

**Original article**

**Efficacy of several insecticide formulations against *Periplaneta americana* (L.) (Blattaria: Blattidae) in sewers**

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**Abstract**

**Objective:** *Periplaneta americana* (L.) is the most important invasive urban pests in sewers with high significance of public health. The aim of the study was to evaluate the efficacy of several insecticide formulations against American cockroaches in sewers. **Methods:** The population density of cockroaches was estimated before and after 1 and 5 months of the use of insecticides in sewer manholes. About 10 manholes were allocated for treatment of each insecticide formulation. Twenty manholes were allocated to controls (without the use of insecticides). Insecticides were considered effective achieving more than of 90% mean density reduction of cockroach population per a manhole. **Results:** The effectiveness of insecticide formulations in sewer manholes were considered effective after 1 month of insecticide treatments while the effectiveness of diazinon EC 5% and 0.05% formulations considered insufficient including 47.% and 19.5% mean density reduction of cockroaches, respectively. The effectiveness of chlorpyrifos EC 5% and Fog, and diazinon EC 5% were observed about 80.5%, 81.5% and 53.5% mean density reduction of cockroaches, respectively after 5 months of treatment while the other formulations did not achieve effectiveness. **Conclusions:** The insecticide formulations were considered effective and ineffective after 1 and 5 months of the use of insecticides, respectively. It would be more satisfied if insecticide formulations repeated every three months. A reasonable manner is using a combination of integrated pest management strategies recommending for successful *P. americana* control.

**Keywords:** American cockroach, insecticide, formulation, sewer, *Periplaneta americana*

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**Introduction**

Cockroaches demonstrate to have miraculous adaptation to a wide range of habitats as important pest of various public places, especially in areas of the tropics and subtropics. In addition to the great medical importance included potential vectors of the opportunistic or pathogenic bacteria and fungi found in drug resistant nosocomial infections and food-borne poisoning their involving as intestinal parasites of human and intermediate hosts, and playing a role as allergens may cause asthma and other long-term health issues in human<sup>1-16</sup>. Cockroaches are one of the substantial insect pests in urban sewers<sup>17</sup>. Among the most common of worldwide cockroaches

included *Blatta orientalis* L. (Blattaria: Blattidae), *Blattella germanica* L. (Blattaria: Ectobiidae), *Periplaneta americana* (L.) (Blattaria: Blattidae) and *Supellalongipalpa* F. (Blattaria: Blattidae), *P. americana* (American cockroach) is one of the most important invasive urban pests<sup>10, 18, 19</sup>. The appropriate conditions of the sewers such as presence of plenty of food and water, and suitable darkness, humidity and temperature have also caused *P. americana* cockroach as the most important pests of sewer environments. Currently, the American cockroaches are considered the most frequent species in sewers. *Periplaneta americana* colonize in sewers as suitable environments for its growth and reproduction with

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high significance of human public health.

Although, researchers are achieving new methods, and effective and appropriate insecticides for control of cockroaches<sup>22</sup>. In sewers the use of spraying insecticides is the most common method. Fogging and fire have been also used to control the American cockroaches in sewers. Because of the high population density of the American cockroaches in Esfahan sewer as a suitable and warm environment, the determination of an appropriate and effective insecticide formulation is necessary for their control. Insecticide formulations of baits, dusts, and sprays have been applied for control of the American cockroaches. In this regard few studies are available about the formulation efficacy of insecticides for control of the American cockroaches in sewers<sup>20,21,23,24</sup>. Therefore, a study designs to evaluate the efficacy of insecticide formulations against the American cockroaches in sewer of Esfahan. The aim of the study was to evaluate the efficacy of insecticide formulations against *P. americana* cockroaches in Esfahan sewer.

## Materials and methods;

### Study area

Esfahan is an area of 250 km<sup>2</sup> with 1,695,789 residents. Its altitude is 1,571 m, latitude 32° 38' 30" N and longitude 51° 39' 40" E. After Tehran, Esfahan is the second most populous metropolitan city located in a dry region in the central of Iran. It has a semi-desert climate with an annual rainfall of 102 mm, average summer maximum and winter minimum temperatures of 37.1°C and -5.8°C, respectively<sup>25</sup>.

### Description and site selection

Esfahan sewer have over 55,375 manholes with an average depth of 9 meter on the main lines and 1 meter on lateral lines. Most of the manhole covers were cast irons with two holes, and the average diameter of the holes was three cm. The shafts of the manholes were made of brick and cement coverings, and their stables moderate warmth and high humidity which provide excellent conditions for cockroaches. According to the field surveys, the most abundant cockroaches were reported from the central regions of Isfahan sewer. The sewer system in the central regions also was old and the most popular complaints were from the central regions. Therefore, three areas were selected from the central regions of Isfahan sewer with permission from Esfahan's Water & Wastewater Company. In total, 164 manholes were selected for this study.

### Insecticide providing

The insecticide formulations which provided from

Bayer Company (Bayer Persian AG), Tehran, Iran were: aqueous sprays of 5% (WP) carbaryl; 5% (WP) diazinon; 5%, 0.5% and 0.05% (EC) diazinon; 5%, 0.5% and 0.05% (EC) chlorpyrifos; 0.02 (SC) responsar Beta-cyfluthrin; thermal fogs of 0.028 g/m<sup>3</sup>(EC)cypermethrin(Cymperator); diazinon 0.5 g/m<sup>3</sup> and chlorpyrifos 0.26 g/m<sup>3</sup>; and baits of 5% carbaryl and 50% boric acid.

### 1.1. Insecticide application

#### 1.1.1. Cockroach density estimation

The population density of cockroaches per manhole was estimated periodically before, and after 1 and 5 months of treatment with insecticide formulations. The cast-iron covers were removed from each manhole, then the adults and nymphs of cockroaches were counted with a strong flashlight and recorded. The shafts with more than 300 cockroaches were estimated by counting of the 0.25 m<sup>2</sup> shaft section and multiplying by the number of infested sections.

#### 1.1.2. Insecticide application procedure

About 10 manholes were allocated for treatment of each insecticide formulation. Each sewer shaft was randomly assigned to one insecticide formulation treatment in an ascending order after estimation of cockroach population density and coding the treatment method with paint on the lower part of the wall near the manhole cover. The manhole shafts were then inspected for cockroach infestation after 1 and 5 months of treatment. All of the insecticide formulations were prepared according to [Bueno-Marí et al. \(2013\)](#) description<sup>21</sup>. Aqueous sprays were applied with HUDSON X-Pert®110 power compression sprayer equipped with a nozzle, flexible hose, stainless steel tubular spray tip extension on the handle grip, delivering 757 cm<sup>3</sup>/minute. The extension tube was lowered to the bottom of the shaft and the tip was raised upwards at a uniform rate of 0.5 m/s while the spray was applied. A 5% spray, therefore delivered about two grams of the active ingredient/m<sup>2</sup>. Boric acid baits in petri dishes were placed in a dry ledge at the bottom of the shaft. Thermal fog with solutions were applied from a "Light-weight Model" TF 30. The TF 30 was operated at a combustion chamber temperature of 600 °C, a dial flow setting of four liters/hour. Each manhole was treated for five seconds per m<sup>3</sup>. Fire with oil (10 g/m<sup>2</sup>) was used to burn manhole shafts. Fire was applied with HODSON X-Pert®110 filled with oil, the extension tube was lowered almost to the bottom of the shaft and spray was applied raising the tip upwards at a uniform rate of 10 g/m<sup>2</sup>. Oxygen also was blown into the manhole with an electrical

fan equipped with a flexible hose. Twenty manholes were allocated to controls (untreated) which were not used any insecticide formulations there.

1.2. Statistical analysis

IBM SPSS Statistics Data Editor Version 24 was used for statistical analyses. Analysis of variance (ANOVA) was used to compare the insecticides and formulations. For any significant of ANOVA, Post Hoc Tests (Tukey) analysis was used to compare the insecticides with control (untreated) and between formulation types. Population density of *P. americana* cockroaches before and after treating of insecticide formulations in manholes of sewer and approximate efficacy of insecticide formulations against *P. americana* were calculated using Microsoft office excel 2013.  $P < 0.05$  was considered significant.

To estimate the approximate efficacy of the insecticide formulations, an equation was designed and calculated as follows:

$$\text{Approximate efficacy} = 10 \times (t - c)/(10c)$$

Where  $t$  is percentage treatment density reduction and  $c$  is percentage control (untreated) density.

Insecticide formulations were considered effective when more than 90% of cockroach population density reduction was achieved after 1 or 5 months

treatment in the manholes of sewer.

**Ethical clearance:** None

**Results**

*Density of cockroaches*

In the present study, the efficacy of several insecticide formulations was investigated against American cockroaches in Isfahan sewer. Tables 1-2 show the data from the application of insecticide formulations against *P. americana* in the manholes of sewer. The population density of *P. americana* cockroaches which was estimated about between 66 and 282 cockroaches before treatment in the manholes of sewer while after 1 month of treatment with the insecticide formulations (except boric acid bait) was decreased to about  $\leq 10$  cockroaches. The cockroach density in the manholes which was treated with boric acid bait decreased from 106-115 before treatment to 15-20 after 1 month of treatment. But the cockroach adult density was decreased from 20-26 to  $< 2$  cockroaches. The density of cockroaches after 5 months of treatment with the insecticide formulations were different results. The density of cockroaches decreased for a few insecticide formulations, did not change for some insecticide formulations and increased for some insecticide formulations (Tables 1-2).

**Table 1.** Data from the application of WP, SC and Fog insecticide formulations against *P. americana* in sewer manholes

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
CarbarylWP 5%							ChlorpyrifosWP 5%						
1	78	67	1	1	215	60	1	96	52	0	0	8	5
2	67	58	1	1	216	63	2	99	58	0	0	5	4
3	91	70	2	2	218	62	3	91	60	0	0	7	4
4	84	65	2	2	219	70	4	112	63	0	0	10	5
5	83	70	4	3	213	71	5	81	68	0	0	8	5
6	87	71	1	1	214	72	6	88	54	0	0	8	6
7	79	70	1	1	212	61	7	106	63	0	0	12	10
8	72	64	0	0	219	65	8	101	60	0	0	10	8
9	69	64	2	1	213	65	9	110	62	0	0	7	5
10	73	66	3	3	215	73	10	98	59	0	0	8	5
DiazinonWP 5% (May)							DiazinonWP 5% (November)						
1	100	91	0	0	306	180	100	85	58	0	0	96	28
2	103	85	0	0	321	178	103	92	54	0	0	95	29
3	92	89	0	0	321	185	92	75	58	0	0	97	28
4	107	92	1	1	301	170	107	90	60	0	0	100	32
5	101	87	0	0	315	174	101	79	63	0	0	101	28
6	99	90	0	0	310	172	99	86	62	0	0	106	29

Efficacy of several insecticide formulations against *Periplaneta americana* (L.) (Blattaria: Blattidae) in sewers

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
7	96	95	0	0	312	184	96	98	55	0	0	92	24
8	92	92	0	0	301	182	92	84	58	0	0	102	25
9	109	95	0	0	300	180	109	78	55	0	0	99	26
10	97	90	1	1	308	178	97	92	61	0	0	98	27
Responсар SC 0.02%							Cymperator Fog						
1	132	34	0	0	34	10	1	179	63	0	0	16	4
2	122	41	0	0	41	9	2	176	61	0	0	16	4
3	119	40	0	0	43	9	3	177	63	0	0	15	3
4	141	35	0	0	42	8	4	170	63	0	0	17	2
5	143	36	0	0	35	8	5	175	68	0	0	19	4
6	131	39	0	0	41	8	6	183	61	0	0	18	5
7	139	37	0	0	38	7	7	181	64	0	0	13	2
8	127	43	0	0	39	8	8	169	62	0	0	15	5
9	135	41	0	0	32	10	9	170	65	0	0	15	4
10	134	38	0	0	38	8	10	180	64	0	0	17	4
Diazinon Fog							Chlorpyrifos Fog						
1	242	105	0	0	47	9	1	149	86	0	0	1	0
2	236	107	0	0	49	8	2	144	77	0	0	1	0
3	246	108	0	0	41	9	3	148	79	0	0	1	0
4	242	105	0	0	47	8	4	154	80	0	0	2	0
5	253	106	0	0	40	6	5	155	82	0	0	0	0
6	236	108	0	0	41	4	6	151	88	0	0	3	1
7	241	100	0	0	47	6	7	149	92	0	0	1	0
8	237	94	0	0	46	10	8	144	74	0	0	2	0
9	238	99	0	0	40	7	9	145	80	0	0	1	0
10	240	105	0	0	44	8	10	152	82	0	0	2	0

SM=sewer manhole.

**Table 2.** Data from the application of EC and bait insecticide formulations, and fire against *P. americana* in sewer manholes

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
Chlorpyrifos EC 0.05% (May)							Diazinon EC 5%						
1	129	26	0	0	96	12	1	270	120	10	5	7	1
2	120	28	0	0	92	13	2	264	112	9	4	4	0
3	125	27	0	0	87	12	3	280	129	9	5	8	1
4	124	29	0	0	88	12	4	274	117	6	3	8	2
5	141	30	0	0	94	11	5	271	122	8	4	7	2
6	122	32	1	0	96	10	6	260	127	7	3	6	1
7	123	25	0	0	95	9	7	261	123	8	3	5	1
8	119	27	0	0	87	13	8	274	124	9	3	2	1
9	137	24	0	0	88	17	9	272	121	9	4	9	1
10	129	23	0	0	84	14	10	282	110	6	2	2	0
11	123	31	1	1	91	15	11	269	111	8	3	4	0
12	134	29	0	0	95	12	12	273	112	7	3	6	1
13	131	27	1	0	91	18	13	270	119	9	4	5	2

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month		
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult	
Chlorpyrifos EC 0.05% (November)							Diazinon EC 0.5%							
1	82	62	0	0	29	11	1	109	43	1	0	39	7	
2	67	68	0	0	26	10	2	102	40	0	0	37	8	
3	75	59	0	0	27	9	3	106	39	0	0	36	9	
4	71	62	0	0	26	8	4	112	41	1	0	34	7	
5	68	61	0	0	24	9	5	114	39	0	0	38	5	
6	66	62	0	0	23	7	6	103	37	0	0	36	5	
7	92	67	0	0	20	6	7	116	42	0	0	28	6	
8	81	65	0	0	21	7	8	115	45	1	1	30	8	
9	72	60	0	0	22	7	9	102	46	1	0	31	5	
10	75	63	0	0	24	9	10	110	42	1	0	34	7	
Chlorpyrifos EC 5%							Diazinon EC 0.05%							
1	114	27	0	0	0	0	1	221	39	1	1	15	4	
2	137	24	0	0	0	0	2	224	42	1	1	14	5	
3	129	26	0	0	0	0	3	219	34	1	0	12	6	
4	127	25	0	0	0	0	4	217	35	0	0	17	4	
5	128	29	0	0	0	0	5	225	38	2	1	17	6	
6	121	25	0	0	0	0	Boric acid bait							
7	132	28	0	0	0	0	1	109	22	20	1	34	5	
8	112	23	0	0	0	0	2	115	20	19	0	28	3	
9	142	27	0	0	0	0	3	106	26	18	1	27	3	
10	121	24	0	0	0	0	4	111	20	15	1	26	3	
11	133	22	0	0	0	0	5	112	23	17	1	30	3	
12	127	25	0	0	0	0								
Carbaryl bait 5%							Control (Untreated)							
1	85	35	0	0	73	7	1	80	40	39	21	159	44	
2	90	39	2	1	65	8	2	81	41	36	20	161	42	
3	91	38	1	1	69	5	3	78	38	37	22	162	41	
4	85	35	1	0	70	6	4	78	37	35	16	150	43	
5	92	41	2	1	72	4	5	81	42	39	24	153	44	
6	90	36	1	1	72	8	6	89	47	42	18	151	38	
7	89	42	3	2	68	6	7	83	41	35	19	152	34	
8	88	41	3	2	65	4	8	84	35	38	19	161	39	
9	93	38	1	1	70	5	9	82	45	44	21	165	42	
Fire								10	85	44	48	25	164	41
1	212	61	0	0	50	11	11	89	40	39	20	156	45	
2	210	63	0	0	51	12	12	79	41	38	21	149	42	
3	215	65	2	1	54	8	13	82	37	34	17	155	36	
4	210	60	0	0	50	8	14	87	44	41	19	158	42	
5	211	64	1	1	52	9	15	85	44	42	18	174	37	
6	207	63	0	0	49	7	16	88	44	38	18	132	34	
7	214	58	1	0	48	8	17	80	41	44	19	145	40	
8	202	61	0	0	57	14	18	81	41	34	17	163	40	
9	219	58	1	0	52	11	19	81	40	42	19	159	42	
10	214	60	1	0	51	10	20	86	39	40	20	156	46	

SM=sewer manhole.

Tables3-4 show the population density of *P. americana* cockroaches before and after application of insecticide formulations in the manholes of sewer. The mean population density of *P. americana* cockroaches in the manholes of sewer which was estimated from 7.7 to 20.0% before treatment while was decreased to about  $\leq 3.0\%$  after 1 month of treatment with insecticide formulations (except boric acid bait). The mean cockroach density decreased from 20.0% before treatment to 16.1% after 1 month of treatment in the manholes which was treated with boric acid bait. But the mean cockroach adult density which were treated with boric acid bait was

decreased from 20% to 3.5%. The mean density of cockroaches after 5 months of treatment with chlorpyrifos Fog, diazinon EC 5%, diazinonEC 0.05% and chlorpyrifosEC 5% formulations decreased from 10.0, 7.7, 20.0 and 8.3% to 1.6, 2.1, 6.8 and 0%, while the mean population density of *P. americana* cockroaches which was treated with the other insecticide formulations did not change (Tables3-4).

**Table 3.** Population density (%) of *P.americana* cockroaches before and after application of WP, SC and Fog insecticide formulations in sewer manholes

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month							
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult						
								CarbarylWP5%						ChlorpyrifosWP 5%					
1	10.0	10.1	1.3	1.3	10.0	9.1	1	9.8	8.7	0	0	9.6	8.8						
2	8.6	8.7	1.5	1.5	10.0	9.5	2	10.1	9.7	0	0	6.0	7.0						
3	11.6	10.5	2.2	2.2	10.1	9.4	3	9.3	10.0	0	0	8.4	7.0						
4	10.7	9.8	2.4	2.4	10.2	10.6	4	11.4	10.5	0	0	12.0	8.8						
5	10.6	10.5	4.8	3.6	9.9	10.7	5	8.2	11.4	0	0	9.6	8.8						
6	11.1	10.7	1.1	1.1	9.9	10.9	6	9.0	9.0	0	0	9.6	10.5						
7	10.1	10.5	1.3	1.3	9.8	9.2	7	10.8	10.5	0	0	14.5	17.5						
8	9.2	9.6	0.0	0.0	10.2	9.8	8	10.3	10.0	0	0	12.0	14.0						
9	8.8	9.6	2.9	1.4	9.9	9.8	9	11.2	10.4	0	0	8.4	8.8						
10	9.3	9.9	4.1	4.1	10.0	11.0	10	10.0	9.8	0	0	9.6	8.8						
Mean (SD)	10.1 (1.0)		2.2 (1.5)		10.0 (0.1)		Mean (SD)	10.0 (1.0)		0 (0)		10.0 (2.4)							
								DiazinonWP 5% (May)						DiazinonWP 5% (November)					
1	10.0	10.0	0.0	0.0	9.9	10.1	10.0	9.9	9.9	0	0	9.7	10.1						
2	10.3	9.4	0.0	0.0	10.4	10.0	10.3	10.7	9.2	0	0	9.6	10.5						
3	9.2	9.8	0.0	0.0	10.4	10.4	9.2	8.7	9.9	0	0	9.8	10.1						
4	10.7	10.2	0.9	0.9	9.7	9.5	10.7	10.5	10.3	0	0	10.1	11.6						
5	10.1	9.6	0.0	0.0	10.2	9.8	10.1	9.2	10.8	0	0	10.2	10.1						
6	9.9	9.9	0.0	0.0	10.0	9.6	9.9	10.0	10.6	0	0	10.8	10.5						
7	9.6	10.5	0.0	0.0	10.1	10.3	9.6	11.4	9.4	0	0	9.3	8.7						
8	9.2	10.2	0.0	0.0	9.7	10.2	9.2	9.8	9.9	0	0	10.3	9.1						
9	10.9	10.5	0.0	0.0	9.7	10.1	10.9	9.1	9.4	0	0	10.0	9.4						
10	9.7	9.9	1.0	1.0	10.0	10.0	9.7	10.7	10.4	0	0	9.9	9.8						
Mean (SD)	10.0 (0.6)		0.2 (0.4)		10.0 (0.3)		Mean (SD)	10.0 (0.8)		0 (0)		10.0 (0.4)							
								Responzar SC 0.02%						Cymperator Fog					
1	10.0	8.85	0	0	8.9	11.8	1	10.2	9.9	0	0	9.9	10.8						
2	9.2	10.68	0	0	10.7	10.6	2	10.0	9.6	0	0	9.9	10.8						
3	9.0	10.42	0	0	11.2	10.6	3	10.1	9.9	0	0	9.3	8.1						
4	10.7	9.11	0	0	11.0	9.4	4	9.7	9.9	0	0	10.6	5.4						
5	10.8	9.38	0	0	9.1	9.4	5	9.9	10.7	0	0	11.8	10.8						

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
6	9.9	10.16	0	0	10.7	9.4	6	10.4	9.6	0	0	11.2	13.5
7	10.5	9.64	0	0	9.9	8.2	7	10.3	10.1	0	0	8.1	5.4
8	9.6	11.20	0	0	10.2	9.4	8	9.6	9.8	0	0	9.3	13.5
9	10.2	10.68	0	0	8.4	11.8	9	9.7	10.3	0	0	9.3	10.8
10	10.1	9.90	0	0	9.9	9.4	10	10.2	10.1	0	0	10.6	10.8
Mean (SD)	10.0 (0.6)		0 (0)		10.0 (0.9)		Mean (SD)	10.0 (0.3)		0 (0)		10.0 (1.1)	
Diazinon Fog							Chlorpyrifos Fog						
1	10.0	10.1	0	0	10.6	12.0	1	10.0	10.5	0	0	0.7	0.0
2	9.8	10.3	0	0	11.1	10.7	2	9.7	9.4	0	0	0.7	0.0
3	10.2	10.4	0	0	9.3	12.0	3	9.9	9.6	0	0	0.7	0.0
4	10.0	10.1	0	0	10.6	10.7	4	10.3	9.8	0	0	1.3	0.0
5	10.5	10.2	0	0	9.0	8.0	5	10.4	10.0	0	0	0.0	0.0
6	9.8	10.4	0	0	9.3	5.3	6	10.1	10.7	0	0	2.0	0.7
7	10.0	9.6	0	0	10.6	8.0	7	10.0	11.2	0	0	7.1	0.0
8	9.8	9.1	0	0	10.4	13.3	8	9.7	9.0	0	0	1.4	0.0
9	9.9	9.5	0	0	9.0	9.3	9	9.7	9.8	0	0	0.7	0.0
10	10.0	10.1	0	0	10.0	10.7	10	10.2	10.0	0	0	1.3	0.0
Mean (SD)	10.0 (0.2)		0 (0)		10.0 (0.8)		Mean (SD)	10.0 (0.3)		0 (0)		1.6 (2.0)	

SM=sewer manhole.

**Table 4.** Population density (%) of *P. americana* cockroaches before and after application of EC and bait insecticide formulations, and fire in sewer manholes

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
Chlorpyrifos EC 0.05% (May)							Diazinon EC 5%						
1	7.8	7.3	0.0	0.0	8.1	7.1	1	7.7	7.8	3.7	4.2	2.6	0.8
2	7.2	7.8	0.0	0.0	7.8	7.7	2	7.5	7.2	3.4	3.6	1.5	0.0
3	7.5	7.5	0.0	0.0	7.3	7.1	3	8.0	8.3	3.2	3.9	2.9	0.8
4	7.5	8.1	0.0	0.0	7.4	7.1	4	7.8	7.6	2.2	2.6	2.9	1.7
5	8.5	8.4	0.0	0.0	7.9	6.5	5	7.7	7.9	3.0	3.3	2.6	1.6
6	7.4	8.9	0.8	0.0	8.1	6.0	6	7.4	8.2	2.7	2.4	2.3	0.8
7	7.4	7.0	0.0	0.0	8.0	5.4	7	7.4	8.0	3.1	2.4	1.9	0.8
8	7.2	7.5	0.0	0.0	7.3	7.7	8	7.8	8.0	3.3	2.4	0.7	0.8
9	8.3	6.7	0.0	0.0	7.4	10.1	9	7.7	7.8	3.3	3.3	3.3	0.8
10	7.8	6.4	0.0	0.0	7.1	8.3	10	8.0	7.1	2.1	1.8	0.7	0.0
11	7.4	8.7	0.8	3.2	7.7	8.9	11	7.6	7.2	3.0	2.7	1.5	0.0
12	8.1	8.1	0.0	0.0	8.0	7.1	12	7.8	7.2	2.6	2.7	2.2	0.9
13	7.9	7.5	0.8	0.0	7.7	10.7	13	7.7	7.7	3.3	3.4	1.9	1.7
Mean (SD)	7.7 (0.4)		0.2 (0.4)		7.7 (0.3)		Mean (SD)	7.7 (0.2)		3.0 (0.5)		2.1 (0.8)	
Chlorpyrifos EC 0.05% (November)							Diazinon EC 0.5%						
1	10.9	9.9	0	0	12.0	13.3	1	10.0	10.4	0.9	0.0	11.4	10.4
2	8.9	10.9	0	0	10.7	12.0	2	9.4	9.7	0.0	0.0	10.8	11.9
3	10.0	9.4	0	0	11.2	10.8	3	9.7	9.4	0.0	0.0	10.5	13.4
4	9.5	9.9	0	0	10.7	9.6	4	10.3	9.9	0.9	0.0	9.9	10.4
5	9.1	9.7	0	0	9.9	10.8	5	10.5	9.4	0.0	0.0	11.1	7.5



Efficacy of several insecticide formulations against *Periplaneta americana* (L.) (Blattaria: Blattidae) in sewers

SM	Pretreatment		After 1 month		After 5 month		SM	Pretreatment		After 1 month		After 5 month	
	Total	Adult	Total	Adult	Total	Adult		Total	Adult	Total	Adult	Total	Adult
6	8.8	9.9	0	0	9.5	8.4	6	9.5	8.9	0.0	0.0	10.5	7.5
7	12.3	10.7	0	0	8.3	7.2	7	10.7	10.1	0.0	0.0	8.2	9.0
8	10.8	10.4	0	0	8.7	8.4	8	10.6	10.9	0.9	0.9	8.7	11.9
9	9.6	9.6	0	0	9.1	8.4	9	9.4	11.1	1.0	0.0	9.0	7.5
10	10.0	10.1	0	0	9.9	10.8	10	10.1	10.1	0.9	0.0	9.9	10.4
Mean (SD)	10.0 (1.1)		0 (0)		10.0 (1.2)		Mean (SD)	10.0 (0.5)		0.5 (0.5)		10.0 (1.1)	
Chlorpyrifos EC 5%							Diazinon EC 0.05%						
1	7.5	8.9	0	0	0	0	1	20.0	20.7	0.5	2.6	6.8	10.3
2	9.0	7.9	0	0	0	0	2	20.3	22.3	0.4	2.4	6.3	11.9
3	8.5	8.5	0	0	0	0	3	19.8	18.1	0.5	0.0	5.5	17.6
4	8.3	8.2	0	0	0	0	4	19.6	18.6	0.0	0.0	7.8	11.4
5	8.4	9.5	0	0	0	0	5	20.3	20.2	0.9	2.6	7.6	15.8
6	7.9	8.2	0	0	0	0	Mean (SD)	20.0 (0.3)		0.5 (0.3)		6.8 (0.9)	
7	8.7	9.2	0	0	0	0	Boric acid bait						
8	7.4	7.5	0	0	0	0	1	19.7	19.8	18.3	4.5	23.4	29.4
9	9.3	8.9	0	0	0	0	2	20.8	18.0	16.5	0.0	19.3	17.6
10	7.9	7.9	0	0	0	0	3	19.2	23.4	17.0	3.8	18.6	17.6
11	8.7	7.2	0	0	0	0	4	20.1	18.0	13.5	5.0	17.9	17.6
12	8.3	8.2	0	0	0	0	5	20.3	20.7	15.2	4.3	20.7	17.6
Mean (SD)	8.3 (0.6)		0 (0)		0 (0)		Mean (SD)	20.0 (0.6)		16.1 (1.8)		20.0 (2.2)	
Carbaryl bait 5%							Control (untreated)						
1	10.6	10.1	0.0	0.0	11.7	13.2	1	4.8	4.9	5.0	5.3	5.1	5.4
2	11.2	11.3	2.2	1.1	10.4	15.1	2	4.9	5.0	4.6	5.1	5.2	5.2
3	11.3	11.0	1.1	1.1	11.1	9.4	3	4.7	4.6	4.7	5.6	5.2	5.0
4	10.6	10.1	1.2	0.0	11.2	11.3	4	4.7	4.5	4.5	4.1	4.8	5.3
5	11.5	11.9	2.2	1.1	11.5	7.5	5	4.9	5.1	5.0	6.1	4.9	5.4
6	11.2	10.4	1.1	1.1	11.5	15.1	6	5.4	5.7	5.4	4.6	4.8	4.7
7	11.1	12.2	3.4	2.2	10.9	11.3	7	5.0	5.0	4.5	4.8	4.9	4.2
8	11.0	11.9	3.4	1.1	10.4	7.5	8	5.1	4.3	4.8	4.8	5.2	4.8
9	11.6	11.0	1.1	1.1	11.2	9.4	9	4.9	5.5	5.6	5.3	5.3	5.2
Mean (SD)	11.1 (0.3)		1.7 (1.1)		11.1 (0.5)		10	5.1	5.4	6.1	6.4	5.4	6.1
Fire							11	5.4	4.9	5.0	5.1	5.0	5.5
1	10.0	10.0	0.0	0.0	9.7	11.2	12	4.8	5.0	4.8	5.3	4.8	5.2
2	9.9	10.3	0.0	0.0	9.9	12.2	13	4.9	4.5	4.3	4.3	5.0	4.4
3	10.2	10.6	0.9	0.5	10.5	8.2	14	5.2	5.4	5.2	4.8	5.1	5.2
4	9.9	9.8	0.0	0.0	9.7	8.2	15	5.1	5.4	5.4	4.6	5.6	4.6
5	10.0	10.4	0.5	0.5	10.1	9.2	16	5.3	5.4	4.8	4.6	4.2	4.2
6	9.8	10.3	0.0	0.0	9.5	7.1	17	4.8	5.0	5.6	4.8	4.6	4.9
7	10.1	9.5	0.5	0.0	9.3	8.2	18	4.9	5.0	4.3	4.3	5.2	4.9
8	9.6	10.0	0.0	0.0	11.1	14.3	19	4.9	4.9	5.4	4.8	5.1	5.2
9	10.4	9.5	0.5	0.0	10.1	11.2	20	5.2	4.8	5.1	5.1	5.0	5.7
10	10.1	9.8	0.5	0.0	9.9	10.2							
Mean (SD)	10.0 (0.2)		0.3 (0.3)		10.4 (0.5)		Mean (SD)	5.0 (0.2)		5.0 (0.5)		5.0 (0.3)	

SM=sewer manhole.



Figs. 1-3 also show the density of *P. americana* cockroaches before and after 1 and 5 months of treatment with the insecticide formulations in sewer manholes.

#### Approximate efficacy of insecticides

Table 5 shows the approximate efficacy of insecticide formulations against *P. americana* in manholes of sewer. Insecticide formulations were considered effective when more than 90% of cockroach population density reduction was achieved. Although the diazinon EC5%, diazinon EC0.05% and boric

acid bait formulations which their effectiveness considered insufficient including 47.0, 19.5 and 39.0%, respectively after 1 month of treatment in the manholes of sewer while the other insecticide formulations were considered effective. The effectiveness of chlorpyrifos EC5%, diazinon EC5% and chlorpyrifos Fog formulations were observed about 80.5, 53.5 and 81.5%, respectively after 5 months of treatment in the manholes of sewer while the other formulations did not achieve effectiveness (Table 5).

**Table 5.** Approximate efficacy (%) of the insecticide formulations against *P.americana* in sewer manholes

Insecticide formulation	Pretreatment	Treatment					
		After 1 month			After 5 month		
		Mean	Reduction	Efficacy	Mean	Reduction	Efficacy
WP							
Carbaryl 5%	10	2.2	7.8	78.0	10	0	0
Chlorpyrifos 5%	10	0	10	100	10	0	0
Diazinon 5% (November)	10	0	10	100	10	0	0
Diazinon 5% (May)	10	0.2	9.8	98.0	10	0	0
EC							
Chlorpyrifos 5%	8.3	0	8.3	83.0	0	8.3	80.5
Chlorpyrifos 0.05% (November)	10	0	10	100	10	0	0
Chlorpyrifos 0.05% (May)	7.7	0.2	7.5	75.0	7.7	0	0
Diazinon 5%	7.7	3.0	4.7	47.0	2.1	5.6	53.5
Diazinon 0.5%	10	0.5	9.5	95.0	10	0	0
Diazinon 0.05%	20	0.5	19.5	19.5	6.8	13.2	13.0
SC							
Responsar 0.02%	10	0	10	100	10	0	0
Fog							
Chlorpyrifos	10	0	10	100	1.6	8.4	81.5
Cymperator	10	0	10	100	10	0	0
Diazinon	10	0	10	100	10	0	0
Bait							
Carbaryl 5%	11.1	1.7	9.4	94.0	11.1	0	0
Boric acid	20	16.1	3.9	39.0	20	0	0
Fire	10	0.3	9.7	97.0	10	0	0

#### Analysis of insecticide applications

Tables 4-5 show the ANOVA and followed Post Hoc tests (Tukey) analysis between applications of insecticide formulations against *P. americana* in the manholes of sewer. There were significance differences between insecticidal effectiveness and formulation types including WP, EC, SC, Fog and Fire ( $P = 0.0001$ ). After ANOVA analysis, Post

Hoc tests (Tukey) showed significance differences between treated manholes with insecticides and untreated (control) manholes ( $P = 0.0001$ ) (Table 6). Post Hoc tests (Tukey) also showed significance differences between manholes which treated with diazinonEC5% and boric acid bait, and the manholes treated with the other insecticide formulations ( $P =$

0.0001) (Table 7).

**Discussion**

Like present study which was observed the *P.americana*, the most prevalent cockroaches in the Esfahan sewer, *P. americana* is the most prevalent insect pests in urban sewers<sup>26</sup> of areas of tropics and subtropics. Large-scale of *P. americana* cockroaches can invade to human apartments through breathing sewer manholes. Unlike *P. americana* being the most important pests of sewer, it is noteworthy that the German cockroach (*Blattella germanica*) is the most invading human dwellings species<sup>27-34</sup>.

Irrespective of considering insufficiency effectiveness of diazinon EC5%, diazinon EC0.05% and boric acid bait formulations observed 47.0, 19.5 and 39.0 percent efficacy, respectively after 1 month of sewer

treatment which confirmed by observing a significance differences between formulation types including WP, EC, SC, Fog and Fire ( $P = 0.0001$ ) and then between manholes which treated with diazinon EC5% and boric acid bait, and the manholes treated with the other insecticide formulations ( $P = 0.0001$ ) followed by Post Hoc tests (Tukey) (Table 7).

It may be due to insecticide resistance<sup>35</sup> and inadequate insecticide doses. While the other insecticide formulations were considered effective after 1 month of treatment in the manholes of sewer. These results confirmed with observing a significance differences between insecticidal effects ( $P = 0.0001$ ). Post Hoc tests (Tukey) also showed a significance differences between treated manholes with insecticides and untreated (control) manholes ( $P = 0.0001$ ) (Table 6).

**Table 6.** ANOVA and Post Hoc Tests (Tukey) analysis between applications of insecticide formulations against *P.americana* in sewer manholes

After 1 month					After 5 month				
ANOVA analysis between insecticidal effects									
Sum of squares	df	Mean square	F	P-value	Sum of squares	df	Mean square	F	P-value
27622.1	17	1624.8	840.8	0.0001	1250405.4	17	73553.3	3976.2	0.0001
Post Hoc Tests (Tukey) after ANOVA analysis between applications of insecticides and control (untreated)									
Formulation	Mean difference	Std. error	P-value	Formulation	Mean difference	Std. error	P-value		
CarbarylWP 5%	37.6*	0.54	0.0001	CarbarylWP5%	-59.2*	1.7	0.0001		
DiazinonWP 5%	39.3*	0.54	0.0001	DiazinonWP5%	57.7*	1.7	0.0001		
ChlorpyrifosEC 5%	39.3*	0.51	0.0001	ChlorpyrifosEC5%	156.3*	1.6	0.0001		
ChlorpyrifosWP 5%	39.3*	0.54	0.0001	ChlorpyrifosWP5%	148.0*	1.7	0.0001		
ChlorpyrifosEC 0.05%	39.3*	0.54	0.0001	ChlorpyrifosEC0.05%	132.1*	1.7	0.0001		
ChlorpyrifosEC 0.05%	39.0*	0.50	0.0001	ChlorpyrifosEC0.05%	65.2*	1.5	0.0001		
DiazinonEC 5%	31.2*	0.50	0.0001	DiazinonEC5%	150.6*	1.5	0.0001		
DiazinonWP 5%	39.1*	0.54	0.0001	DiazinonWP5%	-153.3*	1.7	0.0001		
DiazinonEC 0.5%	38.8*	0.54	0.0001	DiazinonEC0.5%	122.0*	1.7	0.0001		
DiazinonEC 0.05%	38.3*	0.70	0.0001	DiazinonEC0.05%	141.3*	2.2	0.0001		
ResponsarSC 0.02%	39.3*	0.54	0.0001	ResponsarSC0.02%	118.0*	1.7	0.0001		
Cymperator Fog	39.3*	0.54	0.0001	Cymperator Fog	140.2*	1.7	0.0001		
Diazinon Fog	39.3*	0.54	0.0001	Diazinon Fog	112.1*	1.7	0.0001		
Chlorpyrifos Fog	39.3*	0.54	0.0001	Chlorpyrifos Fog	154.9*	1.7	0.0001		
Boric acid bait	21.5*	0.70	0.0001	Boric acid bait	127.3*	2.2	0.0001		
Carbaryl bait 5%	37.7*	0.56	0.0001	Carbaryl bait5%	86.9*	1.7	0.0001		
Fire	38.7*	0.54	0.0001	Fire	104.9*	1.7	0.0001		
ANOVA analysis between formulation types									
Sum of squares	df	Mean square	F	P-value	Sum of squares	df	Mean square	F	P-value
629.1	5	125.8	12.9	0.0001	489832.8	5	97966.6	26.0	0.0001
Post Hoc Tests (Tukey) after ANOVA analysis between formulations									

After 1 month					After 5 month					
ANOVA analysis between insecticidal effects										
Sum of squares	df	Mean square	F	P-value	Sum of squares	df	Mean square	F	P-value	
27622.1	17	1624.8	840.8	0.0001	1250405.4	17	73553.3	3976.2	0.0001	
ANOVA analysis		Mean difference	Std. error	P-value	ANOVA analysis		Mean difference	Std. error	P-value	
Bait –		WP	6.9*	0.97	0.0001	EC	127.5*	12.4	0.0001	
		EC	5.5*	0.92	0.0001	SC	119.6*	21.7	0.0001	
		SC	7.4*	1.3	0.0001	WP –	Fog	137.4*	14.8	0.0001
		Fog	7.4*	1.0	0.0001		Bait	103.0*	19.1	0.0001
		Fire	6.8*	1.3	0.0001		Fire	106.6*	21.7	0.0001

\*The mean difference is significant at the 0.05 level.

These results concordance with results of the previous studies<sup>21,23,36</sup>. Obviously, the effectiveness of the insecticide formulations for 1 month control is very little time that this time should be increased. The effectiveness of chlorpyrifos EC5%, diazinon EC 5% and chlorpyrifos Fog formulations were also observed about 80.5, 53.5 and 81.5 percent, respectively after 5 months of treatment in the manholes of sewer which they are also unsatisfied results. While the other formulations did not achieve effectiveness after 5 months of treatment in the manholes of sewer (Table 5). Even though there was a significance differences between treated manholes with insecticides and untreated (control) manholes (P = 0.0001) by Post Hoc tests (Tukey) (Table 6). There are several solutions to solve the problem. A solution is to reduce the duration time to about 3 months. It would be expected that the results lead up to satisfied results. Paints with insecticide also provided interestingly an optimal reduction of *P. americana* populations for three months<sup>21</sup>. Another appropriate choice is to use baits particularly gel baits. Although the use of bait formulations were considered to be effective against the cockroaches<sup>37-41</sup> while due to their application problems in the sewer failed to provide consistent control<sup>23</sup> and the use of spraying insecticides is the most popular method in the sewers. An important factor that was reported to affect baits performance against American cockroaches is sanitation<sup>42</sup>. Although sanitation has not been having a direct relationship with the domiciliary cockroach infestation levels, its role on bait performance against American cockroaches is unknown. A reasonable strategy is using a combination of integrated pest management strategies with strong vector control management such as sanitation, spraying and bait

formulations which are recommended for successful cockroach pest control including *P. americana*<sup>10,40</sup>.

The effectiveness of chlorpyrifos Fog formulation was also observed about 81.5 percent, respectively after 5 months of treatment in the manholes of sewer which they are also unsatisfied results. It would be more satisfied if it repeated every three months. Thermal fogging was observed to be the best and simplest method for cockroaches control in sewer system. As thermal fogs of this pesticide penetrated deeply into the hiding places and they were particularly useful in basements of buildings, sewers and drainage systems, it would be more successful requiring specialized equipment.

The insecticide formulations are considered effective when more than 90% of cockroach population density reduction is achieved. There are many problems in the control of cockroaches with the use of pesticides. The commonly used insecticides may lead to resistant in cockroaches. To complete the American cockroach life cycle, it takes between 4-12 months. The generations of the American cockroach per year are not as many as of other cockroach species, therefore the expression of resistant genes may take more time. Many pesticides are repellents to cockroaches. Control by chemical provides only temporary control, it is recommended that it accompany by other control methods<sup>43</sup>.

It is also well known that efficacy and persistence of insecticides in sewers depends on several factors such as organic matter amounts, conditions of climates, the cockroach population, the presence of cockroach resistant population, and the kind of active matter and formulation. It seems emerging resistant to insecticides is the most factors for the

efficacy and persistence of insecticides. Although the insecticide resistance in the German cockroaches has been well studied and emerged to a wide range of old and new insecticides including organophosphates, carbamates, pyrethroids, phenyl pyrazoles, spinosad, neonicotinoids and oxadiazines<sup>[29-32, 34, 41, 44-54]</sup>, while in the American cockroaches less studied. Recently has found *P. americana* cockroach resistant to malathion<sup>35</sup> and previously to trichlorfon and diazinon.

According to the study results, aqueous wettable powder of carbaryl and diazinon sprays provides suitable results in the control of *P. americana* population at least for one month. However, the effects of these pesticides on the cockroaches lasted for less than five months. This may be due to the inability of the pesticides to penetrate the egg sacs (oothecae) and the long life cycle and breeding of cockroaches in winter. Some insecticides lose their effectiveness after one month of application, as we observed the population of cockroaches after 5 months not only decreased but also increased. Results show that chlorpyrifos EC 5% and diazinon EC 5% were suitable pesticides for cockroach control which provided a suboptimal reduction of *P. americana* population density for five months respectively. These pesticides provide 80.5 and 53.5 percent efficacy, respectively for five months. Spraying emulsion with chlorpyrifos in water (EC) provides a quick and temporary knockdown of cockroaches, and gives semi-long-term control relatively.

Use of fire with oil as a physical control method which was applied caused a good efficacy against *P. americana* after one month. It would be more satisfied if it also repeated every three months. Because of destroying the oothecae of cockroaches, a suitable strategy in the control of cockroaches in manholes of sewers is using the fire by proper equipment.

Briefly the application of insecticide formulations was considered effective after 1 month of treatment, while did not achieve effectiveness after 5 months of treatment in sewer. It would be more satisfied if it repeated every three months. As insecticide resistance occurs due to the application of insecticides in very long period without field monitoring<sup>55</sup>. A reasonable manner is using a combination of integrated pest management strategies with strong vector control management recommending for successful cockroach pest control including *P. americana*.

**Table 7.** Post Hoc Tests (Tukey) after ANOVA analysis between applications of insecticides after 1 month against *P.americana* in sewer manholes

ANOVA analysis		Mean difference	Std. error	P-value
DiazinonEC 5%-	CarbarylWP 5%	6.4*	0.59	0.0001
	DiazinonWP 5%	8.1*	0.59	0.0001
	ChlorpyrifosEC 5%	8.1*	0.56	0.0001
	ChlorpyrifosWP 5%	8.1*	0.59	0.0001
	ChlorpyrifosEC 0.05%	8.1*	0.59	0.0001
	ChlorpyrifosEC 0.05%	7.8*	0.55	0.0001
	DiazinonWP 5%	7.9*	0.59	0.0001
	DiazinonEC 0.5%	7.6*	0.59	0.0001
	DiazinonEC 0.05%	7.1*	0.73	0.0001
	ResponsarSC 0.02%	8.1*	0.59	0.0001
	Cymperator Fog	8.1*	0.59	0.0001
	Diazinon Fog	8.1*	0.59	0.0001
	Chlorpyrifos Fog	8.1*	0.59	0.0001
	Boric acid bait	-9.7*	0.73	0.0001
Boric acid bait-	CarbarylWP 5%	6.5*	0.60	0.0001
	Fire	7.5*	0.59	0.0001
	CarbarylWP 5%	16.1*	0.76	0.0001
	DiazinonWP 5%	17.8*	0.76	0.0001
	ChlorpyrifosEC 5%	17.8*	0.74	0.0001
	ChlorpyrifosWP 5%	17.8*	0.76	0.0001
	ChlorpyrifosEC 0.05%	17.8*	0.76	0.0001
	ChlorpyrifosEC 0.05%	17.6*	0.73	0.0001
	DiazinonEC 5%	9.7*	0.73	0.0001
	DiazinonWP 5%	17.6*	0.76	0.0001
	DiazinonEC 0.5%	17.3*	0.76	0.0001
	DiazinonEC 0.05%	16.8*	0.88	0.0001
	ResponsarSC 0.02%	17.8*	0.76	0.0001
	Cymperator Fog	17.8*	0.76	0.0001
Diazinon Fog	17.8*	0.76	0.0001	
Chlorpyrifos Fog	17.8*	0.76	0.0001	
CarbarylWP 5%	16.2*	0.78	0.0001	
Fire	17.2*	0.76	0.0001	

\*The mean difference is significant at the 0.05 level.

**Conclusion**

The application of insecticide formulations was considered effective after 1 month of treatment, while did not achieve effectiveness after 5 months of treatment in sewer. It would be more satisfied if it repeated every three months. A reasonable manner is using a combination of integrated pest management strategies with strong vector control management recommending for successful *P. americana* cockroach control.

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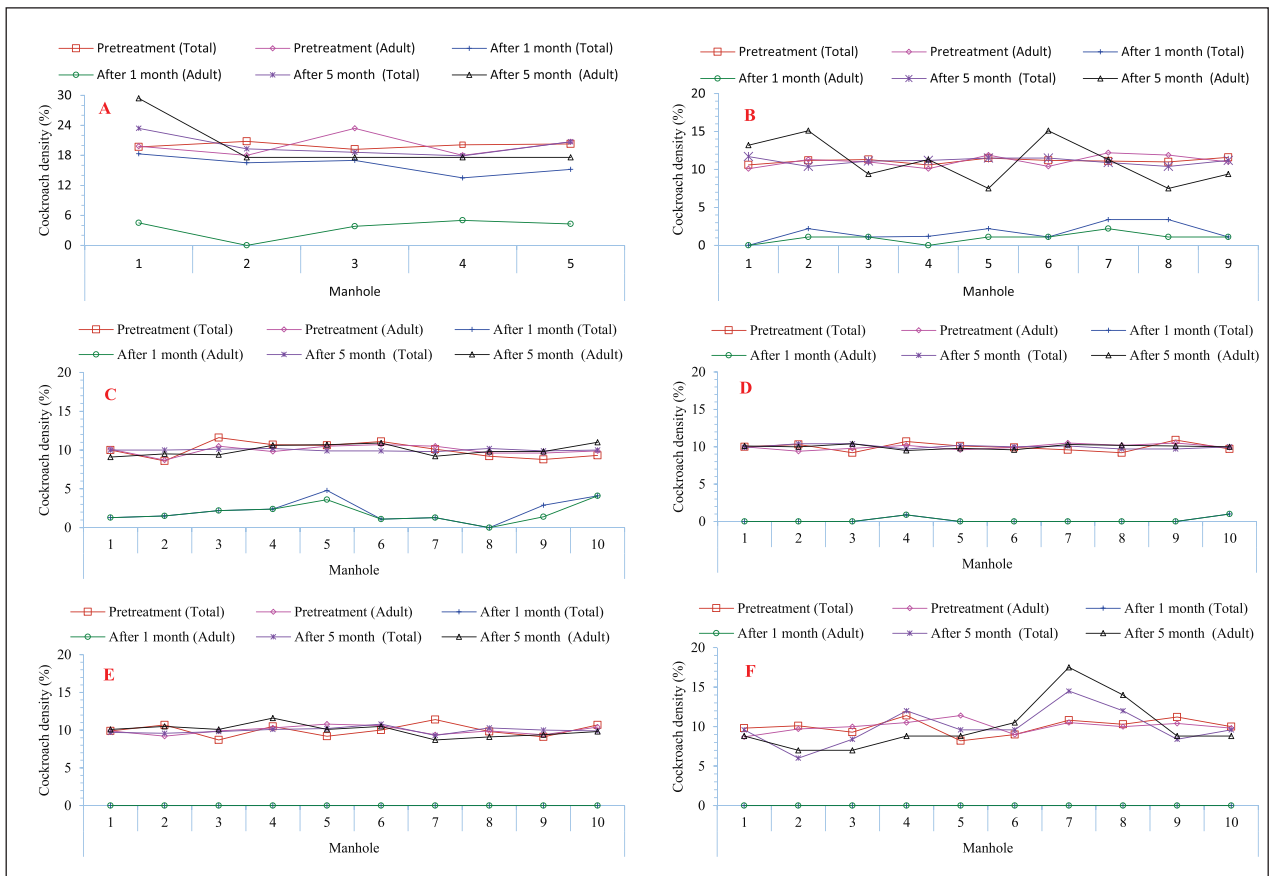
**Authors’s contribution:**

**Data gathering and idea owner of this study:** Saghafipour A.

**Study design:** Saghafipour A.

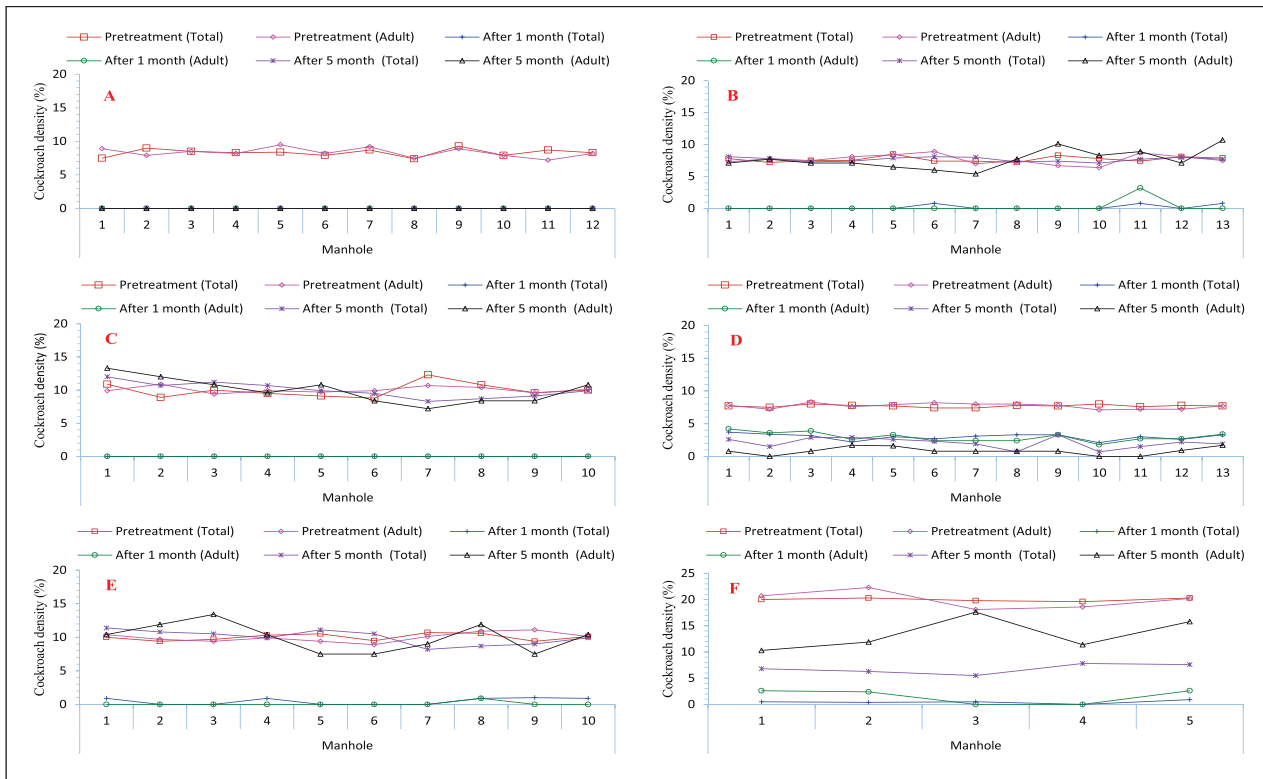
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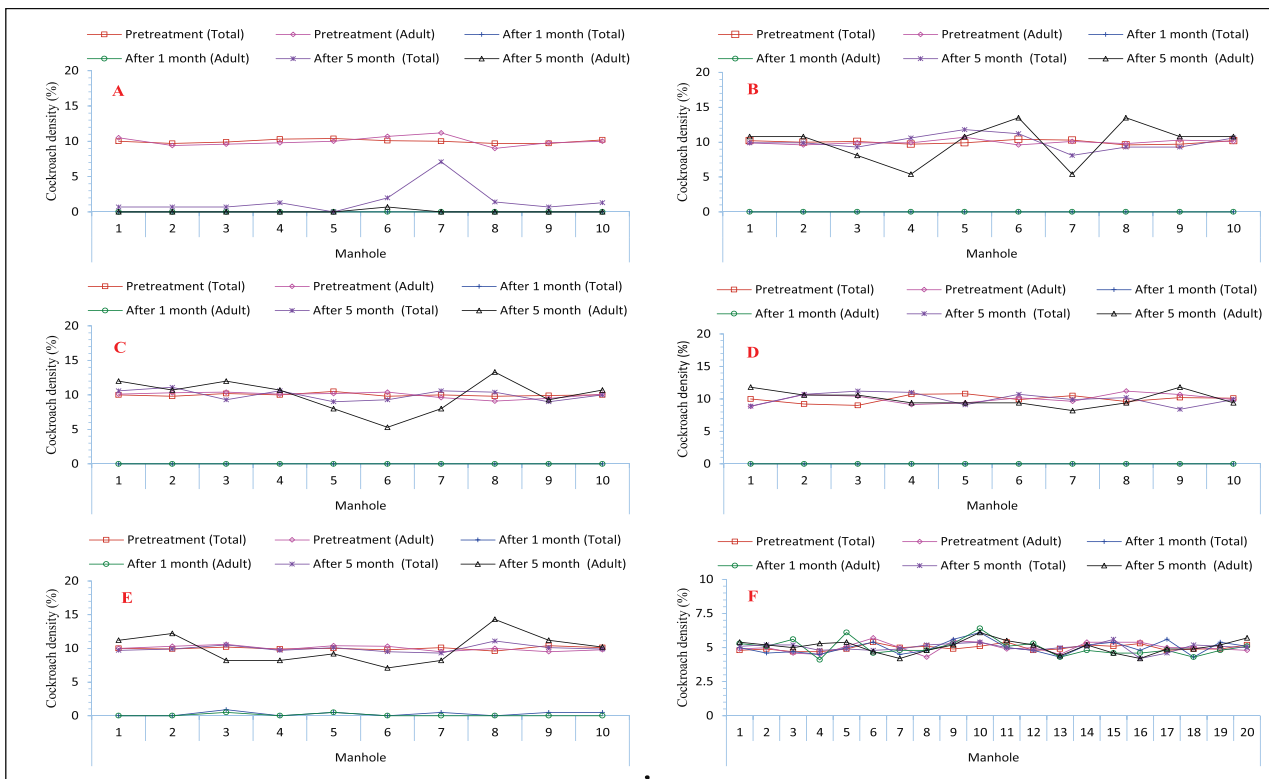


**Fig. 1.** Population density of *P. americana* cockroaches before and after application of bait and WP insecticide formulations in sewer manholes. A. Bait of boric acid, B. Bait of carbaryl 5%, C. Carbaryl WP 5%, D. Diazinon WP 5% (May), E. Diazinon WP 5% (November) and F. Chlorpyrifos WP 5%.

Efficacy of several insecticide formulations against *Periplaneta americana* (L.) (Blattaria: Blattidae) in sewers



**Fig. 2.** Population density of *P. americana* cockroaches before and after application of aqueous sprays of EC insecticide formulations in sewer manholes. A. Chlorpyrifos EC 5%, B. Chlorpyrifos EC 0.05% (May), C. Chlorpyrifos EC 0.05% (November), D. Diazinon EC 5%, E. Diazinon EC 0.5% and F. Diazinon EC 0.05%.



**Fig. 3.** Population density of *P. americana* cockroaches before and after application of thermal fogs SC and fire of insecticide formulations in sewer manholes. A. Chlorpyrifos Fog, B. Cymerator Fog, C. Diazinon Fog, D. Responsar SC 0.02%, E. Fire and F. Control (untreated).



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