Journal of Environmental Health and Sustainable Development

Spatial Distribution of Bedbug Infestation in Infested Houses: Is There an Association between Sanitation of Houses and Bedbug Presence?

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ARTICLE INFO

ORIGINAL ARTICLE

Article History:
Received: 28 January 2020
Accepted: 20 April 2020

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Keywords:
Bedbugs,
Sanitation,
Ahvaz City.

ABSTRACT

***Introduction*:** Nowadays, bedbug infestation is one of the public health problems around the world. The objective of this study was to evaluate the spatial distribution of bedbug in different parts of the infested houses. Moreover, the association between house sanitation and presence of bedbug infestation was determined in infested houses in Ahvaz City, Iran.

***Materials and Methods*:** Totally, 57 bedbug-infested houses were visited door-to-door in Ahvaz City from April 2015 to April 2018. Data were collected by visual inspection. The spatial distribution of bedbug in different parts of the infested houses was assessed visually. Logistic regression was applied to assess the association between bedbug presence and house sanitation level.

***Results*:** In the 57 infested houses, bedroom and living room were the main infested parts in 74% and 26% of the houses, respectively. The highest infestation sources in houses were bedding as well as cracks and crevices with frequency rates of 58% and 18%, respectively. No significant correlation was observed between house sanitation and presence of infestation ($\chi^2 = 3.5$; $df = 4$; $P = 0.522$). In total, 56% of the residents reported high levels of bedbug infestation in their houses. Furthermore, 46% of the participants mentioned that their houses had recently been infested, but many residents did not know the exact time of first infestation in the house.

***Conclusion*:** The present study confirms that bedbugs' infestations cannot be associated with house sanitation. Further research is needed to better understand the association between house situation and bedbug infestations.

Citation: Alizadeh I, Jahanifard E, Sharififard M, et al. ***Spatial Distribution of Bedbug Infestation in Infested Houses: Is there an Association between Sanitation of Houses and Bedbug Presence?***. J Environ Health Sustain Dev. 2020; 5(2): 985-92.

Introduction

The bedbugs *Cimex lectularius* L. and *C. hemipterus* (F.) (Hemiptera: Cimicidae) are nuisance urban pests widely distributed worldwide [1, 2]. These pests are normally adapted to live in close association with human beings in domestic environments. They require blood meal to survive and are attracted by human body heat and carbon dioxide [3]. These urban pests feed exclusively on human blood[2]. Although bedbugs are not vectors for human diseases, their bites can cause allergic reactions [4]. They can cause psychological distress, insomnia, anxiety, social stigma, and avoidance behaviors [5]. Therefore, bedbugs are considered as pests with serious public health importance [3].

Recently bedbug infestation has been increased in urban environments around the world including Asia, America, Europe, Africa, and Australia [2].

Their infestation can occur anywhere including houses, apartments, hotels, motels, hospitals, movie theaters, dormitories, barracks in military industrial complex, nursing homes, official buildings, as well as public transportation systems, such as airplanes, coaches, trains, and subways [6-7].

Bedbugs are nocturnal insects that usually inhabit in protected and inaccessible places within the infested dwellings during the day [8-9]. They can be found in the rest areas such as beds, couches, mattress, desks, walls, curtain, pillow, chairs, sofas, wooden wardrobe, wooden furniture or further away places [10-11]. Bedbugs elimination is very difficult and challenging because they are nocturnal, cryptic, and small insects [3, 9]. Detection of infestation is very difficult visually for the public people and the control program is very high costly for people with average and low-income levels[12-13]. Furthermore, many people believe that bedbugs prefer poor sanitation environments and are attracted to dirty or decayed materials [14-15]. However, our previous field observations showed that even five-star hotels and houses with high sanitary conditions are infested by this insect pest [3, 9].

Unlike other urban pests, such as cockroaches, house flies, and rodents attracted to food, water, and other organic matters inside the houses [16-17], bedbugs are only attracted to human body heat and CO_2. Therefore, we hypothesized that house sanitation was not effective in bedbug infestation and conducted this study to examine out hypothesis scientifically. So, the objective of this study was to evaluate spatial distribution of bedbugs infestation in different parts of houses and find any possible association between house sanitation and presence of bedbug infestation.

Materials and Methods

Study Area

This study was conducted in Ahvaz City (31° 20' N, 48° 40' E), the center of Khuzestan Province, located in southwestern Iran (Figure 1). Ahvaz is located at an altitude of 12 m above the sea level. Karun River passes by the middle of the city. Ahvaz has been well-known for its industries as well as environmental pollution. In the last decade, an anthropogenic source of air pollution (dust storm) has joined to other environmental problems of this city. In Ahvaz, temperature varies within the range of -5 °C to 50 °C in the winter to summer [13].

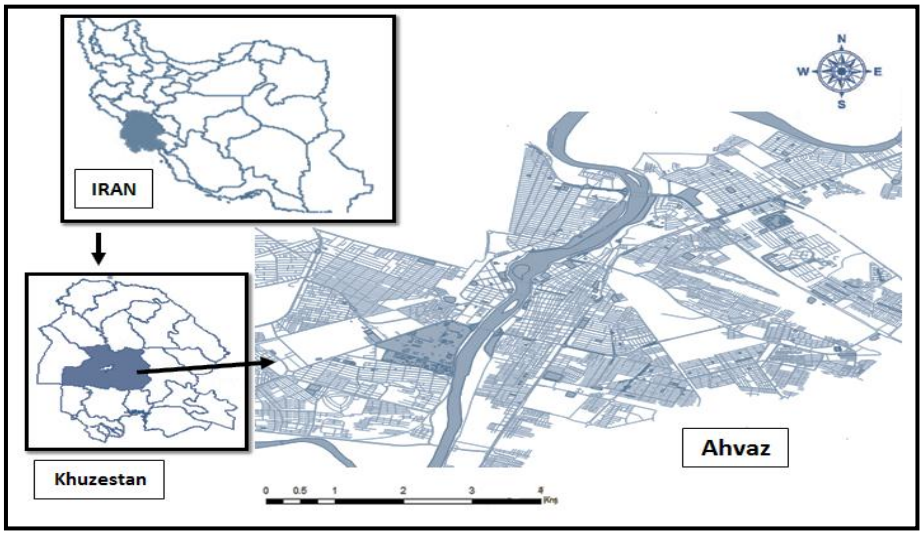

Figure 1: Map of the study area (Ahvaz City, southwest Iran) during 2015 -2018

Study Design and Data Collection

The study sample included houses infested by bedbugs, as reported to health centers or Department of Medical Entomology in Ahvaz City during April 2015 - April 2018. The reported houses were inspected visually by a medical entomology expert to confirm infestation in door-to-door visits (Figure 2). Each house had bedroom, living room, kitchen, and bathroom. In this observation study, a checklist was used to record information of each house such as infested part, source of infestation in each part, infestation level (low, medium, and high), and sanitation level of each house (poor, average, good). Additionally, the residents were interviewed using five questions and their answers were recorded (Tables 1, 2, and 3). Validity of the questionnaire was confirmed by a panel of experts in medical entomology and environmental health engineering. The questionnaire's reliability was also confirmed by Cronbach's alpha coefficient of 0.75.

Table 1: Questionnaire administered by investigator about bedbug infestations

1. Where are bedbugs from? How were they introduced to your house? Second-hand luggage ___, Travelling to infected places ___, Neighbors ___, Others ___
2. How frequently do you see bedbugs in your house? Rarely ___, Too much ___
3. How long have bedbugs been in your house? Recently ___, Long time ___
4. Are you concerned about bedbug infestation in your house? Not concerned __, Moderately concerned __, Highly concerned __
5. Do you have allergic reaction to bedbug bites? Yes ___; No ___

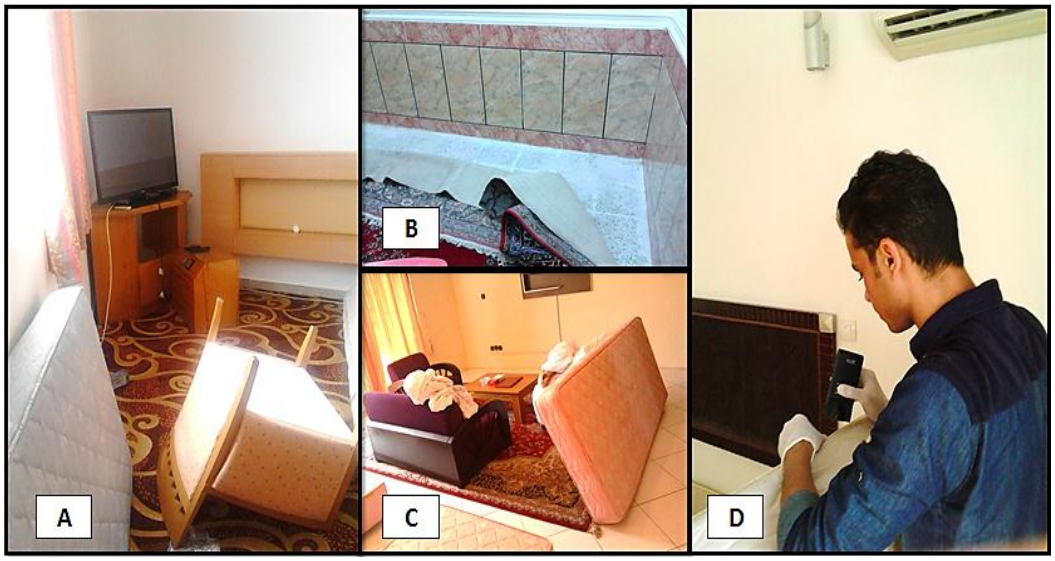

Figure 2: (A) Infested living room, (B) Infested cracks and crevices, (C) Severely infested items including mattress and furniture, (D) Visual observation (Medical entomology expert's inspection)

Table 2: The administered checklist by investigator to evaluate the house- keeping sanitation level

Scale	Description
☐ Good	Living room appeared clean, under furniture, bed, and chairs were clean, no severely infested items including mattress, curtain, and pillow.
☐ Average	Living room, under furniture, bed, chairs, mattress, curtain, and pillow appeared somewhat dirty.
☐ Poor	Living room appeared very dirty; presences of severely infested items including mattress, curtain, and pillow.

Table 3: The administered checklist by investigator to evaluate the bedbug infestation level

Scale	Description
☐ Low	There are 1-10 live or dead bedbugs, few fecal spots, and few cast skins in house.
☐ Medium	There are 11-50 live and dead bedbugs, fecal spots, and cast skins in house.
☐ High	There are > 50 live or dead bedbugs, lots of fecal spots, and cast skins in house.

Data Analysis

Logistic regression was run to analyze the association between bedbug presence and sanitation level of the house. All statistical analyses were conducted using SPSS software (version 16) at significant level of 0.05 ($\alpha = 0.05$).

Ethical issues

This research was approved at the research ethics committee of Ahvaz Jundishapur University of Medical Sciences, Iran with the Ethics Code of IR.AJUMS.REC.1395.443.

Results

Spatial distribution of bedbug in the houses

In this survey, 57 houses were infested by bedbugs. Bedrooms (74%) and living rooms (26%) were the main infestation parts of the inspected houses, respectively (Figure 3). No bedbug infestation was observed in other parts of houses such as kitchen and bathroom. The bed set was the most infested source in 58% of the studied houses, which was significantly higher than other sources. Cracks and crevices were recorded as the second source in 18% of the infested houses. The lowest infestation rate was observed in other sources
such as wooden furniture and under wallpaper (Figure 3).

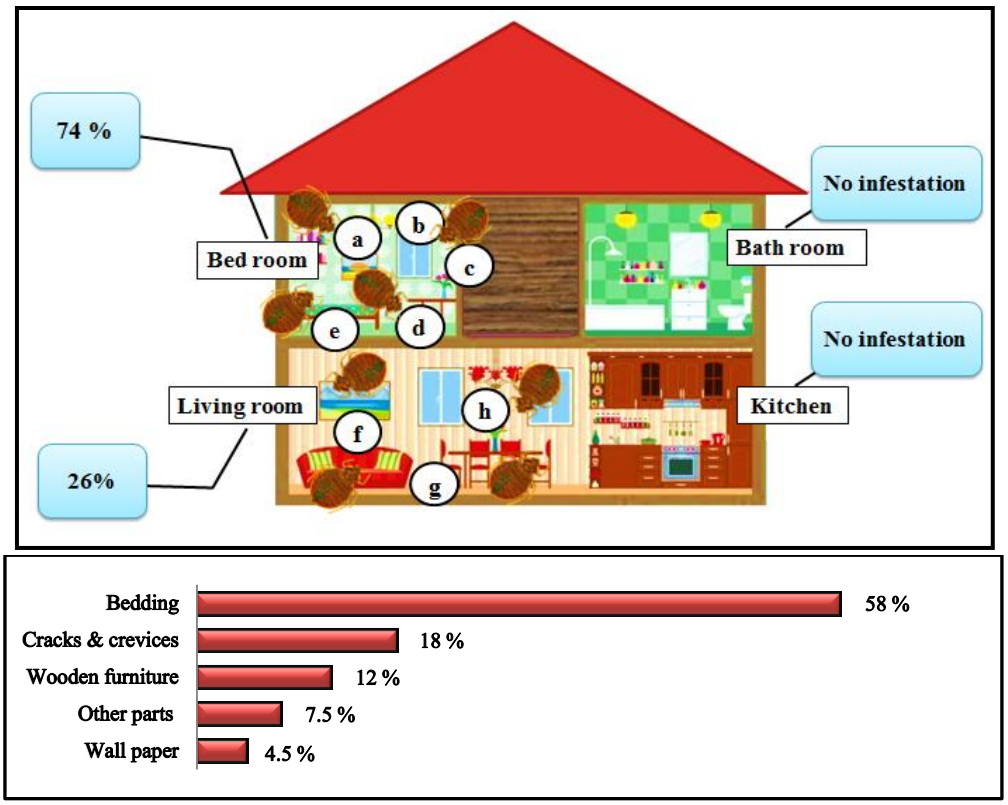

Figure 3: Schematic image of bedbug spatial distribution in infested houses and infestation sources in Ahvaz City, Khuzestan Province, 2015-2018. In the above figure, (a), (b), (c), and (d) represent other parts including under pictures on the wall, curtain, wooden wardrobe, desks, and chairs; (e): bed set; (f): wooden furniture; (g): cracks & crevices; (h): wall paper.

Association between house sanitation and bedbug infestation

Table 4 and figure 4 show the level of house sanitation and bedbug infestation, respectively. No significant correlation was observed between house sanitation and presence of bed bug infestation ($\chi^2 = 3.5$; $df = 4$; $P_{value} = 0.52$).

Table 4: Rate of house sanitation and bedbug infestation in houses

House sanitation	Bedbug infestation (%)		
	Low	Medium	High
Good	38.5	31.9	29.6
Average	40	37.5	22.5
Poor	45.4	28.6	26

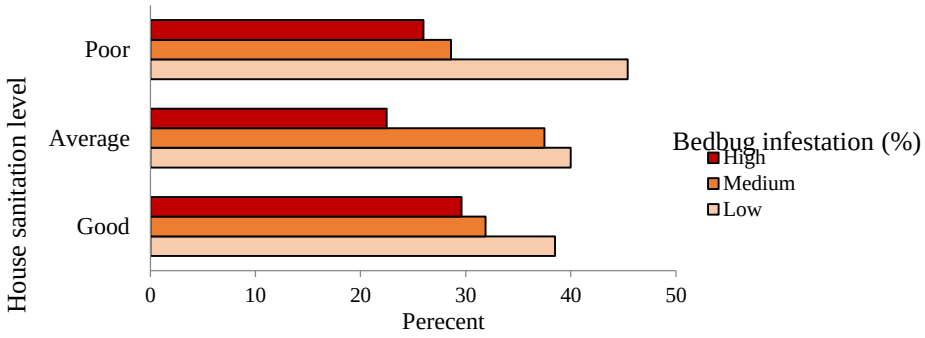

Figure 4: House sanitation level and presence of bedbug infestation

Residents Interview

The results of interviews showed that a total of 123 residents lived in the surveyed houses. Among them, 98 residents answered five questions (Table 5). Base on the residents' answers, travelling to infected places was the major way of bedbugs infestations introduction to the house. In total, 56% of the residents reported that they saw too much bedbug at house. Furthermore, 46% of the participants indicated that bedbugs have recently entered their houses, but most residents were not sure about the accurate time that bedbugs entered their houses. Most residents (87%) declared allergic reaction to bedbug bite. No significant correlation was observed between the allergic reactions to bedbug bite of residents and their gender ($\chi^2 = 2.8$; $df = 1$; $P_{value} = 0.91$). Residents' state of concern about bedbugs was significantly associated with presence of bedbugs at houses based on the findings. In other words, most residents (78.9%) were highly concerned about bedbug infestations at house (Figure 5).

Table 5: Percentage of the answered questions in this survey

Variable	Percentage (%)
How did the bed bug get into your house?	
Second-hand luggage	12
Travelling to infected places	73
Neighbors	7
Other	8
How frequently do you see bedbugs in your house?	
Rarely	44
Too much	56
How long have bedbugs been in your house?	
Recently	46
Long time	54
Do you have allergic reaction to bedbug bites?	
Yes	87
No	13

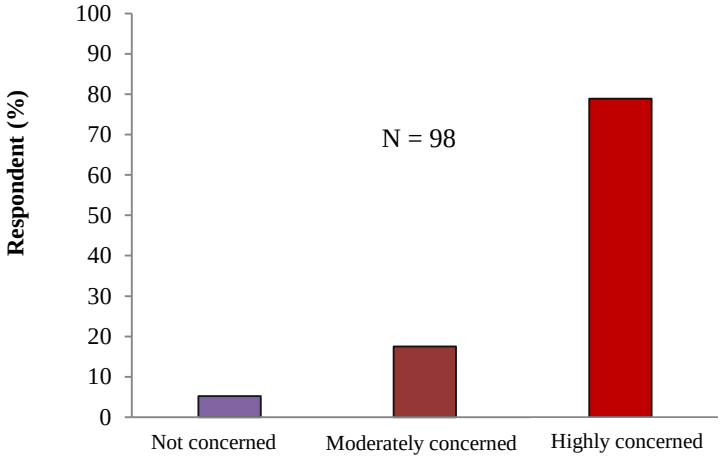

Figure 5: The concern state of residents about bedbug infestation

Discussion

Bedbugs have recently re-emerged with increasing trend in numbers, distribution, and intensity of infestation around the world. Their infestations can result in adverse effects on human health and quality of life. Bedbug infestations in a house can lead to social isolation as well as economic problems since a lot of money should be spent to eliminate infestation and replace the infested furniture [1]. Bedbug control program typically involves chemical and non-chemical techniques/tools [9, 13]. Generally, application of chemical pesticides to control urban pests is one of the most common, simple, and accessible methods preferred over other non-chemical techniques/tools. However, due to the harmful side effects of chemical compounds, especially as indoor residual spraying on human and the environment health, these compounds are recommended to be used in low volumes and in the form of stain treatments [8, 9, 12]. So, identification of the bedbugs' infestation sources in human dwellings can decrease the consumed volume of chemical insecticides, decrease human exposure to insecticides, and increase the effectiveness of control programs.

Bedrooms and living rooms were the most frequent parts infested by bedbug in the studied houses. Bed sets followed by cracks and cervices were the most common harborages in these two parts. Overall, the bed sets such as bed frame, mattress, and sheets were the most frequently infested sources of bedbug in infested houses [14, 15].The results of a study by How & Lee showed that the bed set, headboard, as well as cracks and crevices were the three most common tropical bedbug harborages [15], which is confirmed by our study.

In the literature, bedbug infestations was found among the residents living at the lowest economical level. Therefore, it was associated with poor conditions of households, poor hygiene, and high human population density [2]. Acceding to Cooper et al., 56% of the residents believed that bedbug infestations were caused by lack of cleanliness [14]. However, we found that high infestation rate of bedbug was not associated with house sanitation because we observed bedbug infestations in houses with favorable sanitation level in high- income communities.

Presence of some urban pest infestations including cockroaches, houseflies, and rodents can be associated with poor health situation of human environments[16], so that Wang et al. demonstrated that presence of cockroaches was associated with poor sanitary conditions [17]. However, bedbug infestation is not related significantly with house sanitation. Some factors such as bedbug entrances, bedbug habits, low awareness of residents about identifying infestation, residents' travelling to

infested places, and resistance to insecticides are effective in bedbug introduction and infestation rate [12, 14, 17-18].

Second-hand luggage and travelling to infested places were among the main ways to introduce bedbug infestation in houses according to the residents. Cooper et al. declared that residents were familiar with the ways that bedbugs were introduced by second-hand items (97%), visitors to the apartments (91%), neighboring apartments (80%), and public places (79%) [14]. These findings are in consistence with our results.

The residents' unawareness or lack of knowledge about transfer ways of bedbugs was associated with introduction of bedbug infestation at houses in this study. Long-term presence of bedbug infestation in the homes can be due to inappropriate or incomplete use of control methods [2].

Several studies reported the residents' hypersensitivity, cutaneous allergic, and bullous reactions to bedbug bites [4, 5, 19-22]. The current study showed cutaneous allergic reactions and high concern about bedbug bites among residents of houses exposed to bedbug infestation.

Conclusions

Our study confirmed that bedbug infestation at house was not associated with house sanitation. However, house sanitation after infestation improved the bedbug infestation. To reduce the prevalence of bedbug infestation, it is necessary to increase the residents' knowledge about bedbug identification, medical importance, biology, prevention, and control strategies by holding workshops and seminars or via mass media. Additionally, public health policies should be developed to record bedbug infestation reports in a national system. Further research is needed to better understand the association of house situation and presence of bedbug infestation.

Acknowledgement

We would like to thank all the residents who participated in our study and helped us to complete the research. Furthermore, the authors are grateful to Dr. Maryam Faraji from Kerman University of Medical Sciences and Iman Mirr from Lorestan University of Medical Sciences for providing helpful comments on the earlier draft and reviewing the manuscript.

Funding

This study was financially supported by Social Determinants of Health Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran with Project No. SDH-9510.

Conflict of interests

The researchers declare no conflict of interest.

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