EUROPEAN ACADEMIC RESEARCH
Vol. VI, Issue 10/ January 2019

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Seasonal indices of *Aedes aegypti* (Diptera: Culicidae) in an urban area of Kassala City, Sudan, 2014- 2015

RBAB MOHAMMED HAJHAMED AHMED[1]
Department of Community Medicine
Faculty of Medicine and Health Sciences
University of Kassala, Sudan
SHAWGI MOHAMED HASSAN
Department of Parasitology, Faculty of Veterinary Medicine
University of Khartoum, Sudan

Abstract

An entomological survey was carried out in and outside households in 20 clusters in Kassala City in summer, winter and autumn seasons during 2014/2015 to determine entomological indices of Aedes aegypti. Immature Aedes aegypti were collected in all positive containers. The number of population in each household was recorded to estimate pupal demographic index. All the water holding containers inside the households and around the households were inspected for immature stages of Ae. aegypti. All larvae and pupae were collected and numbers per container were recorded on entomological survey forms and were then counted and classified to larvae and pupae. The results revealed that the house index was recorded highest percent in summer at Alkrmota, and Birai (70%), while Pupal Demographic Index was higher in autumn season in 2014/2015 than other seasons. In winter, the highest percent of Breteau index during 2014 was in Garb Algash2 (18.9%). Most of the clusters were found at high risk in all indices. The study concluded that the information of the seasonal field surveys showed that Ae. aegypti was found in very high densities in some residential areas of Kassala City.

[1] Corresponding author: hababhamed115@gmail.com

Key words: Dengue virus, *Aedes aegypti*, Sudan

INTRODUCTION

Aedes aegypti, the principal vector of dengue viruses, is closely associated with human environments in endemic areas, where indoor and outdoor artificial containers like clay-pots, tires, barrels, flower-vase, cement basins and Jerry cans make adequate habitats for larval development (Troyo *et al*., 2008). Entomologic surveillance has been based on different larval indices (Chadee *et al*., 2007) namely the house index (HI), Breteau index (BI) and container index (CI) (Bowman *et al*., 2014). The entomological indices HI, CI, and BI for *Ae. aegypti* in India increased from July to October, and, thereafter, declined. CI, BI, and HI remained very high during the months of August and September (Sharma *et al*., 2005). In Thailand, HI for *Ae. aegypti* was higher than HI for *Ae. albopictus* in all seasons. HI in summer season was lower than HI in the winter and rainy seasons (Wongkoon *et al*., 2013). Aziz *et al*. (2014) found the relationship between rainfall and BI was able to provide a useful guide for the planning and implementation of *Aedes* spp. prevention activities. Pupal/demographic (PDI) survey was developed to replace the more traditional larval indices (Focks, 2003). The pupal indices (PI) are the best estimators of dengue transmission risk for two reasons. First, the values of the pupae-per-household and pupae-per-person indices were quite similar in the rainy and dry seasons whereas the traditional indices of HI, CI and BI, whose values were higher in the rainy season and fell in the following dry season (Jimenez-Alejo *et al*., 2017). The greatest seasonal variation in PI occurred in non-storage containers such as pots and tyres, with the mean number of pupae per container falling from the rainy season to the dry season (Garelli *et al*., 2009). The aim of

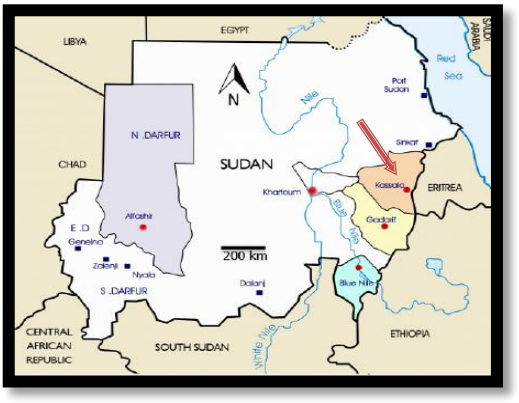
this study was to carry out entomological survey in Kassala City to determine entomological indices of *Aedes aegypti*.

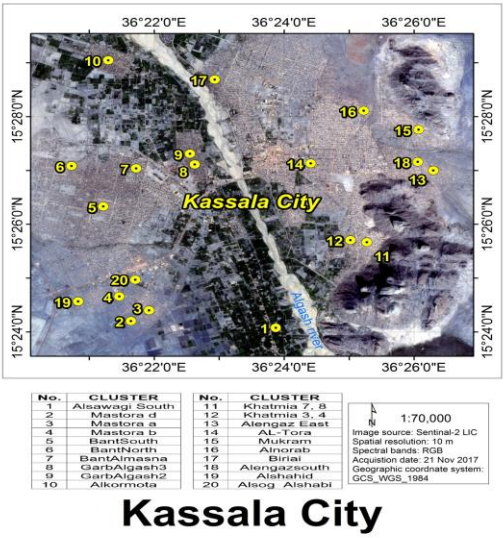
MATERIAL AND METHODS:

Study design: A cross sectional longitudinal entomological study was performed during the three seasons; dry (winter), hot (summer) and wet (autumn) for two consecutive years (2014 and 2015).

Study Site: Kassala City is the capital of Kassala State at the eastern parts of the Sudan (Map 1). The state has a total area of 55,374 km^2, lies between longitudes 34^o 12' and 36^o 57' E, and latitudes 15^o 12' and 17o 12' N. (Himatt *et al*., 2011) (Map 2). Mean maximum temperature occurs in summer months with an average of 40^{o}C in May and mean minimum temperature 15^{o}C in January. The State falls within the arid and semi-arid region where rainfall is unreliable for domestic and economic uses. The average total annual rainfall is about 225 mm occurring dominantly between May to October while evaporation amounts to 2- 2.5 mm.

Map 1: Map of Sudan – Kassala State





No.	CLUSTER
1	Alsawagi South
2	Mastora d
3	Mastora a
4	Mastora b
5	BantSouth
6	BantNorth
7	BantAlmasna
8	GarbAlgash3
9	GarbAlgash2
10	Alkormota

No.	CLUSTER
11	Khatmia 7, 8
12	Khatmia 3, 4
13	Alengaz East
14	AL-Tora
15	Mukram
16	Alnorab
17	Birial
18	Alengazsouth
19	Alshahid
20	Alsog Alshabi

Map 2: Map of Kassala city where sites (o) of sampling are numbered
Source: National Center for Research

Entomological survey:

Present entomological surveillance was undertaken in and outside household in 20 clusters in three different seasons during 2014/2015 in Kassala City. Immature *Aedes aegypti* were collected in all positive containers using a pipette and a sieve. Larvae and pupae were kept in plastic cups with 250 ml of water and labeled indicating location, date, time, house number, type of container, number of sample, indoor or outdoor collection, then, transported to the laboratory. These were identified according to the methods described by Rueda (2004), Cutwa and O'Meara, (2006), and Tun-Lin *et al.* (2009). The number of population in each house was recorded to estimate PDI. In the larval survey, various indices were used to record *Ae. aegypti* density level. They were measured by clusters and overall indices were, also, calculated and then compared according to the season. The entomological indices outcomes, both larval index (HI, CI, and BI) and Pupal index (PI, PDI);

were estimated on a household level. Some indices were calculated for measuring larval population in each cluster. These were HI, CI, BI, PI PDI. These indices were measured as follows: HI (No. of houses positive/No. of houses inspected*100), CI (No. of containers positive/No. of containers inspected*100), BI (No. of containers positive/No. of houses inspected*100), PI (No. of pupae/No. of houses inspected*100), and pupal/demographic index (PDI) (No. of pupae/No. of population*100). Both pupae and number of people associated with them were counted (Sharma *et al.*, 2005).

Statistical analysis:

Data collected on immature stages were subjected to an appropriate general linear model procedure of statistical analyses using EXCEL software.

RESULTS:

The mean average percent of indices of female *Ae. aegypti* in different seasons was recorded higher in PI in autumn season in two years 2014/2015 than other indices (Fig 1). The highest percent of house index of *Ae. aegypti* during 2014 was found in Alengaz East (64.2%), and the lowest in Garb Algash3, Bant North, and Alshahid (3.3%), while at Alsog Alshabi and Mastora Blocks a, b, and d none was recorded in winter. In summer, the highest percent of house index was in Alkrmota, and Birai (70%), and the lowest was in Mukram, Khatmia blocks 3, 4, and Alshahid (0.8%). At Alsog Alshabi and Mastora blocks a, b, and d, none was recorded in summer. In autumn of 2014, the highest percent of HI was in Bant Almasna (13.3%), followed by Khatmia blocks 3, 4 (11.7%), and the lowest was in Mukram and Alshahid (1.7%) (Table 1). The HI was recorded with high percent in winter of 2015 (17.5%) in Alengaz East, followed by Bant Almasna, Khatmia 7, 8, and Altora (9.2%),

and the lowest was in Alsawagi South (0.8%). None was recorded in Alsog Alshabi and Mastora blocks a, b, d in all seasons. In summer in 2015, the house index was recorded with high percent in Alengaz East (63.7%), followed by Khatmia 7, 8 (26.7%), and the lowest was in Birai (0.8%). In autumn in 2015, the highest percent of house index was in Mukram and Khatmia 3, 4 (10.8%), and the lowest in Altora and Alshahid (1.7%) (Table 1). In winter, the highest percent of BI during 2014 was in Garb Algash2 (18.9%) followed by Alengaz East (14.2%), and the lowest was in Alsawagi South (5%), while Alsog Alshabi and Mastora blocks a, b, and d none was recorded in winter. In summer, the highest percent of BI was in Garb Algash2 (28.3%), followed by Alkrmota (19.2%), and the lowest was in Khatmia blocks 3, 4, and Alshahid (0.8%). There was none at Alsog Alshabi and Mastora a, b, and d in summer. In autumn in 2014, the highest percent of BI was in Bant Almasna and Khatmia block 3 and 4 (17.5%), followed by GarbAlgash2 (16.7%), and the lowest at Alshahid (1.7%) (Table 2). The BI was high in winter in 2015 at Bant Almasna (17.5%), followed by Khatmia blocks 7 and 8 (15.8%), and the lowest was in Bant North, Mukram, Alengaz East, Alnorab and Alsawagi South (1.7 %). There was none at Alsog Alshabi and Mastora blocks a, b, d in all seasons. In summer of 2015, the BI was high in Alengaz East (13.3%), followed by Mukram (11.7%), and the lowest was at in Birai (1.7%). In autumn of 2015, the highest percent of BI was in Khatmia blocks 3 and 4 (18.3%), followed by Garb Algash2 and Alengaz South (15.8%), and the lowest was at Alshahid area (5.7%) (Table 2).

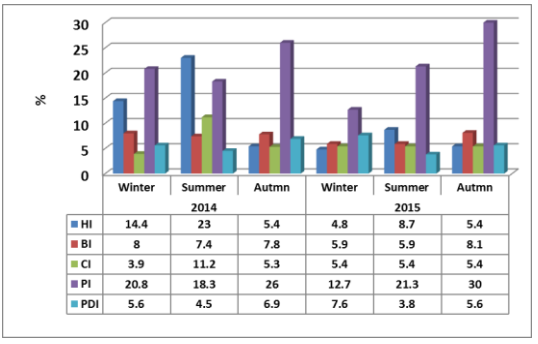
In winter, the highest percent of CI of 2014 was in Alengaz East(10.4%) followed by Khatmia 3,4 and Alengaz South (8.3%), and the lowest was at Alsawagi South (1.8%), while none was recorded at Alsog Alshabi and Mastora blocks a, b, and d in winter. In summer, the highest percent of CI was in Alsawagi South (40.2%), followed by Birai (29.1%), and the

lowest was in Alnorab (1.1%). None was at Alsog Alshabi and blocks a, b, and d in summer. In autumn of 2014, the highest percent of CI was in Mukram (16.7%), followed by Alshahid (15%), and the lowest was in Garb Algash 2 (0.4%) (Table 3). It was high in winter of 2015 at Mukram and Alsawagi South (11.1%), followed by Altora (10%), and the lowest was in Alshahid (0.4 %). None was recorded at Alsog Alshabi and Mastora blocks (a, b, d) in all seasons. In summer of 2015, the CI was high in Alengaz East (10.4%), followed by Khatmia blocks 3 and 4 (10.3%), and the lowest was at Alnorab (1.9%). In autumn of 2015, the highest CI was in Khatmia blocks 3 and 4 (10.9%), followed by Bant Almasna (10%), and the lowest was at Alkrmota, Alengaz South and Alsawagi (3.9%) (Table 3).

In winter, the highest percent of PI of *Ae. aegypti* during 2014 was in Garb Algash3 (82.7%), followed by Alengaz East (49.7%), and the lowest was in Bant South, and Alshahid (1.7%), while there was none at Alsog Alshabi and Mastora blocks a, b, and d in winter. In summer, the highest percent was at Alkrmota (111.7%) followed by Bant South (64.2%) and the lowest were in Alnorab (0.8%). There was none at Alsog Alshabi and Mastora blocks a, b, and d in summer. In autumn of 2014, the highest percent was at Khatmia blocks 7 and 8 (160%), followed by Bant South (80%), and the lowest was at Bant Almasna (0.2%) (Table 4). It was high in winter in 2015 in Bant Almasna (102.5%), followed by Alkrmota (33.3%), and the lowest was in Garb Algash 3 (0.8%). There was none at Alsog Alshabi and Mastora blocks a, b, d in all seasons. In summer of 2015, it was high in Bant Almasna (105.8%), followed by Garb Algash 3 (60%), and the lowest was in Alengaz South (1.7%). In autumn of 2015, the highest was in Garb Algash 3 (108.3%) followed by Biriai (97.5%), and the lowest was in Alengaz East (2.5%) (Table 4).

In winter, the highest PDI of *Ae. aegypti* in 2014 was in Garb Algash2 (49.6%), and the lowest was in Alshahid (0.5%),

while none was recorded in Alsog Alshabi and Mastora blocks a, b, and d in winter. In summer, the highest was in Alkrmota (26.9%) followed by Bant South (19.2%) and the lowest was in Khatmia blocks 3 and 4 (0.2%). None was recorded in Alsog Alshabi and Mastora blocks a, b, and d, Bant Almasna, Mukram, Alengaz South and Alshahid in summer. In autumn of 2014, the highest was in Khatmia blocks 7 and 8 (35.2%), followed by Bant Almasna (28.7%), and the lowest was in Garb Algash 3 (1.7%), There was none in Mukram and Alshahid in this season (Table 5). It was high in winter of 2015 in Alengaz East (84%), followed by Bant Almasna (23.6%), and the lowest was in Alshahid (1.4%). None was recorded in Alsog Alshabi and Mastora blocks a, b and d in all seasons. There was none in Mukram and Alnorab in this season. In summer of 2015, it was high in Bant Almasna (18.9%), followed by Khatmia blocks 3 and 4 (12%), and the lowest was in Alengaz South (0.3%). Bant North and Alshahid recorded none. In autumn of 2015, the highest was in Birai (19.7%) followed by Alkrmota and Alsawagi South (15.4%) and the lowest were in Alnorab (0.5%) (Table 5).



	Winter	Summer	Autmn	Winter	Summer	Autmn
	2014			2015		
HI	14.4	23	5.4	4.8	8.7	5.4
BI	8	7.4	7.8	5.9	5.9	8.1
CI	3.9	11.2	5.3	5.4	5.4	5.4
PI	20.8	18.3	26	12.7	21.3	30
PDI	5.6	4.5	6.9	7.6	3.8	5.6

Fig 1: Mean average (%) of Indices of female *Ae. aegypti* in different seasons in Kassala City during 2014 /2015

Table 1: Percent of House Index of female *Ae. Aegypti* in residential areas in different seasons in Kassala City during 2014 /2015

Residential areas	House Index					
	2014			2015		
	Winter	Summer	Autumn	Winter	Summer	Autumn
Alkrmota	5.8	70	8.3	6.7	5.0	9.2
GarbAlgash2	9.2	27.5	10	5.0	7.5	10
GarbAlgash 3	3.3	58.3	5.8	5.0	7.5	8.3
BantNorth	3.3	23.3	5.8	1.7	4.2	5.0
BantSouth	5.0	35	4.2	6.7	6.7	8.3
BantAlmsna	5.8	58.3	13.3	9.2	4.2	5.8
Mukram	23.3	0.8	1.7	1.7	20	10.8
Alengaz East	64.2	17.5	6.7	17.5	63.7	5.8
khatmia3,4	35	0.8	11.7	8.3	4.2	10.8
Biriai	23.3	70	10.8	3.3	0.8	4.2
khatmia7,8	30	58.3	9.2	9.2	26.7	3.8
Alengazsouth	63.2	1.7	5.0	5.0	5.0	8.3
ALnorab	5.0	1.6	5.5	1.7	3.3	5.8
ALtora	3.7	1.7	5.8	9.2	6.7	1.7
Alsog Alshabi	0.0	0.0	0.0	0.0	0.0	0.0
Alshahid	3.3	0.8	1.7	5.8	3.2	1.7
Alsawagi South	3.7	35	2.5	0.8	5.3	9.2
Mastora a	0.0	0.0	0.0	0.0	0.0	0.0
Mastora b	0.0	0.0	0.0	0.0	0.0	0.0
Mastora d	0.0	0.0	0.0	0.0	0.0	0.0
Mean Average	**14.4**	**23.0**	**5.4**	**4.8**	**8.7**	**5.4**

Risk level of dengue transmission based on larvae indices according to WHO (2000)

HI< 4% low, HI>30% high

Table 2: Percent of Breteau Index of female *Ae. Aegypti* in residential areas in different seasons in Kassala City during 2014 /2015

Residential areas	Breteau Index					
	2014			2015		
	Winter	Summer	Autumn	Winter	Summer	Autumn
Alkrmota	15.6	19.2	10	9.2	6.7	12.5
GarbAlgash2	18.9	28.3	16.7	9.2	15	15.8
GarbAlgash 3	11.7	25	10	6.7	10.8	10.8
BantNorth	4.2	4.2	9.2	1.7	2.5	6.7
BantSouth	7.5	11.7	9.2	9.2	7.5	12.5
BantAlmsna	10	10.8	17.5	17.5	5.8	10
Mukram	13.3	0.8	1.7	1.7	11.7	13.3
Alengaz East	14.2	2.5	8.3	1.7	13.3	5.8
khatmia3,4	9.2	0.8	14.2	9.2	6.7	18.3
Biriai	6.7	15.8	15	5.8	1.7	5.8
khatmia7,8	8.8	10.8	17.5	15.8	8.5	7.0
Alengazsouth	14	1.7	6.7	8.3	7.5	15.8
ALnorab	9.2	3.0	8.3	1.7	3.8	5.8
ALtora	5.4	4.2	5.0	8.3	7.0	5.8
Alsog Alshabi	0.0	0.0	0.0	0.0	0.0	0.0
Alshahid	7.0	0.8	2.7	10.3	1.8	5.7
Alsawagi South	5.0	8.3	3.3	1.7	8.3	10.8
Mastora a	0.0	0.0	0.0	0.0	0.0	0.0
Mastora b	0	0.0	0.0	0.0	0.0	0.0
Mastora d	0	0.0	0.0	0.0	0.0	0.0
Mean Average	8.0	7.4	7.8	5.9	5.9	8.1

Risk level of dengue transmission based on larvae indices according to WHO (2000)

BI< 5% low, BI > 50% high

Table 3: Percent of Container Index of female *Ae. aegypti* in residential areas in different seasons in Kassala City during 2014 /2015

Residential areas	Container Index					
	2014			2015		
	Winter	Summer	Autumn	Winter	Summer	Autumn
Alkrmota	4.25	16.1	3.8	8.0	6.4	3.9
GarbAlgash2	2.1	2.5	0.4	3.5	7.2	4.2
GarbAlgash 3	6.5	14.2	0.6	4.6	6.2	6.6
BantNorth	1.8	20.4	2.6	6.7	10.0	6.7
BantSouth	5.3	12.2	3.5	7.3	6.8	8.1
BantAlmsna	3.1	15.1	4.8	7.0	6.9	10.0
Mukram	5.8	5.6	16.7	11.1	4.1	8.6
Alengaz East	10.4	7.2	10.0	5.4	10.4	6.1
khatmia3,4	8.5	8.3	9.1	4.8	10.3	8.2
Biriai	2.4	29.1	9.1	6.1	6.7	8.3
khatmia7,8	8.3	14.7	10.9	5.9	6.7	10.9
Alengazsouth	8.3	7.4	5.3	6.9	5.3	3.9
ALnorab	2.0	1.1	2.4	9.2	1.9	6.1
ALtora	2.2	13.9	10.0	10.0	6.5	6.1
Alsog Alshabi	0.0	0.0	0.0	0.0	0.0	0.0
Alshahid	4.3	16.7	15.0	0.4	7.5	6.0
Alsawagi South	1.8	40.2	2.2	11.1	5.4	3.9
Mastora a	0.0	0.0	0.0	0.0	0.0	0.0
Mastora b	0.0	0.0	0.0	0.0	0.0	0.0
Mastora d	0.0	0.0	0.0	0.0	0.0	0.0
Mean Average	3.9	11.2	5.3	5.4	5.4	5.4

Risk level of dengue transmission based on larvae indices according to WHO (2000)

CI< 3% low, CI>15% high

Table 4: Percent of Pupal Index of female *Ae. aegypti* in residential areas in different seasons in Kassala City during 2014 /2015

Residential areas	Pupal Index					
	2014			2015		
	Winter	Summer	Autumn	Winter	Summer	Autumn
Alkrmota	41.7	111.7	19.2	33.3	30.0	60.0
GarbAlgash2	44.0	27.5	25.0	13.3	23.3	25.0
GarbAlgash 3	82.7	46.7	12.5	0.8	60.0	108.3
BantNorth	9.7	10	20.0	1.7	0.0	20.0
BantSouth	1.7	64.2	80.0	9.2	19.2	35.0
BantAlmasna	30	8.3	0.2	102.5	105.8	15.8
Mukram	5.8	0.0	0.0	0.0	4.2	21.7
Alengaz East	49.7	2.5	20.0	2.2	48.8	2.5
khatmia3,4	24.7	0.8	72.5	20	51.7	75.0
Biriai	6.7	35	20.0	10.8	29.2	97.5
khatmia7,8	23.8	30.8	160.0	10.8	23.3	50.0
Alengazsouth	47.5	0.0	18.3	20.0	1.7	15.8
ALnorab	28.3	0.8	17.0	0.0	7.3	2.5
ALtora	9.0	2.5	4.2	4.2	18.8	6.7
Alsog Alshabi	0.0	0.0	0.0	0.0	0.0	0.0
Alshahid	1.7	0.0	0.0	10.8	0.0	5.0
Alsawagi South	9.2	24.2	51.7	15.0	2.5	60.0
Mastora a	0.0	0.0	0.0	0.0	0.0	0.0
Mastora b	0.0	0.0	0.0	0.0	0.0	0.0
Mastora d	0.0	0.0	0.0	0.0	0.0	0.0
Mean Average	20.8	18.3	26.0	12.7	21.3	30.0

Risk level of dengue transmission of pupae index not determined by WHO yet.

Table 5: Percent of Pupal Demographic Index of female *Ae. Aegypti* in residential areas in different seasons in Kassala City during 2014 /2015.

Residential Areas	pupal Demographic index					
	2014			2015		
	Winter	Summer	Autumn	Winter	Summer	Autumn
Alkrmota	7.0	26.9	4.7	6.4	6.3	15.4
GarbAlgash2	49.6	4.5	3.5	2.7	3.2	6.4
GarbAlgash 3	9.0	10.3	1.7	8.1	7.2	14.5
BantNorth	1.5	2.2	4.1	0.3	0.0	2.9
BantSouth	0.3	19.2	10.7	1.9	3.2	4.3
BantAlmasna	3.5	0.0	28.7	23.6	18.9	3.0
Mukram	1.1	0.0	0.0	0.0	0.9	2.8
Alengaz East	11.6	0.9	5.8	84.0	10.5	0.5
khatmia3,4	5.0	0.2	18.8	4.9	12.0	7.7
Biriai	1.5	12.6	4.9	3.8	5.9	19.7
khatmia7,8	5.0	7.1	35.2	3.5	3.3	12.6
Alengazsouth	10.1	0.0	4.1	5.8	0.3	2.9
ALnorab	3.5	0.2	3.8	0.0	1.2	0.5
ALtora	1.7	0.8	1.9	1.8	2.9	1.3
Alsog Alshabi	0.0	0.0	0.0	0.0	0.0	0.0
Alshahid	0.5	0.0	0.0	1.4	0.0	1.1
Alsawagi South	1.3	5.7	9.1	2.9	0.5	15.4
Mastora a	0.0	0.0	0.0	0.0	0.0	0.0
Mastora b	0.0	0.0	0.0	0.0	0.0	0.0
Mastora d	0.0	0.0	0.0	0.0	0.0	0.0
Mean Average	5.6	4.5	6.9	7.6	3.8	5.6

Risk level of dengue transmission of pupae index not determined by WHO yet.

DISCUSSION

Seasonal variation and area variation of HI were observed in this study. HI was recorded with high risk in winter at Alengaz East than summer and autumn, and the lowest risk was in summer at Alshahid, Mukram, and Khatmia blocks 3, 4 in 2014. This may be attributed to reduction in water use in winter water storing lasting few weeks a fact which probably enhanced breeding of *Ae. aegypti*. This finding agrees with Oo *et al*. (2011) who found *Ae. aegypti* indices increased during the rainy season compared to the cool/dry and hot/dry seasons. In 2015, HI was high risk level in summer season at Alengaz East. This means that the most of this area inspected was positive for *Ae. aegypti*, which is extremely high compared to the suggested high critical threshold of >30%. This is possibly due to storage of water in this season. The observed differences between the year 2014 and the year 2015 might be due to climatic changes in Kassala City during the year 2015. This fact supported by the differences of meteorological values in Khartoum during the

two years. This disagrees with finding of Wongkoon *et al.* (2013) who found the HI in the summer season was lower than in the winter and rainy seasons. BI was recorded at high risk for dengue virus transmission in all the residential areas in the three seasons of the two years. However, in summer of 2014 most of residential area were at low risk level (BI < 5) similar to Bant North, Mukram, Alengaz East, Khatmia blocks 3 ,4, Alengaz South, Alnorab, Altora, and Alshahid. This finding agrees with Aziz *et al.* (2014) who reported that the relationship between rainfall and BI and the rainfall was not only strongly associated with BI, but influenced by occurrence and spatial pattern of dengue cases.

Container index was at high risk for dengue virus transmission in all the three seasons but at low risk in summer season in Alnorab area in 2015. In 2014, CI was at high risk in summer in six residential areas i.e. Alkrmota, Garb Algash3, BantSouth, Bant Almasna, Khatmia blocks 7 and 8, Alsawagi South. So, the increased number of positive containers lead to new breeding sites and increased adult mosquito population. This finding agrees with that of Sharma *et al.* (2005) in India who found that HI, CI, and BI for *Ae. aegypti* increased from July to October, and declined thereafter. CI, BI, and HI remained very high during the months of August and September, a finding which disagrees with Wijayanti *et al.* (2016) who recorded CI lower in the rainy season.

Bowman *et al.* (2014) found only two studies that calculated pupal indices, although 15 of the 18 studies reviews were published more than three years after WHO (2000) acknowledged that the traditional *Stegomyia* indices were inadequate for the measurement of dengue vector abundance. In the current study, for the calculated pupal indices, only one was reported with increases in the pupal index with no significant differences. It may be attributed to the low numbers of pupae recovered. Pupal index was also recorded with higher

percent in autumn season than winter and summer seasons in the two years. This agrees with Garelli *et al.* (2009) who reported the greatest seasonal variation in pupal index in non-storage containers such as clay pots and tyres, with the mean number of pupae per container falling from the rainy season to the dry season. On the other hand, the total percent of pupal demographic index was recorded higher in autumn season in 2014 than other seasons, but in 2015 it was higher in winter season than other seasons. There is no information on pupal demographic index on dengue virus transmission (Focks *et al.,* 2000).

CONCLUSIONS

We conclude that the indices for larval and pupal habitats (HI, CI, BI, PI and PDI) are good indicators of heavy infestation of residential areas, which is necessary for controlling the *Ae.aegypti* vector.

Recommendations

Routine immature stages controls should be applied in the whole environment. Particular attention should be given to specific containers, which represent the most productive breeding sites of *Ae. aegypti* .

Conflict of Interest

The authors declare no conflict of interest in relation to this work.

Acknowledgements

The authors thank the DAAD scholarship for funding this research and the Ministry of Higher Education and Scientific Research. Thanks are due to Red Crescent for financial support.

They also thank people of Kassala City for willingly collaborating with the project.

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