

# Malaria in Africa and the Historical Perspective: The Journey so Far

Olowe O.A.<sup>1</sup>, Makanjuola O.B.<sup>1,3</sup>, Awa A.O.<sup>2</sup> and Olowe R.A.<sup>3</sup>

1, Department of Medical Microbiology & Parasitology, College of Health Sciences, Ladoke Akintola University of Technology. P.M.B. 4400. Osogbo. Osun State. Nigeria.

2, Seventh Day Adventist Hospital, Laboratory Unit. P.M.B. 5513. Ile-Ife Osun State. Nigeria,

3, Department of Medical Microbiology & Parasitology, (Research Laboratory Unit, Ladoke Akintola University of Technology Teaching Hospital. P.M.B.5000. Osogbo. Osun State. Nigeria

## Abstract

This is a review on the definition of malaria in Nigeria, historical concept and the journey so far. Malaria is a mosquito-borne infectious disease of humans and other animals caused by eukaryotic protists (a type of microorganism) of the genus *Plasmodium*. The protists first infect the liver, then act as parasites within red blood cells, causing symptoms that typically include fever and headache, in severe cases progressing to coma or death. The disease is widespread in tropical and subtropical regions in a broad band around the equator, including much of Sub-Saharan Africa, Asia, and the Americas. Five species of *Plasmodium* can infect and be transmitted by humans. Severe disease is largely caused by *P. falciparum* while the disease caused by *P. vivax*, *P. ovale*, and *P. malariae* is generally a milder form that is rarely fatal. Malaria is prevalent in tropical regions because the significant amounts of rainfall, consistently high temperatures and high humidity, along with stagnant waters in which mosquito larvae readily mature, provide them with the environment they need for continuous breeding. Disease transmission can be reduced by preventing mosquito bites by distribution of mosquito nets and insect repellents, or with mosquito-control measures such as spraying insecticides and draining standing water. The World Health Organization is working hard to reduce the burden of malaria in Nigeria and Africa as a whole.

**Keywords:** Malaria, Plasmodium species, Public health implication, Control

## INTRODUCTION

Malaria is a life threatening protozoan disease caused by malaria parasites belonging to the genus *Plasmodium*. Malaria parasites infecting humans belong to four species: *Plasmodium (P.) falciparum*, *P. vivax*, *P. malariae* and *P. ovale*. While these four species do not ordinarily infect animals; there is evidence that Chimpanzees may act as a reservoir host for *Plasmodium malariae* in Africa, providing a possible source of human infection. Arora and Arora;(2009).

**LIFE CYCLE:** Malaria parasites exhibit a complex life cycle involving alternating cycles of asexual division (Schizogony) occurring in man: an intermediate host and sexual development (sporogony) occurring in female anopheles mosquito which serves as a definitive host. Cheesbrough (2006), Arora and Arora; (2008) and (Ross, 1999).

**HUMAN CYCLE:** The sporozoites are the infective form of the parasite. They are present in the salivary glands of female anopheles mosquito and are injected directly into the blood stream when it bites a man.

**Primary exoerythrocytic schizogony:** After injection, all the sporozoites leave the blood stream and enter into liver parenchyma cells where they undergo development into primary exoerythrocytic schizont. Thereafter, the liver cells rupture and release merozoites into the blood stream Arora and Arora; (2008).

**Erythrocytic schizogony:** The liberated merozoites enter the blood stream and invade red blood cells where they multiply at the expense of the red cells. They pass through the stages of trophozoites, schizonts and merozoites, then the red cell ruptures to release the individual merozoites which then infect fresh red blood cells. This parasitic multiplication at this phase is responsible for clinical attack of malaria. (Arora and Arora; (2008).

This erythrocytic schizogony may be continued for a considerable period, but in the course of time the infection tends to die out. Cheesbrough (2006). (Arora and Arora; (2008).

**Gametogony:** After the malaria parasites have undergone erythrocytic schizogony for a certain period, some merozoites develop within red cells into male and female gametocytes known as microgametocytes and macrogametocytes respectively. The development occurs in the red blood cells of the capillaries of internal organs like spleen and bone marrow. Only mature gametocytes are found in the peripheral blood without causing any febrile condition in human host, they are produced for the propagation and continuance of the species. Cheesbrough (2006). (Arora and Arora; (2008).

**Secondary exoerythrocytic schizogony:** Occurs only in cases of *P. vivax* and *P. ovale*, some injected sporozoites on entering into hepatocytes enter into a resting (dormant) stage, called hypnozoites, before undergoing asexual multiplication while others undergo multiplication without delay. After a period of weeks, months or years these hypnozoites are reactivated to become secondary exoerythrocytic schizonts and they

release merozoites which infect red blood cells producing relapse of malaria. Cheesbrough (2006), (Arora and Arora; (2008). The relapse is the situation in which the erythrocytic infection is eliminated and a relapse occurs later because of a new invasion of the red blood cells from the liver merozoites. Hypnozoites are not formed in case of *P. falciparum* and *P. malariae* therefore relapse does not occur in disease caused by these species. On the other hand, recrudescence occurs when red blood cell infection is not eliminated by the immune system or by therapy and the number in the red blood cells begin to increase again with subsequent clinical symptoms. Cheesbrough (2006), (Arora and Arora; (2008).

**MOSQUITO CYCLE:** Sexual cycle starts in the human host itself by the formation of gametocytes that are present in the peripheral blood. Both sexual and asexual forms of the parasite are ingested by the female anopheles mosquito during its blood meal on infected patient but only the mature sexual forms are capable of further development. In the stomach of the mosquito, microgametes are formed from microgametocyte by the process of exflagellation. It develops into a macrogamete, its nucleus shifts to the surface where a projection is formed. Fertilization occurs when a microgamete penetrates this projection forming the zygote. The zygote matures into Ookinete which penetrates the epithelial lining of mosquito's stomach and lies between the external border of the epithelial cell and peritrophic membrane. Cheesbrough (2006), (Arora and Arora; (2008).

Here it develops into Oocyst inside which, the sporozoite develops. The Oocyst when fully mature, ruptures and releases sporozoites in the body cavity of the mosquito, they accumulate in the salivary ducts and at this stage, the mosquito is capable of transmitting infection to man. Arora and Arora; (2008).

### **HISTORICAL PERSPECTIVES:**

Malaria is an old disease whose name is derived from the Italian (mal-aria) or "bad air" and it was also known as Roman fever, ague, marsh fever, periodic fever, paludism Martin (2003). There were numerous, sometimes bizarre theories on how malaria was transmitted until 1898 when Dr. Ronald Ross discovered that the female Anopheles mosquito was actually responsible for transmitting malaria parasite. This discovery revolutionized malaria control, which had hitherto often been haphazard or based purely on treating the patient by killing the malaria parasites. (Phillips, 2001) Cheesbrough (2006), (Arora and Arora; (2008).

Malaria probably originated in Africa and accompanied human migration to the Mediterranean shores, India and South East Asia. In the past it used to be common in the marshy areas around Rome. As malaria is a disease mostly of tropical and subtropical areas, it is particularly prevalent in sub-Saharan Africa, but also common throughout other tropical regions of China, India, Southeast Asia, South and Central America. Cheesbrough (2006), (Arora and Arora; (2008).

In Nigeria, before independence, the colonialists established Government Reservation Areas (GRA) in an attempt to build their homes far away from the natives as it was found that the travelling/flying distance of these mosquitoes from the breeding grounds was a limiting factor in spreading the parasites. Nigeria's quest for effective control of malaria began well before the WHO global malaria eradication period between 1955 and 1968 Gilles *et al*; (2007). From 1955, however, a more focused egalitarian attempt at evolving strategic plans and interventions resulted in pre-eradication pilot studies such as the Kankiya District Project and the establishment of a division in Ministry of Health to deal with the mosquito and malaria problem.

The National Malaria Control Committee (NMCC) was set up in 1975 with the set mandate to reduce the malaria burden by 25%. It produced a five year plan of action that terminated in 1980, however, it recorded only modest achievements. It took another 8 years before progress was made when a major health system reform was carried out in 1988, with the adoption of a Health Policy for the country. Within this Policy, malaria was to be eradicated using the concept of Primary Health Care. The ministry of Health subsequently prepared guidelines for malaria control in 1989. Government finally came out with a National Malaria Control Plan of Action 1996. Past and present malaria control programmes as well as the most recent Malaria Control Programme Plan achieved limited success in eradicating the scourge. In spite of this, the malaria situation has steadily worsened and currently it is estimated that malaria accounts for 65 percent of all diseases reported in Nigerian health facilities and that 42% of pregnant women are diagnosed with malaria and affects the birth weight of infants. Akanbi (2009).

Moreover, it is estimated that at least 1 million people die of malaria each year, mostly children under 5 years of age WHO; (2005). More than 80% of the deaths worldwide occur in sub-Saharan African. (WHO, 2005, Afolabi et al., 2001)

### **CLINICAL FEATURES AND PATHOLOGY**

Rapid multiplication of the parasites result in destruction of the red cells. This causes a short bout of shivering, fever, sweating and the loss of healthy red cells which could lead to anaemia. When the next batch of parasites are released symptoms reappear. Fairhurst and Wellem; (2009). In addition, it starts with a cold stage (rigor) in which the patient shivers and feel cold, even though his temperature is rising. A hot stage follows in which the temperature rises to its maximum, headache is severe and there are back and joint pains, vomiting and

diarrhoea. The final stage is when the patient perspires, the temperature falls, the headache and other pains are relieved and the patient feels exhausted. Splenomegaly occurs in all forms of malaria with repeated attacks causing a greatly enlarged spleen, jaundice, coma, fatigue, alpha and beta thalassemia. Mockenhaupt *et al*; (2004); Buffet *et al*; (2009). Haemolytic anaemia and acute renal impairment are also features of malaria Sowunmi; (1996).

Malaria caused by *P. falciparum* which is referred to as falciparum malaria, formerly known as subtertian or malignant tertian malaria is the most widespread and pathogenic of the human species with untreated infections causing severe disease and death, particularly in young children, pregnant women and non immune adults Miller *et al*; (1994).

The Pathogenicity of *P.falciparum* is mainly due to: The cytoadherence of *P.falciparum* parasitized red cells, causing the cells to adhere to one another and to the walls of capillaries in the brain, muscle, kidneys and elsewhere. Sequestration of parasitized cells in the microcirculation causes congestion, hypoxia, blockage and rupturing of small blood vessels. Ho and White (1999). High levels of parasitemia resulting in the activation of cytokines and destruction of red cells; Angulo and Fresno (2002)

The factors that contribute to the spread and transmission of malaria depend on the interaction between the human host, anopheles vector, malaria parasite and environmental conditions. Arora and Arora; (2009). The prevalence is higher in rainy season than in dry season due to the breeding habitat of mosquitoes such as water, ponds, potholes and uncovered ditches Cheesbrough; (2006). Other factors contributing to the persistence of malaria in the country include resistance of *P. falciparum* to drugs such as chloroquine and of Anopheles mosquitoes to insecticides, impoverished economy, increased urbanization and development of epidemics following natural disasters and social unrest Cheesbrough; (2006). Furthermore if red cells of donors who recently visited or who have lived in a country where malaria is present are used, malaria parasites, which resist storage at 4°C, may therefore be transmitted to the recipient of infected red cells. Uneke *et al*; (2006)

#### **PREVENTION AND CONTROL:**

Measures necessary for the prevention and control of malaria include the following: Measures directed against the breeding of mosquito larva such as flushing or draining of breeding sites, clearing vegetation and spraying breeding sites with oil or chemicals. Measures directed against mosquito bites such as screening windows and doors with fine mosquito netting, bed netting treated with insecticides, wearing protective clothing, use of mosquito repellent and insecticides. Preventive and creative measures such as early diagnosis and treatment with drugs.

Health education to the people and the community on malaria control measures. ( Hall, 2006).

#### **THE HEAVY BURDEN OF MALARIA IN AFRICA**

Burden of malaria in Nigeria: Nigeria's health care system as provided through the public sector is organised in a three tiered system. The federal government develops policies and guidelines, providing funding and technical support as well as monitoring and evaluating implementation, the 36 states provide the second tier of the system. The third tier is at the level of the local government. Although decentralization is a stated goal of the current health ministry, the states and the local governments primarily implement policies developed at the federal level. Local council health departments are required to establish educational malaria programmes. With the prime focus being malaria control. National Malaria Control Programme (2011). In Nigeria, there is an estimated 25%-30% of mortality in children under five or an estimated 300,000 deaths each year due to malaria. Carson *et al*; (1998). In April 2004 Nigeria's Health minister reported that it spent over \$1 billion annually in treating malaria and that malaria was the cause of one out of three deaths in children and one out of ten deaths of pregnant women English *et al*; (2007). Chloroquine resistance was cited as a growing problem, owing in part to counterfeit drugs Evans *et al*; (2005) and Ajayi *et al*., (2003). Also, a director at the World Health Organisation, disclosed that residents of Lagos State in Nigeria spend about N1trillion annually on malaria treatment.

Malaria in africa: More than 1 million children die annually from malaria in Africa Allen *et al*; (1996), a child dies every 30second from malaria in Africa, 70% of deaths occur in children <5years of age Cheesbrough; (2006), and even in the first 6 months of life. Afolabi *et al*., (2001). Growing political commitment by African leaders for action on malaria was given a boost by the founding of the Roll Back Malaria (RBM) global partnership in 1998. Less than two years later African Heads of State and their representatives met in Abuja, Nigeria to translate RBM's goal of halving the malaria burden by 2010 into tangible political action. The Abuja Declaration endorsed RBM's goal and established a series of interim targets for the number of people having access to treatment, protective measures or, in the case of pregnant women, receiving intermittent preventive treatment to ensure that progress would be made towards the goal and malaria-endemic countries and other RBM partners held responsible. Considerable progress has been made since Abuja. Almost 20 African countries have reduced or eliminated taxes and tariffs on insecticide-treated nets (ITNs) to make them more affordable. More than half the malaria-endemic African countries, representing almost half the

population at risk have established Country Strategic Plans (CSPs) to achieve the RBM goal and the targets set in Abuja. CSPs are all based on the four technical elements of Roll Back Malaria and the evidence-based interventions associated with them prompt access to effective treatment promotion of ITNs and improved vector control, prevention and management of malaria in pregnancy and improving the prevention of, and response to, malaria epidemics and malaria in complex emergencies. Cheesbrough Monica (2006), (Arora and Arora; (2008).

Countries are now working through local partnerships to develop the capacity to fully implement their CSPs using ongoing health sector reforms and linkages to other initiatives, such as IMCI (Integrated Management of Childhood Illness) and MPS (Making Pregnancy Safer), to improve access to key interventions. CSPs have been successful in attracting new resources for malaria control. However, given projected resource needs to the year 2010, only 20% of necessary funds will be available locally. African countries, working with their partners and donors, must identify and mobilize resources for the remainder. Countries are looking to a variety of sources to ensure sustainable financing of their efforts to Roll Back Malaria this includes traditional sources of funding, from the national treasury and donor community as well as the exploration of new opportunities through debt relief schemes and the newly formed Global Fund to Fight AIDS, TB and Malaria WHO: *ROLL BACK MALARIA*; (2000).

### **MALARIA BURDEN AND THE ECONOMY**

Malaria limits international trade and development. The parts of the world that are continuously at high risk of malaria are predominantly the poorest Alnwick; (2001). Malaria is the major cause of absenteeism from work and school in Africa and reduced productivity, reduction in labour supply, illness and death Klausner and Alonso; (2004)

### **MALARIA TRANSMISSION PATTERN**

Malaria transmission and severity of the disease vary greatly from region to region, village to village and even from person to person Beales and Gilles; (2002). Mortality rate from malaria is higher in children between the ages of 6months and 5 years Maitland *et al*: (2004), Afolabi *et al.*, (2001). Children below the ages of 6months are protected due to passive immunity acquired from the mother and the fact that fetal haemoglobin does not support parasite growth Afolabi *et al*; (2001). The protection ceases after 6months and the child is vulnerable till the age of 5years afterwards immunity is then developed as a result of repeated attacks of malaria. Sharma *et al*; (2004). Up to 70% of individuals living in endemic areas carry the parasite without manifesting the symptom (asymptomatic malaria) up to 20% of school age children have been shown to carry sub-microscopic levels of the malaria parasites (sub-patent parasitemia) that can only be detected by polymerase chain reaction (PCR) Bottius *et al*; (1996).

### **MALARIA CONTROL**

Study shows that rate of transmission of parasite causing malaria differ depending on local factors such as rainfall patterns, the proximity of mosquito breeding sites to people and the type of mosquito species in the area. Lehmann *et al*; (2010). Malaria parasites are endemic in some region, where there are fairly constant number of cases throughout the year, while some region have "malaria season" mostly during rainy season. World Malaria report; (2008) shows that large and devastating epidemic can occur when the mosquito-borne parasite is introduced into areas where people had, had little prior contact with infected parasite and have little or no immunity to malaria, or when people with low immunity move into areas where malaria cases are constant. As malaria control intensifies, World malaria report; (2008) suggested that it is vital to monitor malaria burden, trends and track the coverage and impact of interventions while malaria undoubtedly imposes a major public health burden, estimates of the numbers of cases and death have been, for many countries too inaccurate to establish firm baseline against which to evaluate the success of control measures. Hoffman *et al.*, (2003), Hoffman *et al.*, (2002) and Keiser *et al.*, (2004). Study report of Global Burden of Disease; WHO (2004) shows that non immune pregnant women are at high risk of malaria can result in high rate of miscarriage and cause over 10% of maternal deaths, severe anaemia and impaired fetal growth. Sickle cell disease, thalasseмии and other hemoglobinopathies are among the most common genetic disorders of human. Newton and Krishman, (1998) Their high prevalence's in malaria endemic areas are considered to result from balancing selection, in that reduced fitness of affected individuals is counter balanced by some mode of protection against malaria Evans *et al*; (2005). Vector control has saved millions of lives worldwide, through indoor residual spraying, environmental management to eliminate breeding sites and use of mosquito larvicides. Steketee and Campbell; (2010).

Indoors Resident Spraying (IRS): One of the most effective methods of vector control is indoor residual spraying (IRS) In this method the inside wall of houses are sprayed with residual insecticides. When the mosquitoes rest on the wall, they absorb the insecticides through their feet Alnwick; (2001). The pesticides either kill them immediately or soon afterwards. Its cost, logistical complexity and moderate efficacy make it poorly

suited for controlling malaria in rural areas of sub Saharan Africa.

### **INSECTICIDE TREATED NETS**

In another method of control, a person sleeps under insecticide treated nets [ITNS]. The ITN works not only by creating a barrier between the mosquito and the intended meal, but also by killing the mosquito if it lands on the net Grover *et al*; (2006). Reduction of human-vector contact through insecticide-treated bed nets is better suited for malaria control in Africa, it enjoys greater community acceptance and is as efficacious as indoor residual spraying. Although they are inexpensive and effective, fewer than 2% of Africans sleep under them WHO; (2000). Massive campaigns to increase their use are required as a matter of urgency especially in rural Nigeria. Countries around the world use other methods of vector control with varying degrees of success. These methods include larviciding, the removal of breeding grounds by drying up wet lands or ensuring that pools of standing water are drained or by using biological controls such as fish that eats mosquito larvae. Walker (2002). The success of these controls depends highly on the type of vector and its breeding habitat, the geography of the area and the socioeconomic status of the population at risk.

Other strategies include: Intermittent preventive treatment in infants and pregnant women using existing drugs to protect them from the worst effects of the disease. Infants receive an antimalarial three times during the first year of life at the time of routine immunisation, whether or not they have malaria. IPT has the potential to become a major tool for malaria control in Africa because it can be delivered through the Expanded Programme on Immunisation [EPI], one of the best functioning systems of regular health contact with young children in Africa. UNICEF (2003).

### **LABORATORY DIAGNOSIS OF MALARIA MICROSCOPY BASED TESTS**

**STAINS:** A number of Romanowsky stains like Fields, Giemsa, Wrights and Leishmans are suitable for staining the smears. Thick films are ideally stained by the rapid Fields technique or Giemsa stain for screening of parasites. The sensitivity of a thick blood film is 5-10 parasites/ $\mu$ l. The blood films stained by Giemsa's or Leishmans stain are useful for specification of parasites and for the stippling of infected red cells and have a sensitivity 200parasites/ $\mu$ l. Castelli and Carosi; (1997).

The exacting needs of the blood smear examination, detection of low levels of parasitemia, sequestered parasites of *P. falciparum* and past infections in aspiring blood donors, ascertaining viability of the detected parasites, difficulties in maintaining the required technical skills are some of the deficiencies with the blood smear examination Grobusch *et al*;(1999).

Alternative microscopic methods have been tried, including faster methods of preparation, dark field microscopy and stains like benzothiocarboxypurine, acridine orange and Rhodamine-123 Keiser *et al*; (2002). Acridine orange has been tried as a direct staining technique with concentration methods such as thick blood film or the centrifugal quantitative buffy coat system and with excitation filter in the kawamoto technique Lowe *et al*;(1996). Inability to easily differentiate the plasmodium species, requirements of expensive equipment ,supplies and special training as well as the high cost limit the use of these methods Htut *et al*; (2002).

Fixed and preserved blood smears of patients for malaria were used for comparative analysis of acridine orange and giemsa stains Tarimo *et al*; (1998). The acridine orange staining method required less time and was more sensitive under lower magnification than the giemsa staining method. The acridine orange staining method provides an alternative to giemsa for malaria diagnosis in the field and laboratory Kong and Chung; (1995).

**Dip Stick:** The WHO said that the development of quality assured rapid diagnostic tests using a dip stick and a drop of blood necessitated a policy change. The tests can reliably demonstrate the presence or absence of malaria parasites in the blood and can be performed at all levels of the health system, including community settings. Rapid diagnostic tests (rdts), dipsticks or test strip bearing monoclonal antibodies directed against the target parasite antigens are simple to perform and to interpret. No electricity is required electricity, special equipment or training in microscopy They may detect *P. falciparum* infection even when the parasites are sequestered in the deep vascular compartment and undetectable by microscopic examination of a peripheral blood smear Bell; (2004).

They are, however, more expensive than microscopy can detect antigens produced by gametocytes can give positive results in infections where only gametocytes are present. Gametocytes do not cause any febrile condition and those of *P.falciparum* are not affected by schizonticidal drugs. Such positive results can lead to erroneous interpretations and unnecessary treatment Arora and Arora; (2009).

### **Quantitative buffy coat (QBC) test**

This method for identifying the malaria parasites in the peripheral blood was developed by Becton and Dickenson inc. Test involves staining of the centrifuged and compressed red cell layer with acridine orange and its examination under UV light source. It is fast, easy and more sensitive than the traditional thick smear film

examination Arora and Arora; (2009).

## TREATMENT

**Drugs:** Different methods of treatment of malaria has been reported previously and new methods of treatments are daily coming up due to modern techniques of understanding drugs and the parasited and the parasites mode of resistance to these drugs continues daily. (Olowe (2010). Unpublished article.

Quinine which has been used for more than three centuries is one of the four main alkaloids found in the bark of *cinchona* tree, and it's the only drug which over a long period of time has remained largely effective for treating the disease, partly because of undesirable side effects. it is used for treating severe *Falciparum* malaria. Newton and Krishna; (1998).

Chloroquine: First used in the 1940s shortly after the second world war is a low cost drug but very effective for treatment and prophylaxis. It was used in curing all forms of malaria, with few side effects when taken in the prescribed dose. Unfortunately most strains of *falciparum* malaria are now resistant to chloroquine. Meerman *et al*; (2005).

Fansidar: It's a combination drug, each tablet containing Sulphadoxine 500mg and Pyrimethamine 25mg. Resistance to Fansidar is now widespread and side effects have been reported Evans *et al*; (2005).

Maloprim: is a combination of dapsone and pyrimethamine. Resistance to this drug is now so widespread that its use is no longer recommended Murphy *et al*; (1995).

Mefloquine (Lariam) was first introduced in 1971 and it is related structurally to quinine. The compound was effective against malaria. Its long life meant to serve as a good prophylactic increasing resistance and together with undesirable side effects including acute brain syndrome has resulted in a decline in its use, White; (1998).

Halofantrin: belong to a class called the phenanthrene-methanols. It is an effective antimalarial introduced in the 1980s, has a short half life and is therefore not suitable for use as a prophylactic. Unfortunately resistant forms are increasingly being reported, and there is some concern about side effects such as neuropsychiatric disturbances.

Artemisinins is derived from a Chinese herbal remedy and covers a group of products. The two most widely used are Artesunate and Artemether. A high rate of treatment failures have been reported and it is now being combined with mefloquine and other antimalarials (ACT) for the treatment of *falciparum* malaria Hall; (2006). The artemisinin derivatives are the most rapidly schizonticidal antimalarial drugs known to date though do not remain in the blood stream for long. Meshnick *et al*; (1996). It has relatively good safety profile despite initial anxiety following pre-clinical findings and reduction in malaria transmission.

Factors that govern choice of drugs include parasite species, level of resistance to drugs in location, patients general health and medical history and availability of medication.

**Vaccine production:** Many factors make malaria vaccine development difficult and quite challenging. First the size and genetic complexity of the parasite mean that each infection presents thousands of antigens to the human immune system. Secondly, the parasite changes through several life stages even while in the human host, presenting a different substance of molecules for the immune system to combat at each stage. Playfair and Taverne; (1990). Thirdly, the parasite has evolved a series of strategies that allow it to confuse, hide and misdirect the human immune system. To develop vaccines and drugs that exploit their vulnerabilities in the parasites biology necessitates a complete understanding of the parasite and its complex relationship with its human and vector host. This is where unravelling the genetic code of *P. falciparum* published in 2002 presents a ray of hope as this has energised the malaria scientific community and also served to attract a much broader range of scientists to join the effort in discovering an effective vaccine. Scientists have brought technologies such as gene chips, proteomics and comparative genomics to research, though for now, no extraordinary breakthroughs are forthcoming. Malaria vaccine has not been forthcoming for quite sometime, but the rising funding levels, promising scientific advances and heightened global awareness of malaria have increased commitment to develop an effective malaria vaccine as soon as possible.

The malaria vaccine trial is the most promising yet. The vaccine is directed against the sporozoites. The Path Malaria Vaccine Initiative is very encouraging that among the under two year olds studied, the vaccine was about 50% effective against severe malaria. Bejon *et al* (2008).

**Mosquito Modification:** Other genetic approaches include modifying mosquitoes to produce offspring that cannot transmit disease but this failed because where several species of vector are present, a separate transgenic must be created for each one. WHO, (2004; 2005)

**Insecticides:** Dichlorodiphenyltrichloroethane (DDT), an organochlorine pesticide, became widely used in pest control after its discovery in 1972. Fear of it being a potential human carcinogen has limited its use, however,

some nations still effectively use DDT formulae control. Ecuador for example has increased its use of DDT since 1993 and has experienced the largest reduction of malaria rates in the world. Roberts; (1997), Zakai, (2003).

### RECOMMENDATIONS

The use of insect repellent in addition to increasing coverage of long lasting insecticide treated bed nets will provide greater protection.

The current tools for combating malaria such as artemisinin-combination therapy and can result in a major reduction in *Plasmodium falciparum*.

Control of mosquito, vectors of malaria may be enhanced by newer methods of biocontrol such as biopesticides containing a fungus that is pathogenic to mosquitoes hence reducing malaria transmission.

The effectiveness of an intermittent preventive treatment against malaria in children may be hindered by high incidence of malnutrition therefore adequate nutrition will help boost the immune system and may help protect children from malaria.

Existing Programmes such as Expanded Programme on Immunization, one of the best functioning systems of regular health contact with young children in Africa should be strengthened by Government.

The involvement of vaccines in developed countries against malaria parasites should be welcomed and funded by government in Nigeria.

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