diatomaceous Earth**

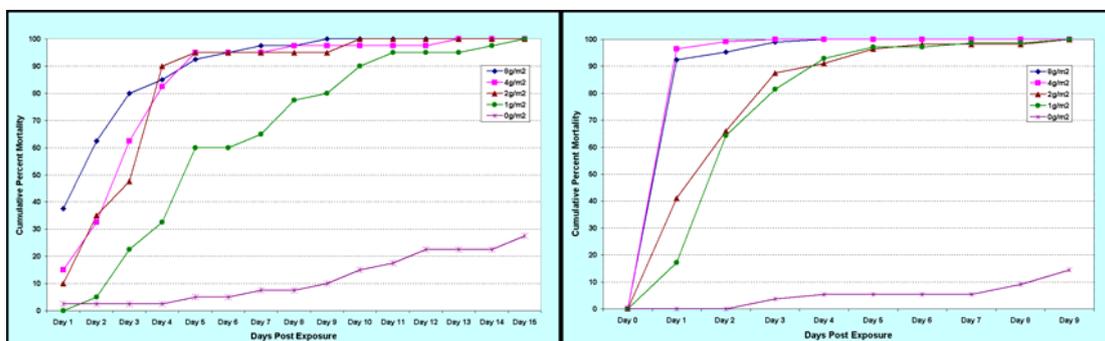
Diatomaceous Earth (DE) is an insecticide dust that has long been used for the control of stored product pests in Australia and elsewhere, and is registered for bed bug control in the United States. DE consists of fossilised diatoms, which is a microscopic aquatic creature, a type of a phytoplankton. Deposits of these diatoms are mined and then milled to produce the DE powder. The mode of action is to absorb the waxy surface of the insect cuticle, which results in the loss of water and eventual death through dehydration and possible abrasion. This mode of action is not rapid like other insecticides and it may take some days before death ensues. Despite this, DE has several advantages:

- *Very low mammalian toxicity*: DE is considered to be 'non-toxic' for humans.
- *Long residual activity*: DE is very stable and can remain active possibly for years; build up of dust and dirt will render it ineffective.
- *Low possibility of resistance development*: due to the mode of action, resistance is unlikely; in fact it is not even listed by the International Resistance Action Committee ([www.irac-online.org](http://www.irac-online.org)).

As DE is a dust, it should only be applied to non-obvious locations such as cracks and crevices, under carpet & straight areas, to wall voids, etc. Therefore it would only be used in conjunction with other insecticides.

Despite being registered overseas against bed bugs, published efficacy data is not available. For the purposes of seeking registration, DE efficacy was tested

by the Department of Medical Entomology using adult and 1<sup>st</sup> instar nymphs of the Common bed bug, *Cimex lectularius* (data unpublished). The results are displayed in Figures 13 & 14. In the case of the adult bugs, 100% mortality was achieved with the highest dose by Day 9 post exposure and by Day 15 for all doses. The 1<sup>st</sup> instar nymphs were more sensitive, 100% mortality occurred with the high dose by Day 3, and by Day 9 with all the doses.



**Figures 13&14.** Cumulative mortality of the Common bed bug, *Cimex lectularius*, exposed to varying doses of Diatomaceous Earth. Figure 13 (left) is for adult bed bugs, Figure 14 for 1<sup>st</sup> instar nymphs. The doses tested were equivalent to 0, 1, 2, 4 & 8g/m<sup>2</sup>.

Thus DE is much slower acting than traditional insecticides. To increase the kill rate, DE could be mixed in with another insecticide dust such as *bendiocarb* and the DE would remain active long after the *bendiocarb* has broken down. The long residual activity is the greatest advantage of DE, as it could be used in a prophylactic sense, i.e. applied to rooms that have yet to experience bed bugs so that if the insects are introduced, the possibility of the development of large infestations may be reduced.

## The Future & Bed Bug Control

Generally it is hard to predict future trends in relation to any pest, however it is clear that infestations will become increasingly common and bed bugs will continue to be a pest for many years to come. The following points cover some future possible scenarios, along with aspects to encourage the 'debugging' of Australia.

*Pheromone lures/traps:* research groups overseas are attempting to develop bed bug lures and traps. The attractants in these may be based on the insects' pheromone (such as the aggregation pheromone) or various chemicals known to attract blood sucking insects (e.g. CO<sub>2</sub>, lactic acid, octenol, etc). The lures would be placed underneath the bed and used for monitoring and detecting early activity. One company is even looking to having the lures computer connected; a bed bug 'hit' will trigger a warning to housekeeping that control action is required.

*New insecticides:* it is unlikely that any new class of insecticide will be developed specifically for bed bug control. This means that in Australia the only new products that may become available are those that are in use and registered overseas (such as Diatomaceous Earth). If pheromone lures are

developed and prove effective, then perhaps the attractant can be added to insecticides; those bed bugs that are not directly contacted by insecticides may be lured to their death.

*Changes in legislation:* in many states there is currently no specific legislation in relation to bed bugs that can be used to enforce the landlord, the homeowner or the accommodation provider to ensure that their premise is made free of bed bugs. For example, under the NSW Public Health Act 1991, the 'Vermin' Statute stipulates that "An occupier of premises must take reasonable measures to keep the premises from fleas, other disease-carrying insects, rats and mice..." As bed bugs are not disease vectors, they are thus currently excluded from the Act. It is envisaged in the future that bed bugs will be incorporated into public health acts, which will give Environmental Health Officers at all levels of government greater power to enforce compliance.

*Training:* training of Pest Managers in the detection and eradication of bed bugs will continue to be imperative while the pest poses a problem. Future courses on bed bugs must be detailed and provide both theoretical and practical components.

*Research in Australia:* urgent research is required to investigate the most effective control strategies to combat bed bugs. Areas of research urgently required include efficacy and resistance testing. Such work can only be undertaken with the support of governments, the accommodation sector and industry.

*The Code of Practice for the Control of Bed Bug Infestations in Australia:* until more effective bed bug detection and control technologies become available, the Code of Practice will continue to provide the most available and current resource on the eradication of bed bugs and should be the document consulted for training purposes. The Code will be annually reviewed and incorporate new technological innovations while bed bugs continue to be problematic. The latest version of the Code can be downloaded from [www.bedbug.org.au](http://www.bedbug.org.au).

### **Conflict of Interest Statement**

Neither author has any direct commercial interest in any of the companies or products mentioned within the text.

### **Acknowledgement**

Garry Jones of Eagle Pest Control provided valuable input on the section 'Bed Bugs in the Socially Disadvantaged'.

## References

Boase C., Small G., Naylor R. (2006). **Interim report of insecticides susceptibility status if UK bedbugs.** *Professional Pest Controller*, Summer: 12-13.

Busvine J.R. (1958). **Insecticide-resistance in bed-bugs.** *Bulletin of the World Health Organisation*, 19: 1041-52.

Doggett S.L., Geary M.J. and Russell R.C. (2006). **Encasing mattresses in black plastic will not provide thermal control of bed bugs, *Cimex* spp. (Hemiptera: Cimicidae).** *Journal of Economic Entomology*, 99(6): 2132-2135.

Moore D.J. and Miller D.M. (2006). **Laboratory evaluations of insecticide product efficacy for the control of *Cimex lectularius*.** *Journal of Economic Entomology*, 99(6): 2080-2086.

Romero A., Potter M.F., Potter D.A., Haynes K.F. (2007). **Insecticide resistance in the bed bug: a factor in the pest's sudden resurgence?** *Journal of Medical Entomology*, 44(2): 175-178.

Todd R.G. (2006). **Efficacy of bed bug control products in lab bioassays: do they make it past the starting gate?** *American Entomologist*, 52(2): 113-116.

### Web sites for information on bed bug sniffer dogs:

<http://listmgr.questex.com/t/2657321/18395352/814509/0/> (A report on the proposed testing to evaluate the effectiveness of bed bug sniffer dogs).

[http://www.jkk9.com/termite\\_dogs.html](http://www.jkk9.com/termite_dogs.html) (J&K Canine Academy: trainers & suppliers of bed bug sniffer dogs from United States).

<http://news.ifas.ufl.edu/story.aspx?id=1222> (University of Florida newsletter describing the use of bed bug sniffer dogs).

[http://www.elder.com.au/commercial/bed\\_bugs.htm](http://www.elder.com.au/commercial/bed_bugs.htm) (Elders Pest Control in Australia who employs bed bug sniffer dogs).

<http://www.hygieniqueselect.com/k9detection.html> (A US pest control company that uses bed bug sniffer dogs).

<http://www.nbc-2.com/articles/readarticle.asp?articleid=9197&z=3&p> (A NBC news report on bed bug sniffer dogs).

<http://www.advancedk9detectives.com/> (A US pest control company that uses bed bug sniffer dogs).

### Web Sites for Cryonite:

<http://www.cryonite.net/> (Cryonite home page)

<http://www.insectomatic.com.au/> (Australian importer of Cryonite)

Note that many of the research articles on bed bugs produced by the Department of Medical Entomology along with the Code of Practice can be downloaded for free from: [www.bedbug.org.au](http://www.bedbug.org.au).