

# Impact of Mass Drug Administration (MDA) on the Transmission of Lymphatic Filariasis in Tono Irrigation Area in Navrongo, Ghana

Elijah Dakorah Angyiereyiri\*

Department of Parasitology, Noguchi Memorial Institute for Medical Research, University of Ghana, P.O. Box LG 581, Legon-Accra, Ghana

African Regional Programme for Insect Science (ARPPIS), University of Ghana, Legon, Ghana  
University for Development Studies, FAS, Dept. of Applied Biology, Box 24, Navrongo, Ghana

Maxwell Appawu<sub>1,3</sub>

Email: [mappawu@noguchi.mimcom.org](mailto:mappawu@noguchi.mimcom.org)

Samuel Dadzie<sub>1,3</sub>

[sdadzie@noguchi.mimcom.org](mailto:sdadzie@noguchi.mimcom.org)

Daniel Adjei Boakye<sub>1,2,3</sub>

[yawbadjei@yahoo.co.uk](mailto:yawbadjei@yahoo.co.uk) [ordboakye@noguchi.mimcom.org](mailto:ordboakye@noguchi.mimcom.org)

Samuel Otoo<sub>1</sub>

1. Department of Parasitology, Noguchi Memorial Institute for Medical Research, University of Ghana, P.O. Box LG 581, Legon-Accra, Ghana

2. African Regional Programme for Insect Science (ARPPIS), University of Ghana, Legon, Ghana

3. Lymphatic Filariasis Support Centre for Africa, Noguchi Memorial Institute for Medical Research, University of Ghana, P.O. Box LG 581, Legon-Accra, Ghana

## Abstract

Lymphatic filariasis is ranked as one of the leading causes of permanent and long-term disability and also oldest and most debilitating neglected tropical disease worldwide. Filariasis is caused by nematode endoparasitic worms transmitted to humans by various mosquito vectors. World Health Organization established Global Programme to Eliminate Lymphatic Filariasis as a public health problem by the year 2020. The strategies employed are to interrupt transmission through mass drug administration (MDA) and to alleviate suffering and disability via morbidity management; and vector control. It is expected that after implementation of the strategies above, transmission assessment surveys are required to ascertain their progress, impact and efficacies. As MDA was the main strategy, this work therefore determined impact of mass drug administration on the transmission of lymphatic filariasis in Tono Irrigation area in Navrongo following more than nine years of its implementation. Human landing and pyrethrum spray monthly collections of mosquitoes in Wuru and Saboro were dissected to determine the transmission level in the study area. The mosquitoes collected in the study comprised 90.22% (3,650) *Anopheles* species and 9.78% (386) *Culex* species with no *Aedes* or *Mansonia* species. The man biting rate computed from (Human Landing Catch) HLC was 162.25 bites/man/night in Wuru and 143.75 bites/man/night in Saboro. Only 3 *An.* species were infected with filarial parasites; 2 in Saboro with 2mf, and 1L2 in a mosquito in Wuru. However, there was no L3 stage recorded in any of the 3,560 mosquitoes macerated implying that there was no ongoing transmission of LF in the study sites since no infective bites were encountered. However, a follow up survey is required to assess the level of transmission since one survey is inadequate to declare the place free of LF.

**Keywords:** *Anopheles* species, *Wuchereria bancrofti*, Mass Drug Administration, Lymphatic filariasis, Ghana

## 1. Background of lymphatic filariasis (LF)

Lymphatic filariasis (LF) is a profoundly disfiguring parasitic disease caused by three species of tissue dwelling filaroid nematodes, namely; *Wuchereria bancrofti*, *Brugia malayi* and *Brugia timori*. *Wuchereria bancrofti* is responsible for 90% of all cases and is found throughout the tropics and in some sub-tropical areas world-wide (WHO, 1997). Infection with *W. bancrofti* can result in elephantiasis or hydrocoele in males (Melrose, 2002; Goldman *et al.*, 2007). Lymphatic filariasis is one of the oldest and most debilitating neglected tropical diseases (NTDs) next to malaria, and a major public health problem globally (Michael *et al.*, 1996; WHO, 1997, 2010a, b). The disease has a long history which dates back into antiquity but in 1997, the World Health Assembly engaged member states to develop national plans to eliminate LF (WHO, 2010a). Currently the global burden of LF is estimated at 120 million people with more than 40 million people in endemic communities incapacitated or

disfigured by the disease. The most affected areas include Africa, Eastern Mediterranean, Asia and South America (Melrose, 2002; WHO, 2010a, b) and that the burden of LF in Africa is approximately 30% (WHO, 2010). However, about 38% of all global cases occur in the continent with about 480 million people at risk of being infected (Gyapong, 2012: in Press).

In Ghana, LF is mainly spread by *Anopheles gambiae* species complex (Sasa, 1976; Appawu *et al.*, 1994, 2001; Zakaria and Savioli, 2002; Boakye *et al.*, 2004). However, Ughasi *et al* (2012) have found that some *Mansonia* species were carrying the infective stages of *W. bancrofti* in two communities in the Western Region of the country.

Research found that extensive dam-building for irrigation, especially of rice; waste-water mismanagement, water storage, or waste accumulation generally lead to increased mosquito biting rates, higher transmission potentials, and a higher proportion of vectors infective or infected with microfilariasis as was observed in Africa and Indonesia (Erlanger *et al.*, 2005). However, separate control measures against LF are not known to exist in most places in water resources development schemes, although China, India and Indonesia have established mosquito control measures in some of their schemes (WHO, 1993).

Ghana is endemic for both LF and onchocerciasis by WHO classification with prevalence of microfilaraemia or antigenaemia being greater than or equal to one percent ( $\geq 1\%$ ). Of the approximately estimated 25 million people living in the country (Population and Housing Census, 2010), the risk population is about 11,587,953 (WHO, 2010a, b).

In the year 2000, WHO established a Global Programme to Eliminate Lymphatic Filariasis (GPELF) with the ultimate goal of eliminating LF as a public health problem by the year 2020 (WHO, 1997, 2000, 2010a, b). The GPELF employed three strategies to achieve the above goal; first, to interrupt transmission using combinations of two medicines in endemic communities as a single dose annually; combination of Diethylcarbamazine citrate (DEC) and Albendazole (ALB) (DEC+ALB) or Ivermectin (IVM) and Albendazole (IVM+ALB), administered to entire eligible populations, a strategy known as “mass drug administration (MDA)”. Secondly, to alleviate suffering and disability by providing improved hygiene and skin care to people with lymphoedema and surgery for men with hydrocoele; a strategy referred to as morbidity management; and via vector control (WHO, 2000; WHO, 2010a, b). According to WHO report of 2012, MDA implementation in Ghana is about 93.2% geographical coverage and targeting a population of 11,925,399 people. In 2009, Ghana’s MDA implementation was about seven rounds, (WHO, 2010b; Appiah-Kubi, 2009).

Administration of these once-yearly, single-dose drug regimens to people in at-risk communities in all endemic countries for 4 – 6years makes feasible the prospect of interrupting transmission and thereby eliminating LF (Ismail, 1998; WHO, 2010a, b), largely because the reproductive life span of the adult worm is estimated to be 4 – 6years (Ottesen, 2000). The control approaches of LF are now integrated and delivered as multi-intervention packages at global, national and local levels in endemic areas.

It is however, important that after 4 or more rounds of annual MDA, the microfilariae in the human system will be so low that the mosquito vectors will not be able to pick them up from infected people during blood feeding and transmit to uninfected people. Hence, to ascertain the efficacy of MDA, transmission assessment surveys are required following four or more years of its inception.

Boakye *et al* (2004) through transmission assessment survey found, that after 6 rounds of MDA undertaken in Central Region of Ghana, LF infestation was still remaining at 10%. However, no studies have been conducted in the KNEM to determine the impact of MDA in LF transmission since its inception in 2001. There is therefore a need to establish whether the MDA’s implementation has resulted in reducing LF transmission in the Kassena-Nankana East Municipal after more than 7 years of MDA implementation hence the significance of this study.

## 1.1 Materials and Methods

### 1.1.1 Description of study sites

Kassena-Nankana East Municipal Assembly (KNEMA) is located about 40 kilometres (km) away from Bolgatanga, the regional capital. The population is about 160,000 (HPC, 2010). The annual average rainfall is 850 mm which occurs within July – September, with the rest of the year being relatively dry. The Tono dam is one of the largest agricultural dams in West Africa and serves as a place for year round farming. The popular cash crops being cultivated on the project are rice, soya bean, tomato and other vegetables.

There are approximately 6000 small scale farmers eligible to farm in the project. They come from the communities around the project. Communities currently under Tono irrigation scheme include Bonia, Wuru, Yigbwania, Yogbania, Korania, Gaani, Biu and Chuchuliga (ICOUR, 1985).

### 1.1.2 Field sampling of mosquitoes

Cross sectional survey was conducted in the municipal for sampling and data collection. This covered the rainy season (October - November, 2011) and the dry season (January -February, 2012).

Adult *Anopheles* mosquitoes were sampled in two communities (Saboro and Wuru) in the KNEMA using human

landing catches (HLC) and pyrethrum spray collections (PSC) to determine the level of LF parasitaemia in them.

### 1.1.3 Processing of mosquitoes

Each *Anopheles* mosquito was identified using the morphological keys of Gillies and De Meillon (1968) and Gillies and Coetzee (1987) and sorted out into the different species of *Anopheles gambiae* complex and *Anopheles funestus*. A total of 3,560 *Anopheles* mosquitoes collected from the study areas were processed for *W. bancrofti* infections, while the *Culex* species were not processed for this study, because the *Culex* species obtained there had not been incriminated as vectors in earlier studies (Appawu *et al.*, 1994, 2001; Dzodzomenyo *et al.*, 1999).

### 1.1.4 Mosquito dissections

The head, thorax and abdomen of each *Anopheles gambiae* complex were separated and each part placed in adrop of **water** or (**1% saline solution**) on a pre-cleaned slide. The legs were removed and placed in 1.5 ml Eppendorf tubes for molecular identification of the species complex.

Each of the body parts were dissected under a dissecting microscope and examined for the presence of *W. bancrofti*.

### 1.1.5 Molecular identification of *An. gambiae* species complex

Genomic DNA was extracted from the legs of *An. gambiae* complex using the method of Scot *et al.* (1987). Identification of the sibling species was done using the method of Scott *et al.* (1993) and that of Fanello *et al.* (2002) used to determine the *An. gambiae* ss M and S molecular forms.

### 1.1.6 Molecular identification of *W. bancrofti*

The dried carcass of dissected mosquitoes together with any *W. bancrofti* larvae found on each slide was scraped into a 1.5 ml Eppendorf tube and then homogenized in phosphate buffered saline (PBS). The genomic DNA was extracted using the DNeasy Tissue Kit (QIAGEN Inc., USA) following the manufacturer's protocol. Polymerase chain reaction to confirm that parasites observed were *W. bancrofti* was then carried out using the method of Ramzy *et al.* (1997).

### 1.1.7 Ethical considerations

Ethical approval for both studies was obtained from the Institutional Review Board of the Noguchi Memorial Institute for Medical Research and verbal/written consents were obtained from each local volunteer who participated in the indoor human landing catches (HLC) during October to February which correspond to the period of highest mosquito breeding in the area. Prior consents to conduct pyrethrum spray catches (PSC) and HLC in rooms were also obtained from the occupants.

## 1.2 Results

A total of 3,946 mosquitoes comprising 90.22 % (N = 3,560) *Anopheles* species and 9.78 % (N = 386) *Culex* species were collected and identified to the genus level (Figure 4.1). Of the *Anopheles* species, 28.23 % (1,005) were from Saboro and 31.74 % (1,130) from Wuru. Also, 42.11 % of *Anopheles* sp were collected using PSC and 57.89 % collected using HLC.

In all the *Anopheles* mosquitoes collected, Wuru recorded the least number of mosquitoes with a total of 1,130 (31.74 %) species while Saboro had the largest with 1,425 (28.23 %) *Anopheles* mosquitoes.

Table 1 (p.11) below presents the monthly distribution of *Anopheles* species collected during the study in all three communities using PSC. A large number of mosquitoes were collected in October in each community but the numbers began to decrease in the subsequent months with February recording the least.

Figure 1 (p. 12) presents the number of mosquitoes caught per room during PSC in Wuru and Saboro in the study area.

A log-transformed HLC data subjected to Student's t-Test analysis showed that mosquitoes in the study areas are more endophilic than exophilic. In Wuru, there was a significant difference between the number of mosquitoes caught indoors and outdoors ( $P < 0.05$ ) but not Saboro.

### 1.2.1 Molecular species of *Anopheles* mosquitoes

When the *Anopheles* species were subjected to PCR analysis for species identification, they were all found to be *An. gambiae* ss. *Anopheles funestus* found were not infected with filarial worms in this study.

### 1.2.2 Filarial infection status of *Anopheles* species in the study area

Upon the maceration of 3,560 *Anopheles* mosquito species, only 3 were found to be infected with various stages of filarial worms. Four *Anopheles* species were infected with microfilariae. One microfilaria each were found in the head and thorax of a mosquito each collected from HLC indoor and outdoor (Tables 4, 5; p. 12) respectively but not in PSC. Also, only one L2 was recorded in the thorax of a mosquito collected during HLC (outdoor) in Wuru (Table 4; p. 12) but none was found in mosquitoes macerated from HLC (indoor) and PSC collections (Tables 3, 5; p. 12).

### 1.2.3 Transmission parameters in the area

#### 1.2.3.1 Transmission parameters for HLC

At the end of the study, the man biting rate and infection rate of *Anopheles* species were computed for the study

areas. For man biting rate (man contact rate), 162.2 bites/man/night (b/m/n) and 143.75 b/m/n were computed for Wuru and Saboro respectively. The infection rates were 0.00154 worms/mosquito (w/m) in Wuru and 0.00348 w/m in Saboro. Generally however, there was no infective bites in any of the two communities hence the infective rate, infective man biting rate, annual infective man biting rate, worm load and annual transmission potential were all zero (Table 6; p. 13).

### 1.2.3.2 Transmission parameters for PSC

For pyrethrum spray catches (Table 7; p. 13), the man biting rate and infection rate were as follows: 108.25 b/m/n with zero worms/mosquito in Wuru, 96.75 b/m/n with zero worms/mosquito in Saboro and 132.25 b/m/n with 0.00170 worms/mosquito in Korania. On the contrary, since no infective stage was found, the infective rate, infective man biting rate, annual infective man biting rate, worm load and annual transmission potentials were nil for all the three study sites.

## 2. Discussion

Monitoring of parasites transmission is an important component of any LF control programme, especially following the implementation of the GPELF in 2000. Transmission assessment is required in order to assess the efficacy of MDA, when to stop MDA and for the certification of elimination of the disease (WHO, 2011). Therefore, monitoring the transmission pattern in insects is ideal since the mosquito vectors may offer real time estimate of the transmission as reported by Goodman *et al* (2003). It, however, could be postulated that the magnification of microfilariae may be marginally quicker in humans as indicated by Boakye *et al* (2007). On the contrary, it is possible that very low level of microfilariae may not be easy to detect in human population. As a result, the detection of infections in mosquito vectors is an indication that there may be positive individuals in the area. Appawu *et al.* (2001) reported that in order to determine the efficacy of LF control programmes, the required monitoring index of transmission is the infection rate which requires large numbers of mosquitoes irrespective of the collection method. This study has shown that in terms of numbers and probably accurate estimation of transmission indices, HLC alone can suffice in situations where the vector population densities are high as conformed were nil. The high biting rate in the study areas is not surprising because the district is known to be highly endemic for malaria to report of Boakye *et al.* (2007) (see Tables 2, 3, 4; p. 13).

However, the Man Biting Rate (MBR) in the study areas was high with low infection rates (Tables 6, 7; p. 13) in all the study sites. The Infective Rate, Annual Infectivity Rate, Annual Infective Man-biting Rate, Annual Transmission Potential and Worm Load in Wuru and Saboro respectively all year round. In all PSC and HLC collections, *Anopheles* mosquitoes constituted over 90 % and many of them were blood-fed.

The absence of L3 after dissection and examination of sampled *Anopheles* mosquito vectors in the area could be as a result of the impact of MDA in the area leading to a massive reduction of the worm load in the human population.

After 10 years of MDA in some areas in Central Region, LF transmission was still ongoing with ATP of 15.21 infective bites/person/year (Amuzu *et al.*, 2010). Previous report from the Tono irrigation area (Appawu *et al.*, 2001) estimated ATP to be 14.30 infective bites/man/year, indicating that transmission was still ongoing. However, 10 years on, the transmission has reduced considerably in the area after MDAs. In addition, the high long-lasting insecticidal nets (LLNs) coverage and usage in the area might have reduced the man-vector contact rates of the major vectors and sustains the gains from the MDAs. According to a report of the Upper East Regional Health Directorate, LLNs coverage in the KND is 87% with 81% usage. Results of the HLC revealed that the active biting hours were from 21:00 hours to 04:00 hours, a time in which many individuals will be sleeping under their protected nets. In literature, vector control alone has been used successfully to eliminate LF in many areas (Bockarie, 1994; Webber, 1977, 1979) and when integrated with MDA has helped to eliminate LF in Papua New Guinea (Burkot *et al.*, 2006).

Vector control also, successfully eliminated lymphatic filariasis when implemented alone or with mass drug administration. For instance, vector control was the primary tool for controlling filariasis in the Pacific before effective antifilarial drugs were available and even after effective antifilarials became available, vector control was preferred by Pacific island ministries and departments of health because MDA campaigns were considered too labour intensive (Burkot *et al.*, 2002).

Where *Anopheles* species are the vectors of malaria and filariasis, filariasis was eliminated from areas where indoor residual spraying (IRS) with DDT to control malaria was undertaken in areas of Papua New Guinea (Bockarie, 1994) and throughout the Solomon Islands (Webber, 1977, 1979). *Wuchereria bancrofti* was also eliminated from Australia by sanitation campaigns that controlled the major vector, *Culex quinquefasciatus* (Boreham, 1986). Vector control, also, played a significant role in elimination of LF from Japan (Sasa, 1976). National scale vector control programmes would have multiple potential benefits for LF elimination programmes. These include (1) the ability to suppress LF transmission without the need to identify all individual 'foci of infection'; (2) minimizing the risk of reestablishment of transmission from imported microfilaria positive individuals; and (3) reducing the spread of any DEC or albendazole resistant *W. bancrofti* which might emerge.



A similar parasitamaie study by Appiah-Kubi in 2009 to assess the effect of 7 years of community-directed treatment (ComDT) in Bui, another endemic area in the Kassena-Nankana District, revealed that only one positive case was detected in an 80-year old man out of 300 samples examined. These findings are in congruence with the principle of MDA that after 4 or more years of its implementation in endemic areas, the microfilariae in the human system should be low enough to reduce the chances of them being taken by blood feeding female mosquito vectors (WHO, 2010a, b). Thus the interventions against lymphatic filariasis in the area have protected neglected populations from infection, prevented disability and its related costs and could have promoted economic productivity.

The study also identified *An. gambiae ss* as the dominant species, with some few members of *Culex* species (Figure 1). *Anopheles gambiae ss* is the major vector of *W. bancrofti* in the study area which supports the findings of Appawu *et al* (1994, 2001) in the same region as well as records of similar results in rural parts of coastal Ghana (Dunyo *et al.*, 1996, Ughasi *et al.*, 2012) where *An. melas* and *An. gambiae ss* were incriminated as a sibling species of *An. gambiae* complex that were infective.

The relatively somewhat higher vector densities in Wuru in particular probably led to the slightly high microfilarial rates in the human population since this community is affected by the Tono irrigation project. This could be due to the fact the opening of the canals for farming activities, the broken down canals, choked canals, the numerous low lands which contain flooded pools coupled with the surrounding streams in these areas led to dry season populations of vectors of LF to increase to levels of the wet season as reported by Dzodzomenyo *et al* (1999). Hence the relative difference in vector density between Saboro and Wuru later in the dry season (Table 1, 2 and Figure 4). These findings agreed with previous reports of Hunter *et al* (1993) and Yewhalaw *et al* (2009) that irrigated projects provide not only opportunities for growing crops throughout the year, but also create large expansions of perennial water, ideal breeding sites with higher humidities for mosquitoes which may favour vector survival to an age in which they can become infective. Apart from that, irrigated areas create new opportunities for fishing activities and attract people, leading to overcrowding and slum settlements. Hence more infective feeds for *Anopheles* mosquitoes that led to a high intensity of disease transmission (Appawu *et al.*, 1994, 2001) before the implementation of the MDA by the National LF Control as directed by the GPELF of World Health Organization.

Although irrigation is relevant for food production to support the ever-increasing human population, to augment the current plan of WHO to eliminate filariasis by the use of MDA with ivermectin plus albendazole and morbidity management in the country, water resources development agencies and health policy makers need to collaborate in the planning and execution of irrigation schemes in order to reduce vector breeding while accruing the benefits of the scheme.

The fact that some *An. gambiae ss* were infected with filarial worms confirmed by molecular analysis using PCR to be *W. bancrofti* could mean that there is possible transmission ongoing despite the absence of L3 infective mosquitoes. It is probable that L3 infective *An.* vectors were not captured during the collection or the mosquitoes might have lost the infective stages during a previous blood meal before being caught since many of the PSC and some HLC collections were blood-fed. This assertion stems from the fact that the reports of Gyapong *et al.* (1994, 1996) and Appawu *et al.* (2001) indicated that the area was highly endemic before MDA implementation.

*Anopheles* species are considered to exhibit the process of facilitation (Weber, 1991; Southgate and Bryan, 1992; Snow *et al.*, 2006); therefore it is assumed that low level microfilaraemia resulting from MDA would lead to interruption of transmission and elimination of lymphatic filariasis in anopheline transmission areas (Amuzu *et al.*, 2010). *Anopheles gambiae ss* on the contrary exhibit facilitation while *An. melas* show limitation in Ghana. The evidence that, at least in Ghana, not all *Anopheles* species may exhibit the process of facilitation and that limitation and facilitation occurred in communities as close as 28 km suggested that vectorial systems at the local level should be taken into account if LF elimination is to be achieved (Amuzu *et al.*, 2010).

Moreover, the fact that limitation and facilitation occur in local mosquito vectors implies that vector control should therefore be considered in addition to MDA for areas where the principal vectors exhibit limitation as is found in the study for *An. melas* in Gomoa in Ghana.

In conformity with GPELF, all members in the studied communities are being treated with IVM/ALB once a year through the Ghana National LF elimination programme (Boakye *et al.*, 2004).

### 3. Conclusion and recommendations

Among the *Anopheles* mosquitoes, *An. gambiae* was the conspicuous species with a couple of *An. funestus*. A thorough analysis of the results indicated that there is no active ongoing transmission of lymphatic filariasis following 10 rounds of MDA in the area. On the contrary, the man biting rate in all the three communities was high including some level of infection in some *Anopheles* species particularly in Korania. This calls for vigilance in the area because it could be that no infective mosquito was collected during the study despite their presence. The high presence of *An.* species in the area calls for intensified vector control strategies because apart

from the fact that ongoing LF transmission was not detected in them, they are still vectors of both malaria and LF and/or they could exhibit limitation in LF transmission. Vector control should also be integrated with MDA in the southern sector where MDA alone is proved not to be efficient in the eradication campaign.

A follow up investigation is required to ascertain the findings of this research in the subsequent years since one research assessment of transmission is inadequate as far as transmission assessment survey is required and if elimination certification is to be considered. Also, similar research projects should be conducted in other endemic regions of sub-Saharan Africa since some of the possible vectors can exhibit limitation in their vectorial capacity.

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### Tables and figures

Table 1: Total number of *Anopheles* sp collected during PSC

Community	Period				Total
	2011 October	November	January	2012 February	
Wuru	198	115	94	74	481
Saboro	164	125	70	71	430
<b>Total</b>	<b>852</b>	<b>364</b>	<b>305</b>	<b>248</b>	<b>1,499</b>

Key: m/r = mosquitoes per room

Table 2: Total number of *Anopheles* sp collected from Wuru, Saboro and Korania using HLC

Community	Period								Total
	2011				2012				
	October		November		January		February		
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	
Wuru	132	116	76	68	68	60	68	61	<b>649</b>
Saboro	115	114	72	69	52	48	55	50	<b>575</b>
<b>Total</b>	<b>384</b>	<b>358</b>	<b>263</b>	<b>227</b>	<b>193</b>	<b>180</b>	<b>243</b>	<b>213</b>	<b>2,061</b>

Table 3: *Anopheles gambiae* positive for *W. bancrofti* and parasite stages (HLC: Indoor)

Site	Date	Molecular <i>An. sp</i>	ID:	Number, Stage and Site of parasite in <i>An. sp</i>			Total
				Head	Thorax	Abdomen	
Saboro	5/2/12	<i>Ag. ss.</i>	1Mf	0	0	0	<b>1</b>
Wuru	Entire Period	<i>Ag. ss</i>	0	0	0	0	<b>0</b>
<b>Total</b>			<b>1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1</b>

Key: Mf - Microfilaria, *Ag. ss* – *Anopheles gambiae* sensu stricto

Table 4: *Anopheles gambiae* positive for *W. bancrofti* and the stages of parasite (HLC: Outdoor)

Site	Date	Molecular <i>An. sp</i>	ID:	Number, Stage and Site of parasite in <i>An. sp</i>			Total
				Head	Thorax	Abdomen	
Saboro	5/2/12	<i>Ag. ss</i>	0	1Mf	0	0	<b>1</b>
Wuru	5/1/12	<i>Ag. ss</i>	0	1L2	0	0	<b>1</b>
<b>Total</b>			<b>0</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>2</b>

Key: Mf - Microfilaria, L2 - Second stage larva, L1 - First stage larva, *Ag. ss* – *Anopheles gambiae* sensu stricto

Table 5: *Anopheles gambiae* positive for *W. bancrofti* and the stages of parasite (PSC)

Site	Date	Molecular <i>An. sp</i>	ID:	Number, Stage and Site of parasite in <i>An. gambiae</i>			Total
				Head	Thorax	Abdomen	
Saboro	Entire Period	<i>Ag. ss</i>	0	0	0	0	<b>0</b>
Wuru	Entire Period	<i>Ag. ss</i>	0	0	0	0	<b>0</b>
<b>Total</b>			<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

Key: L1 - First stage larva, *Ag. ss*: *Anopheles gambiae* sensu stricto



Table 6: Transmission parameters estimated for HLC in the study area

Site	Mosquito sp	No. caught	MBr (b/m/n)	Ir (w/m)	IR (Ib/m/y)	IMBr (%)	AIMBr (%)	WL (Ib/m)	ATP (Ib/m/y)
Wuru	<i>An sp</i>	649	162.25	0.00154	0	0	0	0	0
Saboro	<i>An sp</i>	575	143.75	0.00348	0	0	0	0	0

Key: b/m/n: bites/man/night; W/m: worm/mosquito; Ib/m/m: infective bites/man/month; Ib/m: infective bites/man; Ib/m/y: Infective bites/man/year; WL: Worm load; MBr: man biting rate; Ir: infection rate; IR: infective rate; IMBr: infective man biting rate; AIMBr: Annual infective man biting rate; ATP: Annual transmission potential

Table 7: Transmission parameters for PSC in the study area

Site	Mosquito sp	No. caught	No. of blood-fed	MBr (b/m/n)	Ir (w/m)	IR (Ib/m/y)	IMBr (%)	AIMBr (%)	WL (Ib/m)	ATP (Ib/m/y)
Wuru	<i>An sp</i>	481	433	108.25	0.000	0	0	0	0	0
Saboro	<i>An sp</i>	430	387	96.75	0.000	0	0	0	0	0

Key: b/m/n: bites/man/night; W/m: worm/mosquito; Ib/m/m: infective bites/man/month; Ib/m: infective bites/man; Ib/m/y: Infective bites/man/year; WL: Worm load; MBr: man biting rate; Ir: infection rate; IR: infective rate; IMBr: infective man biting rate; AIMBr: Annual infective man biting rate; ATP: Annual transmission potential

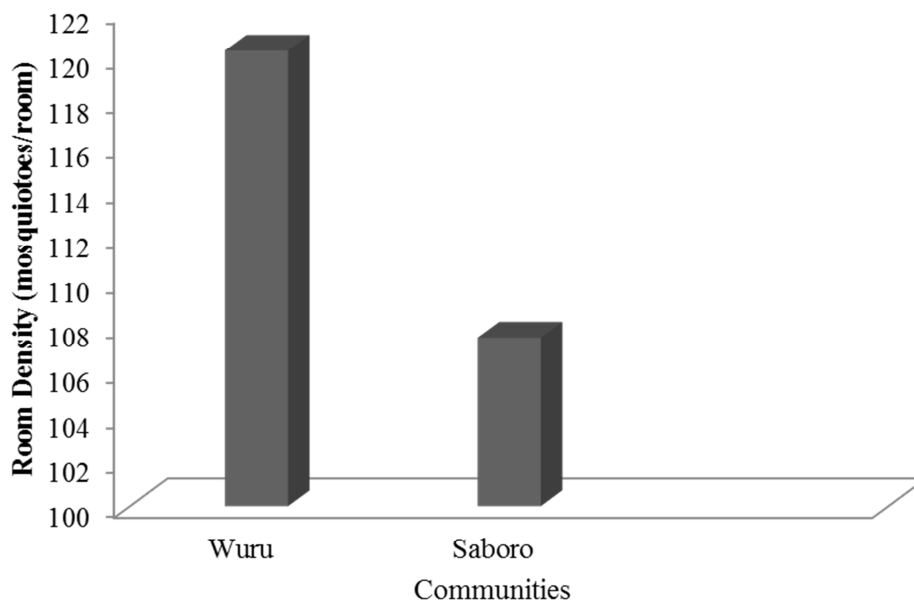


Figure 1: Room density of *Anopheles* spp in Wuru and Saboro

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