Role Of The Construction Industry In Promoting Mosquito Breeding In And Around The Accra Metropolis, Ghana

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Abstract: A wide range of water-holding containers are exploited by mosquito vector as sites for oviposition of eggs and larvae development. The study was aimed at determining the role of the construction industry in promoting mosquito breeding in and around the Accra metropolis, Ghana. A two-month larval survey was carried out at selected construction sites in and around the Accra metropolis. Routine daily larval sampling was done from mosquito breeding sites at the construction sites using the dipper method. Larvae samples were collected from sites such as small pools of water collection and concrete water containers. The larval population was estimated for each breeding site and the physical and chemical characteristics of the breeding sites were recorded. The presence of other aquatic fauna and flora were also noted and recorded. Water samples for a total of 30 different construction sites were sampled. Seventy percent (21/30) of the breeding sites sampled were positive for mosquito larvae. A total of 1475 mosquito larvae comprising of the three main genera: *Culex*, *Aedes* and *Anopheles* were collected. *Culex* species occurred in all the breeding sites and made up 54.1% of the overall sample collection, followed by *Aedes* species (28.1%) and *Anopheles* species (17.8%). A number of other fauna and flora, non-target organisms, were observed both at the sites and in the collected samples. These included *Odonata* nymphs, *Notonectidae*, water snail (*Bulinus* species), tadpoles and algae. The results of this study indicate that residential development sites should be strongly considered for inclusion in the local mosquito surveillance and control programs in order to reduce the public health risk related to the construction industry.

Index Terms: Accra, breeding sites, construction industry, mosquitoes, larvae.

1 INTRODUCTION

Mosquitoes are important vectors of many diseases, of which malaria is the most important. Despite the vast work and literature on malaria, progress in both control of the disease and vectors have been slow. A set of factors has been recorded as contributing to the problem. Malaria control is hampered by a lot of factors such as (1) resistance of the *Plasmodium* parasites to the drugs used to treat them (2) resistance of the mosquito vectors to the insecticides been used to control them (3) differences in the biology of malaria vectors (4) political instability (5) poverty (6) human behavior [1], [2], [3], [4]. These factors hamper the development of universally applicable strategies to malaria control. The success of any control method for malaria will depend entirely on a complete understanding of the transmission pattern of the disease and its vectors as well as the human behavior and activities that aid its transmission. In a six-month preliminary study carried out in the Accra metropolis on mosquito breeding sites, it was observed that mosquito breeding was mainly as a the direct result of changes in the environment caused by the activities for socio-economic development such as the construction industry [5]. This observation had also been documented [6]. There is inadequate data on the link between the construction industry and mosquito breeding in Ghana and the Accra metropolis in particular. This study therefore determined the role of the construction industry on mosquito vector distribution in the Accra metropolis. It is hoped that it will provide an entomological database for the metropolis to aid in the design of appropriate mosquito control strategies to be used by the construction industry in the various construction projects undertaken.

2 MATERIALS AND METHODS

2.1 Study areas

Studies were conducted at different sites within the Accra Metropolitan Assembly and at Pokuase and Gbawe. All the sites are in the Greater Region of Ghana (Fig. 1). The Accra metropolis is the capital of Ghana. The coastal city lies within longitudes 00º 01' East and 00º 21.5' West; and between latitudes 5º 41.5' North and the Gulf of Guinea in the South. The climate is tropical and the vegetation is the semi-arid, coastal savannah type. The city experiences generally low and erratic rainfall pattern. There are two main rainy seasons, the major and minor seasons. Most of the rainfall is recorded between March and July. The population is approximately 2 million, and the population consists of various socio-economic groups whose main activity is non-agricultural [7]. Gbawe is the administrative capital of Ga South Municipal. The Municipality forms part of sixteen (16) Metropolis, Municipalities and Districts in the Greater Accra Region. The Ga South Municipal lies within latitude 5^o 48 North 5^o 29 North and latitude 0^o 8' West and 0^o 30' West. The Municipality shares boundaries with the Accra Metropolitan

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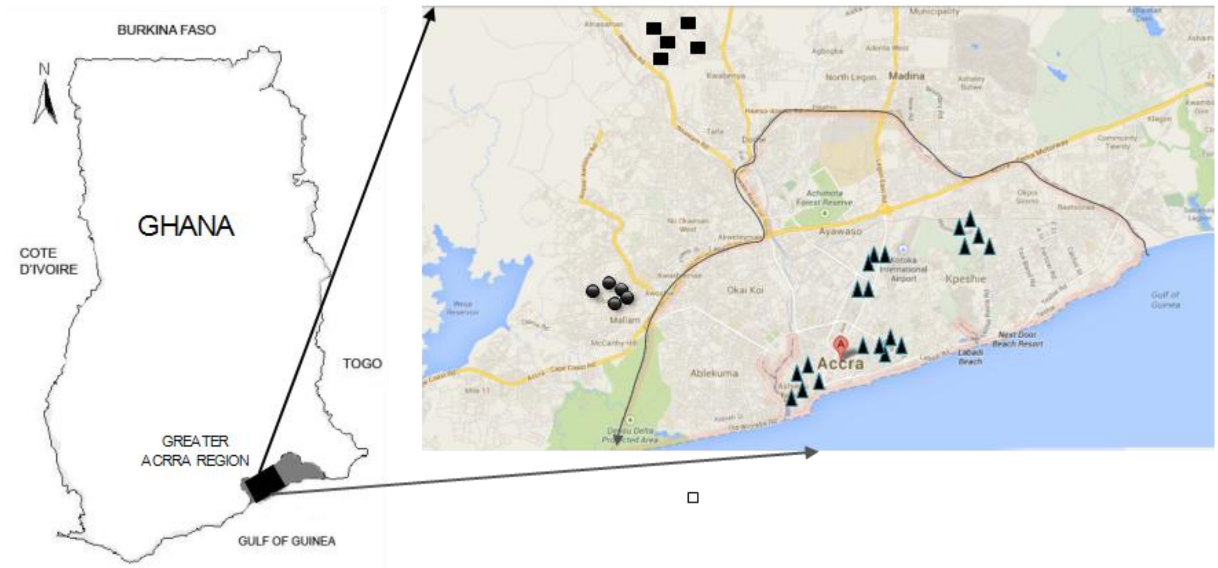

Fig. 1. Map of Ghana showing the sampling sites.

KEY: ■ Sites at Pokuase; ● Sites at Gbawe ▲Sites within Accra Metropolitan Area

to the South-East. The Municipality lies wholly in the coastal savanna agro-ecological zone with secondary forest in the hinterlands where rainfall is high. The rainfall pattern is bi-modal with an annual mean varying between 790mm on the coast to about 1270mm in the extreme north. The annual average temperature ranges between 25.1ºC and 28.4ºC and February and March are the hottest months. It has a relative humidity of about 75%. Pokuase is one of the towns in the Ga West Municipal Assembly. The Municipality forms part of sixteen (16) Metropolis, Municipalities and Districts in the Greater Accra Region. The Ga West Municipal is the second largest of the six Municipalities and Districts in Greater Accra Region. The Municipality lies within latitude 5°35° North, 5°29' North and longitude 0°10' West and 0°24' West. It shares common boundaries with Ga East and Accra Metropolitan Assembly to the East, Akwapem South to the North and Ga South and Ga Central to the South. It occupies a land area of approximately 284.08 sq km with about 412 communities. The vegetation and climate are similar to those of the Ga South Municipal.

2.2 Field Sampling and Larval Collections

Larval collection was made from building sites of offices and houses were construction activities were ongoing at the time of the study (Figs. 2a-d). Sampling was undertaken for a period of two months during in the months July and August, 2002. Construction sites within and outside (i.e. at Pokuase and Gbawe) the Accra metropolis were surveyed. At each site, a search for water pools or collections on the grounds, water storage tanks, drains, dug pits or any part of the building structure that could collect and retain water over a period of time was made. Water pools or collections positive for larvae were sampled using the standard dipping technique [8], [9]. For breeding sites with high larval populations, the larvae obtained from each site were transferred into plastic bottles containing water collected from the site. Each bottle was labelled to indicate the locality, dip number and date of collection and transferred to the laboratory for further analysis. For breeding sites with low larval populations, the larvae collected for all the dips were pooled together using a plastic strainer and transferred into a plastic bottle containing water collected from the site. The bottle was then labelled as described above and transferred to the laboratory for further analysis. Observations of the type of breeding sites were made and recorded e.g. whether the breeding site was under shade or directly in the sun. The presence of other aquatic fauna and flora as well as any type of vegetation was recorded.

2.3 Larval Identification and Population Estimation

For sites with high larvae population density, the larvae were counted for each dip and recorded. The average population density per dip was then estimated and recorded. For breeding sites with low larval populations, population density was estimated from the pooled larval collection. Larvae were killed by gently heating and preserved in 70% alcohol. The larvae were then counted and identified [10]. Third and fourth instars were used for species identification of anophelines.

2.4 Identification of Non-target Organisms

The aquatic organisms, mainly the immature stages of insects, were killed in alcohol and observed under the microscope at X10 magnification. They were identified using the external morphological features and keys [11], [12].

Fig. 2. Examples of different types of construction projects serving as larval breeding sites. (a) uncompleted building in a swampy area (b) rain water collection in a dug out foundation (c) water pool trapped amongst broken pieces of building blocks (d) water dammed behind bridge under construction

The microscopic plants were preserved in 4% formalin solution. A thin layer of the algal scum was fixed on a microscope slide with a cover slip and identified under a Carl Zeiss inverted microscope as described [13].

2.5 Physico-chemical analysis of water samples

Water samples from sites where larval forms of mosquitoes were found were collected into 500 ml bottles for analysis of the following physico-chemical parameters: temperature, pH, conductivity, turbidity, biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Samples for dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected into dark bottles. The pH and temperature were taken *in situ*. Physico-chemical parameters of the water samples were done in duplicates following the methods of APHA [14] and UNEP [15]

3 RESULTS

Water samples for a total of 30 different construction sites were sampled (Fig 1). Seventy percent (21/30) of the breeding sites sampled were positive for mosquito larvae. A total of 1475 mosquito larvae comprising of the three main genera: *Culex*, *Aedes* and *Anopheles* were collected (Table 1). The highest total larval population for a site was recorded at the Agege Road Bridge construction site (n=196), whilst the lowest larval population (n=6) was recorded at the Airport City Project construction site. With the exception of one site which had only *Culex* and *Aedes* larvae, all the other sites had all the three genera co-existing. The breeding sites were created mainly by (1) ongoing construction sites of buildings, hotels, wards, drains, etc. in water collected in pits, pools, ponds of water, drums, open storage tanks (2) abandoned construction of buildings, roads and drains (3) Seepage water due to depressions, water logged area, uncompleted concrete man hole and (4) Blocked drainage as a result of construction. *Culex* larvae were the dominant genera accounting for 54.1% of the collections. *Culex* was found at all the positive sites of the survey, ranging from ground water pools, water seepage pools to large water storage tanks. *Aedes* was the next abundant genus, which made up 28.1% of the total sample number. It occurred in all the different types of breeding sites reported positive. *Anopheles* made up 17.8% of the larval sample. They occurred at all the 70 % positive sites and were found in even drains and vehicular tire prints. Out of the four drains sampled two supported the breeding of *Anopheles*, which prefer clean water. One drain found with *Culex* and *Aedes*,

TABLE 1
NUMBER OF MOSQUITO LARVAE COLLECTED FROM THE DIFFERENT BREEDING SITES

Type of breeding sites (n)	**Characteristics of breeding places**	**Types and numbers of mosquito larval collected**			**Total Larval Population.**
		Anopheles sp.	***Culex sp.***	***Aedes sp.***	
Ongoing construction (7)	Rain pools Water collection from damaged drain Uncovered water tanks, drums etc. Water dam behind sand bags	51	310	180	541
Seepage water from construction sites (12)	Seepage water in a shade Flowing seeping water Water logged area	109	207	111	427
Abandoned construction (10)	Rains pools covered by tall grass Rain pools on concrete floors Large pond surrounded by vegetation	103	139	73	315
Blocked drainage (1)	Water seeping from ground and filling drain	0	142	50	192
Total		**263**	**798**	**414**	**1475**

n= number of sites.

TABLE 2
PHYSICO-CHEMICAL PARAMETERS OF THE WATER SAMPLES

Type of breeding sites (n)	**Water Characteristics**					
	Mean (Range) Temp (ºC)	**Mean (Range) pH**	**Mean (Range) Conductivity (µS/cm)**	**Mean (Range) Turbidity (NTC)**	**Mean(Range) COD (mg/l)**	**Mean (Range) BOD5 (mg/l)**
Ongoing construction (7)	26.6 (25.0-30.0)	8.4 (7.9-9.0)	1254.1 (365.0-3241.0)	319.0 (5.0-568.0)	172.8 (67.1-410.7)	68.2 (1.9-218.0)
Seepage water from construction sites (12)	25.5 (24.0-29.0)	8.1 (7.2-9.2)	1020.0 (370.0-1192.0)	209.6 (49.0-598.0)	96.0 (65.2-111.0)	5.7 (1.6-14.9)
Abandoned construction (10)	26.0 (24.0-28.0)	8.1 (7.2-9.1)	1448.6 (372.0-3195.0)	148.2 (4.0-506.0)	150.5 (59.0 - 457.0)	45.1 (1.0-310.0)
Blocked drainage (1)	27.0	8.1	3200.0.0	171.0	347.5	298.0
Overall mean	**26.0 (24-30.0)**	**8.2 (7.2-9.2)**	**1190.2 (365.0-3241)**	**213.4 (4.0-598.0)**	**140.5 (59.0-457.0)**	**43.2 (1.0-310)**

Statements that serve as captions for the entire table do not need footnote letters.
[a]*Gaussian units are the same as cgs emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.*

however, did not support *Anopheles* breeding. The physico-chemical parameters of the water samples are provided in Table 2. The temperature ranged from 25-30 ^{o}C while conductivity, turbidity, COD and BOD ranged between 365-3241 µS/cm, 4-598 NTC, 59-457 mg/l and 1.0-310 mg/l respectively. The pH of the various breeding sites sampled fell in the range of 7.2 and 9.2 i.e. neutral to slightly basic. The fauna of non-target organisms was observed in the water samples from seven construction sites and included dipteran larvae, Notonectidae, Odonata nymph (Corduliidae), *Phyllomacromia* species, tadpoles and water snail (*Bulinus* species). The flora was observed in 16 sites and comprised of algae, bluegreen algae, grass, *Oedogonium* spp. and weeds.

4 DISCUSSION

Construction was observed to be taking place in water logged areas that provided many breeding sites for mosquitoes. Human activities seemed to promote breeding as adequate checks were not put in place by the local authorities to ensure compliance with environmental laws. In almost all the sites all the three genera were found co-existing in the various types of the breeding sites. This could be explained in terms of succession. For example, Anopheles breeds in clear, well lit water so may have been first at the breeding site, with time as changes occur in the water it is replaced by *Culex* [16]. The trend observed in this study agrees with the reports of Chinery (1969) [6] where a shift in dominance from Anopheles to *Culex* in Accra was observed. *Culex* is found in most cities of the world [17]. Probably, the genus must have adapted a close relationship with human and human activities. *Culex* usually breed in polluted waters and their presence in all the different breeding sites is a probable indication that the mosquito can adapt easily to various conditions in the water [18]. Hence, they can breed readily in any type of breeding sites. Similar findings have been reported in the Accra metropolis [5],[6]. *Aedes* species occurred in all the different types of breeding sites that were found positive. This finding differs from previous report where this genus was mainly found in small artificial water containers and water pools on concrete floors [6]. *Anopheles* mosquitoes were also not limited in their distribution. The sampling was done in the rainy season and the polluted water may have been flushed out by the rains and replaced by clean one water. This may explain the presence of *Anopheles* in the drains. Eighteen out of 30 (60 %) breeding sites were in low-lying areas and hence the water table level is raised, in the wet season, resulting in swamps and water seepage. These have been documented as the breeding sites of *Anopheles* [19] though five were found negative for mosquito larvae. The temperature of the water is important to the development of the aquatic stages of the mosquito. For example, the aquatic stages of the mosquito life cycle take two weeks at a water temperature between 23ºC and 27ºC, in the tropics [20]. The temperature of the water sampled was between 24ºC to 30ºC. These temperatures are likely to create adequate warmth that enable the larvae to exploit the resources of the warm, open habitats for rapid development [21],[22]. Warmer temperatures encountered in small and open habitats (during daytime hours) shorten larval-to-pupae development time while also reducing mortality associated with desiccation [21]. The highest mean turbidity were recorded in water at abandoned sites and in blocked drains, and these sites also recorded lower larvae numbers. Turbidity determines the depth to which light penetrates the water and also affects water temperature, as suspended particles in a water column absorb and scatter sunlight and hence determine the extinction of solar radiation [23]. Changing the water temperature will change larval development rate and survival [24],[25]. Water turbidity can also affect mosquito immatures in several other ways: it may alter their distribution as females of *An. gambiae* s.l. for example seem to prefer darker substrates [26]; can be advantageous as a higher turbidity may decrease the chance of being preyed upon due to a lower visibility; particles that contribute to turbidity may also directly interfere with larval feeding and, hence, slow larval growth and decrease larval survival [27]. The pH of all the water sites were favorable for mosquito breeding. The overall mean pH of the sites of was 8.2 which is the optimum pH requirement by mosquitoes. Hence the mosquito population was found least affected by pH [28]. The oxygen content of the water governs the selection of the breeding sites. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are important as they show the amount of oxygen present or required in the water. They both indicate the degree of pollution in the water but differ in the type of pollution. As revealed from the present work, mosquitoes may tolerate various degrees of water pollution as indicated from the BOD content of the mosquito larval breeding places [29]. *Culex* species tolerate comparatively higher BOD in the breeding sites as compared with other mosquito larvae [30]. The presence of the non-target organisms may be beneficial or detrimental to mosquito larvae. Some invertebrates predate on mosquito larvae (for example, Notonectidae, *Toxorhynchites* species, frogs and so on) [31]. Vegetation in the breeding sites has been observed to be important for some mosquito larvae. The vegetation provides protection for mosquitoes against the wave actions at the water surface and predators [32]. Vegetation also provides shade. It is known that the light requirement characterizes each mosquito species individually [33]. Algae are frequently favorable as larval food or an aid in maintaining balance of dissolved gasses and in utilizing organic materials unfavorable for the larvae [34].

5 CONCLUSION

Larval habitats are important determinants or adult distribution and abundance. Although the study was carried out over a short period of time, our results suggest that the activities of the construction industry creates breeding sites by making changes in the ecology of the environment. These changes create increase in the number of breeding sites suitable for supporting prolific mosquito breeding. Since the problem created by the industry is related to sanitation, mosquito control must be separated from disease control and rather linked with sanitary services. Integrated mosquito control with emphasis on environmental management and biological control as well as adequate sensitization of construction workers and owners will help reduce these breeding sites.

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REFERENCES

[1] D. Ofori-Adjei, “Chloroquinine-resistant P. falciparum malaria: An emerging problem in Ghana”, Ghana Medical Journal, vol. 22 no. 1, pp 2-5, 1988

[2] World Health Organization, “Resistance of Vectors of Diseases to Pesticides”. 5th Report of the WHO Expert Committee on Vector Biology and Control, WHO Technical Report Series № 683, 1980

[3] F. H Collins and S. M. Paskewitz, “Malaria: current and future prospects for control”, Annual Review of Entomology, vol. 40, pp. 195-219, 1995.

[4] M. Coetzee, P. van Wyk, M. Booman, L. L. Koekemoer and R. H. Hunt, “Insecticide resistance in malaria vector mosquitoes in a gold mining town in Ghana and implications for malaria control”, Bulletin de la Société de Pathologie Exotique, vol. 99, pp. 400-403, 2006.

[5] V. Afutu-Vanderpuye, “Preliminary study in the Accra Metropolis to determine the impact of urbanization on the mosquitoes”, Unpublished data. Water Research Institute. Accra, 1998.

[6] W. A. Chinery, “A survey of mosquito breeding in Accra, Ghana, during a 2-Year period of larval mosquito control: The mosquito collected and their breeding places”, Ghana Medical Journal, vol. 8 , pp. 266-274, 1969.

[7] Ghana Statistical Service, “2010 Population & Housing Census Summary Report of Final Results”, Sakoa Press Limited, 2012.

[8] World Health Organization, “Manual on Practical Entomology in Malaria. Geneva”, World Health Organization, 1975.

[9] M. W Service, “Sampling the adult resting population. Mosquito Ecology. Field Sampling Methods”, UK: Chapman and Hall, pp. 210–290, 1993.

[10] G. A. Verrone, “Outline for the determination of malarial mosquitoes in Ethiopia. Part II. Anopheline larvae”, Mosquito News, vol. 22, pp. 394–401, 1962.

[11] W. P. McCafferty and A. Provonsha, “Aquatic Entomology: The Fisherman's And Ecologist's Illustrated Guide To Insects and Their Relatives”, USA: Jones & Bartlett Learning, 1983.

[12] R. W. Merritt and K. W. Cummins, “An Introduction to the Aquatic Insects of North America”, 3rd edition, Dubuque: Kendall Hunt Pub Co., 1995

[13] J. Seubin-Reyssre, “Manual of Algal Species Drawings from LaboratoireD’Ichthyologie”, Museum National D’Histoire Naturelle, Paris, 1988.

[14] APHA, AWWA, WPCF, “Standard Methods for the Examination of Wastewater”, 19th Edition, New York, 1995.

[15] UNEP, WHO, UNESCO, WMO. () GEMS/Water Operational Guide. ETS/78.8/Rev., 1987

[16] W. A. Chinery, “Effects of ecological changes on the malaria vectors Anopheles funestus and Anopheles gambiae complex mosquitoes in Accra, Ghana”, Journal of Tropical Medicine & Hygiene, vol. 87, pp. 757-781, 1984.

[17] A. Molina-Cruz, T. Lehmann and J. Knöckel, “Could culicine mosquitoes transmit human malaria?”, Trends in Parasitology, vol. 29, no. 11, pp. 530-537, Epub Oct 16, 2013.

[18] R. I Burke, R. Barrera, M. Lewis, T. Kluchinsky and D. Claborn, “Septic tanks as larval habitats for the mosquitoes Aedes aegypti and Culex quinquefasciatus in Playa-Playita, Puerto Rico”, Medical and Veterinary Entomology, vol. 24, no. 2, pp. 117-123, Epub Mar 31, 2010.

[19] J. F. Trape, E. Lefebvre-Zante, F. Legros, G. Ndiaye, H. Bouganali, P. Druilhe and G. Salem, “Vector density gradients and the epidemiology of urban malaria in Dakar, Senegal”, American Journal of Tropical Medicine & Hygiene, vol., 47, pp. 181-189, 1992.

[20] World Health Organization, “Manual On Environmental Management For Mosquito Control (with emphasis on malaria vectors)”, Offset Publication № 66, 1982.

[21] M. T. Gilies and B. de Meillon, “Anophelinae of Africa South of the Sahara (Ethiopian Zoogeographical Region)”, 2nd edn. Publication No. 54. South African Institute for Medical Research, 1968

[22] J. E.Gimnig, M. Ombok, S. Otieno, M. G. Karfman, J. M. Vulule and E. D. Walker “Density-dependent development of Anopheles gambiae (Diptera: Culicidae) larvae in artificial habitats”, Journal of Medical Entomolgy, vol. 29, pp. 162–172, 2002.

[23] K. P. Paaijmans, W. Takken, A. K. Githeko and A. F. Jacobs, “The effect of water turbidity on the near-surface water temperature of larval habitats of the malaria mosquito Anopheles gambiae”, International Journal Biometeorology, vol. 52, no. 8, 747-753, Epub Jul 17, 2008.

[24] E. O Lyimo, W. Takken and J. C. Koella, “Effect of rearing temperature and larval density on larval survival, age al pupation and adult size of Anopheles gambiae”, Entomologia Experimentalis et Applicata, vol. 63, pp. 265-271, 1992.

[25] M. N. Bayoh and S. W. Lindsay, “Temperature-related duration of aquatic stages of the Afrotropical malaria vector mosquito Anopheles gambiae in the laboratory”, Medical and Veterinary Entomology, vol. 18, pp. 174–179, 2004.

[26] J. Huang, E. D. Walker, J. Vulule and J. R. Miller, “The influence of darkness and visual contrast on oviposition by Anopheles gambiae in moist and dry substrates”, Physiological Entomology, vol. 32, pp. 34–40, 2007

[27] Y. Ye-Ebiyo, R. J. Pollack, A. Kiszewski and A. Spielman () Enhancement of development of larval Anopheles arabiensis by proximity to flowering maize (Zea mays) in turbid water and when crowded, American Journal of Tropical Medicine & Hygiene, vol. 68, pp. 748–752, 2003.

[28] K. Rydzanicz and E. Lone, “Species composition and seasonal

dynamics of mosquito larvae in the Wrocław, Poland area", Journal of Vector Ecology, vol. 28, no. 2, pp. 255-266, 2003

[29] O. Z. Unit, "Practical Malariology". Philadelphia: W.B. Saunders Co., 1943.

[30] A. M. Salit, S. S. Al-Tubiakh, S. A. El-Fik and 0. H. Enan, "Physical and chemical properties of different types of mosquito aquatic breeding places in Kuwait state", Proceedings of the Second international Conference on Urban Pests, K. B. Wildey (editor), 1996

[31] E. A. S. Shaalan and D.V. Canyon, "Aquatic insect predators and mosquito control", Tropical Biomedicine, vol. 26, pp. 223-261, 2009

[32] S. Tóth, "Identification keys to Mosquitoes I. (Larvae). Pannónia Füzetek 1, Pannónia Központ Kft., Keszthely (In Hungarian), 2007.

[33] J. E. Joy and J. T. Clay, "Habitat use by larval mosquitoes in West Virginia", American Midland Naturalist, vol. 148, no. 2, pp. 363–375, 2002.

[34] G. H. E Hopkins, "Mosquitoes of the Ethiopian Region,I. larval bionomics of mosquitoes and taxonomy of culicine larvae", London: British Museum (Natural History), 1936.