

Infestation of cockroaches (Insecta: Blattaria) in the human dwelling environments: A systematic review and meta-analysis



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ABSTRACT

Periplaneta americana, *Blatta orientalis*, *Blattella germanica* and *Supella longipalpa* are the most common worldwide cockroaches that mentioned in the “22 common pest” or “22 dirty” species named as “group I”. They are able to infest any type of buildings. A meta-analysis review was conducted between January 2015 and July 2016 on any literature published about infestation of cockroaches. Scientific reports and papers about infestation of cockroaches and relevant topics were collected from various specific scientific websites such as PubMed, Web of Science, ScienceDirect, Springer, Elsevier, Scopus, and Google Scholar. About 271 scientific reports and papers were collected and after a preliminary review, 63 were selected to become part of the detailed synthesis review and meta-analysis. Results showed that the global world mean infestation trend of cockroaches, and *B. germanica* and *P. americana* cockroach species ranged 49.0–55.0, 40.0–70.0 and 60.0–70.0%, respectively suggests that their infestation trend are increasing. The global world mean infestation of cockroaches, and *B. germanica* and *P. americana* cockroach species were 52.3, 55.2 and 65.4, respectively. There was a significant difference between the global world mean infestation of cockroaches and *P. americana* cockroach species ($P=0.019$). The global mean infestation trend of cockroaches in the human dwelling environments and world ranged 55.0–65.0 and 50.0–70.0%, respectively suggests that their infestation trend are increasing. The global world mean infestation of cockroaches in the human dwelling environments and world were 60.4 and 57.7%, respectively. Although some factors affect the infestation of cockroaches and the sanitation and quality structure of the buildings are also being improved. While as present study reveal that the globally the world infestation trend of cockroaches are being increased and recent studies also indicate that the prevalence of asthma has increased dramatically over the decades suggest that infestation of cockroaches can directly affect the development of asthma.

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1. Introduction

Periplaneta americana (American cockroach), *Blatta orientalis* (Oriental cockroach), *Blattella germanica* (German cockroach) and (*Supella longipalpa*) (Brown-banded cockroach) are the most common worldwide cockroaches (Lihoreau et al., 2012; Nazari et al., 2016) that are mentioned in the “22 common pest” or “22 dirty” species categorized into four groups named as “four cockroach species (group I)” (Sulaiman et al., 2011; Nasirian, 2016). They are able to infest any type of buildings (Paksa et al., 2011, 2012; Nasirian et al., 2006a,b,c,d,e, 2009, 2011; Nasirian, 2010, 2008, 2007; Limoe et al., 2010; Ladonni et al., 2013; Dehghani et al., 2014) and distribute some disease agents (Menasria et al., 2015; Go Pets America, 2015; Brown and Alhassan, 2015; Zahradnik and Raulf, 2014; Wannigama et al., 2014; Vazirianzadeh et al., 2014; Hamu et al., 2014; Kassiri and Quaderi, 2014; Motevali Haghi et al., 2014). There are more asthmatics in homes with high cockroach infestation (Sarinho et al., 2004). Animate foreign bodies constitute up to 14% of cases, majority being the cockroaches (Somayaji and Rajeshwari, 2007).

Although many researchers have been reported the infestation of cockroaches, so far a full review meta-analysis has not been conducted to synthesize the state of our understanding and knowledge gaps about these pests. In order to identify possible appropriate management approaches and research needs for researchers, this meta-analysis review was conducted between January 2015 and July 2016 on any literature published about infestation of cockroaches.

2. Materials and methods

2.1. Data collection and selection

Scientific reports and papers about infestation of cockroaches and relevant topics were collected from various websites such as PubMed, Web of Science, ScienceDirect, Elsevier, Springer, Scopus, and Google Scholar, as well as specific scientific sites, between January 2015 and July 2016. About 271 scientific reports and papers were collected from the above mentioned scientific sources and after a preliminary review, 63 were selected to become part of the detailed synthesis review and meta-analysis.

2.2. Meta-analysis of scientific information

The scientific reports and papers about infestation of cockroaches were read carefully and the useful subjects were extracted and sorted. Infestation of cockroaches mainly categorized in the three parts including hospitals, households and miscellaneous environments. As the hospitals and households are the important human dwelling environments, the infestation of cockroaches categorized in the two these distinct parts, while the

other type infestation of cockroaches was arranged in the miscellaneous part. The results summarized in the Tables 1–3. Tables 4 and 5 summarize the global infestation of cockroaches in the different types of environments and world. Figs. 1–5 also show the infestation, infestation trend and global infestation trend of cockroaches. Figs. 4 and 6 show the global infestation trend of cockroaches in the human dwelling environments and world.

2.3. Statistical analysis

The global trend and global mean infestation of cockroaches were calculated and estimated by Microsoft Excel 2010. The global trend cockroach infestation was drawn by clicking on graph line distribution and selecting ‘add trendline’ option. The global cockroach infestation was calculated by insertion function and selecting “average” option. IBM SPSS Statistics Data Editor Version 23 was used to analyze any statistical analysis of the data. One-sample Kolmogorov-Smirnov test was used to check the normality of the data distribution. After checking to make sure that the distribution of data was normal, paired-samples *t*-test was used to compare infestation of cockroaches between two groups, while ANOVA was used to compare infestation of cockroaches among more than two groups including the hospital, household and miscellaneous environments for any significant difference.

3. Results

3.1. Infestation of cockroaches

3.1.1. Infestation trend of cockroaches

As observed in Fig. 1 the mean infestation trend of cockroaches in the hospital and household environments during the years that studies were conducted have been generally increased, while in the miscellaneous environments has not been nearly increased. The infestation of cockroaches in the hospital environments ranged from 50.0 to 80.0% while in the household and miscellaneous environments ranged from 30.0 to 70.0 and 47.5–52.5%, respectively (Fig. 1). The mean infestation of cockroaches in the hospital environments (68.6%) were more than the household (52.0%) and miscellaneous (50.3%) environments. There was not a significant difference among the mean infestation of cockroaches in the hospital, household and miscellaneous environments ($P > 0.05$) (Data not shown).

3.1.2. Infestation of cockroaches in the any environment parts

Locker rooms were the most parts in the hospital environments that had the highest cockroach infestation. Kitchens had a second rank and the other parts were in the next ranks. Bathrooms, toilets and kitchens had the highest cockroach infestation in the household environments while the other parts were in

Table 1
Infestation of cockroaches and cockroach species in the hospital and household environments.

Place	%	Reference
Cockroaches		
Hospitals		
Iran (Isfahan)	Mild	(Fathpour et al., 2003)
Iran (Isfahan)	Sever	(Fathpour et al., 2003)
Taiwan	46.7	(Pai et al., 2004)
Iran (Yasuj)	59.0	(Mouchtouri et al., 2008)
Japan	100	(Saitou et al., 2009)
Households		
Thailand (Bangkok)	15.1	(Sriwichai et al., 2002)
Iran (Isfahan)	Mild	(Fathpour et al., 2003)
Iran (Isfahan)	Sever	(Fathpour et al., 2003)
Taiwan	50.0	(Pai et al., 2004)
USA (California)	60.0	(Bradman et al., 2005)
Korea (Seoul)	9.0	(Jeong et al., 2006)
Korea (Seoul)	62.0	(Jeong et al., 2006)
USA (New York)	77.0	(Chew et al., 2006)
India (Varanasi)	54.0	(Wannigama et al., 2014)
India (Varanasi)	25.0	(Wannigama et al., 2014)
Iran (Shahin Shahr)	67.5	(Wannigama et al., 2014)
<i>Blattella germanica</i>		
Hospitals		
Turkey (Trabzon)	98.25	(Kutrup, 2002)
Poland	70.0	(Gliniewicz et al., 2003)
Taiwan	31.5	(Pai et al., 2004)
Iran (Sanandaj)	55.6	(Vahabi et al., 2007)
Iran (Yasuj)	93.3	(Mouchtouri et al., 2008)
Iran (Tehran)	12.1	(Zarchi and Vatani, 2009)
Iran (Hamedan)	88.8	(Nejati et al., 2012)
Iran (Shiraz)	89.7	(Fakoorziba et al., 2014)
Households		
Thailand (Bangkok)	26.7	(Sriwichai et al., 2002)
Taiwan	45.6	(Pai et al., 2003)
Republic of Korea (Busan)	56.9	(Lee et al., 2003)
Republic of Korea (Seoul)	76.2	(Lee et al., 2003)
Taiwan (Kaohsiung: storage rooms)	51.5	(Pai et al., 2004)
Taiwan (Kaohsiung: kitchens)	36.9	(Pai et al., 2004)
Korea (Seoul)	36.0	(Jeong et al., 2006)
Iran (Yasuj)	94.9	(Mouchtouri et al., 2008)
Iran (Sanandaj)	54.0	(Vahabi et al., 2011)
Iran (Shahin Shahr)	32.0	(Wannigama et al., 2014)
India (Varanasi)	18.0	(Wannigama et al., 2014)
<i>Periplaneta americana</i>		
Hospitals		
Turkey (Trabzon)	0.63	(Kutrup, 2002)
Taiwan	68.5	(Pai et al., 2004)
Iran (Sanandaj)	44.4	(Vahabi et al., 2007)
Iran (Yasuj)	1.6	(Mouchtouri et al., 2008)
Iran (Tehran)	65.6	(Zarchi and Vatani, 2009)
Iraq (Diyala)	52.6	(Al-bayati et al., 2011)
Iran (Hamedan)	8.0	(Nejati et al., 2012)
Egypt (Ismailia: Urban)	92.5	(Mahmoud, 2013)
Egypt (Ismailia: Rural)	63.1	(Mahmoud, 2013)
Iran (Shiraz)	10.3	(Fakoorziba et al., 2014)
Households		
Thailand (Bangkok)	50.0	(Sriwichai et al., 2002)
Republic of Korea (Busan)	8.2	(Lee et al., 2003)
Republic of Korea (Seoul)	0.6	(Lee et al., 2003)
Taiwan	54.4	(Pai et al., 2003)
Taiwan (Kaohsiung)	70.7	(Pai et al., 2004)
Iraq (Diyala)	47.4	(Al-bayati et al., 2011)
Iran (Sanandaj)	46.0	(Vahabi et al., 2011)
Nigeria (Arkilla Federal Low Cost)	77.2	(Bala and Sule, 2012)
Nigeria (Calabar)	100	(Etim et al., 2013)
Nigeria (Owerri)	58.8	(Ajero et al., 2014)
Iran (Shahin Shahr)	45.0	(Wannigama et al., 2014)
India (Varanasi)	57.0	(Wannigama et al., 2014)

the next ranks. The infestation of cockroaches in the miscellaneous environments ranged from 12.0 to 70.0%. Food-handling establishments and hotels had the highest and lowest cockroach infestation among miscellaneous environments, respectively (Fig. 2).

3.2. Infestation trend of cockroach species

3.2.1. Infestation trend of *Blattella germanica*

As observed in Fig. 1 the mean infestation trend of *Blattella germanica* cockroaches in the hospital, household and miscellaneous

Table 2
Infestation of cockroaches and cockroach species in the different types of environments.

Environment type	%	Place	Reference
Cockroaches			
Miscellaneous			
Poultry sheds	Mild	Iran (Isfahan)	(Fathpour et al., 2003)
Poultry sheds	Sever	Iran (Isfahan)	(Fathpour et al., 2003)
Ferries	52.3	Greece	(Mouchtouri et al., 2008)
Urban communities	39.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Dormitories	37.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Housing complex buildings	26.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Official place buildings	18.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Hotels	12.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Care facilities and nursing homes	65.2	Taiwan (Kaohsiung)	(Pai, 2013)
Migrant farmworker camps	45.9	USA (Carolina)	(Quandt et al., 2013)
Food- handling establishments	77.0	India (Varanasi)	(Wannigama et al., 2014)
Food- handling establishments	28.0	India (Varanasi)	(Wannigama et al., 2014)
Hospitals			
Locker rooms	66.7	Japan	(Saitou et al., 2009)
Kitchens	17.8	Japan	(Saitou et al., 2009)
Dining room	8.9	Japan	(Saitou et al., 2009)
Washing room	2.2	Japan	(Saitou et al., 2009)
Electricity distribution board	2.2	Japan	(Saitou et al., 2009)
Pipe space	2.2	Japan	(Saitou et al., 2009)
Households			
Bathrooms	35.0	USA (New York)	(Chew et al., 2006)
Bathrooms and toilets	41.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
Kitchens	74.0	USA (New York)	(Chew et al., 2006)
Kitchens	39.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
Yards and parkings	14.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
Bedrooms	35.0	USA (New York)	(Chew et al., 2006)
Bedrooms	4.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
Guest rooms	2.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
<i>Blattella germanica</i>			
Households			
Households: Busan	56.9	Republic of Korea (Busan)	(Lee et al., 2003)
Households: Seoul	76.2	Republic of Korea (Seoul)	(Lee et al., 2003)
Houses: Busan	72.9	Republic of Korea (Busan)	(Lee et al., 2003)
Houses: Seoul	93.8	Republic of Korea (Seoul)	(Lee et al., 2003)
Apartments: Busan	54.2	Republic of Korea (Busan)	(Lee et al., 2003)
Apartments: Seoul	68.3	Republic of Korea (Seoul)	(Lee et al., 2003)
Villas: Busan	43.6	Republic of Korea (Busan)	(Lee et al., 2003)
Villas: Seoul	66.4	Republic of Korea (Seoul)	(Lee et al., 2003)
Storage rooms	51.5	Taiwan (Kaohsiung)	(Pai et al., 2004)
Kitchens	36.9	Taiwan (Kaohsiung)	(Pai et al., 2004)
Miscellaneous			
Clinical areas	78.1	Taiwan	(Pai et al., 2004)
Urban communities	80.0	Iran (Yasuj)	(Mouchtouri et al., 2008)
Ferries	9.96	Greece	(Mouchtouri et al., 2008)
Addis Ababa localities	100	Ethiopia (Addis Ababa)	(Kinfu and Erko, 2008)
Ziway localities	50.0	Ethiopia (Ziway)	(Kinfu and Erko, 2008)
Dormitories	97.6	Iran (Yasuj)	(Mouchtouri et al., 2008)
Housing complex buildings	94.9	Iran (Yasuj)	(Mouchtouri et al., 2008)
Residential dwellings	54.0	Iran (Sanandaj)	(Vahabi et al., 2011)
Care facilities and nursing homes	78.7	Taiwan (Kaohsiung)	(Pai, 2013)
Washrooms, kitchens and gardens	48.0	Pakistan (Quetta)	(Masood et al., 2014)
Food- handling establishments	20.0	India (Varanasi)	(Wannigama et al., 2014)

Table 3
Infestation of cockroach species in the different types of environments.

Environment type	%	Place	Reference
<i>Periplaneta americana</i>			
Hospitals			
Urban	92.5	Egypt (Ismailia)	(Mahmoud, 2013)
Rural	63.1	Egypt (Ismailia)	(Mahmoud, 2013)
Urban: kitchens	98.4	Egypt (Ismailia)	(Mahmoud, 2013)
Urban: dry food stores	70.0	Egypt (Ismailia)	(Mahmoud, 2013)
Urban: furniture rooms	25.9	Egypt (Ismailia)	(Mahmoud, 2013)
Urban: patient rooms	8.9	Egypt (Ismailia)	(Mahmoud, 2013)
Households			
Kitchens	70.7	Taiwan (Kaohsiung)	(Pai et al., 2004)
Kitchens, parlours, bedrooms, refuse dumps and toilets	77.2	Nigeria (Arkilla Federal Low Cost)	(Bala and Sule, 2012)
Kitchens, living rooms, bedrooms and toilets	100	Nigeria (Calabar)	(Etim et al., 2013)
Kitchens, store rooms, living room and toilets	58.8	Nigeria (Owerri)	(Ajero et al., 2014)
Miscellaneous			
Offices	61.8	Thailand (Bangkok)	(Sriwichai et al., 2002)
Nonclinical areas	64.5	Taiwan	(Pai et al., 2004)
Housing complex buildings	4.4	Iran (Yasuj)	(Mouchtouri et al., 2008)
Cities	75.3	China (Hainan)	(Lin et al., 2008)
Dormitories	0.78	Iran (Yasuj)	(Mouchtouri et al., 2008)
Open-air shopping markets	97.5	Thailand (Samutprakarn)	(Chamavit et al., 2011)
Care facilities and nursing homes	21.3	Taiwan (Kaohsiung)	(Pai, 2013)
Washrooms, kitchens and gardens	52.0	Pakistan (Quetta)	(Masood et al., 2014)
Food- handling establishments	53.0	India (Varanasi)	(Wannigama et al., 2014)
<i>Supella longipalpa</i>			
Offices	58.8	Thailand (Bangkok)	(Sriwichai et al., 2002)
Households	17.2	Thailand (Bangkok)	(Sriwichai et al., 2002)
Localities of city	9.9	Ethiopia (Ziway)	(Kinfu and Erko, 2008)
Housing complex buildings	0.7	Iran (Yasuj)	(Mouchtouri et al., 2008)
Dormitories	0.07	Iran (Yasuj)	(Mouchtouri et al., 2008)
<i>Blatta orientalis</i>			
Hospitals	1.12	Turkey (Trabzon)	(Kutrup, 2002)
Hospitals	40.0	Poland	(Gliniewicz et al., 2003)
Hospitals	22.3	Iran (Tehran)	(Zarchi and Vatani, 2009)
Households: kitchens, parlours, bedrooms, refuse dumps and toilets	78.1	Nigeria (Arkilla Federal Low Cost)	(Bala and Sule, 2012)
Households: kitchens, store rooms, living rooms and toilets	41.2	Nigeria (Owerri)	(Ajero et al., 2014)
Households	23.0	Iran (Shahin Shahr)	(Wannigama et al., 2014)
Dormitories	0.02	Iran (Yasuj)	(Mouchtouri et al., 2008)
<i>Blatta lateralis</i>			
Dormitories	1.5	Iran (Yasuj)	(Mouchtouri et al., 2008)
Hospital	5.1	Iran (Yasuj)	(Mouchtouri et al., 2008)
Official place buildings	100	Iran (Yasuj)	(Mouchtouri et al., 2008)
Hotels	100	Iran (Yasuj)	(Mouchtouri et al., 2008)
<i>Periplaneta brunnea</i>			
Localities of city	24.5	Ethiopia (Ziway)	(Kinfu and Erko, 2008)
Open-air shopping markets	2.5	Thailand (Samutprakarn)	(Chamavit et al., 2011)
<i>Pycnoscelus surinamensis</i>			
Localities	16.03	Ethiopia (Ziway)	(Kinfu and Erko, 2008)

Table 4

Global infestation of cockroaches in the different types of environments.

Year	Hos	Hous	Mis	Global (Mean)
2002	98.25	30.6	60.3	63.05
2003	55.0	63.8	–	59.4
2004	48.9	50.5	71.3	56.9
2005	–	60.0	–	60.0
2006	–	46.0	–	46.0
2007	50.0	–	–	50.0
2008	76.15	94.9	53.2	74.8
2009	50.0	–	–	50.0
2011	52.6	49.1	75.8	59.2
2012	88.8	77.5	–	83.2
2013	72.2	100	52.8	75.0
2014	50.0	43.7	46.3	46.7
Global (Mean)	64.2	61.6	59.9	61.9

Hos = Hospitals (Mean), Hous = Households (Mean) and Mis = Miscellaneous (Mean).

Table 5

Global infestation of cockroaches in the world.

Year	Cockroaches				<i>B. germanica</i>				<i>P. americana</i>				Global (Mean)
	Hos	Hous	Mis	Total	Hos	Hous	Mis	Total	Hos	Hous	Mis	Total	
2002	–	16.2	58.8	37.5	–	26.7	–	26.7	–	50.0	61.8	55.9	40.0
2003	60.0	60.0	60.0	60.0	–	64.6	–	64.6	–	62.6	–	62.6	62.4
2004	46.7	50.0	–	48.4	31.5	44.2	78.1	51.3	68.5	70.7	64.5	67.9	55.9
2005	–	60.0	–	60.0	–	–	–	–	–	–	–	–	60.0
2006	–	45.4	–	45.4	–	36.0	–	36.0	–	–	–	–	40.7
2007	–	–	–	–	55.6	–	–	55.6	44.4	–	–	44.4	50.0
2008	59.0	–	39.4	49.2	93.3	94.9	82.9	90.4	–	–	75.3	75.3	71.6
2009	43.14	–	–	43.14	12.1	–	–	12.1	65.6	–	–	65.6	40.3
2011	–	–	–	–	–	54.0	54.0	54.0	52.6	46.7	97.5	65.6	59.8
2012	–	78.1	–	78.1	88.8	–	–	88.8	–	77.2	–	77.2	88.8
2013	–	–	55.6	55.6	–	–	78.7	78.7	72.21	100	21.3	86.1	73.5
2014	–	39.4	52.5	46.0	89.7	25.0	34.0	49.6	10.3	54.9	52.5	53.7	49.8
Global (Mean)	52.2	42.2	53.3	48.2	61.8	49.3	65.5	55.3	48.3	57.0	62.2	64.1	57.7

Hos = Hospitals (Mean), Hous = Households (Mean) and Mis = Miscellaneous (Mean).

environments during the years that studies were conducted had different pattern. It had a mean constant trend ranged from 65.0 to 70.0% in the hospital environments than the household environments which were fluctuated around 50.0% while were generally decreased in the miscellaneous environments ranged from 90.0 to 45.0% (Fig. 1). The mean infestation of *B. germanica* cockroaches in the hospital (67.4%) and miscellaneous (68.2%) environments were more than the household (49.3%) environments. There was not a significant difference among the mean infestation of *B. germanica* cockroaches in the hospital, household and miscellaneous environments ($P > 0.05$) (Data not shown).

3.2.2. Infestation trend of *Periplaneta americana*

As observed in Fig. 1 the mean infestation trend of *Periplaneta americana* cockroaches in the hospital and household environments during the years that studies were conducted were generally increased while decreased in the miscellaneous environments. It had a mean increasing trend ranged from 30.0 to 45.0 and 50.0–75.0% in the hospital and household environments, respectively than the miscellaneous environments which had a mean decreasing trend ranged from 75.0 to 50.0% (Fig. 1). The mean infestation of *P. americana* cockroaches in the household (64.7%) and miscellaneous (62.2%) environments were more than the hospital (38.2%) environments. There was a significant difference between the mean infestation of *P. americana* cockroaches in the hospital and household environments ($P = 0.016$) while there was not a significant difference between the mean infestation of *P. americana* cockroaches in the hospital and miscellaneous, and household and miscellaneous environments ($P > 0.05$) (Data not shown).

The mean infestation of *P. americana* cockroaches were observed higher in the urban hospitals (92.3%) than the rural hospitals (63.1%). Kitchens were the most parts in the urban hospital environments that had the highest *P. americana* cockroach infestation (98.4%). Dry food stores had a second rank (70.0%) and the other parts were in the next ranks. The mean infestation of *P. americana* cockroaches ranged from 98.4 to 8.9% in the different parts of the urban hospital environments. There was not a significant difference between the mean infestation of *P. americana* cockroaches in the kitchens of urban hospital environments than the other parts of the urban hospital environments ($P = 0.073$) (Fig. 3).

3.2.3. Infestation trend of other cockroach species

As observed in Fig. 3 the mean infestation trend of *Blatta orientalis* cockroaches were generally increased and had a mean increasing trend ranged from 10.0 to 50.0 in the miscellaneous environments during the years that studies were conducted. The mean infestation of *B. orientalis* cockroaches in the miscellaneous environments were 30.0% (Fig. 3). The mean infestation of *B. orientalis* cockroaches were observed 59.6, 31.2 and 23.0 in the household parts such as kitchens, store rooms, etc.; hospitals and households. Household parts were the most environments that had the highest *B. orientalis* cockroach infestation (59.6%). Hospitals had a second rank (31.2%) and the others were in the next ranks. The mean infestation of *B. orientalis* cockroaches ranged from 59.6 to 0.02% in the different miscellaneous environments (Fig. 3).

There was not sufficient information to draw the mean infestation trend of other cockroach species. While the mean infestation of *Supella longipalpa* cockroaches were observed different in the

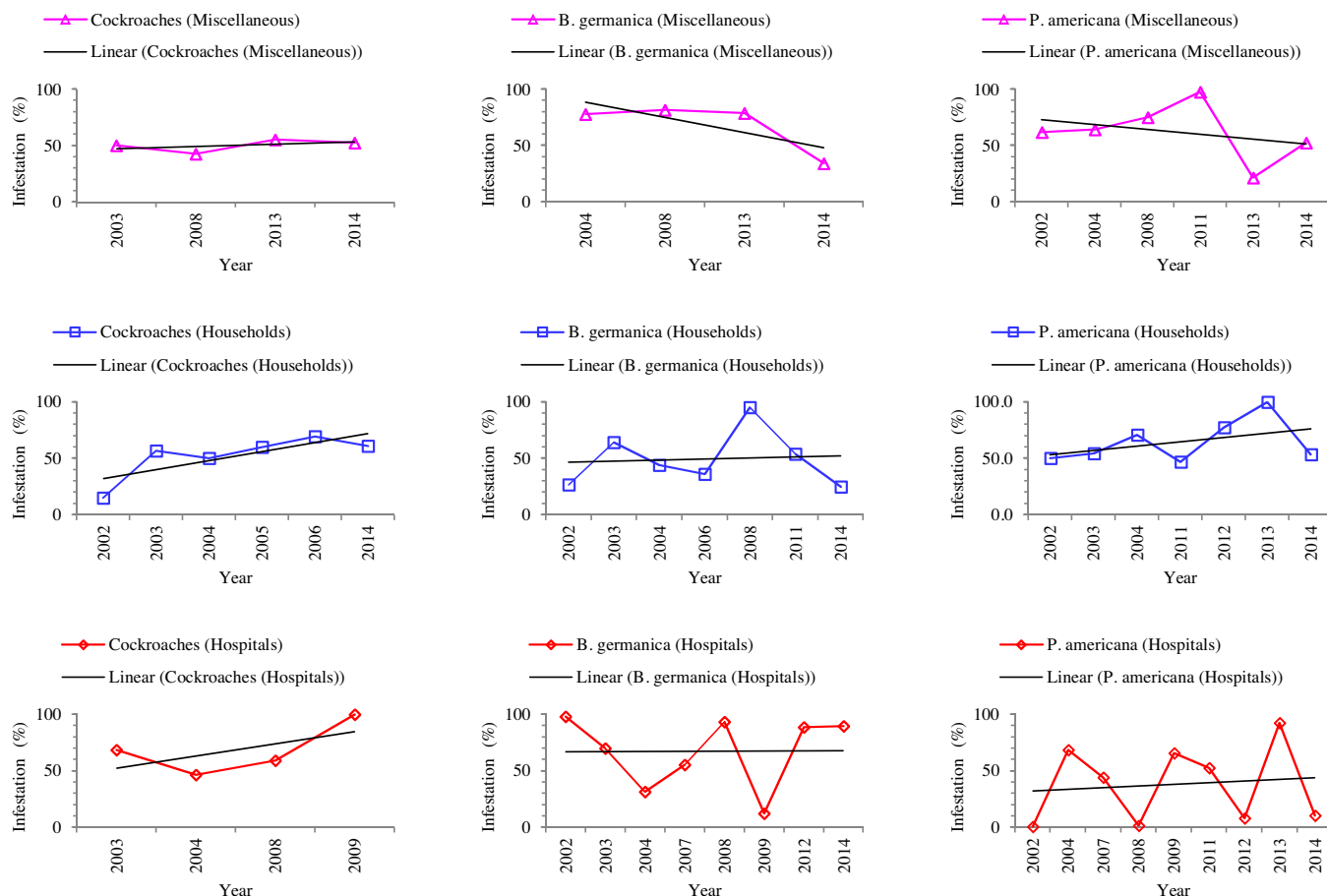


Fig. 1. Infestation trend of cockroaches and cockroach species in the different types of environments.

various miscellaneous environments ranged from 58.8 to 0.07. Offices were the most environments that had the highest *S. longipalpa* cockroach infestation (58.8%). Households had a second rank (17.2%) and the others were in the next ranks (Fig. 3).

3.3. Global infestation of cockroaches

3.3.1. Global infestation of cockroaches in any type environment

As observed in Fig. 4 the mean global infestation trend of cockroaches in the hospital, household and miscellaneous environments were different during the years that studies were conducted. The mean global infestation trend of cockroaches in the hospital environments has been very slightly decreased ranged from 70.0 to 60.0%, while in the household environments has been generally increased ranged from 45.0 to 75.0%. It has been nearly decreased in the miscellaneous environments ranged from 70.0 to 55.0% (Fig. 4).

The global mean infestation of cockroaches was 64.2, 61.6 and 60.0 in the hospital, household and miscellaneous environments, respectively. Compared to the mean infestation of cockroaches, the global mean infestation of cockroaches were closed to each other in the hospital, household and miscellaneous environments. There was not a significant difference between the global mean infestation of cockroaches among the hospital, household and miscellaneous environments ($P > 0.05$) (Data not shown).

3.3.2. Infestation trend of cockroaches in the world

As observed in Fig. 5 the mean infestation trend of cockroaches in the hospital, household and miscellaneous environments of the

world were different during the years that studies were conducted. The mean infestation trend of cockroaches in the hospital environments of the world has been very slightly decreased ranged from 60.0 to 45.0%, while in the household environments has been generally increased ranged from 40.0 to 60.0%. It has been nearly decreased in the miscellaneous environments of the world ranged from 60.0 to 50.0% (Fig. 5). The mean infestation of cockroaches in the hospital, household and miscellaneous environments of the world were 52.2, 49.9 and 53.3, respectively. There was not a significant difference between the mean infestation of cockroaches among the hospital, household and miscellaneous environments of the world ($P > 0.05$) (Data not shown).

3.3.3. Infestation trend of *Blattella germanica* cockroaches in the world

As observed in Fig. 5 the mean infestation trend of *Blattella germanica* cockroaches in the hospital, household and miscellaneous environments of the world during the years that studies were conducted had different pattern. The mean infestation trend of *B. germanica* cockroaches in the hospitals environments of the world has been very highly increased ranged from 40.0 to 80.0%, while in the households environments of the world have been very slightly increased ranged from 45.0 to 50.0%. It has been very highly decreased in the miscellaneous environments of the world ranged from 80.0 to 45.0% (Fig. 5). The mean infestation of *B. germanica* cockroaches in the hospital, household and miscellaneous environments of the world were 61.8, 49.3 and 65.6, respectively. There was not a significant difference between the mean infesta-

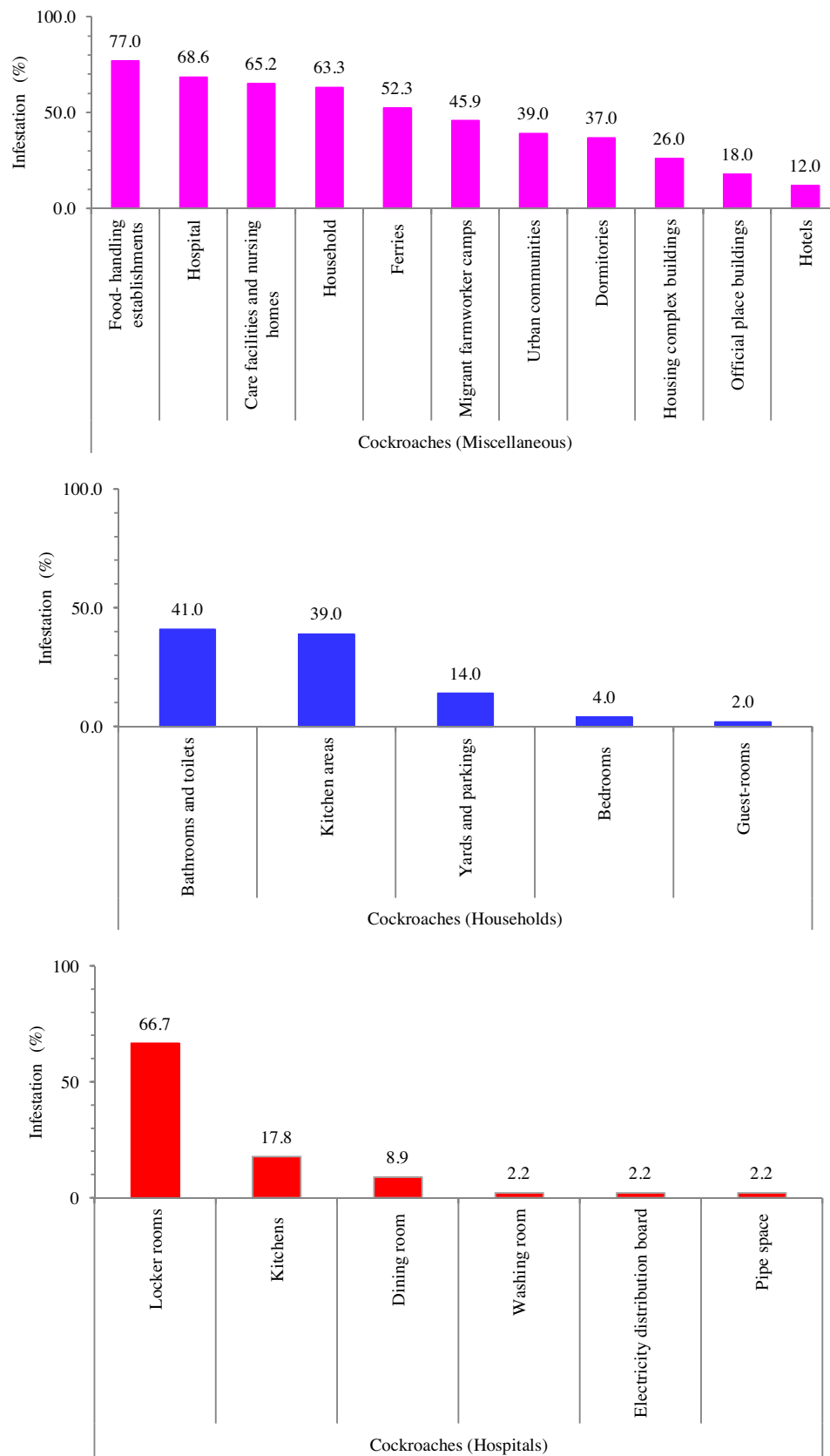


Fig. 2. Infestation of cockroaches in the any part of environments.

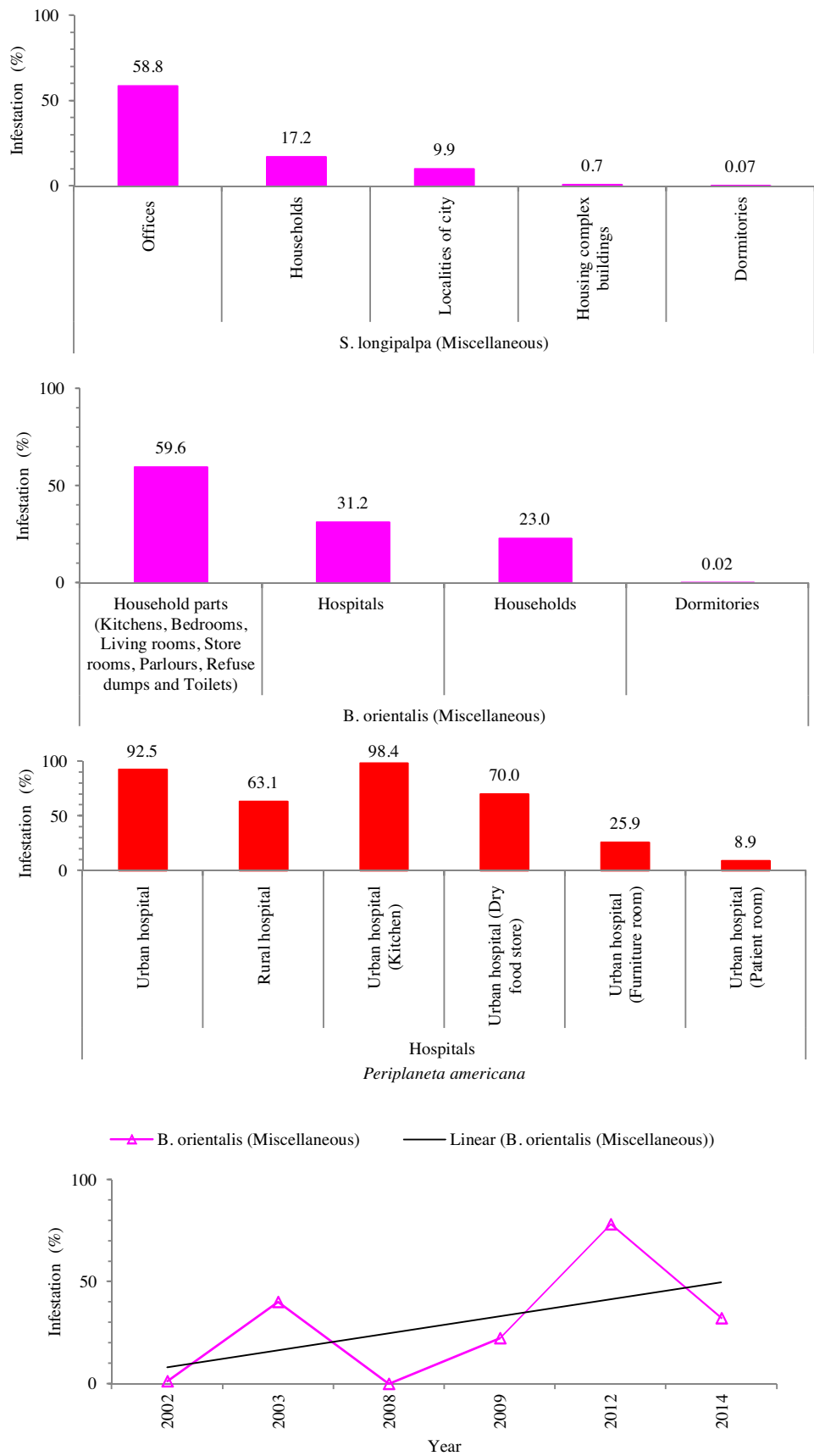


Fig. 3. Infestation of cockroach species in the different types of environments.

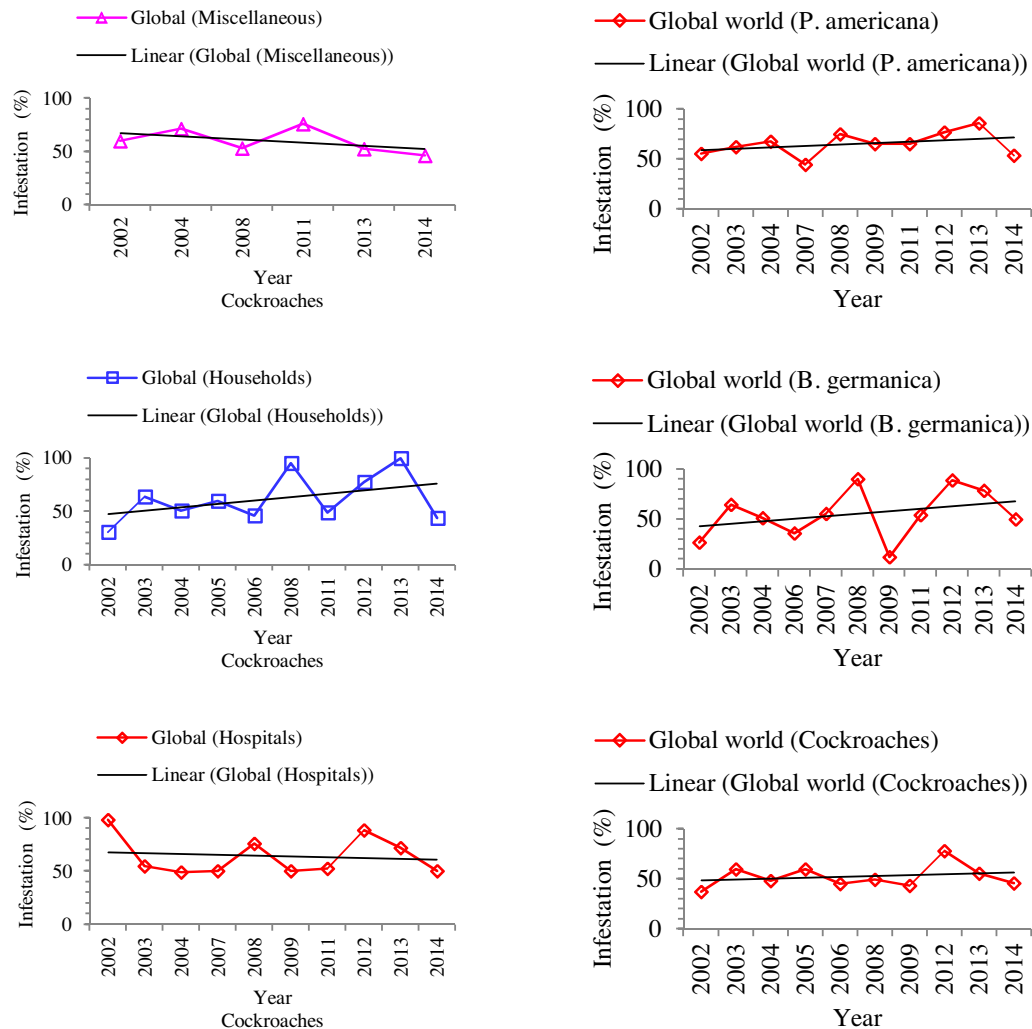


Fig. 4. Global infestation trend of cockroaches in the different types of environments and world.

tion of *B. germanica* cockroaches among the hospital, household, and miscellaneous environments of the world ($P > 0.05$) (Data not shown).

3.3.4. Infestation trend of *Periplaneta americana* cockroaches in the world

As observed in Fig. 5 the mean infestation trend of *P. americana* cockroaches in the hospital and miscellaneous environments of the world during the years that studies were conducted has been decreased ranged from 70.0 to 35.0 and 75.0–50.0%, while in the households of the world have been increased ranged from 55.0 to 75.0% (Fig. 5). The mean infestation of *P. americana* cockroaches in the hospital, household and miscellaneous environments of the world were 52.3, 66.0 and 62.2, respectively. There was not a significant difference between the mean infestation of *P. americana* cockroaches among the hospital, household and miscellaneous environments of the world ($P > 0.05$) (Data not shown).

3.3.5. Global infestation trend of cockroach species in the world

Globally the mean infestation trend of cockroaches is being increased in the world (Fig. 4). The global world mean infestation of cockroaches ranged from 49.0 to 55.0% suggests that their infestation is increasing. The global world mean infestation trend of *B. germanica* and *P. americana* cockroaches is being increased. The

global world mean infestation trend of *B. germanica* and *P. americana* cockroach species ranged from 40.0 to 70.0 and 60.0–70.0% suggests that their infestation are increasing (Fig. 4). The global world mean infestation of cockroaches, and *B. germanica* and *P. americana* cockroach species were 52.3, 55.2 and 65.4, respectively. There was a significant difference between the global world mean infestation of cockroaches and *P. americana* cockroach species ($P = 0.019$), while there was not a significant difference between the global world mean infestation of cockroaches and *B. germanica*, and *B. germanica* and *P. americana* cockroach species ($P > 0.05$) (Data not shown).

3.3.6. Global infestation of cockroaches in the human dwellings and world

As observed in Fig. 6 the global mean infestation trend of cockroaches in the human dwelling environments and world has been increased ranged from 55.0 to 65.0 and 50.0–70.0%, respectively suggests that their infestation are increasing (Fig. 6). The global world mean infestation of cockroaches in the human dwelling environments and world were 60.4 and 57.7%, respectively. There was not a significant difference between the mean infestation of cockroaches in the human dwelling environments and world ($P > 0.05$) (Data not shown).

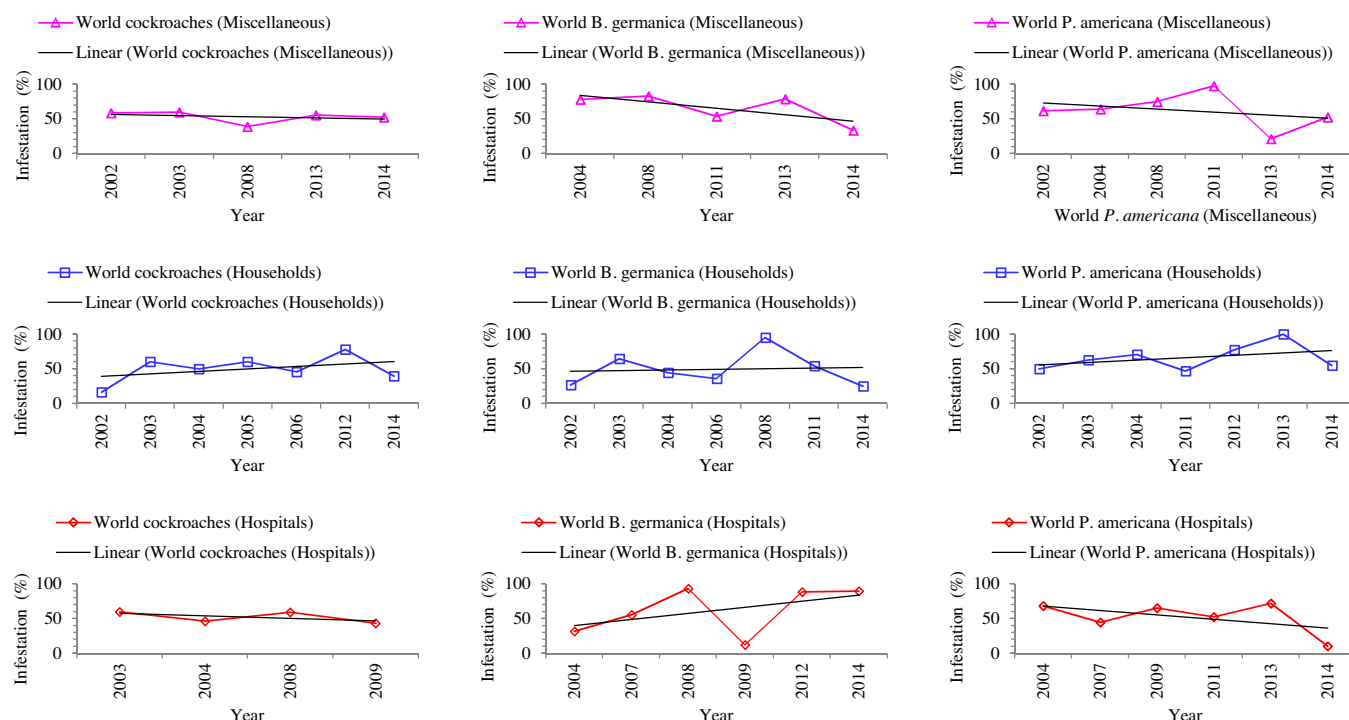


Fig. 5. Infestation trend of cockroaches and cockroach species in the world.

4. Discussion

The results of present study show that bathrooms, toilets and kitchens had the highest cockroach infestation in the household environments (Fig. 2). Some factors affect the infestation of cockroaches. Studies indicate that is a significant correlation between infestation and poor sanitation, and infestation and sanitation in a biorational system. IPM is not only effective to prevent and reduce the infestation of cockroaches but also can lead to long-term reductions in cockroach allergen concentrations, resulting in a healthier environment for human (Shahraki et al., 2011, 2010). Researchers found significant relationships between infestation of houses and the age of building ($P < 0.001$), the type of building ($P = 0.009$) and the education level of the family ($P < 0.001$). Significant differences were found between houses that their doors and windows equipped by tulle and without tulle ($P = 0.03$). Most infestation was found in the houses which sheltered 5 and more people (72.3%). Significant correlation was also found between the infestation and the number of family members ($P = 0.0012$) (Dehghani et al., 2014). Low-income housing affect to increase cockroach infestation (Wang et al., 2008). Educational program and sanitation has reduced German cockroach infestation (Shahraki et al., 2010).

A recent study showed that among 1000 studied houses, 675 (67.5%) were infested and 32.5% were not infested by cockroaches. Among infested houses, 46.0% had few, 30.0% had medium and 24.0% had high cockroach infestation. Bathrooms and toilets were recognized as the most infested places (41.0%) (Dehghani et al., 2014). The German cockroach is the most common infesting indoor species, especially in housing areas (Shahraki, 2013). Present study indicate that there is a significant difference between the mean infestation of *P. americana* cockroaches in the hospital and household environments ($P = 0.016$) and between the global world mean infestation of cockroaches and *P. americana* cockroach species ($P = 0.019$) (Fig. 4). The mean infestation of *P. americana* cockroaches were observed higher in the urban hospitals (92.3%) than the rural

hospitals (63.1%). Kitchens were the most parts in the urban hospital environments that had the highest *P. americana* cockroach infestation (98.4%). Dry food stores had a second rank (70.0%).

Although in the recent decades, the sanitation and quality structure of the buildings has been improved while as observed in Figs. 4 and 6 the globally mean infestation trend of cockroaches is being increased (Fig. 4). The global world mean infestation trend of cockroaches, *B. germanica* and *P. americana* cockroach species ranged 49.0–55.0, 40.0–70.0 and 60.0–70.0%, respectively (Fig. 4). The global mean infestation trend of cockroaches in the human dwelling environments and world has been also increased and ranged 55.0–65.0 and 50.0–70.0%, respectively. These data suggests that globally world infestation trend of cockroaches, *B. germanica* and *P. americana* cockroach species are increasing (Figs. 4 and 6).

Like other allergens, early life exposure to cockroach allergens has been implicated in the development of asthma in high risk children. As present study reveal that the infestation of cockroaches are increasing and recent studies indicate that the prevalence of asthma has increased dramatically over the past several decades (Gaffin et al., 2014) suggest infestation of cockroaches can directly affect the development of asthma.

5. Conclusion

As cockroaches are able to infest any type of buildings and spread some disease agents and asthmatics are also more in homes with high cockroach infestation, a meta-analysis review was carried out on any literature published about infestation of cockroaches. As present study reveal that the infestation of cockroaches are increasing even though the sanitation and quality structure of the buildings are being improved in the recent decades. There are too many methods to decline cockroach infestation while there need to investigate new methods to prevent cockroach infestation.

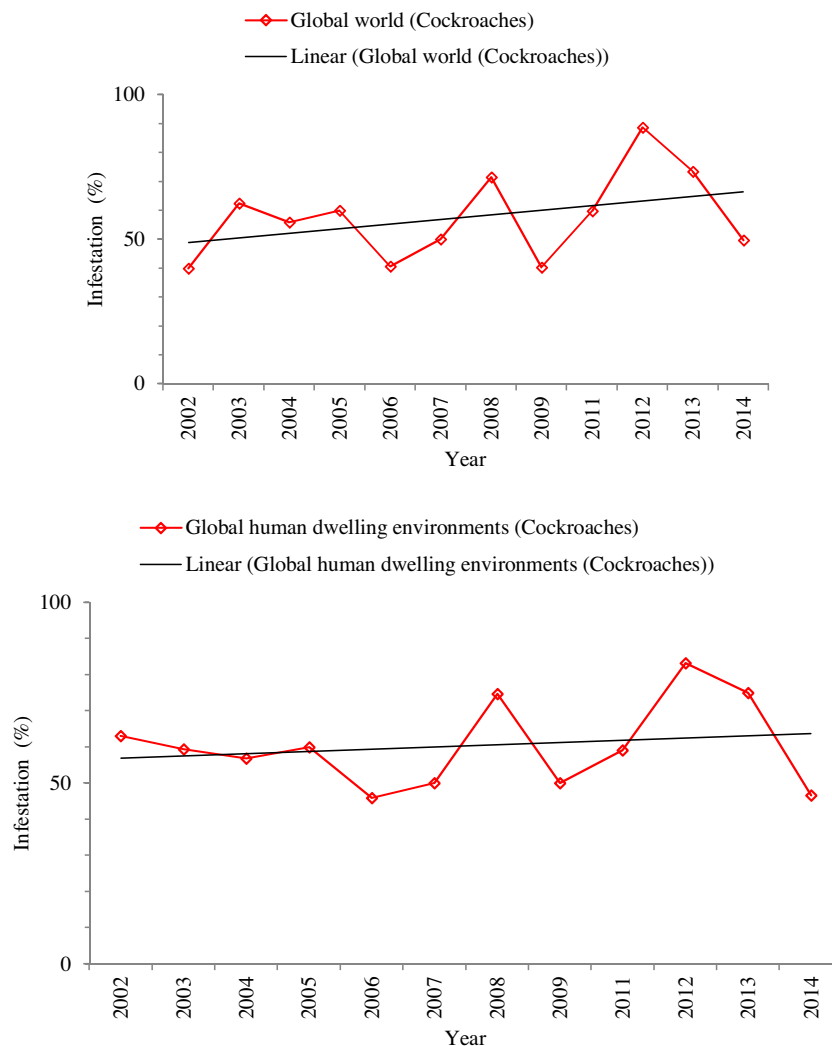


Fig. 6. Global infestation trend of cockroaches in the human dwelling environments and world.

Conflict of interest statement

The author declares that he has no conflict of interest.

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