Chapter

Nipping the Malaria Vectors in the Bud: Focus on Nigeria

Omolade Olayinka Okwa

Abstract

Vector control is an important component of malaria control. Human malaria is a mosquito-borne parasitic disease which causes up to a million deaths a year and is estimated to infect over 212 million people worldwide. It is present in 97 countries covering half of the world's population. Around 90% of deaths occur in sub-Saharan Africa, especially Nigeria and the Democratic Republic of the Congo (DRC). Malaria is the most widespread mosquito-borne disease in Nigeria where it has a holoendemic status. Of the four malaria parasites in Africa, *Plasmodium falciparum* is the most common malaria species, while *Anopheles gambiae sensu stricto* is the predominant vector in Nigeria. This review discusses the challenges to control malaria in Nigeria which gives a larger picture of sub-Saharan Africa. These challenges include the adaptability of the anopheles mosquito to the environment, their diversity, and their different vectorial capacities. Despite all the efforts to control malaria, it is still a public health challenge in Nigeria and in sub-Saharan Africa. However, one of the basic challenges is the source which are the diverse breeding sites. This problem is enhanced by malariogenic activities of humans. Salient recommendations for vector control by nipping the malaria vector in the bud were identified and advocated.

Keywords: *Anopheles*, malaria, *Plasmodium*, vectors, Nigeria

1. Introduction

Human malaria is a parasitic disease caused by five species of *Plasmodium* (a protozoon) such as *P. falciparum*, *P. ovale*, *P. malariae*, *P. vivax*, and the zoonotic *P. knowlesi* in Asia. Globally, malaria causes up to a million deaths a year and is estimated to infect over 212 million people. It is present in 97 countries covering half of the world's population [1]. Around 90% of deaths occur in sub-Saharan Africa, especially in Nigeria and the Democratic Republic of the Congo (DRC) [2]. It is an established fact that malaria kills over a million children every year in sub-Saharan Africa [1, 3].

As a vector-borne disease, malaria vector control is an important component of malaria control. The malaria parasite has a complex life cycle, having a series of stages in the mosquito and the human host. The transmission of malaria takes place when the parasite enters the host through the saliva of the insect during a blood meal. As mosquitoes continue to threaten human health and existence, there is a need to continually fight back by nipping the malaria vectors in the bud by diverse mosquito control methods.

These concerns necessitate preventive approaches to control malaria by mosquito control methods that involve "nipping in the bud" from the source of the malaria problem.

2. Mosquitoes as deadly insect vectors

Mosquitoes are slender, fragile, flying insects of about 3–6 mm in the order Diptera (true flies) within the invertebrate super-phylum Arthropoda. These insects are the deadliest animals on the planet earth, transmitting not only malaria parasites but also filariasis, yellow fever, dengue fever, Zika virus, Mayaro virus, Ross River virus, West Nile virus, Rift Valley fever, Japanese encephalitis, St. Louis encephalitis, chikungunya, and other pathogens and bringing death and misery to millions every year [4]. There are about 40 mosquito genera, and Africa is the home to three important, efficient, and deadly mosquito genera which are *Anopheles*, *Culex*, and *Aedes* species [5]. The female *Anopheles* belonging to one of these deadly genera transmits malaria even more than wild fire!

3. The adaptability of the *Anopheles* mosquitoes

Malaria is a problem in the tropics and not in temperate regions of the world. In the temperate countries, there are mosquitoes, but the life of the malaria parasite inside the mosquito is a race against time. The time taken for the malaria parasite to go through its growth and development is close to the average life span of the mosquito itself. This period is longer in the temperate areas where the survival of the parasite is on the knife edge, and temperature below certain point reduces the life span of the mosquito before it can transmit malaria [6].

The adaptability of *Anopheles* mosquitoes in the tropics and the ability to thrive in variety of habitats are a big challenge, and this is tantamount to greater spread of malaria.

Mosquitoes naturally infest ponds, marshes, puddles, swamps, and other wetland habitats. However, mosquitoes can also breed in any collection of still or stagnant waters [7].

Adult female mosquitoes may live up to a month in extreme cases in captivity but up to 2 weeks in nature. They are poikilothermic and have amazing adaptability such as suctorial mouthparts, holometabolous life cycle, and great diversity which are some of the secrets behind their success [8].

Both male and female *Anophele*s mosquitoes feed on sugary and plant juices as source of energy, flight, and dispersal. However, only the female mosquitoes feed on blood which is required every 2–3 days for the maturation of its eggs as the plant sources are inefficient. This blood sucking instinct is a mandatory biological process [9]. Female mosquitoes mate once in a lifetime and require still waters to oviposit. Mosquito goes through four stages during its life cycle. The first three stages egg, larva, and pupa are aquatic, but the adult is aerodynamic but may also rest on vegetation. More so, in Africa, malaria-carrying mosquitoes typically bite between dusk and dawn which coincides with the sleeping patterns of the people [3, 6].

3.1 The environment and the human malaria vectors

Distribution and incidence of vector-borne diseases are determined by the ecological conditions that favours them [10]. There is a relationship between the environment and mosquito abundance [11]. There are evidences that mosquito can adapt to environmental changes and even water pollution [12]. Today's mosquito breeds even where we thought they can never thrive due to environmental changes [9]. It has been established that climatic factors have profound influences on mosquito's life span [13]. As ecosystems are being modified across the planet, the habitat is altered, and malaria territories are being extended because of global warming.

Consequently, any small variations in microclimate can affect the mosquito's chances of survival or longevity [14].

3.1.1 Environmental factors

These include factors such as temperature, rainfall and humidity which are important factors for mosquito development, and longevity [15]. Changes in the local environment are important as they create or reduce the number of suitable breeding sites for vectors, so affecting their abundance and transmission pattern [16]. Temporal and spatial changes in temperature, precipitation, and humidity under different climatic conditions will affect the biology and ecology of malaria vectors and consequently the risk of malaria transmission [15].

3.1.2 Temperature

This factor has been regarded to be the most important factor affecting mosquitoes [17, 18]. A drop in temperature can change a mosquito's life span by more than 1 week. Small changes in temperature result in large differences in availability and development of mosquitoes. This implies that if temperature rises, the larvae takes a shorter time to mature and more offspring are produced. In fact, temperature affects metamorphic changes of mosquitoes in their breeding water sites [18]. This also means that the frequency of sucking and digesting of blood meal by female mosquitoes increases, and this has grave implications for malaria transmission [17].

3.1.3 Rainfall

This factor also plays a role in mosquito ecology as it increases the availability of surface water and so more breeding sites and affects relative humidity and hence longevity of the adult mosquito [6]. There is relatively lower temperature but higher relative humidity. Biting intensity of mosquito reduces as rainfall reduces and can be suspended at low temperature. Rainfall also determines the type of predominant malaria vector species. For example, *An. arabiensis* prevails in the dry season, while *An. gambiae sensu stricto* (ss) is a rainy season vector [8, 9].

3.1.4 Vegetation

Mosquitoes will rest in houses after feeding if there is no outdoor resting site. Vegetation increases outdoor resting sites and mosquito abundance, and type of species could relate to type of vegetation cover [19]. For example, it has been reported that *Anopheles arabiensis,* a malaria vector in Nigeria, predominates in the arid savanna, while *An. gambiae ss* is a forest-loving vector. *An. arabiensis* has been identified in deforested areas within forested areas in urban areas [6, 9].

4. The challenges of malaria vector control in Nigeria

4.1 Human malaria in Nigeria

Malaria is the most widespread mosquito-borne disease in Nigeria where it has a holoendemic status, the most vulnerable groups being children aged 0–5 years and pregnant women [3]. The disease accounts for 25% of infant mortality and 30% of childhood mortality [2]. Nigeria contributes the highest burden to global malaria morbidity and deaths. This is about 25% of global malaria cases, about 30% of global malaria deaths [20]. Malaria is one of the greatest causes of outpatient visits and work and school absenteeism in Nigeria [21, 22]. It has a familiar reputation of causing fever, headache, and teeth chattering shills and shakes [22]. Malaria is the number one killer disease in Nigeria where unfortunately, it is called "common" malaria. This is an irony! Malaria death has been described by an expert as causing death more than the deaths due to the first and second world wars [9]. No wonder the World Health Organization described mosquitoes as the deadliest animals on the planet earth [4].

P. falciparum is the most virulent species of malaria parasite in Nigeria. It causes 95% of infections, while *P. malariae* causes 5% of infections in Nigeria [23]. *P. ovale* is rarely seen, while *P. vivax* is absent in the whole of West Africa [24]. The risk of malaria exists throughout the country where it is a disease of public health concern. Malaria imposes immense morbidity and mortality as well as socioeconomic burdens on both individuals and the nation at large [21, 22].

4.2 Efforts to control human malaria in Nigeria

Nigeria is a large country and the most populous country in Africa (169 million; Nigeria population commission) and one of the hardest hit by malaria in the entire globe [25].

The Nigeria Federal Ministry of Health reported that Nigeria loses about 1.1 trillion naira annually to control malaria. A lot of funds have been invested on malaria drugs, insecticides, and mosquito nets for control of malaria. The Nigerian Minister of Health claimed that malaria reduces the country's gross domestic product (GDP) by 1% annually [26].

The burden of malaria in Nigeria is being managed through effective case management and vector control measures, including the use of insecticide-treated bed nets (ITNs) and indoor residual spraying (IRS). ITNs are now distributed freely to vulnerable groups in Nigeria. IRS is also one of the major vector control interventions used in Nigeria today. However, these methods have limitations in their usage [27].

Vector control has proven record in the prevention and control of vector-borne diseases. However, it is bad news that despite all the efforts to control mosquitoes in Nigeria, they are not even threatened or on the verge of extinction [9]. Malaria still remains a deadly scourge and formidable foe of public health concern. These are the main challenges:

4.3 Diverse anopheles species complexes and sibling species

Malaria transmission dynamics is a complex system that is superficially understood. For example, one has to deal with diversity of mosquito species in the tropics. The *An. gambiae* complex is the predominant vector in sub-Saharan Africa, but it is not the only vector in the field [18, 23].

- The *Anopheles gambiae* species complex consists of at least eight different sibling species: *An. gambiae (ss), An. arabiensis*, *An. melas*, *An. merus*, *An. quadrimaculatus A*, *An. quadrimaculatus B*, *An.bwambae*, *and An. coluzzi* [9, 23, 28].

- *An. funestus* species complex is another group of mosquitoes that play significant role in malaria transmission in sub-Saharan Africa. This complex occurs in sympatry with the *An. gambiae* complex [23, 29]. The eight sibling species of the *An. funestus* species complex are *An. funestus* ss, *An. rivulorum*, *An. vaneedi*, *An. leesoni*, *An. parensis*, *An. brucei*, *An. confuscus*, and *An. aruni*.

An. funestus ss like *An. gambiae ss* is also very widespread, highly endophilic, and anthropophilic and hence anthropophagic. Both complexes are polymorphic, biologically and genetically. Evidences suggest that they may share the same habitat, although *An. funestus ss* is more restricted in habitat choice than *An. gambiae ss* [18, 23, 30].

The behavior of each of the sibling species in both complexes varies and so their roles in malaria transmission. Hence, targeting only one sibling species by whatever method is not going to curb the menace of malaria. The diversity of the epidemiological situations within sub-Saharan ecotypes presents different malaria situation [31]. Comprehensive knowledge of behavior and heterogeneities that exist within, and among these vectors, will always be of benefit. Any strategy aiming at control will have to account for this heterogeneity in species diversity [32].

Malaria transmission dynamics is variable throughout Africa with huge variability in transmission patterns even within villages few kilometers apart [33]. The correct analysis of the distribution of specific malaria vectors is one of the prerequisites for meaningful epidemiological studies and for planning and monitoring of successful malaria control or eradication program [34].

In the past, large areas of Nigeria had no reliable data in the past on presence and absence of vectors [23]. It has been established that there are diversities of malaria vectors in Nigeria and they have different bionomics and vector competences. In Nigeria today, 35 *Anopheles* species have so far been recognized, but they do not all transmit malaria under the same circumstances. Some *Anopheles* mosquito species have unknown vector status, while some are non-malaria vectors ([9, 12]. However, the malaria transmission dynamics in Nigeria is mainly vectored by members of the *An. gambiae* complex such as *An. gambiae ss*, *An. coluzzi*, and *An. arabiensis*. *An .funestus s*s is also an important main vector, while *An. nili*, *An. melas*, and *An. moucheti* are localized vectors in Nigeria [9, 23, 29]. Secondary vectors in Nigeria include *An. pharoensis*, *An. coustani*, *An. hancocki*, and *An. longipalpis* [9, 12].

Control measures can only be effective if the abundance, behavior, and proportion of the vectors are known. The existence of species complexes containing morphologically cryptic sibling or isomorphic forms presents a major challenge to malaria control program as these require vector identification using molecular techniques [32].

Failure to know which sibling species one is dealing with will result in wasting scare resources and time to control non-malaria vectors [9].

4.4 Vectorial capacity and vectorial competence of the malaria vectors

The malaria problem in sub-Saharan Africa represents a peculiar case because the vectorial system is the most complex anywhere. This vectorial system diversity absolutely impacts malaria epidemiology and control [35].

Vectorial capacity and vectorial competence have been used interchangeably to describe the ability of mosquitoes to serve as a disease vector. The two terms are not synonyms because vectorial capacity is qualitative and is influenced by such variables as vector density, longevity, and vector competence itself [3]. Vectorial capacity takes into account environmental, behavioral, and cellular and biochemical factors that influence the association between a vector, the pathogen transmitted by the vector, and the host to which the pathogen is being transmitted [36].

However, vectorial competence is a component of vectorial capacity which is governed by intrinsic and generic factors that influence the ability of a vector to transmit a pathogen. For example, the susceptibility of an *Anopheles* mosquito to sporozoite stage of *Plasmodium* species is an important component of vectorial competence [37]. Vector competence, however, differs from one species to another and from place to place. There are *Anopheles* species complexes that vary in their behaviors, vectorial competences, and capacities, and these present a real problem to malaria control in the tropics [35].

The main factor governing the ability of *Anopheles* species to act as malaria vector is the frequency with which it feeds on humans [37]. These malaria vectors associated with stable malaria are those which are strongly antropophagic, often feeding on humans to the exclusion of other hosts. Anopheline vectors of malaria consist of various behaviors associated with their biting activities and hence transmission dynamics [38].

4.5 Malariogenic activities and lifestyles of humans

Malariogenic activities and lifestyles are human activities that promote the transmission of malaria. The ability of mosquitoes to thrive even outside their natural habitat makes them a nuisance to mankind. Man and environment are created to interact with each other on a balance basis, but man has failed in his duty to the environment. The responsibility of man is to respect, protect, and care for the environment [9, 12].

By sheer negligence, mosquito breeds just under our nose, right inside our homes, so house spraying and screening are obviously inadequate. People store water in containers in their homes because of poor water supply, being ignorant of the consequences.

In residential areas, human activities create mosquito breeding sites such as discarded trash cans, open buckets, clogged gutters, abandoned vehicles, tires, drainages, ditches, natural depressions, or just anywhere that can retain water. Inside homes, endophilic female mosquitoes rest in dark places, corners of rooms, and behind curtains, but the exophilic biters rest on vegetation after feeding. When the eggs are about to be laid, they go into any suitable water within and outside the houses to oviposit.

4.6 Diverse breeding sites of the anopheles mosquito

It will be cost-effective to deal with mosquitoes by "nipping them in the bud" through eliminating their very source. The remote source of the malaria problem in the tropics is the mosquito's adaptability to environmental conditions and diversity and indiscriminate types of breeding sites which are of great importance [16]. The crux of the matter is that the intricacy of mosquitoes extends even into their breeding sites [9].

There is a considerable paucity of adequate information regarding vector oviposition habits, where *Anopheles* rest during the day and in their preferred breeding sites [39].

This information is critical for control efforts as we will not need to bother too much on the species or sibling species type or their vectorial capacities.

However, most researchers do not take into account the menace of mosquito breeding sites and the attendant environmental factors. The source of mosquito problem can be just near you or about anywhere where stagnant or still water collects or is stored in homes. This should be appropriately incorporated into vector control program.

5. Recommendations for action

- Integrated management approach has been said to be the best for malaria control program, but they must take into account the breeding sites of mosquitoes.

- Knowledge, attitude, and practices (KAP) is the educational diagnosis of a community and is also essential for control program.
- Health and environmental education of the populace on preventing domestic mosquito breeding is essential. The following steps should be noted.
- Objects, excavations, plants, and anything that can hold water must be eliminated. Water storage containers in homes should always be covered.
- People should dispose unused containers and place useful ones upside down under a roof or seal with a tight cover.
- People must change frequently the water troughs of domestic and pet animals and garden flower pots around homes.
- People should keep trash cans tightly sealed and drill a hole at the bottom in order not to retain water that may serve as breeding sites.
- People should fill up eroded soils, natural depressions, and excavations and empty rain-filled receptacles. Swimming pools in homes should not be left unused and untreated.
- Outdoor spraying of domestic animal shelters, garages, outdoor latrines, and tree hole fillings must be carried out regularly.
- People should spray oil on stagnant pools around them to kill mosquito aquatic stages.
- Drainage system, ditches, and gutters must not be dumped with waste to avoid clogging, thereby making them stagnant for mosquitoes to breed.
- People should take action to prevent sewage effluents, soakaway, domestic run-offs and empty soft drink bottles from becoming breeding sites of mosquitoes.
- People should adhere to basic architectural designs; house designs with excavations or rain-filled receptacles should be discouraged such as the eave tube technology in Benue State, Nigeria [40]
- Environmental sanitation should be everybody's business. Enforcement of environmental sanitation by clearing bushes, cleaning drainages and open gutters, destruction and removal of containers, plants, tires, sachets, and anything that can hold water around homes will go a long way. Therefore education of the populace on mosquito breeding sites in homes is advocated.

6. Conclusion

No doubt, human malaria affects the health, wealth, and welfare of human populations.

The disease causes serious morbidity, human suffering, and mortality. These adverse consequences have led to increased need to wage a continuous war against malaria vectors by prevention not only at the local, national, and global levels but also at the domestic level.

Malariologists and vector biologists will benefit tremendously if the source of mosquito breeding sites is located and destroyed. This will reduce the transmission threshold of malaria to a considerable level. Malaria will not be readily controlled if we continue to ignorantly breed mosquitoes domestically.

Health education, the principle by which individuals and groups of people learn to behave in a manner conducive to the promotion, maintenance, or restoration of health, is applicable to malaria control. It not only teaches prevention and basic health knowledge but also conditions ideas that reshape everyday habits of people with unhealthy lifestyles in developing countries. This type of conditioning not only affects the immediate recipients of such education, but it also impacts the future generations who will benefit from improved and properly cultivated ideas about health that will eventually be ingrained with a ripple effect.

Acknowledgements

I thank Intech for the invitation to contribute this book chapter.

Conflict of interest

The author confirms that there is no conflict of interest.

Author details

Omolade Olayinka Okwa
Department of Zoology and Environmental Biology, Faculty of Science,
Lagos State University, Lagos, Nigeria

*Address all correspondence to: okwaomolade@hotmail.com

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