Physico-chemical characteristics of the mosquito breeding water in two urban areas of Cairo Governorate, Egypt

M.A. Kenawy,[1] S.E. Ammar,[2] H.A. Abdel-Rahman[1]

[1]Department of Entomology, Ain Shams University, Cairo; [2]Biology Department, School of Science and Engineering (SSE), American University (AUC), Cairo, Egypt

Abstract

Certain physico-chemical characteristics of mosquito breeding habitats [temperature, pH, salinity, turbidity, dissolved oxygen (DO) and nitrite] were examined relative to the distribution of mosquito larval species in two urban areas of Cairo Governorate namely El-Muqattam (M) and Abu-Seir (A). Mean values and ranges of such characteristics for the reported mosquito species (*Culex pipiens*, *Cx. perexiguus*, *Ochlerotatus caspius*, Cx. *pusillus* and *Culiseta longiareolata*) were reported. In conclusion, based on the significant correlations of the different characteristics with the abundance of the two common larval species (*Culex pipiens* and *Cx. perexiguus*), salinity and DO may be considered the predictor variables associated with the immature abundance. Considering altogether mosquitoes, there is an increasing presence from planned safe (M) to unplanned unsafe (A) habitats mainly due to turbidity and nitrite.

Introduction

Twenty nine mosquito species belong to five genera (*Culex*, *Anopheles*, *Culiseta, Ochlerotatus* and *Uranotaenia*) are indigenous in Egypt, of which seven species*:* *Culex* (*Culex*) *pipiens* Linnaeus, *Cx.* (*Cx.*) *perexiguus* Theobald*, Cx. (Cx.) antennatus* Becker *Cx.* (*Barraudius*) *pusillus* Macquart, *Ochlerotatus* (*Ochlerotatus*) *caspius* (Pallas), *Culiseta* (*Allotheobaldia*) *longiareolata* (Macquart) and *Uranotaenia* (*Pseudoficalbia) unguiculata* Edwards**)** are present in the urban areas of Cairo Governorate (Tawfick, 1990; Morsy *et al*., 2003).

Culicine mosquitoes in Egypt mainly *Culex pipiens* and *Cx. perexiguus* are vectors of filariasis (Harb *et al.,* 1993), Rift valley fever virus (Meegan *et al*, 1980), West Nile virus and several other viruses (Darwish & Hoogstraal, 1981).

To control mosquitoes, a good knowledge and understanding of the relevant biology and ecology of the target species is of paramount importance (Seghal & Pillai, 1970; Gimnig *et al.,* 2001). Moreover, the knowledge of the ecological characteristics of the breeding habitats and the environmental factors affecting mosquito abundance can help in designing optimal vector control strategies (Overgaard *et al.,* 2001)

Generally, mosquitoes breed in a wide range of habitats with different types of waters that are known to be specific for many species. The physical and chemical nature of the water probably determines the selection of the breeding sites (Seghal & Pillai, 1970). It was reported (Piyaratnea *et al.,* 2005) that breeding water quality is an important determinant of whether female mosquitoes will lay their eggs, and whether the resulting immature stages will successfully complete their development to the adult stage.

In Egypt, apart from comparatively little information on certain physical and chemical factors mainly temperature, pH and salinity relative to mosquito breeding; (Kenawy *et al.*, 1996, 1998; Abdel-Hamid *et al.,* 2009, 2011a, 2011b, 2011c) no additional information is available. Hence, detailed studies on the physico-chemical properties of the different types of mosquito breeding habitats in Egypt are lacking.

This study was undertaken to characterize the larval habitats of culicine mosquitoes in two urban areas of Cairo Governorate and to examine the relation of the physico-chemical factors of the breeding waters with the occurrence and abundance of particular mosquito species.

Materials and methods

The study area

The study was carried out in two localities representing different levels of urban planning in Cairo Governorate (Figure 1): El-Muqattam (30°21'21"-29°58'52" N latitudes and 31°20'52"-31°16'1" E longitudes) which is located in southeast of Cairo and Abu-Seir (30°10'43"-30°09'11" N and 31°23'56"-31°22'11" E) which is located in northeast of Cairo within El-Marg district. El-Muqattam (M) is considered as a planned area, but some parts of it are considered as unsafe because it

Correspondence: Mohamed A. Kenawy, Department of Entomology, Faculty of Science, Ain Shams University, Abbassia, Cairo 11566, Egypt.
Tel.: +202.24821633/24821096/24821031, Ext: 711 - Fax: +202.26839622 - Mobile: +2.01223540005/01111151554.
E-mail: mohamedkenawy85@yahoo.com

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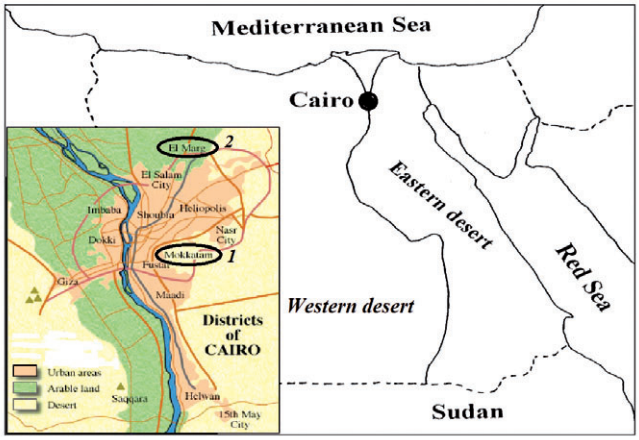

Figure 1. Location of the two study localities: El-Muqattam (1) and Abu-Seir (2) within Cairo Governorate.

lacks a piped sewage system. Abu-Seir (A) is considered as unplanned unsafe area according to the National slum upgrading policy criteria (Ammar *et al.,* 2012). Furthermore, Abu-Seir is surrounded by agriculture lands with associated farm animals. The two localities differ in the distribution of mosquito breeding habitats: springs and spring canals (planned safe M), cesspools and cesspits (planned unsafe M) and cesspits, cesspools, drainage canals, irrigation ditches and seepage water (A).

Water sampling and collection of mosquito larvae

Water samples for physico-chemical analysis were collected (March to July 2011) from the different breeding habitats in the two localities. Samples were collected in plastic wide mouth bottles (1000 mL) and immediately placed in a lightproof insulated box containing ice and transported to the laboratory for analysis.

Simultaneously with water sampling, larvae were collected by dipping (WHO, 1975) using a plastic dipper, 125 mm in diameter with a 900 mm wooden handle. Collected larvae were placed in labeled plastic bags (Whirl-Pak® 4002 filline, Nasco Corp., Fort Atkinson, WI, USA) and transported to the laboratory in a picnic icebox containing cold water to prevent overheating. At the laboratory, 3rd and 4th larval instars were identified according to the Keys of Harbach (1985) and counted. For each breeding habitat, 2-3 survey stations (each represented by 10 dips) were selected for larval collection once a month during the study period. Larval density was expressed as the number of larvae collected per dip.

Water analysis

Physico-chemical parameters (temperature, pH, salinity, turbidity, dissolved oxygen: DO and nitrite) were determined for the seven types of mosquito breeding habitats considered in El-Muqattam (M) and Abu-Seir (A); spring, spring canal, cesspit, cesspool, drainage canal, irrigation ditch and seepage water.

The water temperature was measured in situ before the samples were collected. The water samples were analysed for pH, salinity (%) and dissolved oxygen (DO, mg/L) using a Horiba Water Quality Checker U-10™ (Horiba Instruments Inc., Irvine, CA, USA). The turbidity in nephelometric turbidity unit (NTU) was measured onsite using a HACH turbidimeter 2100N™ (HACH Company, Colorado, USA) while the nitrite (mg/L) was measured by a Unicam UV2-300™ spectrophotometer (Unicam Ltd., Cambridge, UK). Analysis was carried out according to the standard methods of the American Public Health Association (APHA, 1998).

Statistical analysis

Means and Standard Deviations were calculated and compared by the one-way ANOVA. If the ANOVA shows significant inequality of the means at P=5%, they were exposed to pairwise comparisons based on Tukey's honestly significant difference (HSD) test. The multiple regression analysis was applied to examine the relation of the mosquito larval densities to the physico-chemical factors of the breeding water. The slopes (regression coefficients) of the regression equations were tested for deviation from zero by t-test. The SPSS software (Version 11 for windows, SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Results

Relative abundance of mosquito larvae

A total of 3194 larvae of five species were collected from the two localities of which *Culex pipiens* (72.2%), *Cx. perexiguus* (19.6%) were the common species, whereas *Ochlerotatus caspius* (5.8%), *Cx. pusillus* (2.1%) and *Culiseta longiareolata* (0.3%) were uncommon.

Physico-chemical characteristics

The compiled ranges of the determined physico-chemical parameters in the different breeding habitats were calculated for each species of mosquito larvae in the two localities. The comparative results (Table 1) show that: i) *Cx. pipiens* and *Cx. perexiguus* have lower temperature and pH ranges, higher salinity and turbidity ranges and narrower DO range in M than in A; ii) *Oc. caspius*: has lower temperature and DO ranges, higher pH, and salinity ranges in M than in A, while turbidity ranges are

Table 1. Ranges of physico-chemical parameters of the mosquito breeding water in El-Muqattam and Abu-Seir.

Species	Locality	Temp (°C)	pH	Salinity (%)	Turbidity (NTU)	DO (mg/L)	Nitrite (mg/L)
Cx. pipiens	M	17-26	5.1-7.8	0.62-1.21	4.4-400.7	3.3-7.6	0-0.6
	A	20-30	5.0-8.7	0.05-0.49	4.0-333.5	2.1-8.7	0
Cx. perexiguus	M	17-26	5.0-7.8	0.62-1.21	4.4-485.2	2.8-7.6	0-0.6
	A	20-30	5.0-8.7	0.05-0.49	4.0-333.5	2.1-8.7	0-25.0
Cx. pusillus	A	20-30	5.0-5.5	0.05-0.49	21.9-333.5	2.1-5.1	0-25.0
Oc. caspius	M	17-23	7.7-7.8	0.95-1.21	4.4-5.4	6.9-7.6	0-0.6
	A	22-30	6.8-7.0	0.05-0.09	4.0-5.1	7.4-8.7	0
Cs. longiareolata	M	17-23	7.7-7.8	0.95-1.21	4.4-5.4	6.9-7.6	0-0.6

DO, dissolved oxygen; M, El-Muqattam; A, Abu-Seir.

nearly similar in the two localities; iii) *Cx. pipiens* and *Oc. caspius* breed in water free of nitrite in A, while in M breeding water has 0-0.6 mg/L; iv) *Cx. perexiguus* has a lower nitrite range (0.0-0.6 mg/L) in M than in A (0-25.0 mg/L); v) *Cx. pusillus* present only in A and *Cs. longiareolata* present only in M with different ranges.

Comparison of the mean values for such parameters (Table 2) revealed that in M, significantly higher means of temperature in cesspools, pH, salinity and DO in springs and spring canals and turbidity in cesspits and cesspools. Insignificantly higher mean of nitrite (P>0.05) was observed in springs. In A, significantly higher means of pH in irrigation ditches and seepage water, salinity in seepage water, turbidity in cesspits and DO in irrigation ditches. Higher means (P>0.05) of temperature and nitrite were recorded in cesspools than in the other habitats.

Means for the different breeding habitats were compiled and compared to detect any difference between the two localities and results (Table 3) revealed that: i) significantly lower temperature and higher pH, salinity and DO in planned safe area (M) than in unsafe areas whether planned in M or unplanned in A; ii) significantly higher turbidity in planned unsafe area (M) than in planned safe in M or unplanned unsafe in A; iii) insignificantly different (P>0.05) means of nitrite in the three areas; and iv) considering altogether mosquitoes, there is an increasing presence from planned safe to unplanned unsafe habitats mainly due to turbidity and nitrite.

Effect of physico-chemical factors on larval densities

Multiple regression analysis for the effect of physico-chemical factors on densities of the two common species (Table 4) revealed that densities of both *Cx. pipiens* and *Cx. perexiguus* in the two localities were directly related to temp, pH, DO and nitrite but were indirectly related to salinity and turbidity.

Discussion

The different breeding habitats in the two localities showed difference in their physico-chemical characteristics

Mosquito immature stages are poikilothermic and therefore, their activity depends to a large extent on the temperature of the water they inhabit. Besides nutrition, temperature is the main factor that affects the development and growth of mosquito larvae (White, 1974). In general, an increase in water temperature will result in faster development of aquatic stages, but will decrease the size of the emerging adults (Bayoh & Lindsay, 2003) and at higher temperatures fewer adults are produced due to increased mortality (Bayoh & Lindsay, 2004). WHO (1975) stated that the average optimum temperature for development of most mosquito species is around 25-27°C. In the present study, a temperature range of 17-30ºC was observed for the five reported species. In the other parts of Egypt, the reported temperatures ranged between 19 and 34°C (Kenawy *et al.,* 1996; Abdel-Hamid *et al.,* 2011c).

MacGregor (1927) recorded acidophile and alkalinophile mosquito larval species. The observed acidic to alkaline range of 5.0-8.7 for *Cx. pipiens*, *Cx. perexiguus* and *Oc. caspius* is similar to 6.4-9.0 observed by Gad & Salit (1972) in the Red Sea. Alkalinity was observed for *Cs. longiareolata* (7.7-7.8) while the acidophilly *of Cx. pusillus* (5.0-5.5) may be due to the nature of its breeding habitats (cesspits and cesspools).

Based on water salinity, Kirkpatrick (1925) classified mosquito fauna of Egypt to purely fresh water breeders, purely salt water and more or less indifferent. It was observed that in general breeding habitats of the five species having fresh/brackish water (0.05-1.2%) in agreement with the observation of Abdel-Hamid *et al*. (2011c) for *Cx. pipiens* and *Cx. perexiguus* in El-Ismailia. Gad *et al*. (1987) found that *Oc. caspius* inhabited

Table 2. Physico-chemical characteristics of the breeding water in El-Muqattam and Abu-Seir.

Parameter	Locality	Mean (SD)						
		Spring	Spring canal	Cesspit	Cesspool	Drainage canal	Irrigation ditch	Seepage water
Temperature (°C)	M	20.00 (2.23)^{a}	20.00 (2.24)^{a}	22.60 (2.07)^{a}	23.70 (2.00)^{b}	-	-	-
	A	-	-	23.70 (2.70)^{a}	26.60 (3.58)^{a}	22.80 (2.80)^{a}	26.50 (3.39)^{a}	26.30 (2.59)^{a}
pH	M	7.76 (0.05)^{a}	7.76 (0.05)^{a}	5.40 (0.39)^{b}	5.30 (0.14)^{b}	-	-	-
	A			5.22 (0.15)^{a}	5.32 (0.19)^{a}	6.26 (0.21)^{b}	6.90 (0.07)^{c}	6.75 (0.05)^{c}
Salinity (%)	M	1.08 (0.11)^{a}	1.25 (0.11)^{a}	0.83 (0.06)^{b}	0.69 (0.08)^{c}	-	-	-
	A	-	-	0.37 (0.08)^{a}	0.17 (0.06)^{b}	0.23 (0.02)^{b}	0.07 (0.02)^{c}	2.10 (0.22)^{d}
Turbidity (NTU)	M	4.88 (0.41)^{a}	4.36 (0.79)^{a}	419.22 (44.47)^{b}	335.98 (79.51)^{b}	-	-	-
	A	-	-	252.52 (48.97)^{a}	52.10 (22.82)^{b}	82.10 (12.79)^{b}	3.82 (1.07)^{c}	9.50 (2.05)^{c}
DO (mg/L)	M	7.19 (0.28)^{a}	7.43 (0.31)^{a}	2.92 (0.11)^{b}	3.75 (0.32)^{c}	-	-	-
	A	-	-	2.46 (0.61)^{a}	4.55 (0.72)^{b}	3.75 (0.47)^{c}	7.97 (0.57)^{d}	3.05 (0.64)^{ac}
Nitrite (mg/L)	M	0.20 (0.23)^{a}	0.02 (0.04)^{a}	0^{a}	0^{a}	-	-	-
	A	-	-	0^{a}	7.40 (11.13)^{a}	0^{a}	0^{a}	0^{a}

M, El-Muqattam; A, Abu-Seir; DO, dissolved oxygen. ^{a,b,c,d}Means followed by the same letters are not significantly different at (P>0.05) using ANOVA and Tukey's HSD test.

Table 3. Comparative physico-chemical characteristics of the breeding water and associated mosquito larvae in the two localities.

	Mean		
	El-Muqattqm		Abu-Seir
	Planned safe (n=10)	Planned unsafe (n=10)	Unplanned unsafe (n=25)
Temperature (°C)	20.0 (2.11)[a]	23.15 (2.00)[b]	25.18 (3.22)[b]
pH	7.76 (0.05)[a]	5.35 (0.28)[b]	6.09 (0.73)[c]
Salinity (%)	1.16 (0.14)[a]	0.76 (0.10)[b]	0.59 (0.79)[c]
Turbidity (NTU)	4.62 (0.66)[a]	377.60 (74.92)[b]	79.81 (95.58)[c]
DO (mg/L)	7.31 (0.31)[a]	3.34 (0.50) [b]	4.36 (2.06) [c]
Nitrite (mg/L)	0.11 (0.19)[a]	0[a]	1.48 (5.46)[a]
All mosquito species	5.38 (4.91)[a]	15.69 (15.65)[b]	41.69 (50.43)[c]

DO, dissolved oxygen. [a,b,c,d]Means followed by the same letters are not significantly different, (P>0.05) using ANOVA and Tukey's HSD test.

Table 4. Multiple regression analysis for the effect of physico-chemical factors on larval densities of the two common mosquito species.

Factor	The slope (regression coefficient)			
	Cx. pipiens		*Cx. perexiguus*	
	El-Muqattam	Abu- Seir	El-Muqattam	Abu- Seir
Temperature (°C)	1.35	1.23	1.02	0.26
pH	9.46	83.43*	4.33	18.29*
Salinity	-21.55*	- 4.04*	- 7.86*	- 20.72*
Turbidity	- 0.03	- 0.02	- 0.01	- 0.04
DO	6.11*	30.61*	2.01	8.05*
Nitrite	15.37*	0.25	21.17*	0.02

DO, dissolved oxygen. *Significantly deviated from zero (P<0.05, t-test).

breeding pools that were characterized by brackish water having high salt content.

It was reported (Sattler *et al*., 2005) that in turbid breeding sites culicine larvae were much more likely to be present, whereas *Anopheles* larvae were much more likely to be absent. This is supported by the wide ranges of turbidity (up to 485.2 NTU) reported for the three *culex* species: *Cx. pipiens*, *Cx. perexiguus* and *Cx. pusillus* which indicates the tolerance of such species of highly turbid water. The preference of culicine mosquitoes for turbid water is coherent with their known breeding site preferences, as they breed successfully in rather polluted environments such as blocked drains and septic tanks (Chavasse *et al.,* 1995). The low turbidity ranges reported for *Oc. Caspius* (4.0-5.4 NTU) agrees with Seghal & Pillai (1970) observation in Delhi where *Anopheles* and *Culex* were found to breed in highly turbid waters, in contrast to the three species of *Aedes*, which inhabited waters of low turbidity.

Sehgal & Pillai (1970) observed that breeding waters of *Aedes* showed higher oxygen content than those of *Culex* and *Anopheles*. Similarly in this study, higher DO range was reported for *Oc. caspius* (6.9-8.7 mg/L) than those for the other species.

Mosquitoes were found breeding in water free of nitrite or that having low content (0.6 mg/L) such as *Cx. pipiens*, *Oc. caspius* and *Cs. longiareolata* or that having higher content (25 mg/L) such as *Cx. perexiguus and Cx. pusillus.* Although there are no available reports on nitrite contents for such species, however Salit *et al*. (1996) detected that *Cx. pipiens* larvae in Kuwait State may tolerate various degrees of nitrite content as compared with other mosquito species. The higher nitrite content associated with higher larval density in A may be attributed to the use of fertilizers in the exiting fields. Sunish & Reuben (2002) in India reported that the application of synthetic nitrogenous fertilizers to the rice fields was followed by a rise in concentration of ammonia nitrogen and a subsequent increase in nitrate nitrogen level in the rice field water, during which an increase in the density of larval instars was observed. Considering the compiled density of all mosquito species, there is an increasing occurrence from planned safe (M) to unplanned unsafe (A) habitats mainly due to turbidity and nitrite.

Sunish & Reuben (2002) investigated the relationship of 13 abiotic variables with the abundance of *Cx. vishnui* immatures in rice fields in south India. The results from the multiple regression models suggested that water temperature (+ve), DO (–ve), ammonia nitrogen (–ve) and nitrate nitrogen (+ve) to be the best predictor variables associated with the immature abundance. In this study, densities of both *Cx. pipiens* and *Cx. perexiguus* in the two localities had +ve relation with temperature (P>0.05) and pH (P>0.05 in M and P<0.05 in A) and –ve relation with salinity (P<0.05). Almost similar results were obtained by Kenawy *et al*. (1996) and Abdel-Hamid *et al*. (2011a) in other Egyptian Governorates. The two species were positively associated with DO while it was reported that mosquito breeding is negatively correlates with DO (Adebote *et al*., 2008) and chloride (Muturi *et al*., 2007, 2008). It was found that turbidity was negatively associated (P>0.05) and nitrite was positively associated with the abundance of the two species. Mala & Irungu (2011) showed that the levels of nitrogen in different habitats are not affected by the presence of larvae although there was evidence for decreasing nitrogen levels with increasing larval densities.

In conclusion, based on the significant relations of the characteristic variables with the abundance of the two common larval species, salinity and DO can be considered as the predictor variables associated with the immature abundance. Considering altogether mosquitoes, there is an increasing presence from planned safe to unplanned unsafe habitats mainly due to turbidity and nitrite. The obtained results may be of help in designing and implementing control program based on environmental manipulation.

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