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MANAGEMENT OF BED BUGS ON COMMERCIAL AIRCRAFT

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Abstract Bed bug (*Cimex lectularius*) infestations on board aircraft is a growing concern and has substantial financial impact on commercial airlines, in some cases it has resulted in Port Health Authorities grounding aircraft. Airlines that have a proactive approach to bed bug management fare much better than those with a reactive approach, suffering 80% fewer seats infested and 69% fewer insects in the heaviest seats. A range of detection systems were evaluated with detection rates on known infestations ranging from 12.5% to 95% accuracy. The withdrawal of methyl bromide left European carriers without an eradication system, its reputation of achieving 100% eradication in a single treatment was confirmed in this study. With limited insecticides holding Aerospace Materials Standard (AMS) 1450A approval and the ethical issues of pesticide use in passenger cabins new technologies were needed. Chemical treatment strategies achieved an average 15% reduction in infested seat count. Heat treatment in its different forms was seen as a direct replacement to methyl bromide. Open and recirculating heat capsule systems were evaluated and achieved 95% and 92.5% reduction in infested seat count respectively. However the frequency that recirculating heat treatments caused damage to aircraft and the reduced efficacy compared to open systems made this technique unpopular with aircraft operators.
Key words Aircraft fumigation, heat treatment, methyl bromide

INTRODUCTION

Biting insects on aircraft have been a concern since the beginning of commercial and international air travel (Griffitts and Griffitts, 1931). Swain (1952) predicted that aircraft would be a major distributor of insect pests, Sullivan (1958) reported on how insects may survive on aircraft. Public health pests have received the most attention (Evans et al., 1963; Basio et al., 1970; Otaga et al., 1974; Russell et al., 1984; Goh et al., 1985). The World Health Organisation (WHO) published a revised bulletin to cover the increased risk of vector borne disease. Disinsection of cabin environments to control mosquito species is required under the WHO International Health Regulations when flying from certain destinations. An overview of pest control methods, both chemical and non-chemical is provided by Story (1985) and Gratz et al. (2000). The resurgence of bed bugs (*Cimex lectularis*) around the world (Robinson and Boase, 2011) has included their appearance on commercial aircraft. The negative publicity suffered by airlines (Haiken, 2011) will affect a passengers' choice when selecting a carrier.

Over a three-year study comprising over 100 infested aircraft inspections of different carriers, aircraft models and configurations. The range and severity of infestation was monitored. Many infestations had spread through multiple cabins and consisted of multiple insects per seat. Cases ranged from single insects in single seats to infestation of many thousand insects spread through multiple cabins. The complex nature of aircraft interiors and the time constraints of a commercial aviation operation limit the potential detection systems that could be deployed. A range of systems including human

inspection, refuge monitors, lure based monitors, electronic detectors and scent detection dogs were assessed. The ability of detection dogs to locate live bed bug infestations in a controlled environment is well known (Pfiester et al., 2008) however their performance in a highly complex environment with multiple competing scents was unknown.
The withdrawal of methyl bromide in Europe left European carriers without an effective eradication system, the insecticidal properties of fumigants including methyl bromide in upholstered environments is well documented (Sherrard 1942). With limited insecticides holding AMS approval and the ethical issues of wide spread pesticide use in passenger cabins, new and innovative eradication technologies were needed. Different airlines approached this issue in different ways allowing the assessment of multiple technologies. Aircraft were inspected prior to and 28 days after treatment to assess the efficacy of the treatment process. The objective of this study was to assess the current management systems with the view to providing base line data to guide further developments.

MATERIALS AND METHODS

All detection technologies were assessed based on their ability to detect known infestations in a commercial aircraft environment. The accuracy of the systems was assessed along with their acceptance in the aviation industry. Due to legal constraints, refuge and lure based monitors could not be tested on aircraft, as none of these technologies would pass the fire safety tests needed to be installed on a commercial aircraft. As such these monitors were tested on infested seat sets that had been removed from the aircraft. All other systems were assessed on active aircraft.
Detection and infestation levels. A primary hand search was undertaken by experienced bed bug technicians to confirm the presence of bed bugs to test criteria. To prevent cabin disruption biasing test results, only one technology was deployed per aircraft per day. The following detection systems were deployed, refuge monitors, lure monitors, electronic air sampling detector and scent detection dogs. Refuge and lure monitor devices were installed 1 per seat in the test arena. The electronic detector was worked systematically through the test cabin sampling likely refuge sites following the search protocol recommended by the supplier. The search dog handlers were instructed to search the test cabins as a normal search. All systems were assessed based on percentage accuracy of known infestations, number of false positive readings and the acceptance of the system by contributing airlines. Infestations were graded based on the number of seats infested and peak insect count in the seat of heaviest activity. Aircraft presenting bed bug activity were inspected using canine and visual inspection process to identify the spread and severity of the infestation. Insects were removed from infested seats using a vacuum powered aspirator and insects counted post inspection in a counting arena.
Eradication. Eradication systems were assessed based on efficacy and acceptance within the aviation industry. Using a combined approach of canine and visual inspection, known infestations where documented prior to and 28 days after treatment to assess the efficacy of the systems. The following systems were analysed. Methyl Bromide Fumigation, this was carried out by a specialist aircraft fumigation company. The whole aircraft was fumigated not just the infested area as this was their normal process. High concentration of 100% methyl bromide was maintained for the treatment period.
Two available chemical treatments were evaluated, only Ficam W and K-othrine have approval to Aerospace materials specification 1450A. Applications were made using compression sprayers applying the pesticide to label conditions onto non-passenger contact surfaces. Seat covers were removed to facilitate access to key harbourages and replaced after the application had dried.
Two heat treatments were evaluated. The first where the heat capsule is closed with the air recirculating

within, with hot air heaters placed in the capsule either electrically powered or using ethylene glycol transfer systems. The second system used forced hot air ducted into the treatment capsule and vented to prevent the capsule pressurising. Both systems require the treatment to run until the core temperature of all treated material reached 60°C this exceeds the known thermal tolerance of bed bugs (Schrader and Schmolz, 2011) and should result in complete control of the infestation.

RESULTS

Detection

	Replicates	Mean infested seat count	% known infested seats detected	Mean false positive per replicate	Airlines surveyed deploying system
Refuge Monitors	2	8	12.5%	0	0
Lure Monitors	2	8	62.5%	0	0
Electronic detector	10	14.3	59.44%	26.2	2
Scent detection Dogs	10	15.6	95.51%	0.3	2

Infestation Levels

	Sample Size	1-10 infested seats	11-20 infested seats	21-50 infested seats	50+ infested seats	Mean peak seat insect count (range)
Proactive Detection	76	59	12	3	2	22(1-82)
Reactive Detection	32	11	5	7	9	71(10-140)

Eradication

	Sample size	Mean Infested seats before treatment	Mean Peak seat insect count before treatment	Mean Infested seats 28 days post treatment	Mean Peak seat insect count 28 days post treatment
Methyl Bromide	1	114	140	0	0
Ficam W	4	22.5	23	14	7
K-Othrine	4	19.25	21	21.5	9
Recirculating heat treatment	3	62.6	46.3	4.6	6
Forced air heat treatment	5	71.2	38.2	3.2	3.6

DISCUSSION

Detection

Harbourage and lure based monitors were the first to be assessed by the airlines and were quickly discounted as unfeasible. As these systems need an initial visit to deploy the monitors and follow up visits to check for activity. This alone made them unfavourable with airline operators. Harbourage based devices do not seem to be able to compete with the refuge rich environment in an airline seat however as this system was evaluated in the absence of a host it is possible that the absence of stimulus skewed this result. The only real advantage of these systems is that they produce no false positive results. Although in this trial the lure based devices produced reasonable results, none of the airline operators surveyed in this study are using either system due to the fire safety implications.

The air sampling device gave a large number of false positive results, this system is based on an Infrared absorption cell calibrated to the absorption spectrum of gasses resulting from digestion. It is likely that these false positives are due to the localised warm air pockets on aircraft seats caused by in seat electronics such as in flight entertainment units. It also did not detect some of the known infestations. Even with these limitations two airlines are operating this system as reactive survey system following passenger complaints.

Scent detection dogs provided the most reliable data to enable eradication efforts to be focused. A small number of false positive results were noted predominantly on the perimeter of the known infestations. Similarly the small number of infested seats that were not indicated by the scent detection dogs were on the perimeter of an infestation where a higher scent load towards the core of infestation drew the dog away. Throughout this survey accuracy in excess of 95% was achieved however the use of scent detection dogs must still be seen as a presumptive test not an evidentiary result as is the case with narcotic and explosive detection dogs.

Infestation Levels

Infestations studied ranged vastly in terms of spread and severity. Many of the proactively detected infestations consisted of single or small clusters of insects in a limited number of seats. The heaviest infested aircraft in this study contained 126 infested seats with a peak seat insect count of 140, in this case over 25g of live insects were collected during the survey. This level of activity was the exception rather than the rule however it illustrates the extent that infestations can develop to if left unchecked. As would be expected there is clear advantage to proactive detection in terms of infestation size and severity, not to mention the legal and ethical obligations to passengers. Those airlines that were engaged in a process of proactive detection averaged 80% fewer seats infested and 69% fewer insects in the heaviest seat, when compared with reactive airlines. In the absence of details of uninfested aircraft it is not possible to pass comment on the frequency of infestation, however due to the nature of a mass transit system it is likely that commercial aircraft are exposed to bed bugs on a daily basis and that the rate of transference is relatively low.

Eradication

Methyl bromide fumigation was the primary eradication system up until its revocation. The closed nature of aircraft favour a fumigation based approach and the non-corrosive, non-flammable properties made this system the benchmark that all treatment systems are measured against. Due to the timing of this study only one fumigation was assessed, however it was the only treatment strategy that achieved 100% eradication in a single treatment. Chemical treatment produced disappointing results. In some cases a dispersal of the infestation was noted. This was probably due to natural progression of the infestation rather than a repellent effect of the treatment. Deltamethrin is known to increase mobility in bed bug populations (Romero et al., 2009) and in a closed aircraft environment resulted in an increase in passenger complaints. As chemical control is the mainstay of the global bed bug control industry it was hoped that a chemical solution would replace aircraft fumigation. However the complex nature of aircraft seating products and the restrictions on dismantling seats does not allow the technician access to properly apply a pesticide. The aggressive nature of a cabin environment degrades both AMS approved preparations exceptionally quickly resulting in negligible residual value to chemical treatments, coupled with the elevated tolerance profile of field strain bed bugs (Boase et al., 2006; Romero et al., 2007) it is unlikely that a pesticide based approach will achieve the levels of control needed, even with further approval of pesticides for cabin use. Heat treatment being an environmental manipulation technique has many supporters in the aviation industry. The levels of control achieved are the closest to methyl bromide fumigation but still a degree of survival did occur. If carried out correctly it has no deleterious effects on the aircraft, however close attention needs to be paid to temperature monitoring to ensure safe treatment and the desired level of control. In one recirculating system treatment overheating of the environment resulted in warping of plastic components in seating products and cabin side walls. The need to use either fluid transfer or electric filament heaters within the aircraft raised further objections to recirculating heat treatments due to the risk of fire or flood. As only ducted hot air enter the aircraft and the more controllable nature of a forced air systems this has become the favoured eradication system. The increased air turbulence in a forced air treatment capsule results in greater energy transfer to the treatment substrate and consequently a greater reduction in population. With further developments in this area or if coupled with another eradication technology it is possible that the levels of eradication achieved with methyl bromide will be matched without the environmental impact.

CONCLUSION

Bed bugs on commercial aircraft will become more of an issue over the coming years. Most of the aviation industry have a reactive approach to bed bug management, relying on passenger complaints to drive treatment. Massive advances have been made over the past 3 years in detection and eradication systems resulting in workable proactive detection and risk management systems. As the bed bug issue develops globally the swing from reactive bed bug control to proactive management is inevitable.

The complex nature of aircraft seating products and regulatory constraints limit the detection systems that can be used. By far the most accurate and time efficient method in this environment is the use of scent detection dogs. This is followed by hand searching in terms of accuracy but the time input needed makes this system less attractive.

The severity and spread of bed bug activity is obviously directly correlated with duration since the inoculating event. Once established within the aircraft cabin, infestations develop very quickly due to the stability of the environment, extensive harbourage close to the host and the abundance of feeding opportunities. Those airlines that were engaged in a process of proactive detection averaged 80% fewer seats infested and 69% fewer insects in the heaviest seat, when compared with infestations detected by passengers or Port Health authorities. As preventing the inoculation is not possible, the early detection of infestations is vital particularly in view of reduced efficacy of eradication systems. In view of an aircrafts' likely exposure to bed bugs further research is needed to study passenger boarding behaviour with a view of reducing the rate of inoculation. Seating product design could also be vastly improved to reduce rates of establishment following inoculation and subsequent spread throughout the cabin environment.

As yet there is not a direct replacement for methyl bromide fumigation. No system evaluated during this study achieved the levels of control that were possible before its withdrawal. However workable alternatives are available, forced air heat treatment shows great potential and with future development it is likely that this system will become the direct replacement for methyl bromide.

The aviation industry harbours widespread misconceptions regarding the management of bed bugs. Many who responded to our survey questionnaire believe that bed bugs can be eradicated in a single treatment as was possible with methyl bromide. Some believe that only aircraft flying to USA are at risk of infestation. There is a clear need for a central resource centre for the aviation industry to allow best practice to be shared across the industry.

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