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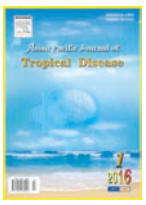

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A survey on the infestation levels of tropical bed bugs in Peninsular Malaysia: Current updates and status on resurgence of *Cimex hemipterus* (Hemiptera: Cimicidae)

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ABSTRACT

Objective: To survey current bed bugs infestation status in 11 states and federal territory in Peninsular Malaysia.
Methods: Targeted sampling in the urban areas was performed and the sites in each state were selected based on foreign workers' abundance and reports from pest control professionals in Malaysia. The collected bed bugs were classified into different strains obtained at the respective sites.
Results: Out of all 185 surveyed sites, approximately 38 of them have been actively infested with one species, *Cimex hemipterus* (F.). A high number of collected bed bugs were found in the states of Perak (24.8%), Selangor (21.0%) and Kedah (16.1%). In terms of preferred harborages, bedding, crevices in walls and floors and cushion seats were common locations with 49.2% infestation. Bed bugs were dominantly found in dormitories of foreign workers (51.6%) compared to residential houses and public accommodations such as hotels and airports.
Conclusions: Migration activities and reused infested furniture probably were the possible reasons to bed bug resurgence.

1. Introduction

Bed bugs from the order of Hemiptera under the family of Cimicidae are obligate blood-feeding ectoparasites of humans and occasionally on several other vertebrates[1-3]. Over 90 species of cimicids have been identified throughout the years[4]. Cimicids are also known as human bed bugs, bat bugs, chicken bugs, swallow bugs and pigeon bugs. Two important species that commonly pester humans are common bed bug and tropical bed bug [*Cimex lectularius* and *Cimex hemipterus* (*C. hemipterus*)][4,5]. These bugs initially made humans as their primary blood source except for *Leptocimex boueti*, bat bugs which are dominantly found in West Africa, relying on bat's blood to survive. However, they are also known to feed on humans as an alternative nutrient supply[6]. Common bed bugs are widely distributed in America, Africa, Australia and Thailand, specifically in Chiangmai. On the other hand, *C. hemipterus* prefers to live in tropical and subtropical habitats especially in Southeast Asia regions including Singapore, Vietnam, Indonesia, Taiwan and Malaysia[4,7].

Bed bugs have become a medical concern to humans as their bites can produce irritating, itching and burning sensations[8]. The bites are usually painless or they may only cause a slight irritation. They can vary from puncture marks on the skin to large red bumps[9]. The skin reaction to the bites varies for different people except for the person who has an allergic history may develop secondary infections[10]. Bullous cimicosis is a related type of allergy resulted from the bites by the bed bugs. Nitrophorin, anesthetic, antiplatelet, anticoagulant and compounds which can cause dilation of blood vessels are the components found in the salivary gland of *Cimex lectularius*. The stimulation of these contents is probably due to immunoglobulin E (IgE) mediated response[11].

Hypothesis about the causes of bed bugs resurgence include worldwide travelling activities by locals and foreigners, the use

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of second-hand furniture, poor knowledge among professionals in handling bed bugs and the development of resistance in the pest themselves[12,13]. The bed bugs are usually found in bedrooms but hide in cracks and crevices during the day. The most common shelters for bed bugs are the seams of mattresses and the crevices of the bed frames, headboards or inside walls[1,5,14]. More than 80% of bed bugs infestation occured in apartments and condominiums as well as residential houses in United States[15]. Professionals in the country encountered infestations in more than 60% of the hotels and motels, followed by college dorms (35%), daycare centers (24%), public transportations, laundries, cinema theaters and restaurants, each with less than 10% infestations.

Low awareness of bed bugs among the residents was reported in United States due to failure in detecting any signs of infestations occurring in their territories, causing the increase in number of pests[16]. Surveys in Nigeria also indicated a high infestation rate of bed bugs in human settlement areas including Lagos, Benue State and Gbajimba[17,18]. Series of bed bug cases also occurred in mainland China when the workers found that these creatures had seriously infested their dormitories. Two years later, another report was published by Emmanuel *et al*. in relation to bed bugs infestation in Guangdong Province in Southern China due to high percentages of immigrant workers in the cities who were infected[14]. In contrast, minimum awareness level among the residents resulted in a reduced amount of reported cases in other Asian countries. In view of this, the main objective of this research is to conduct a survey on bed bugs infestation in urban areas in Peninsular Malaysia.

2. Materials and methods

2.1. Sampling sites

A total of 185 survey sites in 11 out of 13 states in Malaysia were visually inspected. The sites were categorized based on their state divisions and federal territories on the map. The 11 states and a federal territory inspected were as follows: Pulau Pinang, Perlis, Kedah, Perak, Kelantan, Terengganu, Pahang, Selangor, Negeri Sembilan, Melaka, Johor and Kuala Lumpur (Figure 1). The survey was targeted mainly in the urban areas where abundant foreigners were found in each state such as dormitories and hotels. Selective premises were also based on the reports of infestation from pest control operators in Malaysia. Since the sampling was conducted randomly, only one visit was required in this survey. Each visit had a limited period of 30–45 min per site to collect all bed bugs found in the premises. Bed bugs were manually handpicked according to the tell-tale signs of infestation like fecal spots on mattress, cast of molting skins and the presence of live or dead bed bugs near the harborage sites. The collected bugs were then marked based on different strains obtained at the respective sites.

2.2. Collection of bed bugs

Targeted sites in the survey included hotels or motels, workers dormitories, residential houses, flats and apartments and public transportation area. The materials used in the inspections were fine forceps, flashlight, brush, vial bottle, organza cloth, and camera. Harborage sites within the premises were divided into beddings (pillows, mattresses, bed frames, bed sheets, and mosquito nets), headboards, walls and floors (in cracks and crevices), sofas and cushions, wooden furniture, rattan chairs and electrical appliances. Visual inspections were initially made within the period before collecting the samples using forceps, with the aid of flashlights. Samples consisted of eggs, nymphs as well as alive and dead adult bed bugs. The live bed bugs were placed in vial bottles covered with netting; whereas the dead bed bugs were placed in vial bottles with alcohol.

2.3. Classifying bed bugs strains

Samples of eggs, nymphs, and live adult bed bugs collected were reared and kept under laboratory condition. Adult bed bugs were used to identify the species according to the key of Usinger[5] under stereo microscope (Olympus SZ61). All strains were separated and labelled based on their location sites. They were placed in the plastic containers and maintained at laboratory temperature and relative humidity [(26 ± 2) ℃ and (60 ± 10)%, respectively].

2.4. Statistical analysis

The percentage of collected bugs on strains basis were used for analysis. *Chi*-square test for association relating two factors, harborage sites and types of premises were analyzed statistically using SPSS version 22.0 (IBM Corp., Armonk, New York, USA).

3. Results

All 185 survey sites indicated both positive and negative infestations. Targeted sites in each state were divided into 4 clusters. A total of 104 sites belonged to Cluster 1 within Pulau Pinang, Perlis, Perak and Kedah; 29 sites formed Cluster 2 within Kelantan, Terengganu as well as Pahang; Cluster 3 was from Selangor and Federal Territory of Kuala Lumpur with 13 sites while the other 39 sites belonged to Cluster 4 within Negeri Sembilan, Melaka, and Johor. From the total number of sites, only one species of bed bugs, *C. hemipterus* was found in 38 (20.5%) positive infested premises. According to the survey data, the positive sites were found in almost all states in Peninsular Malaysia except Kelantan with zero sample collected. Traces of infestation was found in one premise in Kelantan, however no live bed bugs were detected near the area. Mapping of surveyed sites was plotted in Figure 1 while sampling details were tabulated in Table 1.

Figure 1. Survey sites of bed bugs in each state of Peninsular Malaysia.

The number of collected bed bugs according to the states was concluded in percentage values (Figure 2). Index of infestation was rated depending on the number of bed bugs collected in each surveyed sites within 30–45 min. For instance, Rate 1 indicated 1–10 bed bugs found, followed by 2 (11–20 bed bugs), 3 (21–30 bed bugs), 4 (31–40 bed bugs), and 5 (> 41 bed bugs). Among the 11 states, Perak had the highest amount of bed bugs collected amounting to 24.83% but on the contrary, Negeri Sembilan had the lowest collection with the percentage of only 0.54%. High infestations were also observed in Selangor with 21% bed bugs collection, followed by Kedah with 16.09%. Johor had medium infestation rate which was 8.35% in four urban areas. fewer infestations were found in Perlis, Pahang, Melaka, Terengganu, and Kuala Lumpur ranging from 1.15% to 5.75%, indicating low prevalence of this insect in these sites.

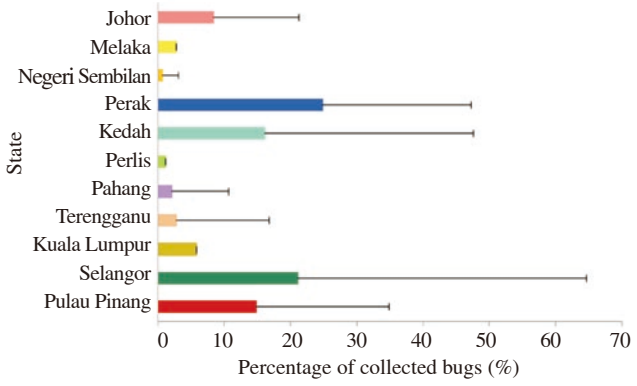

Figure 2. Percentage of bed bugs collected in the studied states.

Table 1
Total bed bugs collected within premises in each state and federal territory in Peninsular Malaysia.

Survey sites	Location	Strain	Premises types	Date collected	*Infestation rate	Total bed bugs collected
Pulau Pinang	Gelugor	TB	Residential houses	3 Nov 2013	5	44
	Gelugor	PI	Flats and apartments	20 Dec 2013	5	65
	Bayan Lepas	BL	Flats and apartments	13 Feb 2014	1	4
	Tanjung Bungah	TT	Flats and apartments	28 Feb 2014	1	9
	Batu Feringgi	BF	Flats and apartments	25 Nov 2013	1	6
	Seberang Perai Utara	LT	Residential houses	18 Nov 2013	5	57
Perlis	Arau	AR	Workers dormitories	24 Sep 2014	2	17
Kedah	Alor Setar	TS	Residential houses	25 Sep 2014	5	107
	Alor Setar	JS	Workers dormitories	25 Sep 2014	4	39
	Jitra	JR	Workers dormitories	25 Sep 2014	1	2
	Sungai Petani	PY	Workers dormitories	26 Sep 2014	2	14
	Sungai Petani	AY	Workers dormitories	26 Sep 2014	2	13
	Langkawi	PC	Hotels and motels	27 Oct 2014	2	13
	Langkawi	KH	Workers dormitories	28 Oct 2014	3	25
Perak	Kerian	KR	Workers dormitories	16 Oct 2014	2	12
	Padang Rengas	PR	Residential houses	17 Oct 2014	1	2
	Kuala Kangsar	KK	Residential houses	17 Oct 2014	2	11
	Ipoh	IP	Workers dormitories	17 Oct 2014	5	211
	Teluk Intan	TI	Residential houses	18 Oct 2014	5	110
	Hutan Melintang	HM	Workers dormitories	18 Oct 2014	5	41
	Tanjung Malim	TM	Workers dormitories	19 Oct 2014	2	15
Terengganu	Kuala Terengganu	KT	Flats and apartments	20 Aug 2014	4	32
	Dungun	DN	Flats and apartments	20 Aug 2014	1	3
Pahang	Kuantan	KN	Workers dormitories	22 Aug 2014	2	17
	Cameron Highlands	CH	Workers dormitories	23 Aug 2014	1	6
Selangor	Petaling Jaya	PJ	Residential houses	25 Feb 2014	5	43
	KLIA	KLIA	Airports	25 Feb 2014	2	20
	Rawang	RW	Workers dormitories	25 Nov 2014	2	13
	Klang	KG	Residential houses	25 Nov 2014	5	198
Kuala Lumpur	Cheras	CR	Flats and apartment	27 Nov 2014	5	75
Negeri Sembilan	Paroi	PA	Workers dormitories	28 Nov 2014	1	1
	Senawang	SW	Flats and apartment	29 Nov 2014	4	35
	Port Dickson	PD	Workers dormitories	29 Nov 2014	1	6
Melaka	Bandar Hilir	ML	Workers dormitories	26 Dec 2014	4	35
Johor	Kempas	KM 1	Workers dormitories	23 Dec 2014	1	5
	Kempas	KM 2	Workers dormitories	23 Dec 2014	1	3
	Johor Bahru	JB	Workers dormitories	23 Dec 2014	1	4
	Kluang	KU	Workers dormitories	24 Dec 2014	5	56
	Muar	MU	Workers dormitories	25 Dec 2014	5	41

*: Infestation rate based on total collected bed bugs: 1 (1–10 bed bugs); 2 (11–20 bed bugs); 3 (21–30 bed bugs); 4 (31–40 bed bugs); 5 (> 41 bed bugs).

Of all 379 surveyed harborages, *C. hemipterus* has dominantly infested the bedding area (48.4%), especially mattresses and mosquito nets. All stages of bed bugs including eggs, nymphs, and adults were found despite of typical signs of infestations like fecal spots and casts of exoskeletons near the harborage places. About 30.6% would also aggregate in cracks and crevices of the walls and floors aside from the common areas. In addition, 4.8% of bed bugs colony have infested wooden furniture like cupboards and chairs. Heavy infestation could lead these creatures to crawl up to the ceiling of the premises by hiding in the circuit of electrical appliances. In this survey, only 3.2% of them infested appliances. A small population of bed bugs preferred headboards and rattan chairs as their hiding spaces, each with 1.6% respectively (Table 2).

Table 2
Number of surveyed and infested harborage sites with collected bed bugs.

Harborage sites	Surveyed harborage	Infested harborage	No. of bed bugs collected
Bedding	133	30 (48.4%)	789
Headboard	47	1 (1.6%)	12
Walls and floor	67	19 (30.6%)	333
Sofa and cushion	23	6 (9.7%)	108
Rattan chairs	7	1 (1.6%)	12
Wooden furniture	72	3 (4.8%)	36
Appliances	30	2 (3.2%)	15
Total	379	62	1305

Meanwhile, statistical analysis on the association between harborage types of different premises (Figure 3), relatively showed a significant difference [χ^2 (32) = 3966.881, $P < 0.05$]. The results also revealed that 51.6% of the bed bugs were likely to be found in workers' dormitories

compared to other premises including public areas. Bed bugs inhabit abundantly in the surrounding areas like beddings, in crevices of walls and floors, sofas and cushions in the workers' dormitories. Some dormitories had appliances affected with minor population of this pest. We also found nymphs and adults hiding in sleeping mattresses, underneath wooden furniture, in gaps in walls and floors, in screw holes or even curtains of residential premises.

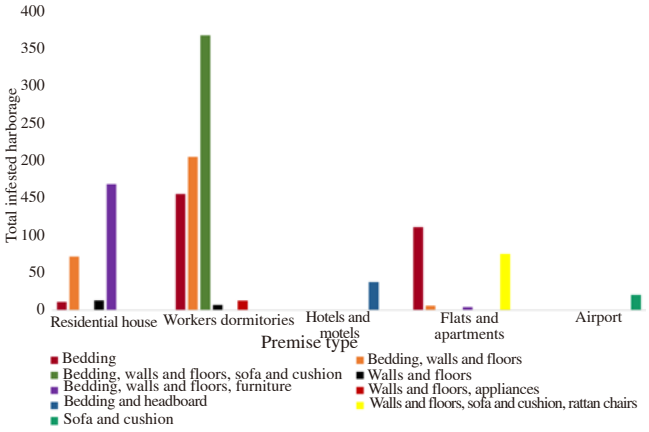

Figure 3. Preferred harborage sites on different types of premises.

4. Discussion

Bed bugs cause nuisance and discomfort to the community although they do not transmit any harmful infections or diseases. Previously, bed bugs have been linked to poverty and bunkers from the wars in past centuries[17]. Migrated workers and second-hand furniture are probable factors for bed bugs resurgence to date[18]. Many surveys on bed bugs infestation have been conducted in other foreign countries to prove the above hypotheses, but rare reports were found in regions of Malaysia. Our survey results showed that low infestation levels of tropical bed bugs were detected in all states of Peninsular Malaysia. Even though only 20.5% of the surveyed sites were infested, the number may increase within short amount of time if preventive measurements are disregarded especially on hygienic practices in the surrounding.

From the survey conducted by How and Lee in 2005 to 2008, 39 sites had already showed active infestation in Pulau Pinang and Kuala Lumpur in Peninsular Malaysia[12]. The sites included residential houses, flats and dominantly hotels. It can be seen that the trend of bed bug infestations in Malaysia to recent date had yet to be resolved. Although the premises had been treated consecutively with chemical insecticides, still high bed bug populations were found in the remaining sites. Most European countries have been battling with bed bugs issues for years, but it is difficult to propose suitable solutions depending on the actual circumstances. The high prevalence of this species found in several sites with heavy infestations indicates that the bed bugs problems are relatively serious. Low awareness and level of concern among the inhabitants let the bugs have access to small disparate areas with ease.

C. hemipterus has abundantly affected the tropic regions, according to previous studies[5,12,19,20]. Although some reports stated that bed bugs tend to invade mainly in low budget hotels and motels[21-23], our survey results discovered that greater numbers of bed bugs were found within the immigrants' residential area. The insect pest cling onto their luggage and belongings since there were traces of bed bug infestations and cast of molting skins. Due to their small and flattened size, they were able to disperse easily via clothing or travel bags[18]. Locals may also infested with these pests via frequent trips to foreign countries by being in public places like airport, bus stations or even underground subways. Reports from the mainland, south of China and Australia also obtained similar results pertaining to bed bugs infestation[18,24]. Their studies indicated that 90% of the bed bugs were found in the workers' sleeping quarters in Dongguan, whereas in Shenzhen 91% of their apartment rooms were heavily infested. The migration of workers in the mainland of China was associated with the bed bugs resurgence, since the infestation signs can be seen especially in their dormitories[25].

The most favorable harborage sites for bed bugs usually was bedding area where people sleep at night. Bed bugs prefer living in an enclosed and dark environment yet near to their food source like bedding area as it provides oviposition site and shelter for them[20]. Previous reports also supported the claim that mattresses were the most common location for the pest to harbor and aggregate[25]. We also found similar situation that the owner placed an infested mattress beneath the curtains that allowed these bugs to spread even more in the room, in the walls' crevices and up to the ceiling of the house. A recent study of Cooper *et al*. also stated that a wider distribution can occur from a small population of bed bugs in common hiding place to a further distance depending on the mobility of the host[26].

Various typical sites, however, were found in hotels and motels such as beddings and headboards as these places were the main points of infestation[13]. These tropical bed bugs may have a direct route to harbor around the bedding spaces and other rooms in the hotels and public accommodations compared to organized residential houses[27,28]. Flats and apartments also had infestation sites including rattan chairs which displayed detectable signs of bed bugs. In contrast, our observation on public places like airport showed that it does not have many harborage sites for this pest except for the cushion seats for their passengers' comfort. Based on the previous studies, bed bugs which initially harbor in the belongings could later infest the waiting area, commonly underneath cushion seats in the airport[13,29,30]. This has indeed supported our study that also found an active bed bugs infestation in the Malaysian airport. Replacing the cushion seats with metal will probably deter the invasion of this pest to other places.

In total, only one species of bed bugs (*C. hemipterus*) was found in this survey across Peninsular Malaysia. International migration and recycle of used items and furniture may have been the possible reasons of bed bugs resurgence. Majority of them have been found to establish their population in the foeign workers' dormitories, predominantly around the bedding areas. Bed bugs issues in Peninsular Malaysia may arise due to the dispersal of bed bugs from public transport to their own territories. As such, a thorough inspection of belongings while travelling and vigilant inspections of infestation signs on second-hand furniture can reduce the probability of having bed bugs cases in

their territories.

Conflict of interest statement

We declare that we have no conflict of interest.

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