J Vector Borne Dis 44, December 2007, pp. 241–244

Anopheles gambiae s.s. breeding in polluted water bodies in urban Lagos, southwestern Nigeria

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Abstract

Background & objective: Urban malaria is on the rise in Nigeria due to rapid industrialisation and developmental activities. A study was undertaken in Lagos, Nigeria to study the *Anopheles* breeding in polluted water bodies.

Methods: Anopheles larval breeding habitats were surveyed and water samples from 24 larval breeding sites from four strategic areas in urban Lagos were analysed. The relationship between eight abiotic variables (pH, dissolved oxygen, conductivity, hardness, nitrate, total dissolved solids, turbidity and oil) and density of *Anopheles* larvae were investigated. The levels of heavy metals (Zn, Co, Cu, Pb, Mn, Fe, Hg and Ni) pollution were analysed by Atomic Absorption Spectrophotometry.

Results: Morphological and PCR analysis of 2358 anopheline larvae revealed only the presence of two members of the *Anopheles gambiae* complex consisting of 93.1% *Anopheles gambiae s.s.* and 6.9% *An. arabiensis*. Multiple regression analysis revealed a significant association between occurrence of *An. arabiensis* larvae and two independent variables: pH and turbidity but not for *An. gambiae s.s*. The levels of three heavy metals: Fe, Cu and Pb from more than half of the sites surveyed were three times higher than the values obtained in natural breeding sites of *An. gambiae s.s.* from a rural area of Lagos. Over 85% of *An. gambiae s.s.* larvae were found in water bodies characterised by low dissolved oxygen (<3 mg/L), high conductivity (>900 uS/cm), turbidity (>180 FAU), oil (>11 mg/L) and heavy metals: Fe, Cu, and Pb (>0.4 mg/L).

Interpretation & conclusion: These results indicate that *An. gambiae s.s*. is adapting to a wide range of water pollution in this urban area. The survival of the mosquito in widespread polluted water bodies across Lagos metropolis could be responsible for the rise in the incidence of malaria.

Keywords *Anopheles gambiae* – larval habitat – pollution – urban Lagos

Introduction

Malaria is a major public health problem but has been considered a predominantly rural disease in Africa, primarily because suitable *Anopheles* mosquito breeding sites are few in highly populated urban areas[1–2]. Malaria transmission depends on a number of hydrology-driven factors that affects the vector survival, including the presence of suitable habitats for the development of anopheline larvae. In urban centres, water pollution is believed to be a major factor that generally reduces the development of anopheline larvae and there is evidence that *Anopheles* mosquito breeding sites decrease from rural to urban areas and transmission intensity is on the average eight times greater in African rural areas than urban centres[3–5]. Even so, malaria transmission still occurs in most urban cities and pregnant women and children <5 years are at risk. The potential of urban malaria has long been recognised in sub-Saharan Africa[6], but the complex factors contributing to malaria risk in urban areas are not fully understood[7]. *Anopheles gambiae sensu stricto* (Diptera: Culicidae), the major African malaria vector is known to breed in temporary clean and clear water[8]. But, the rapid unplanned urbanisation observed in many parts of Africa is changing the context of human population and natural ecosystem interaction. Poverty, deteriorating infrastructure and overcrowding are some of the factors that contribute to the development of conditions that modify anopheline breeding sites.

As more people move into cities and industrialisation proceeds, urban malaria is on the increase in Nigeria[9]. Malaria control programme in most parts of the country, however, focus on rural communities. As a result, the bio-ecology of *Anopheles* breeding habitats in urban areas has received very little attention. Here we report on a survey conducted in urban Lagos and the possible implication of *Anopheles* breeding in polluted water bodies across the metropolis.

Material & Methods

The study was carried out in Lagos (03º 24'E, 06º 27'N) in southwestern Nigeria. Lagos with a population of 10 million people is the most populous city in Africa with two-third of the people living below the poverty line. The Lagos metropolis consists of four main areas— Ikoyi, Apapa, Yaba and the Island (approximately 250 km^2)[10], with small drains, creeks and swamps which provide suitable breeding sites for mosquitoes. The scarcity of water in urban Lagos has been compounded by rapid population growth and increasing pollution from human and industrial wastes. This survey covered four localities— Apapa (the area adjacent to the National theatre, a tourist area close to the Lagos Lagoon), Ikoyi (a low density Government reservation area in the Island), Yaba (a densely populated commercial area) and Ilupeju (an industrial estate) about 15 km from the Lagos Lagoon. Ilupeju and Yaba are located on the mainland and feature drainage canals and roads with blocked gutters and potholes that are filled with rain water during the wet season (April–October).

A total of 292 open aquatic habitats consisting of at least 70 from each of the four localities were sampled for *Anopheles* larvae using standard dipping method[8] from April to June 2005, the peak period of malaria in southwestern Nigeria. At each breeding site, 10 dips were taken with a standard white 300 ml dipper. If *Anopheles* larvae could be seen without dipping or when every dip contained more than five *Anopheles* larvae, the site was defined as having a high *Anopheles* density. Sites with <5 but >1 larvae per dip were considered moderate while sites with an average of one larva per dip or where only one or two dips out of 10 contained *Anopheles* larvae were defined as having a low *Anopheles* density[11]. Sites where no *Anopheles* larvae could be found in 10 dips were recorded as negative. Anopheline larvae were identified morphologically[12] and the average density per site was computed. Mosquitoes belonging to the *An. gambiae* complex were subjected to PCR assays designed for this species complex[13]. At each locality, six larval habitats (approximately 500 m apart) positive for *Anopheles* larvae were randomly selected for water analysis. To study the magnitude of water pollution at the breeding sites, eight abiotic factors including pH, dissolved oxygen, conductivity, total hardness, oil, nitrate and turbidity were analysed from replicate water samples collected over three months. Water pollution associated with heavy metals (Zn, Cu, Fe, Pb, Co, Hg, Ni and Mn) were measured using the Atomic Absorption Spectrophotometry. Controls included water samples from natural breeding sites of *An. gambiae* in a rural area of Lagos. The continuous physicochemical variables were categorised into quartiles for ease of interpretation. Multilevel regression analysis was carried out to account for physicochemical variables that determine the presence and abundance of *Anopheles* larvae at each breeding site. Only variables with p-values <0.05 were considered in the final discussion.

Results & Discussion

Of the 292 potential mosquito breeding sites surveyed, 71 (24.3%) were positive for *Anopheles* larvae, 35% of the positive sites were from Apapa, 16% from Ikoyi, 21% from Ilupeju and 28% from Yaba. Only 8 (11.3%) of the 71 positive larval breeding sites (five from Yaba and three from Apapa) were characterised as having a high *Anopheles* density. A total of 2358 *Anopheles* larvae were collected from the 24 breeding sites randomly selected in the four localities. All were morphologically identified as members of the *An. gambiae* Complex. The PCR analysis showed that 2196 (93.1%) were *An. gambiae s.s*. and the remainder were *An. arabiensis. An. gambiae s.s.* was the only species found at Apapa, Ilupeju and Yaba while *An. arabiensis* was predominant at Ikoyi although both species were present. *An. gambiae s.s.* was the only species found in the rural site used as control. The average larval density per dip per site was higher in Apapa (4.2) and Yaba (5.8). This is in contrast to the average larval density (<1) previously reported in the wet season in this area[9].

The results of the multiple regression analysis suggest that pH and turbidity are the variables most strongly associated with the abundance of *An. arabiensis* larvae at Ikoyi ($p < 0.02$). We could not identify key variables for *An. gambiae s.s*. at Apapa, Yaba and Ilupeju. The data on conductivity, turbidity and oil content of the water samples from Apapa, Ilupeju and Yaba were similar but two fold higher than the rural control samples (Table 1). Similarly, the conductivity, turbidity and oil content at Ikoyi were significantly lower when compared to Apapa ($p < 0.01$), Yaba ($p < 0.03$.) and Ilupeju ($p < 0.04$). This is an interesting result since Ikoyi is less populated compared to other study areas. The level of three heavy metals (Fe, Cu and Pb) were more than two fold higher at Apapa and Ilupeju than those obtained from the site used as control. Very low levels of these heavy metals were detected at Ikoyi. Over 85% of *An. gambiae s.s.* larvae from Apapa, Ilupeju and Yaba were found in water bodies characterised by low dissolved oxygen (<3 mg/L), high conductivity (>900 uS/cm), turbidity (>180 FAU), oil (>11 mg/L) and heavy metals:

Table 1. Density of *Anopheles gambiae* and physicochemical parameters of the mosquito breeding sites in urban Lagos

Study areas	No. of *Anopheles* larvae	Mean density/ site	Abiotic variables*					Heavy metals*		
			pH	Dissolved O_2 (mg/l)	Conductivity uS/cm	Turbidity (FAU)	Oil (mg/l)	Cu (mg/l)	Pb (mg/l)	Fe (mg/l)
Apapa	756	4.2	8.58 (± 0.34)	2.45 (± 0.24)	1550 (± 384)	230 (± 16.33)	14.56 (± 1.61)	0.72 (± 0.06)	0.53 (± 0.1)	0.52 (± 0.05)
Ikoyi	162	0.9	7.51 (± 0.27)	3.28 (± 0.27)	385 (± 9.13)	85 (± 6.35)	8.67 (± 1.1)	0.35 (± 0.02)	0.42 (± 0.07)	0.34 (± 0.04)
Ilupeju	396	2.2	8.02 (± 0.18)	2.70 (± 0.16)	965 (± 80.75)	187 (± 7.53)	11.28 (± 0.92)	0.74 (± 0.07)	0.62 (± 0.09)	0.66 (± 0.06)
Yaba	1044	5.8	8.28 (± 0.25)	2.62 (± 0.19)	913 (± 37.39)	409 (± 13.1)	12.88 (± 1.38)	0.62 (± 0.04)	0.24 (± 0.09)	0.46 (± 0.09)
Ahoya (Rural; control)	1476	8.2	7.42 (± 0.31)	5.38 (± 0.32)	257 (± 6.68)	68 (± 5.53)	7.85 (± 0.13)	0.31 (± 0.03)	0.25 (± 0.12)	0.30 (± 0.07)

*Mean value of different variables and the Standard deviations (± S.D.).

Fe, Cu, and Pb (>0.4 mg/L) suggesting high level of water pollution in the breeding sites when compared to water samples from the control site. Although a 'polluted habitat' of *An. gambiae s.s*. has not been clearly defined[11], in two particular instances at Apapa near the National theatre, larvae of *An. gambiae s.s*. were found in a sewage pond polluted with human faeces and oil from petrol tanks. It appears that pollution inhibits the development of *An. arabiensis* than *An. gambiae s.s.* in this area. Nonetheless, the survival of *An. gambiae s.s.* in widespread polluted water across Lagos metropolis could be responsible for the rise on the incidence of malaria in urban Lagos. These findings from Lagos, together with other studies from sub-Saharan Africa[1,11,14,] indicate that *An. gambiae s.s*. is adapting to a wide range of water pollution in urban settings which could have serious implications on the epidemiology of urban malaria.

Acknowledgement

This investigation received financial support under the Multilateral Initiative on Malaria (MIM) project A30026 through the UNICEF/UNDP/World Bank/ WHO Special Programme for Research and Training in Tropical Diseases (TDR).

References

1. Gardiner C, Biggar RJ, Colling WE, Nkrumah FK. Malaria in urban and rural areas of southern Ghana: a survey of parasitaemia, antibodies and antimalarial practices. *Bull WHO* 1984; *62:* 607–13.
2. Keating J, Macintyre K, Mbogo CM, Githure JI, Beier JC. Characterisation of potential larval habitats for *Anopheles* mosquitoes in relation to urban land-use in Malindi, Kenya. *Intl J Hlth Geograph* 2004; *3:* 9.
3. Trappe JF, Zoulani A. Malaria and urbanization in central Africa: the example of Brazzaville. Pt II: results of entomological surveys and epidemiological analysis. *Trans R Soc Trop Med Hyg* 1987; *81:* 10–8.
4. Robert V, Macintyre K, Keating J, McWilson W, Trappe JP, Duchemin JB, Beier JC. Malaria transmission in urban sub-Saharan Africa. *Am J Trop Med Hyg* 2003; *68:* 169–76.
5. Hay SI, Rogers DJ, Toomer JF, Snow RW. Annual *Plasmodium* entomological inoculation rates across Africa. Literature survey, internet access and review. *Trans R Soc Trop Med Hyg* 2000; *94:* 113–27.
6. Bruce-Chwatt LJ. *Essential Malariology*, II edn. London: Heinemann Medical Books, Ltd. 1985; p. 264.
7. Donnelly MJ, McCall PJ, Lengeler C, Bates I, D'Alessandro U, Barnish G, Konradsen F, Klinkenberg E, Townson H, Trappe JF, Hastings IM, Mutero C. Malaria and urbanization in sub-Saharan Africa. *Malaria J* 2004; *4:* 12.
8. Service MW. Studies on sampling larval population of *Anopheles gambiae* complex. *Bull WHO* 1971; *45:* 169–80.
9. Brieger WR, Sesay HR, Adesina H, Mosanya ME, Ogunlade PB, Ayodele JO, Orisasona SA. Urban malaria treatment behaviour in the context of low levels of malaria transmission in Lagos, Nigeria. *African J Med Sci* 2001; *30:* 7–15.
10. Mabogunje AL. *Cities and African development*. Ibadan: Oxford University Press (Studies in the Development of African Resources), No. 3, 1976.
11. Sattler MA, Mtasiwa D, Kiama M, Premji Z, Tanner M, Killeen GF, Lengeler C. Habitat characterisation and spatial distribution of *Anopheles* sp mosquito larvae in Dar es Salaam (Tanzania) during the extended dry season. *Malaria J* 2005; *4*: 4.
12. Gillies MT, Coetzee M. *A supplement of the Anophelinae of Africa South of the Sahara (Afrotropical Region). Publications of the South African Institute for Medical Research* 1987; *55:* 143.
13. Scott JA, Brogdon WG, Collins FH. Identification of single specimen of the *Anopheles gambiae* complex by polymerase chain reaction. *Am J Trop Med Hyg* 1993; *49:* 520–9.
14. Chinery WA. Effects of ecological changes on the malaria vectors *Anopheles funestus* and *Anopheles gambiae* complex of mosquitoes in Accra, Ghana. *Am J Trop Med Hyg* 1984; *87:* 75–81.

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Received: 5 February 2007 *Accepted:* 18 May 2007