

Bed Bugs – A Growing Problem Worldwide. Australian and International Trends Update, and Causes for Concern. 28/Apr/2011.

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Aims

- To provide an update of the current bed bug situation worldwide,
- To present some of the recent trends such as the development of industry standards along with information on the factors contributing to the bed bug resurgence,
- To present some of the issues that threaten the continuing maintenance of quality education on bed bug management,
- To present research of recent efficacy trials conducted at the Department of Medical Entomology on new products, including: the *BB Secure Ring*; *Agrisense Bed Bug Monitor* tape; permethrin impregnated mattresses and covers; and *Phantom Insecticide*,
- To provide an overview of new bed bug management products and services.

Introduction

The global bed bug resurgence continues to escalate around the world. Until very recently co-ordinated efforts to defeat this pest have been disorganised and extremely *ad hoc*. Most pest management associations have been negligent in failing to respond to the resurgence and the consequence has been that the bed bug problem simply became worse. Infestations are being reported from right across society, from home to hotel, from the retail sector to the office environment, to even the transport systems that move us about. Now industry standards in bed bug management are starting to appear and these should encourage 'best practice' in bed bug eradication. Yet quality education is under threat, via the flood of pseudoscientific articles within pest management magazines that are just advertorials, via companies who promote products at the expense of impartial information and even by the very organizations who have developed the industry standards.

Bed bugs have brought out the best and, sadly, the worst of humanity. There are tireless campaigners who seek to have bed bug legislation implemented to protect the public, while others encourage government funded control for those who can not afford the substantial expense of bed bug eradication. This is negated by companies who seek to ruthlessly exploit the pest manager and their client; the driving force for this is greed. The market is being flooded with

devices for bed bug management, many of which are simply ineffectual. It is very difficult for the pest manager to obtain impartial advice and to sort through the good from the bad.

This article provides an update on the worldwide bed bug situation and discusses many of the recent trends. The development of industry standards has been somewhat abated by threats to quality education and advice is provided on how to seek out appropriate information. Finally, new products are discussed, with the focus on four products that have undergone efficacy evaluation at the Department of Medical Entomology, Westmead Hospital, Sydney, Australia.

Bed Bugs Infestations Worldwide – An Update

The bed bug resurgence is truly a global event. Increases in infestations have been reported across Europe, Asia and the Americas, as well as Australia (Birchard 1998; Pinto 1999, Boase 2001; Doggett *et al.* 2003, 2004, 2008; Lee *et al.* 2008; How & Lee 2009; Kilpinen *et al.* 2008; Potter *et al.* 2010; Suwannayod *et al.* 2010; Hirao 2010; Wang & Wen 2011). Few countries from tropical regions have reported on the return of bed bugs; however, generally these are areas where there tends to be less wealth and poorer health infrastructures. Such regions have higher entomological priorities in having potentially fatal endemic vector-borne diseases such as malaria and dengue to combat. Bed bugs being a public health pest and not a disease vector are therefore largely ignored. In those countries where the organophosphates (OPs) are still registered and widely used, bed bugs are not considered a difficult pest to control (Potter *et al.* 2010). This is not surprising as resistance to the OPs has never been documented.

Most reports on the bed bug resurgence are coming from the United States, which is perhaps not surprising considering the high population (~300million), the large number of socially disadvantaged (with a reluctance to often help those in such circumstances with infestations), the fact that close to half of the population reside in high density living (poverty and high density housing are bed bug risk factors), and, until recently, no industry standard in bed bug management.

In a recent survey of the public perceptions of bed bugs in the US it was estimated that an extraordinary one in five people either had experienced an infestation or knew someone who had (see www.pestworld.org/bedbugs-in-america). Other key findings included that infestations were more prevalent amongst younger renters living in urban areas, bed bugs have been found in all 50 states, most Americans were concerned about bed bugs (not surprising considering the medias' love of this insect), many individuals are now modifying their behaviour to avoid bed bugs, and misconceptions are still common. It is important to note that the survey was online and self administered; presumably most respondents would have experienced bed

bugs or were concerned about them. Thus, presumably, these percentages are a gross overestimate of the actual situation.

It is in the US where bed bugs have become a huge societal pest. Infestations are being reported in the retail sector and office blocks, as well as the home and hotel. In some apartment complexes 80% of units have become infested: a situation that tends to be more common amongst the socially disadvantaged. In response, various levels of government are considering or undertaking laws, statutes and/or ordinances in relation to bed bugs (Harrington 2011). As the US now has a bed bug industry standard, hopefully any legislation will from herein conform to 'best practice', which it has failed to do in the past.

In Australia, it has been previously reported that a survey of the pest management industry in 2006 revealed that infestations had increased across the nation by an average of 4,500% since the start of the decade (Doggett *et al.* 2008, 2011). In early 2010, another bed bug survey of pest managers was conducted by the authors to ascertain if the Australian bed bug code of practice (CoP) was achieving its long term vision of a reduced number of infestations. Superficially, the data indicated a continuing rise in bed bugs; however, this time there were few respondents, with most of the infestations reported being from members of the Working Party behind the CoP. These pest managers have become recognized experts and are sought after for bed bug control. The second survey is thus biased by the existence of the CoP and it will probably become impossible to obtain accurate bed bug infestation data into the future.

Despite this, anecdotal evidence suggests the CoP has been beneficial. The authors of this report are hearing of fewer treatment failures and less inappropriate advice given to clients, while massive infestations involving tens of thousands of bed bugs have not been seen since 2008. The senior author of this report is now receiving fewer bed bug related communiqués. Interestingly, when the draft 3rd edition of the CoP was put out for public comment, almost no feedback was obtained, perhaps indicating that bed bugs were less often in the public mind. Additionally, some insecticide suppliers are no longer seeing increased sales in bed bug related products. Thus, perhaps overall, numbers of bed bug infestations have stabilised, even if maybe yet to fall.

Perhaps the major difference between the first and second bed bug survey was the increase in bed bug infestations being reported from socially disadvantaged housing. It appears that such groups were not impacted heavily until around the middle years of the first decade in the new millennium. From 2006 on, infestations involving tens to hundreds of thousands bed bugs were being seen by the authors within NSW. It was not until the main authority, NSW Housing, decided to pay for control that these massive infestations no longer occurred. Yet bed bugs are still common in public housing and, if funding for control was cut by the new incumbent government, then massive infestations would be seen again, and infestations across society would soon rise.

The Resurgence & Industry Standards for Bed Bug Management

The resurgence of bed bugs has been blamed on a number of factors. This includes the growth in international travel, insecticide resistance and the lack of effective products, immigration (although these accusations may be racially- rather than evidence-based), and lack of awareness in bed bug management.

Clearly, resistance was the key trigger for the resurgence, and the spread of resistant bed bugs was aided by increases in international travel as a result of it becoming more affordable over the last three decades. However, neither of these factors alone can explain the magnitude of the resurgence. Evidence now indicates that poor pest management practice has been a major contributing aspect in the degree of the resurgence (Doggett *et al.* 2011). Poor pest management can be directly linked to inadequate training of technicians in controlling insecticide resistant bed bugs. This is compounded by the lack of industry standards which set the benchmark for quality control. Somewhat tongue-in-cheek, it could be stated that the failure of peak pest industry associations to tackle the appropriate training of pest managers has resulted in more business to their members!

Fortunately, many industry associations are now realising that appropriate training of technicians is essential and have begun to produce standards on bed bug management (Figs. 1a-d). In Australia, we have had the Code of Practice (CoP) for over half a decade, and arguably even longer, as this was directly developed from an earlier document (Doggett 2005). More recently in May 2010, a bed bug management policy was developed to aid the accommodation industry in appropriately dealing with infestations. The key areas within the policy include; defining responsibilities, education, documentation, occupational health and safety, eradication processes, bed bug prevention, and handling the media. Like the CoP, the management policy is freely available from www.bedbug.org.au.



Figure 1a-d. Current industry standards in bed bug management. From left to right, (a) from Australia, 'A Code of Practice for the Control of Bed Bug Infestations in Australia, 3rd ed' and (b) 'A Bed Bug Management Policy for Accommodation Providers', (c) from Europe, the 'European Code of Practice Bed Bug Management', and (d) from the United States, 'NPMA BMP Bed Bugs Best Management Practices'.

It is clear that the Australian CoP has provided many tangible benefits. A number of pest managers have stated to the authors that the CoP has aided client communication, helped streamline the treatment processes and, if clients adhere to the processes as outlined with the CoP, then this is more likely to result in a successful treatment. One insecticide manufacturer has commented that the CoP promotes integrated pest management and prolongs the market life of products, thereby helping to maintain long term profits for the company. Also, companies have begun referencing the CoP on labels of products being registered against bed bugs. Thus, it appears that many of the objectives of the CoP are becoming realized, notably better education of all stakeholders in bed bug management and requirement for observing best practice.

In Europe, the Bed Bug Foundation (BBF, www.bedbugfoundation.org) is a charitable body that aims to be an '*International independent knowledge base for information, training and advice on prevention and treatment of Bed Bugs*'. The BBF has now produced the 'European Code of Practice Bed Bug Management' and this is also freely available, from: <http://www.bedbugfoundation.org/downloads/Bedbug140311.pdf>. This Code was initially based on the Australian version and in fact the principal author of our CoP (Stephen Doggett) is on the panel of experts for the European CoP. Oliver Madge the lead author of the European CoP has understandably adapted the document to make it more Eurocentric and has produced a very refined and excellent manuscript on appropriate bed bug management. It is expected that the next edition of the Australian CoP will cherry pick the European version. In a cross axial agreement, the Working Party behind the Australian CoP and the BBF shares information on all aspects of bed bug management in order to advance each organisation's aims and industry standards.

In the United States, the National Pest Management of America (NPMA) has recently developed the '*NPMA BMP Bed Bugs Best Management Practices*' (BBBMP). This can be freely downloaded from the following web site: www.npmapestworld.org/publicpolicy/documents/NPMABedBugBMPAPPROVED20110124_prettified.pdf. The NPMA has taken a very different approach in the development of their industry standard compared with those mentioned above. The BBBMP was produced in a very short time without the public consultation process deemed so critical to the Australian and the European CoPs. The BBBMP is a much smaller document and is in point form; without the flow of a grammatically developed article, dot points can be open to misinterpretation. It may also be argued that the BBBMP may be somewhat curiously structured in having the OH&S section after control, which may seem illogical. Despite these quibbles, it is encouraging the NPMA has developed a document that encourages 'best practice' in bed bug management. They also have a consumer version of the BBBMP, which is not very different and is available from: <http://www.bedbugbmps.org/>.

It is important that all of these organisations ensure that their industry standard remains impartial and not influenced by any commercial group which could comprise 'best practice'. Similarly, such organisations have a moral duty

to their members to ensure their daily activities also do not compromise the demonstration of 'best practice' in bed bug and other pest management practices. Sadly this has not always been the case (see discussion below under 'Quality Education').

As mentioned above, one of the major triggers to the bed bug resurgence is insecticide resistance. Modern bed bug strains are highly resistant to the synthetic pyrethroids (SPs) and somewhat less resistant to the carbamates (Lilly *et al.* 2009). Compounding the resistance problem is the failure of insecticide registration authorities around the world to ensure that appropriate efficacy evaluation is undertaken on new (and past) products. In the United States, the Environment Protection Authority does not always require that a product undergoes efficacy evaluation before it appears on the market. Similarly in Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) also does not always require efficacy data for all insects on the label, and certainly does not insist that new products are tested on modern resistant strains, despite the number of publications on the existence and prevalence of resistance. As a result, many products have been registered by the APVMA that are likely to be ineffective against current bed bug field strains. A serious problem with these products is that a sublethal dose of the SPs can lead to the infestation dispersing by the very nature of the insecticide class, which has an excito-repellent effect. The dispersal of bed bug infestations to adjoining tenants through treatments involving the SPs has been documented on numerous occasions (Doggett *et al.* 2011). It is clear that the current policies of registration authorities have greatly contributed to the bed bug resurgence.

Ideally, only recently collected field strains should be used. Products registered based on efficacy evaluations using laboratory strains not demonstrating current resistance profiles should be deregistered.

Quality Education in Bed Bug Management? We Hope!

Key strategies in combating the bed bug resurgence have been the development of industry standards, and training of pest managers and other stakeholders in best practice management processes, based on the standard. However with the bed bug resurgence, quality education has often taken second place to making money. Many companies and organisations are seeing the resurgence merely as a means of increasing the profit margin. The result is that quality is often compromised and there is a real challenge in finding impartial information.

Many articles in pest management magazines present 'pseudoscience' and are simply advertorials posing as impartial research. Insecticide efficacy data are regularly presented on old susceptible strains and such data are useless when most bed bugs are highly resistant to many of the products on the market. Most companies fail to highlight the limitations and deficiencies of their product. For example, insect growth regulators (IGRs) are promoted for bed bug management in most parts of the world, but nymphal stages of bed

bugs must obtain a blood meal prior to these products taking effect and, thus your client must suffer for an IGR to work (but you will not see this stated on product brochures)! It therefore appears that if money is at stake, human morality is thrown out the window.

These many people are giving bed bug presentations in order to promote company products (and profits), even if they have had little to no practice in bed bug management, no research background, and they may not have ever seen the insect. With such individuals, one should not expect to hear or see impartial information on bed bug management. For example, at a recent bed bug seminar in Sydney, one speaker mentioned how the company's insecticides could be used in different circumstances, without one mention of non-chemical procedures for control. They even ignored the fact that some of their products have been shown ineffective on modern bed bug strains. Another speaker presented grossly inaccurate information, for example stating that freezing bed bugs for two hours would kill them (not with modern frost free freezers)! While a third speaker recounted old pest controller tales such as bed bugs living for two years without a blood meal (not in Sydney, most would be dead within a few weeks and all by five months when the temperature averages 22°C). Increasingly, it seems that in many cases *the promotion of a company's product is allowed to come before provision of quality information.*

But do not expect industry associations to be necessarily any better. Recently the NPMA announced that Allergy Technologies would sponsor their upcoming bed bug workshops in Apr-May of 2011 (www.pctonline.com/Allergy-Technologies-ActiveGuard-Bed-Bug-workshop-sponsor.aspx). Allergy Technologies is the manufacturer of a permethrin impregnated mattress cover called the *ActiveGuard Mattress Liner*. Research undertaken by our Department (detailed below) has found that this product is largely ineffective at controlling a modern Australian SP resistant strain of bed bugs, and the research was presented last year at the NPMA's own conference, PestWorld 2010 (in Honolulu, Hawaii). Thus despite knowing the shortcomings of the product, the NPMA decided to go in partnership with a company whose products are in question; *this is simply not best practice and contrary to the rules of propriety!* Such activities compromise the provision of quality education as they indicate that the organisation promotes technologies that would not meet 'best practice' bed bug management criteria. In the end, it appears that the organisation is treating their members with disdain, just for a few dollars.

Finally, some of the highly recognisable scientists are on retainers, while others have their names on patents; we should not always expect independent research from those that are so involved. We should always seek potential conflicts of interest - without such declarations, research can appear to be tainted.

So how can you ensure that you are receiving quality information?

- Read widely, and read with an open and sceptical mind,

- Look for industry standards produced by peak pest management associations,
- Look for presenters who are willing to speak the truth and *be questioned on their views in public*,
- Look for the 'big' names in bed bug management and urban pest control research, especially those with a history of publications and a record of providing quality presentations (however note that some may be on retainers or involved in patents),
- Scientific publications which have undergone peer review usually are more impartial (however note that conflicts of interest by authors may not be publicly declared by the authors),
- Always seek for potential conflicts of interest,
- Look at the affiliations of the authors of articles; do they belong to the company of which the product is being promoted? Is the article an advertorial, rather than quality science?
- Is the presenter just selling a product? Then if so, an impartial presentation is unlikely.
- In insecticide efficacy trials, were these done by reputable scientists or by the company selling the product?
- Were the insecticide efficacy trials undertaken on modern resistant bed bug strains? (note that some modern strains can be mildly resistant),
- In speaking to company representatives, ask what the *limitations* of the product are (there are always some, otherwise we would have no bed bug problem). If none are stated or admitted *then beware!*
- Always be cautious of company provided information.
- *Use the information in the Australian Bed Bug Code of Practice*. The Working Party is making a serious effort to minimize the influence of vested interests in the CoP.

New Products

The market place is being flooded with bed bug management products. Over the last two years, new devices include those that attempt to detect bed bugs (i.e. traps and monitors), those that act as barriers, heating and freezing units, various containment and encasement devices (including insecticide impregnated mattress covers and encasements), insecticides and repellents, personal protective equipment and application equipment, to name but a few. Service companies have also emerged, including those that specialise in selling bed bug products, those that undertake site preparation prior to treatment, and even bed bug brokers who organize treatments rather than undertake them.

Many of the new devices are conceptually flawed and have no place in bed bug management, while most do not have independent published efficacy data. Every product has limitations, and it is important for the pest manager to know and understand these. Sadly, too many unscrupulous groups with ineffective products have jumped on the bed bug bandwagon with the sole

aim of obtaining your and your client's money. *If the product or management device is not specifically recommended within the CoP then buyer beware and use it at your own risk.*

The following section contains detailed research information on products recently tested at the Department of Medical Entomology. This includes a bed bug barrier (the *BB Secure Ring*), a monitoring tape (the *AgriSense Bed Bug Monitor*), permethrin impregnated mattresses and encasements (including the *ActiveGuard Mattress Liner*), and Phantom insecticide. This is followed by an overview of some of the new bed bug products and services now available. **Note that most of these products, unless otherwise stated, are presently not yet recommended for use within the Australian CoP due to the lack of independent efficacy data.**

Efficacy of the BB Secure Ring

Bed bugs have simple feet and lack pulvilli (the suction-cap like structure that enables insects such as flies to walk on vertical glass surfaces). This can be exploited in bed bug management through the installation of ultra-smooth barriers that prevent bed bug access. The *BB Secure Ring* (www.bedbugsecure.com) is a very simple technology and



consists of PTFE, a Teflon-like material, which is placed between the bed leg and the bed as per the image on the right. A video of bed bugs attempting to climb over a *BB Secure Ring* is available on the above web site.

Laboratory evaluation of this product was undertaken by the Department of Medical Entomology at Westmead Hospital (Doggett *et al.* 2010). Via the use of a model bed, the *BB Secure Ring* prevented access to the 'bed' by 100% of bed bugs, of all stages and strains. Overall, 1,844 bed bugs in the *BB Secure Ring* trials were prevented access and this total included 212 females, 275 males, 89 5th instars, 91 4th instars, 174 3rd instars, 369 2nd instars and 637 1st instars. In contrast, the trial without the *BB Secure Ring* contained a total of 1,890 bed bugs and 1,700 (89.9%) of these were able to access the upper part of the model bed. The full report can be downloaded from: www.bedbugsecure.com/BB%20Secure%20Ring%20Laboratory%20Investigation%20Report.pdf, which includes detailed experimental procedures.

It would be expected that the *BB Secure Ring* will not stop all primary infestations, particularly in the situation where bed bugs have been brought in via luggage that had been placed onto the bed, or in heavy infestations. However, once in a hotel or multiple occupancy dwelling, the bed bug

infestation often spreads from the initial site. It is not uncommon for bed bugs to spread to 20% or more rooms within a facility (Doggett & Russell 2008). The *BB Secure Ring* may well prove most effective against these secondary types of infestations and, if it does, then the hotelier may expect to save considerable money in control costs, have reduced risk of litigation, and help maintain their brand reputation. As such, the *BB Secure Ring* may prove to play an important role in risk management against bed bug infestations. Field evaluations will be required of the *BB Secure Ring* in the hotel situation to determine any limitations of the product on an 'as-used' basis and these have yet to be conducted.

Efficacy of AgriSense Tape

The *AgriSense Bed Bug Monitor* (www.agrisense.co.uk) is a double sided tape with a low tack side for attaching to walls, skirtings, bed legs and other furnishings, and a high tack side for capturing bed bugs. A study to evaluate the efficacy of this product to act as a monitor was undertaken at the Department of Medical Entomology at Westmead Hospital. Forty adult bed bugs in four replicates of ten were placed at the base of a dowel leg that had the tape installed (pictured right, note that this is the same experimental set up as the *BB Secure Ring* evaluation above). Bed bugs will readily climb the dowel and should be captured, if the product



does what it claims. Yet over four weeks only two bed bugs were captured and it appeared that the bugs were actually repelled by the tape. This in fact, has been a general observation within the laboratory that bed bugs tend to be repelled by tacky surfaces, which is a problem for traps and monitors that use such materials. However, because no bed bugs were able to walk over the tape, it seemed to provide an effective barrier and perhaps some rebranding might be useful. In light of the poor performance of this product as a monitoring tool to capture bed bugs (as claimed), it could not be recommended for surveillance as part of a bed bug management program.

Efficacy of Permethrin Impregnated Mattresses and Covers

In recent years, products are being marketed with mattresses that have ticking (mattress fabric) and mattress covers impregnated with permethrin

impregnated. In Australia, this includes a product from *Sleepmaker* (www.sleepmaker.com.au) and in the US, the *ActiveGuard Mattress Liner* (www.allergytechnologies.com).

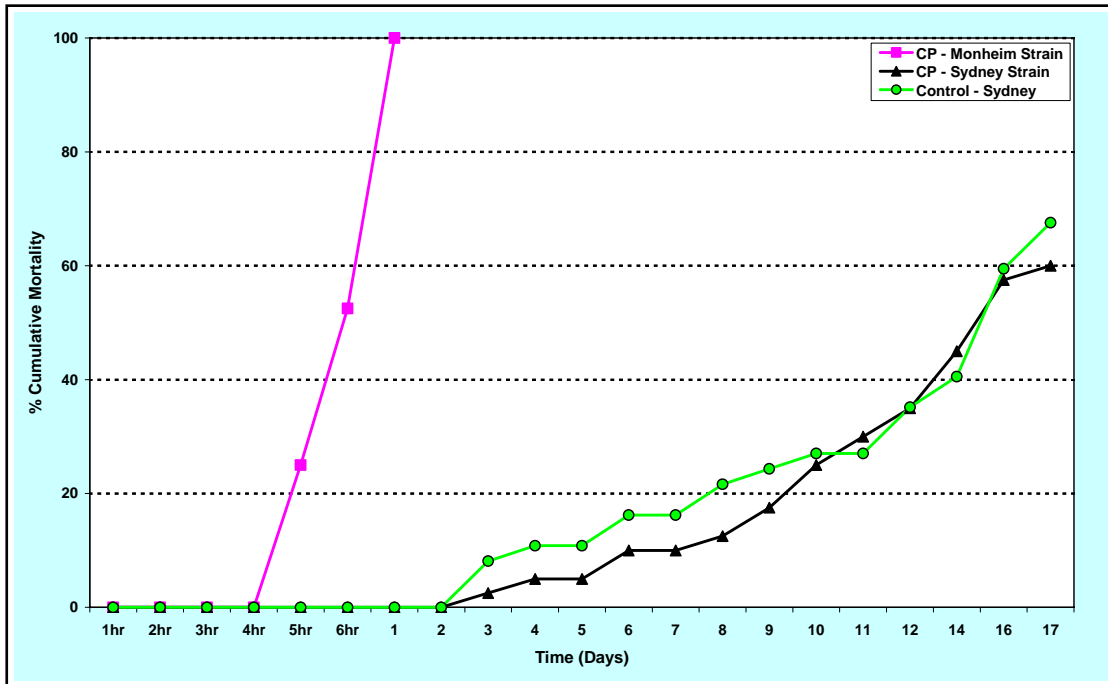
Conceptually, the use of permethrin for killing modern field strains of bed bugs appears problematic. Resistance to the synthetic pyrethroids (SPs) is well known (Myamba *et al.* 2002, Boase *et al.* 2006, Potter *et al.* 2006), even to the later generations of pyrethroids (permethrin is an older SP, belonging to the 3rd generation). In Australia, investigations comparing resistance between an old susceptible laboratory strain of common bed bugs (the 'Monheim' strain) and a modern resistant strain (the 'Sydney' strain) found that it took an increased dose of 1.4million times the LD₅₀ with permethrin to kill the modern strain (Lilly *et al.* 2009).

Thus, to suggest that permethrin could be employed for killing bed bugs on mattresses seems flawed. However, to be fair, it is always important to test the efficacy of any product, no matter if there appears to be conceptual challenges.

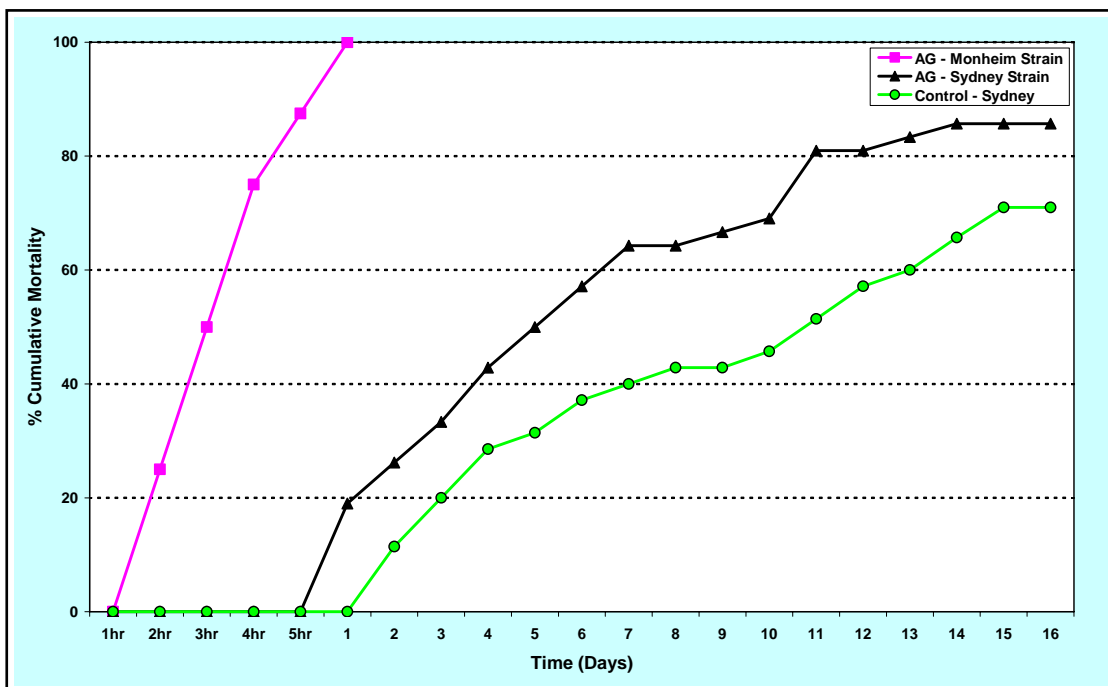
According to the Sleepmaker web site, bed bugs are killed within 48 hours (see www.sleepmaker.com.au/The-Sleepmaker-Difference/Sleepmaker-Hospitality.asp and the catalogue at the bottom of the page), while a representative from ActiveGuard stated that bed bugs will start to die within 10-12 minutes and are completely killed within 48 hours, and that bed bugs are repelled (stated publicly at the 2010 North American Bed Bug Summit held in Chicago). A paper (the author of which is employed by the company) stated that bed bugs were killed within 72 hours (Ballard 2008).

To test the above claims of lethality (repellency has yet to be evaluated) mattress ticking impregnated with the permethrin used on the Sleepmaker mattresses was obtained and an ActiveGuard Mattress Liner purchased from the US. Adults of two bed bug strains of the common species (*Cimex lectularius*) were employed in the trials; the 'Monheim' is an old laboratory strain that is susceptible to the SPs, and the 'Sydney' which is a modern strain and resistant to the SPs.

For each test evaluation, four swatches of 9cm diameter were cut out of each fabric such that could be fitted into 9cm Petri dishes. An equivalent number and size of untreated ticking was used as a control. Onto each swatch 10 bed bugs were placed. Thus for each fabric, there were four replicates each with the Sydney and Monheim strain, and an equal number of controls. Mortality was recorded hourly for up to six hours and then daily for up to 17 days post-exposure of the bed bugs.



Graph 1. Percent cumulative mortality of bed bugs exposed to the permethrin treated mattress ticking. The pink line (square data points) represents the Monheim strain, the black (triangular data points) the Sydney strain. Only the control for the Sydney strain (green, circular data points) is depicted as there was minimal mortality in the Monheim controls.



Graph 2. Percent cumulative mortality of bed bugs exposed to the ActiveGuard Mattress liner. The pink line (square data points) represents the Monheim strain, the black (triangular data points) the Sydney strain. Only the control for the Sydney strain (green, circular data points) is depicted as there was minimal mortality in the Monheim controls.

For the permethrin treated mattress ticking all the Monheims died within 24hours (unexposed control mortality was 2.5% at 24hrs, Graph 1). However

for the Sydney strain mortality at 17 days was 60%, while unexposed control mortality was even greater; 68% (Graph 1). For the ActiveGuard, all the Monheim bed bugs also died within 24hrs (Graph 2). Even by 16 days post-addition of the Sydney bugs 100% mortality was not achieved (Graph 2). By Day 16, test mortality was 86% yet unexposed control mortality was 71%.

Thus while the companies' claims of the products killing bed bugs within 48 hours may be true for an old laboratory susceptible strain of bed bugs, it is not true for a modern, resistant and relevant strain. In fact at 48 hours for the permethrin impregnated ticking, not one of the Sydney bed bugs died, while mortality was only 19% for the ActiveGuard. For the permethrin impregnated mattress ticking, test mortality was not significantly different to the controls for the Sydney strain. There was around 15-20% mortality with the ActiveGuard from Day 2, however this did not increase above control mortality for the remainder of the trial. One of the worrying aspects of this product is that it had no effect on around 80% of bed bugs of the modern strain, i.e. resistant bed bugs were left intact. The exposure to sublethal doses of insecticides is a factor that can lead to more rapid development of resistance and so such products may result in even greater problems.

On the basis of these experimental results, the conclusion is that permethrin impregnated mattresses or mattress covers have no place in the control of modern bed bug infestations. While repellency was not scientifically measured in the experiments, the test bugs of the Sydney strain did not appear to be anymore excited when on the treated fabrics than the control bugs. Considering that the manufacturers' claims of lethality as tested were grossly invalid, there are grounds to be sceptical about the other claims of repellency.

Efficacy of Phantom Insecticide

Phantom Insecticide, when first announced, was depicted as the new panacea for bed bug management. The Australian Bed Bug CoP even (perhaps unwisely in hindsight) included this as a potential new insecticide in the 3rd edition (Doggett 2010). Most approved products on the market were (and still are) synthetic pyrethroids and, as noted above, modern bed bugs are highly resistant to these compounds. The active ingredient of Phantom is Chlorfenapyr and, being from an insecticide class (arylpyrrole) with a very different mode of action, it would be expected that cross resistance with the pyrethroids would be unlikely. A product that can readily kill modern resistant strains would naturally be of great benefit and thus Phantom Insecticide was viewed with great promise. However, the results of the first published field trial indicated that this great promise was perhaps not yet quite justified.

In an evaluation of the product, 15 apartments were treated with Phantom Insecticide (Potter *et al.* 2008). Ten of these units had mild infestations with less than 100 bed bugs observed, while five units had between 100 to ~1,000 bugs. Some non-chemical control options were undertaken, such as bagging and washing clothing, and some infested furniture was removed. Nine of the units were treated with a limited application of a siliceous product in addition

to Phantom, which was widely sprayed throughout the 15 apartments. Phantom reapplications were undertaken monthly and bed bug counts were also recorded monthly. At the 4, 8 and 12 weeks post-treatment evaluations, 14, 11 and 10 units, respectively, still had live bed bugs. It took an *extraordinary five months before bed bugs could not be detected in 12 of the units, yet three remained infested!* Interestingly, if a room was left unoccupied at an average temperature of around 23°C, then the bed bugs would die out naturally during this time. It was not stated within the paper if the rooms were left vacated.

Clearly these trials revealed the slow nature of the action of Phantom. It is unlikely that such results from a product would be unacceptable to the accommodation industry or to the vast majority of people who wished these insidious pests were gone yesterday. Not surprisingly, the authors concluded that Phantom Insecticide was not the miracle 'silver bullet' and that it should be always applied in conjunction with quicker acting products.

Subsequent to this trial, other authors at various meetings have cast doubt upon the effectiveness of Phantom Insecticide for bed bug management. As a result of these equivocal findings and the fact that the product was recently registered on the Australian market, a series of laboratory based efficacy trials were undertaken at the Department of Medical Entomology. The aim was to evaluate mortality by direct topical and spray application, and by residual exposure of dried product against adults of the common bed bug, *Cimex lectularius*.

Methods: in the trials, mixed adults of both the SP susceptible (Monheim) and resistant (Sydney) strains of the common bed bugs were employed. In the topical application trials, Phantom Insecticide was diluted with tap water to label rate and 1µl applied to the ventral side of each bed bug, which was immobilized with tape, and the product allowed to dry. Ten treated bugs were placed into one 9cm diameter Petri dish fitted with a 9cm diameter disc of filter paper. This was repeated a further three times to give four replicates for each bed bug strain. The control consisted of an equivalent number of bed bugs treated with the diluent (i.e. 1µl of tap water). Mortality was recorded from 1 to 6 hours post-treatment and thereafter daily for up to 22 days. Both strains were tested twice with the same batch of Phantom insecticide; however, dilutions were made on the day of the test.

In the direct spray evaluation, for each strain, ten bed bugs each were placed into four Petri dishes that held a 9cm diameter disc of filter paper. The eight petris (four containing Monheim and four with Sydney bed bugs) were placed within a marked 50cm square of paper. Phantom insecticide was diluted to label rate with tap water and applied evenly over the 50cm² paper according to label directions via a B&G sprayer. An equivalent number of controls were used and these were sprayed with the diluent (i.e. tap water) at the same application rate. Mortality was recorded from 1 to 6 hours post-treatment and thereafter daily for up to 22 days. The direct spray application trial was designed to simulate product application by a pest manager.

For the residual trials, Phantom insecticide was diluted with tap water according to label rate, applied to the equivalent of run off by adding 1.2mls of diluted product to 9cm diameter filter papers, which were then allowed to air dry overnight. These were placed into individual Petri dishes and ten bed bugs added to each treated paper, with a total of four replicates for each strain. The control consisted of filter paper treated with an equivalent amount of tap water, which was also allowed to air dry overnight. Mortality was recorded from 1 to 6 hours post-exposure and thereafter daily for up to 22 days. The Sydney strain was evaluated on three occasions with two different batches of Phantom, while the Monheim strain was evaluated on two occasions with different Phantom batches.

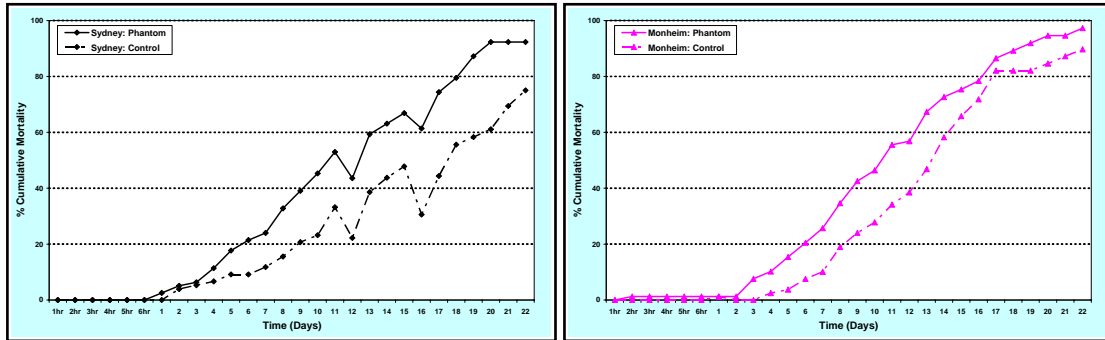
Results & Discussion: In the total of seven trials testing the efficacy of Phantom insecticide against adults of the common bed bug, at no time was 100% mortality achieved over the 22 days of experimental monitoring. For the topically applied product, cumulative mortality of 92% and 97% was achieved with the Sydney (Graph 3a) and Monheim (Graph 3b) strains, respectively, yet unexposed control mortality was 75% and 90%, respectively. In fact there was virtually no difference between control and test mortality with the Monheim strain, suggesting that Phantom provided minimal control. Note that in Graph 3a (and some others such as 5b) there were two days when results were not recorded, hence the appearance of an artificial decline in cumulative mortality.

The direct spray trials performed even more poorly; at Day 22 the cumulative mortality was 65% (Graph 4a) and 75% (Graph 4b), respectively, for the Sydney and Monheim strains, while control cumulative mortality was 65% and 75%; the control mortality with the Monheim strain was thus greater than the test. In reality, it appeared that Phantom provided no control when applied as a direct spray. In our experience a direct spray application results in less product being applied to the insect compared to a topical application, and so the lower mortality rates are not unexpected

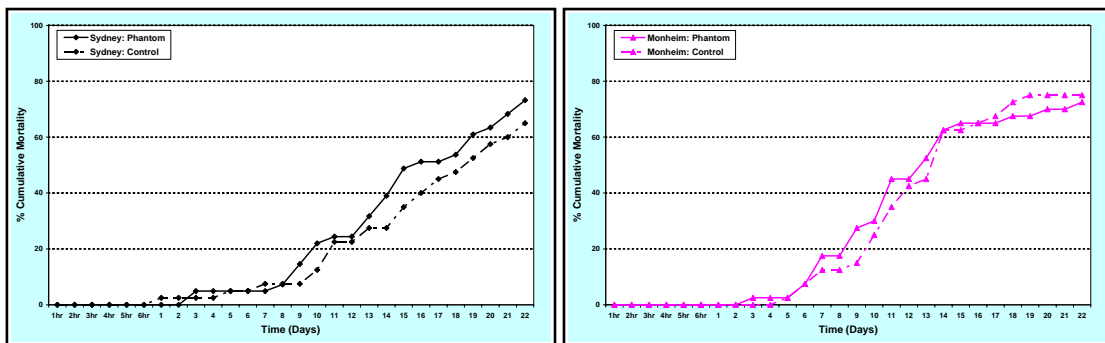
The residual trials fared little better. At Day 22 the cumulative mortality was 87% (Graph 5a) and 88% (Graph 5b), respectively, for the Sydney and Monheim strains, while control cumulative mortality was 63% and 64%. Again, Phantom provided little mortality.

Due to the poor performance of the product in the initial trials, most experiments were repeated, even using different batches of Phantom. However, the poor performance of the product continued. Not only was Phantom largely ineffective against the Sydney strain, but also the Monheim strain as well. **Never before has testing been undertaken by our group where a product failed to kill the highly susceptible Monheim bed bug strain within less than a day, let alone over three weeks.**

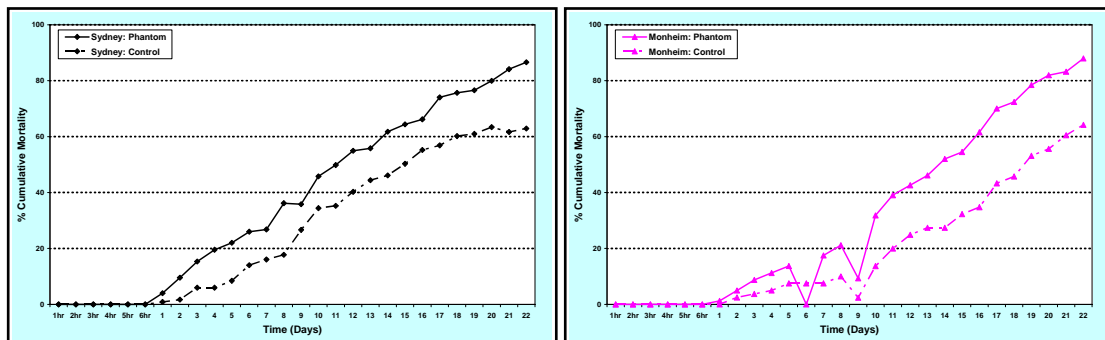
In light of the results obtained, the use of Phantom Insecticide against adult bed bugs is not recommended.



Graph 3a (left) & 3b (right). Percent cumulative mortality over time of Phantom insecticide against adults of the common bed bug, *Cimex lectularius*, when applied topically. Graph 3a is the results of the Sydney strain, Graph 3b is the Monheim strain results. The solid lines are the tests, the dotted lines the unexposed controls.



Graph 4a (left) & 4b (right). Percent cumulative mortality over time of Phantom insecticide against adults of the common bed bug, *Cimex lectularius*, when applied by direct spray. Graph 4a is the results of the Sydney strain, Graph 4b is the Monheim strain results. The solid lines are the tests, the dotted lines the unexposed controls.



Graph 5a (left) & 5b (right). Percent cumulative mortality over time of Phantom insecticide against adults of the common bed bug, *Cimex lectularius*, when applied as a residual product. Graph 5a is the results of the Sydney strain, Graph 5b is the Monheim strain results. The solid lines are the tests, the dotted lines the unexposed controls.

Miscellaneous Products & Services

Bed Bug Detection

One of the major areas of innovation is in the area of bed bug traps and monitors. In recent years this includes the *Nightwatch*, *CDC3000*, *Bed Bug*

Dome, and the *BB Alert Active* and *Passive*. More recently the trend has been towards simple and small disposable harbourage type traps, which contain no attractants. Two of these include the '*Bedbug Card Monitor*' (left below) available from *Barrettine* in the UK, and the '*Bedbug Detection System*' or *BDS* (below right) from *Catchmaster* in the US.



Other similar traps include the '*Bed Bug Inn*', the '*Bed Bug Trap*' and the '*3 Way Bed Bug Trap*', all available from *Barrettine* (www.barrettine.co.uk). All of these small traps require constant monitoring to check for bed bugs. The conceptual problem with all of these is that within a room there are numerous alternative potential harbourages, so why would bed bugs go into such small devices and when they do, just how long has the infestation been present? Also, bed bugs release aggregation pheromones and tend to return to the same place after feeding. Thus, there are questions about the sensitivity of these simple bed bug traps. Another monitor which was released late last year is the '*NightStick*' (<http://bedbug-nightstick.com/>, pictured right). This is a much bigger unit and provides a greater harbourage area for bed bugs and thus should be more successful at detection than the smaller units, *as long as it is regularly inspected*.



Fewer traps have been developed in recent times that contain attractants. One that has is the *Bed Bug Beacon* (pictured right), from the same manufacturer as the *Packtite*. This device produces carbon dioxide, a general attractant for haematophagous (blood-feeding) arthropods. With an attractant, it is likely that this device will more likely detect bed bugs than the passive monitors. The unit however does appear clumsy and could be designed with greater aesthetic appeal.



Sadly not one trap or monitor has quality independent data to testify to its efficacy and so none are presently recommended within the CoP.

The only other form of detection being increasingly used is that of bed bug detection dogs. In the US, there are several companies that supply such dogs and they are now widely used. Often two dogs will be employed in a hotel environment; the second dog will be used to confirm the first if bed bugs are indicated. Dogs are an expensive technology; typically costing around US\$15,000 per dog, they require daily training, along with specialized training for the handler. Dogs do have 'off' days and the trainer must be able to detect this through ongoing quality control checks. In Australia, there are hotel chains that refuse to have dogs on their premise, the concern being that guests may think that drugs, bombs or even bed bugs could be present. Yet such concerns are largely unfounded as dogs can be taken into rooms in covered trolleys, without guests being aware. There is footage on the internet of bed bug dogs jumping on beds and scratching at mattresses; this is not a good look and such activities should be avoided. Sadly, in the US, dogs are being misused by unscrupulous operators to falsely indicate bed bugs in order to obtain business. There are research groups working on artificial 'sniffer' technology and such devices could revolutionize bed bug management. However, until such devices appear on the market and prove to be as sensitive, dogs will remain as the most effective bed bug detection technology. It is a great pity that more Australian companies do not use them.

Bed Bug Barriers

The '*Bed Moat*' (top right) and the '*BB Stop*' (bottom right) are blatant copies of the '*Climbup Insect Interceptor*'. All of these devices are placed under bed legs and have two functions; they aim to stop bed bugs climbing onto the bed and they also have a monitoring function; bed bugs caught in the device find it difficult to escape and so these units can act as a monitoring tool. The *Climbup Insect Interceptor* is recommended within the CoP and presumably the other two copies should also function as stated, although testing is yet to be undertaken. The *Bed Moat* and the *BB Stop* are aesthetically more pleasing (the *Climbup* having unsightly tape around the outside) and thus may have more commercial appeal.



Bed Bug Barrier Tape: Tony Abraham, the inventor of the *Bed Bug Barrier* has now produced a Teflon tape that can be applied to bed and furniture legs that do not readily accommodate other forms of bed bug barriers (pictured in this section). Like the *BB Secure Ring*



mentioned above, bed bugs find ultra-smooth surfaces difficult to climb. The tape is thin and may need regular replacing to maintain integrity of the barrier.

Bed Bug Containment/Encasements

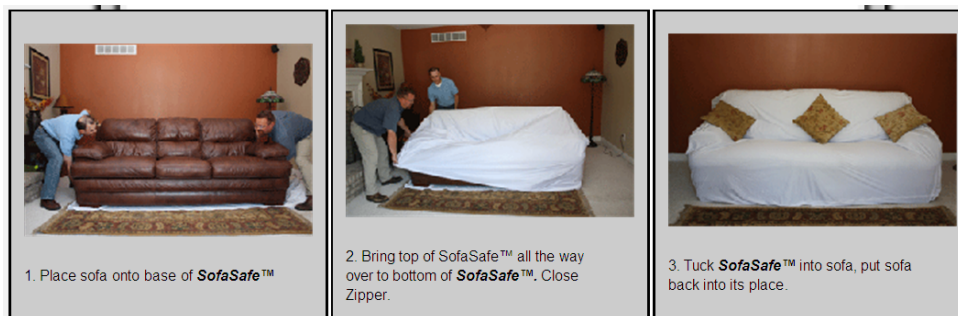
A number of companies are now producing encasements for mattresses, luggage and furniture to prevent bed bugs from either entering the item or, in some cases, escaping. This is just a small selection of such management devices.

BugZip produce anti-bed bug encasements for travelers to enclose their luggage (pictured right).



The removal of infested mattress from a room for treatment or disposal presents a risk of spreading bed bugs unless the mattress is completely sealed. *Protect-a-bed*, better known for their mattress encasements, now produce sealable bags for mattress disposal (pictured left). This company is also now marketing alginate bags (dissolvable laundry bags) for washing of infested clothing and linen.

Typically in many infested premises, bed bugs will get into other furniture, especially couches and sofas, which are very difficult to treat. *Sofa Safe* (www.thesofasafe.com, pictured below) now market encasements for such furniture and, while not aesthetically pleasing, they may prevent a significant bed bug harbourage.



BB Alert, the manufacturer of the bed bug monitors (*BB Alert Active* and *BB Alert Passive*) now markets a range of encasements for mattresses, pillows, laundry and luggage. For details see: www.bedbugsalert.com/index.asp?page_ID=30

Non-Chemical Control: Heat

With the problem of resistance, and the low probability of any new and efficacious insecticide products becoming available in the near future, there has been much interest worldwide in the use of heat for bed bug management. Heating units



vary from the small and highly portable *Packtite* (pictured right), which can be used on luggage and small items (and is recommended within the Australian CoP), to *much* larger containment structures. *Quest* produce a number of heaters aimed at bed bug management as well as having larger portable



containers that can even treat whole beds, furniture and other bigger items (pictured left). There are now many companies in the US selling heating appliances for bed bug control (e.g. *Thermal Remediation*, *Insect Inferno*, *ThermEx*). Some of these companies also promote the use of whole room or structure heating; however, containment heating has a higher degree of success. There are also specialized steam heads for bed bug

management from *Vapor SteamDome*. Heat for bed bug management is presently big business in the US.

Non-Chemical Control: Cold

Just as carbon dioxide has been proposed for use in bed bug management, now liquid nitrogen is as well. The Spanish company *Sanitrade* is marketing a device that instantly freezes bed bugs with a spray of super cool liquid nitrogen (pictured right). While no independent efficacy evaluation has been undertaken to date, there are concerns that this product, like the *Cyronite*, may non-lethally blow bed bugs about thereby possibly spreading an infestation (note that the *Cyronite* is not recommended in the Australian CoP). The liquid nitrogen container appears quite heavy and imposes a manual handling risk. The transportation of pressurized cylinders is also an OH&S threat.



Chemical Control: Bed Bug Repellent

Products are being marketed that claim to repel bed bugs. *Rest Easy*, for example (pictured right), contains a variety of essential oils, which can be applied to areas around the bed and/or luggage. Some of the constituents are known to have a minor degree of repellency against other haematophagous arthropods but the effectiveness against bed bugs of this product is unknown. It is also not known for how long the repellency effect may last.



Chemical Control: Insecticides

Diatomaceous Earth Dust (DED): DED is likely to be registered for bed bug control in Australia within the next year. This is great news for the pest manager as DED has several advantages over traditional insecticides; DED has long residual and shelf life, low mammalian toxicity (and is often seen as a 'green' product), and there is a reduced risk of resistance developing due to its mode of action. Also, application rates are less critical than other products; if under-applied, DED still is efficacious but it takes longer to work (Doggett *et al.*, 2008). DED does have some disadvantages in that as it is a dust, the product is obvious and so can not be applied to all locations, and it is slow acting. Despite the disadvantages, DED will have a place in the arsenal of products available to the pest manager. In the UK, DE is now available as an aerosol product, it is a pity that none of the silicate base aerosols are registered in Australia.

Phobi Dose: is a new insecticide claimed to control bed bugs and it was released in the UK during April 2011. According the company web site (www.lodi-uk.com/index.php?act=viewProd&productId=95):

“Phobi Dose is an innovative and highly effective liquid concentrate formulation containing the active ingredients Imiprothrin and Cyphenothrin. The active ingredients in Phobi dose are unique to the UK market in a liquid formulation and offer the pest controller a highly effective form of pest control. As these actives have not been used by the UK pest controller there is a lot lesser chance of resistance and a much greater chance of success.”

All the actives listed above end in “thrin” and indicate that they are synthetic pyrethroids and thus resistance is probable (resistance to one pyrethroid infers resistance to them all). The above marketing hype suggesting that there is a lesser chance of resistance is nonsensical. According to one web site (www.pestmagazine.co.uk/content/NewsItem.aspx?id=595) the product can knockdown all bed bugs with 25 minutes; however, the strain of bed bug is not listed and it is hard to imagine this would occur with SP resistant strains. Independent efficacy evaluation using modern resistant bed bugs strains is required.

Enzymes: over the last year, one of the buzz words in the world of bed bugs has been 'enzymes'. Various companies are marketing these products (e.g. www.bbxeliminator.com, www.bedbug911.com), but data on efficacy is notably wanting. What exactly these products are and how they work is not clear nor explained by the companies, but there are claims that the products can kill bed bugs almost instantly, even resistant strains. Sadly, these are US EPA exempt and do not require the detailed efficacy (and safety) evaluation of other insecticidal products. It is unlikely such products will appear on the Australian market.

Personal Protection Equipment

Rest Assured Hand Sanitizer Spray: It is a good idea for Pest Managers to include a hand sanitizer as part of their pest control



kit. The company Rest Assured has now produced an alcohol based hand sanitizer for those who handle items that may be infested with bed bugs (pictured right). However, anyone who handles mattresses and other potentially infested items should be wearing gloves. Sanitizers are widely available and include many non-flammable types, which would be better suited if left in vehicles that become hot in the Australian sun.

Insecticide Application Equipment

As bed bug treatments tend to be more commonly undertaken in the home or hotel, where space is limited, many companies are now marketing compact insecticide application equipment. These have the added advantage of being very light. B&G have the '*Portable Aerosol System*' which is a compact spray system. They also an aerosol delivery unit which can tightly control the flow of rate of aerosols, which may reduce the risk of blowing bed bugs about. *Actisol* also has a compact unit for insecticide delivery.

Service Companies

In the many parts of the world, bed bugs have become so problematic that many specialized service industries have recently emerged. There are now suppliers that only market bed bug related products, e.g. *USBedBugs* (www.USBedBugs.com) in the US or *Germaway* in Australia (www.germaway.com.au). Bed bug management brokers now exist who do no actual control themselves but organize the management of bed bug infestations. Companies such as *Bed Bugs and Beyond* (www.bedbugsandbeyond.com) have had several high profile clients including Niketown, Abercrombie & Fitch, Victoria's Secret, President Clinton's Office, the Empire State building, and the United Nations building. The preparation of a site prior to the instigation of treatment can be extremely laborious especially if clutter is abundant and the client is a hoarder. Many pest control companies may not have the logistical resources to prepare a site for treatment and so a number of companies have begun, which offer this service; '*Bug n' Scrub USA*' is just one of these companies.

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Jenny Clifton from AH Beard kindly provided the permethrin impregnated mattress ticking. Gary Stephenson of BASF supplied the original sample of Phantom Insecticide. Marilyn Geary from the Department of Medical Entomology assisted in the recording of results in the efficacy trials. The authors would like to acknowledge the efforts of the Working Party behind '*A Code of Practice for the Control of Bed Bug Infestations in Australia*'.

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