ASSESSMENT OF KNOWLEDGE ON FACTORS CONTRIBUTING TO HIGHLAND MALARIA OUTBREAKS IN GUCHA DISTRICT AND AVAILABLE PREVENTIVE AND CONTROL MEASURES

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NOVEMBER, 2012
DECLARATION

This thesis is my original work and has not been presented for a degree or any other awards in any other university.

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This work is dedicated to my supervisors, Dr Michael Gicheru and Professor Zipporah Ng’ang’a who took their golden time to advise and encourage me during the entire period of this research work.
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ABSTRACT

Malaria is a mosquito-borne infectious disease of humans and other animals caused by protists of the genus *Plasmodium*. Malaria is responsible for high morbidity and mortality rates among children under five years and pregnant women. Recent climatic changes leading to global warming has resulted in the emergence of malaria in highlands in Africa where malaria never existed before. In Kenya, highland malaria is very rampant in Nyanza, Gucha District and some parts of Rift Valley province where it occurs as epidemics. Annually Malaria in Kenya claims the lives of 26,000 children aged less than five years old with an average death of 72 children per day. In order to curb these epidemics, prevention and control measures should be intensified. The strengthening of malaria surveillance and monitoring needs to be given priority in parallel with efforts to control the malaria vector. This will involve a combination of environmental, physical and chemical control measures, through joint efforts of both governmental and non-governmental agencies. A cross sectional descriptive study was carried out aimed at collecting both qualitative and quantitative data on knowledge on factors contributing to highland malaria outbreak and available control and preventive factors in Gucha District, Kenya. Data were collected using structured open-ended questionnaires, focus group discussions and desk reviews of health records and data at Gucha District hospital and some rural health facilities in Gucha District. The sample size was four hundred respondents. The study population consisted of adult patients and patient attendants aged 18 years and above who sought health care in Gucha district hospital and some rural facilities in Gucha District. Fifteen study sites were selected for representative coverage of the district. Data analysis was carried out by use of GraphPad InStat software and utilized one-way analysis of variance and Tukey-Kramer test. The study revealed that over 90% of Gucha District residents had completed secondary level education and over 78% of the respondents did not live in modern houses. Fever and feeling chilly were the most common symptoms of malaria infection reported by 51% and 20% of the respondents respectively. *Plasmodium* was cited by 55% while a combination of bites by mosquitoes and existence of stagnant waters were cited by 20% of the respondents as the main causes of malaria. Twenty nine percent of the respondents bought drugs from local sources while only 15.75% visited hospital for treatment against malaria. Forty four percent and 31% of the respondents reported a combination of bush clearing and drainage of stagnant waters and use of mosquito nets respectively as the most important mosquito control methods. Twenty eight percent of the respondents ate goats offal while the rest burnt various herbal plants as traditional methods for control of malaria. Hospital records data did not show any significant difference in malaria morbidity cases for the period from 1998-2006 ($P = 0.0546$) while higher number of children of 5 years or below were significantly infected with malaria compared to other age groups ($P = 0.0001$). There was no difference in mean monthly temperatures (0.8659), rainfall (0.6124) or humidity (0.5322) recorded between 2002 and 2006. The study concludes that although Gucha District residents are educated and do not use improved methods for control of malaria. Furthermore, majority of the people only go to hospital for malaria treatment following failure of self medication. The findings of this study are of high value to the ministry of health and other stakeholders in the fight against highland malaria in Kenya. Local people should be educated on proper environmental management to create unfavorable conditions for mosquito breeding. They should be educated on: bush clearing, draining of stagnant waters, planting food crops away from houses, proper construction of houses to eliminate cracks on walls and open eaves and filling up depressions created during brick making among other methods.
CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Malaria continues to be a major impediment to health in Africa south of the Sahara, where it frequently takes the greatest toll on young children and pregnant women (WHO, 2005; Hamel et al., 2011; Kendall, 2011). Malaria epidemics in highland areas of East Africa have caused considerable morbidity and mortality in the past two decades (Mouchet et al., 1998; Ernst et al., 2006). About 90% of all malaria deaths occur in Africa south of the Sahara (Sachs, 2002; Sachs and Malaney, 2002; MOH, 2003). More than a million people die of the disease every year, most of them children under the age of five (Coll-Seck et al., 2008; Wandiga et al., 2010). Some children suffer acute attacks of cerebral malaria that lead to coma and death. Others succumb to severe anemia that follows repeated infections or due to the consequences of low birth weight caused by malaria infection in pregnancy (MOH, 2003). In severe cases of cerebral malaria, surviving children may be left with epilepsy, speech disorders and blindness (WHO and UNICEF, 2003; CDC, 2004).

In endemic areas, the disease is responsible for 40% of all outpatient visits to clinics and up to 50% of hospital admissions. Malaria consumes a significant proportion of time, money and human resources available to health systems in Africa (Malaney et al., 2004). Malaria is caused by a protozoan parasite of genus *Plasmodium*. There are four species of *Plasmodia*, which infect man: *Plasmodium vivax*, *P. falciparum*, *P. malariae* and *P. ovale*.

Malaria is widespread in Kenya and varies from region to region due to diverse climatic and ecological conditions that range from semi-arid, deserts, to cold highlands. This diversity leads itself to a wide variation in malaria risk and subsequent malaria epidemiology. There are four malaria ecological zones in the country which include the hyper-holoendemic (stable) areas in
the western and coastal regions; the hypo-mesoendemic (unstable) areas in Rift valley, Central and Eastern regions, the highlands malaria epidemic zones in Western Kenya and Rift valley, and the arid epidemic zones in North Eastern Province (MOPHS, 2009). Illness due to malaria has reduced between 56% and 63% in many parts of Kenya especially in the Rift valley, Central, Eastern, North Eastern and Coast Provinces. However, the disease burden remains high in Western and Nyanza Provinces (DOMC, 2010; Mulambalah et al., 2011).

New analyses confirm that malaria is a principal cause of at least one – fifth of all young children deaths in Kenya. The burden of vector borne diseases in Kenya is intolerably high. Approximately 20 million Kenyans are at risk of contracting malaria. Each year, about 3.5 million Kenyan children below the age of five years are infected and an estimated 34,000 die due to malaria (MOPHS, 2009). The Ministry of public health and sanitation through the division of malaria control is committed to achieving the targets of Roll Back Malaria initiatives, the Abuja Declaration and the Millennium Development Goals (MDGS) via the Economic Recovery Strategy (ERS) and scaling up of effective interventions (MOPHS, 2009).

Malaria is the leading cause of morbidity and mortality in Gucha District (MOH, 2004). It affects people of all ages, but mostly children under five years and expectant mothers. There have been sporadic epidemics of highland malaria affecting 79% of children under five years and 37% of adults, causing deaths of 47% of the infected population in Gucha District (Merlin, 1999). In 1990, Western Kenya was devastated by a malaria outbreak and Merlin (an NGO dealing with epidemics) launched an immediate intervention in the worst affected district of Kisii and Gucha. An epidemiological survey was carried out throughout the area to determine the full extent of the epidemic. This revealed a worrying situation with up to 47% of the total population infected with malaria. Merlin is currently running four health clinics to provide medical care to the people in Kisii and Gucha Districts. At the same time, they have supported and expanded three regional health centres, thereby providing extra beds and staff
to cope up with the increasing number of patients (Merlin, 1999). Variations in rainfall and ambient temperature, between years can lead to epidemics affecting all members of the community (MOH, 2008; Wanjala et al., 2011).

1.2 Problem statement
The epidemiology of malaria over small areas remains poorly understood, and this is particularly true for malaria during epidemics in highland areas of Africa, where transmission intensity is low and is also characterized by acute illness within and varies between years (Brooker et al., 2004). There have been sporadic epidemics of highland malaria affecting 79% of children under five years and 37% of adults, causing deaths of 47% of the infected population in Gucha District (Merlin, 1999). A common feature of malaria in highland districts is that there is always overall low potential disease risk in an average year. Despite the availability of basic malaria control tools, it has not been clear why highland malaria has been on the increase. It was therefore important to establish the knowledge levels of the community on the causes of highland malaria and the available control strategies, with the aim of controlling and preventing future outbreaks.

1.3 Study justification
In collaboration with the Ministry of Health, Medicines San Frontiers (MSF) treated over 3,000 severe malaria cases and 30,000 uncomplicated cases in three hospitals in Gucha District between May and August, 2003 (MOH, 2004). Despite the work of MSF, since 1999 there has been a continued annual increment in the number of malaria cases within Gucha District. The cases of malaria infections in Gucha District were 89,158 and 125,328 in 1998 and 2003 respectively (MOH, 2004). The use of insecticide impregnated bed nets is one of the mosquito control measures available to children under five years and pregnant mothers in Gucha District (Merlin, 1999). Although the causes of malaria are known, there has been recent increase in incidence of highland malaria with current strategies of prevention and
control being unsuccessful (WHO and UNICEF, 2003). Indoor residual spraying (IRS) and insecticide treated nets (ITNs) alone have not given a breakthrough in preventing and controlling the highland malaria epidemics (WHO and UNICEF, 2003). An understanding of the causes of sporadic episodes of highland malaria and the people’s knowledge on the disease will be important in strategizing on the best preventive and control measures. Furthermore, assessing and analyzing local malaria problems are a prerequisite for successful control interventions (Erhun et al., 2005).

1.4 Research Questions
i. What are the underlying causes of the highland malaria outbreaks in Gucha District?

ii. What is the level of knowledge of the community on the causes of highland malaria?

iii. What are the control and preventive measures available in the District for the prevention of highland malaria?

1.5 Objectives
1.5.1 General Objective
To assess knowledge on factors contributing to highland malaria outbreaks in Gucha District and the available control and preventive measures.

1.5.2 Specific Objectives
i. To determine the climatic and socio-economic related to the outbreaks of highland malaria in Gucha District.

ii. To determine the level of knowledge of the community on the causes of highland malaria in Gucha District.

iii. To determine the control methods used in the prevention and control of highland malaria in Gucha district.
1.6 Significance of the study
The study was important as it tried to identify gaps in knowledge on factors contributing to increasing cases of malaria infections among residents of Gucha District. The study identified environmental-economic factors that are associated with high rates of malaria transmission. Knowledge on the peoples behavior, education levels, methods used by the local population to control malaria, hospital attendance behavior as well as how the residents use the environment is very important as a guide on how to formulate effective and important malaria control programs targeted at this population. The findings of this study will therefore assist policy makers in planning malaria control and preventive measures.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of malaria
Malaria is a life threatening parasitic disease transmitted by the female *Anopheles* and ulicidae mosquitoes. It was once thought that the disease came from fetid marshes, hence the name “mal aria” (bad air). In 18th century, scientists discovered the real cause of malaria as a one-celled parasite called *Plasmodium* (Manson *et al.*, 1978). Later, they discovered that the parasite is transmitted from one person to another through the bites of a female *anopheles* mosquito, which requires blood meal to nurture her eggs (WHO and UNICEF, 2003). The
disease affects all age groups. Each year, more than 26,000 children die in Kenya from the direct consequences of malaria (MOH, 2001).

The World Health Organization identified malaria as a key priority disease and announced the launch of the “Roll Back Malaria” initiative campaign, which aims to bring about a significant reduction in the global burden, with an initial emphasis on the high transmission areas of Africa (Coll-Seck et al., 2008). The malaria health burden has an important morbidity and mortality component, with the severe forms of the disease forming the majority of the hospital admission of young children in malaria endemic areas (Goodman et al., 2000). Epidemic malaria in highland areas represents a significant public health problem (Mouchet et al., 1998). Rising malaria rates are more likely the result of increased drug resistance of malaria parasites and the infrequent use of pesticides in mosquito breeding grounds.

Historically, low exposure to infection, has led to low levels of mortality in adults and children during epidemics. At the same time, national malaria control programmes are poorly equipped in terms of identifying and responding to outbreaks, and many previous outbreaks have been allowed to develop more or less unchecked. There is a dual need for scientific understanding of highland malaria on one hand and greater local capacity building in epidemic surveillance and response on the other hand (Mouchet et al., 1998).

Highland Malaria is the malaria which is affecting the highland dwellers where the disease used not to be reported due to the influence of the recent climatic changes leading to global warming causing the increase in temperatures therefore, supporting and sustaining the disease vector and the causative organism. Highland malaria in this case implies those malaria transmission factors which are directly or indirectly affected by altitude that are of epidemiological significance (Baraun et al., 1997). Most of these are environmental factors and temperature which affects the development and survival of the vector and more
significantly, the duration of *Plasmodium* development within the invertebrate host (Pampana, 1969). Spatial and temporal variations in precipitation are important in determining the nature and scale of malaria transmission in highland areas. The effects of rainfall and temperature are linked to relative humidity which has a significant effect on the longevity of adult vectors (Martens *et al*., 1995; McMichael *et al*., 1998; MOH, 2008). Relative humidity of 60% or more is necessary for effective malaria transmission (Molineaux, 1998). Once disturbed, the malaria transmission system will either reach a new equilibrium or return to its original position, depending on the nature of the original disturbance and the resilience of the system (Najera *et al*., 1993). In the African highlands, it has been noted that epidemics reflect irregular temporary disturbances to this equilibrium, most commonly associated with meteorological conditions.

### 2.2 Epidemiology of Malaria

Malaria is a complex and deadly disease that puts approximately 3.3 billion people at risk in 109 countries and territories around the world. In 2000, malaria caused 350 to 500 million clinical episodes world-wide annually (Korenromp, 2005) and resulted in over one million deaths (Rowe *et al*., 2006), most of which affect children under 5 years old in sub-Saharan Africa (WHO, 2008). Malaria is the fifth cause of death from infectious diseases worldwide (after respiratory infections, HIV/AIDS, diarrhoeal diseases, and tuberculosis) and the second in Africa, after HIV/AIDS (WHO, 2002). Recent estimates show that as many as 3.3 billion people live in areas at risk of malaria in 109 countries or territories (WHO, 2008). In addition to its health toll, malaria puts a heavy economic burden on endemic countries and contributes to the cycle of poverty people face in many countries. For example, it is estimated to have in Africa alone contemporaneous costs of at least US$12 billion per year in direct losses (e.g.
illness, treatment, premature death), but many times more than that in lost economic growth (Gallup and Sachs, 2001).

The malaria parasite responsible for human infections belongs to the genus *Plasmodium*. *Plasmodium falciparum* causes sub-tertian or malignant tertian, *P. malaria* causes quartian malaria, *P. Vivax* causes benign tertian or simple tertian malaria and *P. ovale* causes ovale malaria. *Falciparum* malaria exists in most of the tropic, but also in some temperate areas. *Vivax* is prevalent in some sub tropical areas, but is also found in some parts of the tropics and temperate regions. Quartian malaria is common in tropical areas. Ovale malaria is more prevalent in West Africa. The *Plasmodium* species are closely related but different in their ecology and epidemiological importance (Mutinga et al., 1993).

The geographical distribution of malaria depends on the survival of the vector. The vector needs a humid climate with relative humidity of 55 – 65%, warm average temperatures of 12 - 30°C and suitable breeding sites. In some places, transmission occurs throughout the year such as in the humid coastal belt and the lowland areas. Other areas are free of malaria such as those above altitudes of 1500 m (Rukunga, 2001). The epidemiology of malaria across sub-Saharan Africa is far from homogeneous, with variations from intense perennial transmission to highly seasonal low transmission in areas normally free of malaria. Across this range of transmission intensity, there are age specific associated patterns of malaria related morbidity (Rukunga, 2001).

In order to classify malaria endemicity in an area, the spleen enlargement rate of the patient is measured because repeated attacks of malaria often cause progressive enlargement of the spleen. The spleen enlargement rate is the percentage of children between the age of two and nine years with an enlarged spleen. Depending on the spleen enlargement rate, an area can be classified as hypo – endemic with very intermittent transmission; mesoendemic which has
regular seasonal transmission; hyperendemic characterized by intense, but with periods of no transmission during dry season or holo-endemic where transmission occurs all year long (Rukunga, 2001).

Recent links between climate change and malaria transmission has brought to the fore front the issues of malaria as an emerging disease in non-endemic areas, including areas where malaria had previously been controlled (Mouchet et al., 1998). Particular attention has focused on the highlands of Sub-Saharan Africa, which have been regarded as areas with little or no malaria transmission. This picture appears to be changing, with recent evidence indicating an increase in the number of malaria epidemics occurring in the highland areas and increasing stability of transmission in highland fringes (Molineaux, 1998). Changes in temperature can affect the development and survival of malaria parasites and the vectors that carry them. Rainfall also influences the availability of habitats and the size of mosquito population (Wandiga et al., 2006).

Anthropogenic factors may alter malaria transmission dynamics by increasing the emergence of efficient vectors, increasing the number of breeding sites through land use change, reduction in vector control activities leading to increased contact between man and the vector in occupational activities and seasonal migration (Khaemba et al., 1994). Increasing highland malaria transmissions have occurred at times when basic health services and malaria control activities have been in decline. Emerging drug resistance and uncertain drug supplies have compounded this problem. Under these conditions, a rise in observed morbidity and mortality may reflect an increase in malaria transmission and represents a significant problem in national malaria control programmes (Lepers et al., 1991).

Age is not a factor in temperate climates, but a potent factor in endemic areas, where the degree of infection is related to the duration of exposure of the individual and the community
to intense malaria (Moody and Chiodini, 2000). The environment, composed of physical, biological and socio-economic elements has a potent effect on the transmission of malaria. Temperature, rainfall and humidity determine the physical environment which acts on both man and the mosquito. The presence of stagnant water points and certain plants which provide breeding sites or animals which deviate the blood-feeding habits of Anopheles affect the biological environment. The occupation, habits and activities of human beings produce conditions of social and economic environment which have often a decisive effect on the extent of malaria transmission (Moody and Chiodini, 2000).

2.3 Life cycle of Plasmodium
The four species of Plasmodium species casing malaria in humans have a common life cycle. The parasites are transmitted by the infected female Anopheles mosquito (Najera et al., 1993). Infections of the human host begin when sporozoites are introduced into the blood of a susceptible host during a blood meal. The sporozoites travel into the liver where they multiply and develop into exo-erythrocytic schizonts. From the liver the parasites cause cell rupture releasing several merocytes, which re-enter the blood stream. Here, they invade the red blood cells and develop into trophozoites, then schizonts that release new merocytes. Anopheles mosquitoes that feed on infected humans with gametocytes in the blood become infected and the macro and micrometocytes fuse to form a zygote within the mosquito (Beier, 1998). The zygote transforms into an ookinete, which penetrates the midgut epithelium of the mosquito and settles at the basal lamina layer, where it develops into an oocysts. Numerous sporozoites develop within the oocysts, after which the oocysts break open causing numerous of the sporozoites to enter the hemolymph. The sporozoites migrate to the salivary glands of the mosquito where they remain until the mosquito bites another person and injects them together with saliva (Miller et al., 1994; Rozendaal, 1997; Figure 2.1).
Figure 2.1 Life cycle of *Plasmodium* (Source: http://ocw.jhsph.edu/).
2.4 Clinical Manifestations of Malaria

Malaria manifests in a variety of disease forms ranging from asymptomatic to life-threatening symptoms. It usually begins as a flu-like illness 8-21 days after infection. Symptoms include fever, headache, joint pains, muscular aches, backache, general malaise, vomiting, diarrhea, splenomegaly, mental confusion, abdominal pains, nausea, and irritability, loss of appetite, dizziness, rigors and sweating among other symptoms. These features may occur singly or in combination. The outcome of infection depends on the species and strain of *Plasmodium*, the host’s history of infection with malaria, the age and other host related variables (Spitz, 1945).

2.5 Pathogenesis of malaria

All the manifestations of malarial illness are caused by the infection of the red blood cells by the asexual forms of the malaria parasite and the involvement of the red cells makes malaria a potentially multisystem disease, as every organ of the body is reached by the blood (Omer *et al.*, 2003; Greenwood *et al.*, 2008). All types of malaria manifest with common symptoms such as fever, some patients may progress into severe malaria. Although severe malaria is more often seen in cases of *P. falciparum* infection, complications and even deaths have been reported in non-falciparum malaria as well. The infection of the red cells by malaria parasites, particularly *P. falciparum*, results in progressive and dramatic structural, biochemical, and mechanical modifications of the red cells that can worsen into life-threatening complications of malaria. While the vast majority of severe malaria and related mortality are caused by *P. falciparum* infection, complications can occur in non-falciparum infections as well. In recent years, several cases of severe infection and even deaths have been reported following infections with *P. vivax* and *P. knowlesi* infections (Price *et al.*, 2007). Several
pathophysiological factors such as the parasite biomass; 'malaria toxin(s)' and inflammatory response; cytoadherence, resetting and sequestration; altered deformability and fragility of parasitized erythrocytes; endothelial activation, dysfunction and injury; and altered thrombostasis have been found to be involved in the development of severe malaria. All these phenomena are more profound and widespread in *P. falciparum* infection compared to non- *falciparum* infections. As a result, except for severe anemia, complications such as cerebral malaria, hypoglycemia, metabolic acidosis, renal failure, and respiratory distress are more commonly seen in *P. falciparum* infections (Chen et al., 2000; Miller et al., 2002; Anstey et al., 2009).

2.6 Diagnosis of Malaria

Malaria is diagnosed by thick and thin blood smears. The thick smear is more reliable, with a detection sensitivity of 10-30 times as compared to the thin smear (Moody and Chiodini, 2000). Several alternative methods have been developed, including the quantitative buffy-coat centrifugal hematology system, Immunofluorescence, ELISA and Polymerase Chain Reaction (PCR) for the detection of *P. falciparum* infection. Malaria may also be diagnosed based on clinical features (Karani, 1998). Thick blood smears are recommended for parasites detection and for measuring parasite density (quantification) and can be used to monitor response to treatment. Thin blood smears are recommended for species identification. Various factors such as stage of malaria infection and previous medication may reduce parasitaemia below detectable threshold and necessitate repeat examinations. If the blood slide is negative, further investigations for the cause of febrile disease including the repeating the blood slide after 24 hours should be carried out (MOH, 2008).
2.7 Control of Malaria

The aim of prevention and control of malaria is to reduce the damage caused by the disease, while protecting the human health, conserving the environment and reducing the economic loss. The rise in the number of people infected with malaria in many tropical countries and the consequence of impoverished economies have given rise to the need to adopt integrated control strategies for malaria management. Strategies to prevent malaria may focus on either preventing mosquito bites or eradicating the parasite. The most effective technique available to date for control of mosquitoes is the use of ITNs which act as barriers to prevent mosquito bites (MOH, 2001; Hamel et al., 2011). Although WHO has launched massive malaria control programmes, the disease is difficult to control, as the malaria parasite has developed resistance to some drugs such as chloroquine based drugs.

People traveling to malaria endemic areas should take prophylactic measures: non-visitors should take mefloquine or doxycycline; patients with sickle cell should take proguarine and patients with tropical splenomegaly syndrome /hyper immune malaria splenomegaly are recommended to take proguaril (MOH, 2008). They should seek early medical care if they develop fever three months after travel to an endemic area, even if adequate prophylaxis had been taken. Travelers should carry a full dose of Artemether Lumefantrin (stand by treatment) for use in the event they develop a fever and have no immediate access to health services (MOH, 2008).

Environmental modification helps to eliminate the mosquito breeding sites, playing an important role in vector control. This method aims at managing the environment by making it unsuitable for mosquito breeding. Since the immature stages of the mosquito are aquatic, proper management of the environment through use of lavicides can help to suppress vector densities (WHO, 1997). Climatic change coupled with indispensable human activities such as tea growing, banana and maize planting, deforestation, dam construction, fish ponds and
irrigation projects contribute to vector occurrence, due to creation of suitable breeding grounds (Thin et al., 2002). Proper management of these breeding sites may significantly reduce the mosquito breeding sites, therefore contributing to malaria control. In Kenya, there has been high mortality of mosquito larvae after periodic drainage of intermittently irrigated subplots, thus demonstrating the positive effect of this method in the control of the mosquitoes (Mutero et al., 2000). The rapid increase in human population exerts much pressure on the environment, creating diverse breeding grounds for the mosquitoes which are difficult or expensive to control (Oaks et al., 1991).

Mosquito skin repellants have also been found to prevent the transmission of malaria (Apiwat et al., 2001). Extracts from Neem tree and cloves have been studied as possible mosquito repellants and have demonstrated good efficacy against some mosquito species (Sharma et al., 1993). The use of predators, parasites or automopathogens as control agents, commonly called biological control measures have been exploited as possible means of vector control (Priyanka et al., 2001). The mosquito eating fish, Gambusia affinis contributed to the reduction of malaria in Europe (Rozoendaal et al., 1997). These can impact positively on malaria control especially in dams, fish ponds and rivers and other mosquito breeding sites (Martens, 1990). In Gucha, community awareness campaigns, the distributions of ITNs and the spraying of indoor residual spraying (IRS) chemicals (icon and k-orthorine sachets) are in place as control measures against vectors of malaria. For curative purposes, the current government policy is the use of Artemisinin combination therapy, which is now available in all government hospitals.

Currently, in Gucha district, there is use of artemisinin combination therapy as the first line drugs for simple malaria infections and quinine for severe malaria (MOH, 2008). The elements of integrated vector management can be applied in the management of malaria and this includes: advocacy, social mobilization and legislation, embedding of integrated vector
management (IVM) principles in development of policies, strengthening regulatory and legislative controls for public health and empowerment of communities (MOPHS, 2009).

Integrated vector management also includes public and private sectors sharing and optimizing the use of available resources, building capacity for planning, monitoring and decision making at lowest possible operational level, integrated approaches like integration of chemical and non chemical vectors control methods with other disease control measures. In addition, evidence-based decision making, adoption of strategies and interventions to the local context guided by operational research, entomological and epidemiological surveillance and evaluation, capacity building, development of adequate human resources, training and career structures at national and local levels to manage IVM programmes. The development of physical infrastructure and provision of financial resources are also very important elements (MOPHS, 2009). During the 1950s and 1960s, malaria was effectively controlled by IRS, mass drug administration and chemoprophylaxis (Roberts, 1964). Between 1980s and 1990s, a series of malaria epidemics were reported in the highlands (Malakooti et al., 1998). Insecticide treated nets are now widely used as a means of preventing man-vector contacts, in the control of malaria, and forms the major components of disease prevention methods.

A reports by Desowitz (1999) suggested that the combination of improved access to medical services and protection against the bites of the adult mosquitoes by application of ITNs by all would reduce the malaria morbidity cases by half by the year 2010. However, use of ITNs by all, is yet to be achieved and parasite resistance to some anti-malarials is on the increase (Desowitz, 1999). Through an integrated control of all parasitic infections, the government can minimize the malaria problem though the promotion of ITNs and mass treatment of the sick with approved anti-malarial drugs.
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Gucha District, which is one of the twelve (12) districts of Nyanza Province. The district shares common borders with Kisii central to the north, Migori district to the west and Transmara District to the south (Appendix II). Gucha District lies between latitude 0º30’ and 0º58’ south and longitude 34º42’ and 35º50 and at an altitude of 1420 m -2200 m above sea level. The district has a highland equatorial climate receiving an
average annual rainfall of 1500 mm, with the long rains between March and June while the short rains are received from September to November. Gucha District is warm with an average temperature of 12°C-24°C. The district covers an area of 660.8 Km² with a total population of 460,939 people. Gucha is subdivided into seven (7) divisions, thirty (30) locations and seventy-eight (78) sub-locations.

3.2 Study population
The study was designed to recruit a population consisting of adults of 18 years and above, who were able to communicate and had stayed in Gucha District for more than one year and who consented to the study. However, at the time of recruitment, the minimum age of the study population recorded was 26 years as the people studied were those at their homes without extension to those in schools where the younger population would be found. The exact population studied therefore consisted of adults of 26 years and above.

3.3 Ethical Considerations
Clearance for the study was obtained from the Ministry of Education, Science and Technology (Appendix III and IV). Further permission was sought from the Gucha district medical officer of health (DMOH) and the community leaders. The purpose of the study was explained to the respondents. All the collected data was treated confidentially.

3.4 Study Design
This was a cross-sectional descriptive study of highland malaria outbreaks aimed at collecting qualitative and quantitative data on causes, control and preventive measures of highland malaria outbreaks in Gucha District. Information was obtained using structured open-ended questionnaires (Appendix VI) and discussion with the provincial administrators and Ministry of Health staff and residents of Gucha District.
3.5 Sample size determination and selected units of sampling

Sample size was determined using the formula as used by Fisher et al. (1998) and was as follows:

\[ n = \frac{z^2 \cdot p \cdot q \cdot D}{d^2} \]

n = Desired sample size of population, valid only where the population is more than 10,000

z = the standard deviation, usually 1.96 which corresponds to 95% confidence level.

P= Proportion of the target population estimated to have highland malaria. 50% (0.5) of Gucha District’s population is infected by highland malaria (MOH, 2003)

\[ p = 0.5 \]

\[ q = 1 - p = 1 - 0.5 = 0.5 \]

\[ d = \text{Degree of accuracy} = 0.05 \]

\[ D = \text{Design effects} = 1 \]

Thus,

\[ n = \frac{(1.96)^2(0.5)(0.5)(1)}{(0.05)^2} \]

= 384 (calculated), rounded to 400 to give room for attrition.

Fifteen (15) study sites (Health facilities) were purposely selected (Table 1.2) for representative coverage of the district. The number of respondents per site varied depending on the local population statistics with more respondents being recruited in more densely populated sites.
<table>
<thead>
<tr>
<th>Division</th>
<th>Health Facility</th>
<th>No. of respondents selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sameta</td>
<td>Nyansakia Dispensary</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Kenyerere dispensary</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Nyamagwa Mission Hospital</td>
<td>27</td>
</tr>
<tr>
<td>Nyamache</td>
<td>Nyamache health centre</td>
<td>35</td>
</tr>
<tr>
<td>Nyacheki</td>
<td>Nyacheki Health Centre</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Gucha District Hospital</td>
<td>50</td>
</tr>
<tr>
<td>Ogembo</td>
<td>Magena Dispensary</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Misesi Dispensary</td>
<td>15</td>
</tr>
<tr>
<td>Kenyenia</td>
<td>Kenyanya Health Centre</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Magenche Dispensary</td>
<td>15</td>
</tr>
<tr>
<td>Nyamarambe</td>
<td>Nyatike Dispensary</td>
<td>18</td>
</tr>
</tbody>
</table>
Tabaka Mission Hospital 27
Nduru Health Centre 36

<table>
<thead>
<tr>
<th>Etago</th>
<th>Etago Health Centre 35</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moticho Dispensary 12</td>
</tr>
</tbody>
</table>

Totals 15 400

3.6 Data collection and research instruments
Data were collected using structured open-ended questionnaires (Appendix VI), direct communication and desk review of health records from the district health information systems on the current and previous morbidity and mortality cases due to highland malaria.

3.7 Data Analysis
Data analysis was carried out using GraphPad InStat software and involved one-way analysis of variance (ANOVA) statistic followed by Tukey-Kramer test in case of significant conclusion. A $P$ value $< 0.05$ was considered significant.
CHAPTER FOUR

4.0 RESULTS

4.1 Demographic characteristics of the respondents

The respondents’ demographic characteristics that were studied included age of the respondents, level of education and types of housing as indicated below.

4.1.1 Age of respondents

The ages of respondents ranged between 26 and 56 years (Table 4.1). Over half (50.75%) of the respondents were aged between 26 and 35 years. Those aged between 46 and 55 years were 79 respondents forming 19.75% being slightly higher in numbers than respondents (67; 16.75%) who did not know their exact years of age. The respondents aged between 36 and 45 years were 45 individuals forming 11.25% while the oldest individuals were only 6 (1.5%) out of the total population of 400 respondents. The study did not include any individual aged below 25 years as no one was available in this age category for recruitment.
Table 4.1 Age characteristics of respondents

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Number of respondents (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25 years</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>26-35</td>
<td>203</td>
<td>50.75</td>
</tr>
<tr>
<td>36-45</td>
<td>45</td>
<td>11.25</td>
</tr>
<tr>
<td>46-55</td>
<td>79</td>
<td>19.75</td>
</tr>
<tr>
<td>56-65</td>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>67</td>
<td>16.75</td>
</tr>
<tr>
<td>Total</td>
<td>400</td>
<td>100</td>
</tr>
</tbody>
</table>

4.1.2 Level of education

Most of the respondents (75.7%) had secondary level of education. These were followed by those with tertiary education (15%) with the minority (9.3%) of the respondents having studied up to the primary level (Table 4.2).

Table 4.2 Level of education of respondents
<table>
<thead>
<tr>
<th>Level of education</th>
<th>Number of respondents (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>37</td>
<td>9.3</td>
</tr>
<tr>
<td>Secondary</td>
<td>303</td>
<td>75.7</td>
</tr>
<tr>
<td>Tertiary</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>400</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

4.1.3 Types of housing

A larger proportion (78%) of the studied population, making a total of 312 individuals reported to be living in iron roofed or grass thatched houses without closed eaves while 80 (20%) respondents lived in mud walled houses with openings or cracked walls and open eaves. Only a small population of 8 (2%; Table 4.3) respondents were found to be living in well constructed houses with closed eaves.

<table>
<thead>
<tr>
<th>Type of house</th>
<th>Number of respondents (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron roofed/grass thatched with</td>
<td>312</td>
<td>78</td>
</tr>
</tbody>
</table>

Table 4.3 Types of housing
<table>
<thead>
<tr>
<th>closed eaves</th>
<th>Mud walled with openings/cracked walls and open eaves</th>
<th>Well constructed with closed eaves</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>8</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

4.2 Most prevalent signs and symptoms reported

Two hundred and six (51.5%) respondents stated fever as the sole symptom of malaria while 80 (20%) respondents reported ‘feeling chilly’ as the only symptom of the disease (Table 4.4). Combined vomiting and lack of appetite were mentioned by 29 (7.25%) respondents as the symptoms of malaria. Lack of appetite alone was stated by 24 (6%) respondents as associated with malaria infection while headache combined with aching joints was stated by 21 (5.25%) respondents as the only symptoms of malaria. Sixteen respondents (4%) mentioned aching of joints alone as the only symptom associated with malaria infection. The smallest percentages of the respondents cited vomiting (3.25%) and headache (2.75%) as the symptoms associated with malaria.

**Table 4.4 Most reported clinical signs and symptoms of malaria**

<table>
<thead>
<tr>
<th>Sign/symptom</th>
<th>Number of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>206</td>
<td>51.5</td>
</tr>
<tr>
<td>Feeling chilly</td>
<td>80</td>
<td>20.0</td>
</tr>
<tr>
<td>Vomiting and lack of appetite</td>
<td>29</td>
<td>7.25</td>
</tr>
<tr>
<td>Causes of Malaria</td>
<td>Number of respondents</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
<td>-----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Lack of appetite</td>
<td>24</td>
<td>6.0</td>
</tr>
<tr>
<td>Headache and aching joints</td>
<td>21</td>
<td>5.25</td>
</tr>
<tr>
<td>Aching joints</td>
<td>16</td>
<td>4.0</td>
</tr>
<tr>
<td>Vomiting</td>
<td>13</td>
<td>3.25</td>
</tr>
<tr>
<td>Headache</td>
<td>11</td>
<td>2.75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>400</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

### 4.3 Knowledge on causes of malaria

Majority of the respondents totaling to 220 (55%) cited *Plasmodium* as the cause of the disease while 80 (20%) respondents mentioned bites by female mosquitoes and stagnant waters as the causes of malaria. Bushes around homesteads was mentioned by 29 (7.25%) respondents as the major cause of malaria while 21 (5.25%) respondents reported bites by female mosquitoes as the only cause of the disease. Other respondents including 15 (3.75%), 13 (3.25%), 12 (3%) and 10 (2.5%) mentioned transmission from other patients, stagnant waters and climatic changes, stagnant waters alone and climatic changes alone respectively, as the cause of malaria infections (Table 4.6).

### Table 4.5 Causes of malaria

<table>
<thead>
<tr>
<th>Causes of Malaria</th>
<th>Number of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasmodium</td>
<td>220</td>
<td>55.0</td>
</tr>
<tr>
<td>Bites of female mosquitoes and stagnant waters</td>
<td>80</td>
<td>20.0</td>
</tr>
<tr>
<td>Bushes around the compound</td>
<td>29</td>
<td>7.25</td>
</tr>
<tr>
<td></td>
<td>Number of respondents</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Bites of female mosquitoes</td>
<td>21</td>
<td>5.25</td>
</tr>
<tr>
<td>Transmission from other patients</td>
<td>15</td>
<td>3.75</td>
</tr>
<tr>
<td>Stagnant waters and climatic changes</td>
<td>13</td>
<td>3.25</td>
</tr>
<tr>
<td>Stagnant waters</td>
<td>12</td>
<td>3.0</td>
</tr>
<tr>
<td>Climatic changes</td>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>400</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

### 4.4 Treatment options for malaria

Residents of Gucha reported various methods which they employ in treating those suffering from malaria attacks (Table 4.5). Majority of the respondents (142/400; 50.5%) visits the hospital for treatment against malaria following failure of self medication. Twenty percent (80/400) of the respondents only visits the hospital when they are severely infected and when they have a mild infection, they buy and take oral antimalarial tablets. One hundred and fifteen (28.75%) respondents treat themselves by taking oral tablets (Fansidar) obtained from nearby shops, kiosks or chemists as most of the shopkeepers have been trained by Merlin (Medical emergency relief international) on the sale of anti-malarial drugs over the counter (MOH, 2002). Only 63 (15.75) of the total respondents reported visiting hospitals for treatment when they suffer from malaria.

**Table 4.6 Malaria treatment options by respondents**

<table>
<thead>
<tr>
<th>Treatment option</th>
<th>Number of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visited hospitals after failure of self medication</td>
<td>142</td>
<td>50.5</td>
</tr>
<tr>
<td>Self medication (oral tablets)</td>
<td>115</td>
<td>28.75</td>
</tr>
<tr>
<td>Preventive measure</td>
<td>Number of respondents</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Bush clearing and drainage of stagnant waters</td>
<td>176</td>
<td>44.0</td>
</tr>
<tr>
<td>Using mosquito nets</td>
<td>123</td>
<td>30.75</td>
</tr>
<tr>
<td>Use of mosquito repellants</td>
<td>43</td>
<td>10.75</td>
</tr>
<tr>
<td>ITNs</td>
<td>23</td>
<td>5.75</td>
</tr>
<tr>
<td>Combining IRS and ITNs</td>
<td>20</td>
<td>5.0</td>
</tr>
</tbody>
</table>

4.5 Knowledge on preventive measures against malaria

One hundred and seventy six (44%) of the respondents cited a combination of bush clearing and drainage of stagnant waters as the major preventive measures against malaria infections while a total of 123 (30.75%) of the respondents cited the use of mosquito nets as the only preventive measure against malaria (Table 4.7). The preventive measures known by respondents against malaria were use of ITNs alone which was reported by 23 (5.75%) respondents, a combination of IRS and ITNs cited by 20 (5%) respondents and IRS alone mentioned by 15 (3.75%) of the total respondents. The compounds used in ITNs or IRS found in local sources include Deltamethrin and Alphacypermethrin.

Table 4.7 Preventive measures against malaria by respondents
<table>
<thead>
<tr>
<th>IRS</th>
<th>15</th>
<th>3.75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>400</td>
<td>100</td>
</tr>
</tbody>
</table>

4.6 Traditional methods of malaria prevention and control in Gucha district

The communities were aware of traditional methods used for the control of malaria. The methods mentioned included consumption of goats’ offal (Matumbo) which was cited by 111 (27.75%) of the respondents and burning of unspecified herbs cited by 87 (21.75%) respondents. Burning of cow dung, cypress leaves and pyrethrum flowers was mentioned by 68 (17%) respondents while burning of cow dung and cypress leaves was cited by 60 (15%) of the total respondents (Table 4.8). Thirty one (7.75%) and 27 (6.7%) respondents cited burning of pyrethrum flowers and cow dung respectively. A small proportion comprising only 16 (4%) respondents reported burning of Cypress leaves as the only traditional malaria preventive method.

Table 4.8 Traditional methods of preventing and controlling malaria

<table>
<thead>
<tr>
<th>Traditional method of malaria control</th>
<th>Number of respondents</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating of goats’ offal (Matumbo)</td>
<td>111</td>
<td>27.75</td>
</tr>
<tr>
<td>Use of herbs</td>
<td>87</td>
<td>21.75</td>
</tr>
<tr>
<td>Burning of cow dung, cypress leaves and pyrethrum flowers</td>
<td>68</td>
<td>17.0</td>
</tr>
<tr>
<td>Burning of cow dung and cypress leaves</td>
<td>60</td>
<td>15.0</td>
</tr>
<tr>
<td>Burning of pyrethrum flowers</td>
<td>31</td>
<td>7.75</td>
</tr>
<tr>
<td>Burning of cow dung</td>
<td>27</td>
<td>6.75</td>
</tr>
<tr>
<td>Burning of cypress leaves</td>
<td>16</td>
<td>4.0</td>
</tr>
</tbody>
</table>
4.7 Malaria morbidity in Gucha district between 1998 and 2006

Desk reviews from health records and information systems from 1998 to 2006 showed that there was an increase in the incidence of malaria cases during the months of May to August of each year as shown in Table 4.9. However, analysis of the data did not indicate any significant difference in morbidities recorded from 1998 to 2006 ($F = 1.996; P > 0.05$).

<table>
<thead>
<tr>
<th>Month</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>3040</td>
<td>6262</td>
<td>5972</td>
<td>9944</td>
<td>10334</td>
<td>18368</td>
<td>8590</td>
<td>12122</td>
<td>9032</td>
</tr>
<tr>
<td>Feb</td>
<td>16926</td>
<td>3929</td>
<td>6307</td>
<td>12899</td>
<td>7903</td>
<td>17933</td>
<td>9566</td>
<td>14371</td>
<td>9638</td>
</tr>
<tr>
<td>Mar</td>
<td>14815</td>
<td>8687</td>
<td>6872</td>
<td>11634</td>
<td>7067</td>
<td>10698</td>
<td>12110</td>
<td>10567</td>
<td>9622</td>
</tr>
<tr>
<td>Apr</td>
<td>7382</td>
<td>5964</td>
<td>7656</td>
<td>6804</td>
<td>6804</td>
<td>6968</td>
<td>9138</td>
<td>8561</td>
<td>8242</td>
</tr>
<tr>
<td>May</td>
<td>5875</td>
<td>12128</td>
<td>8273</td>
<td>5970</td>
<td>7428</td>
<td>7660</td>
<td>10090</td>
<td>9560</td>
<td>11483</td>
</tr>
<tr>
<td>Jun</td>
<td>4798</td>
<td>16119</td>
<td>7896</td>
<td>8134</td>
<td>13932</td>
<td>8720</td>
<td>14131</td>
<td>9972</td>
<td>12314</td>
</tr>
<tr>
<td>July</td>
<td>7491</td>
<td>22411</td>
<td>8969</td>
<td>9001</td>
<td>21308</td>
<td>19450</td>
<td>16165</td>
<td>13020</td>
<td>10140</td>
</tr>
<tr>
<td>Aug</td>
<td>6066</td>
<td>11261</td>
<td>6632</td>
<td>8358</td>
<td>10354</td>
<td>9685</td>
<td>9913</td>
<td>15380</td>
<td>15380</td>
</tr>
<tr>
<td>Sep</td>
<td>5699</td>
<td>6088</td>
<td>6239</td>
<td>6172</td>
<td>6571</td>
<td>7150</td>
<td>8893</td>
<td>14839</td>
<td>9234</td>
</tr>
</tbody>
</table>
4.8 Groups at risk of malaria infection

Malaria affected all the age groups in a trend that indicated decreasing susceptibility to the infection from children aged five years to persons aged 15 years or more (Figure 4.1). There was a significant difference in malaria infections between the age groups analyzed ($F = 26.359; P < 0.05$). Infections in children aged five years and below were significantly higher compared to infections in the age groups of 6 – 14 and 15 + years as well as pregnant mothers ($P < 0.05$). Cases of malaria infections between individuals in age groups 6-14 years were statistically comparable to infections recorded for the age group of 15 + years ($P > 0.05$). Significantly higher numbers of individuals aged 6 - 14 years were infected with malaria compared to pregnant mothers ($P < 0.05$). Likewise, more individuals aged 15 years and above were malaria patients compared to pregnant mothers ($P < 0.05$).
Figure 4.1: Outpatient department malaria data on age structure in Gucha district in 2003.

4.9 Inpatient admissions and deaths associated with malaria in Gucha district in 2002

The highest admissions were recorded in June and July 2002 and these admissions were associated with the highest deaths reported in the year due to malaria infections as shown in figure 4.2. The months of January to May and August were associated with moderate number of malaria patient admissions and deaths. October, November and September were associated with the least number of admissions and deaths due to malaria infections.
In 2003, admissions and deaths were higher during the months of January, February and July as shown in figure 4.3. Admissions and death were moderate in March. From March to June the number of admissions and deaths gradually reduced and this was followed by the highest peak in July then admissions and deaths gradually reduced between the month of August and December, with November recording the least number of admissions and deaths. In total 14406 admissions and 390 deaths were recorded during the year.
4.11 Annual weather characteristics in Kisii between 2002 and 2006

Mean monthly temperatures in the years between 2002 and 2006 ranged between 20.8°C and 21.2°C. There was no statistical difference in the mean monthly temperatures during this period (F = 0.3162; P = 0.8659). The average monthly rainfall ranged between 138.7 ± 73.5 mm in 2005 and 183.5 ± 89.6 mm in 2006 and there was no significant difference between these values (F = 0.6746; P = 0.6124). The proportions of monthly relative humidity in these years ranged between 57.4 ± 5.6 in 2003 and 62.2 ± 9.4 in 2006 and these proportions were comparable for the months in these years (F = 0.7971; P = 0.5322) as shown in Table 4.10.

Table 4.10 Annual weather characteristics in Kisii County between 2002 and 2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean monthly</th>
<th>Mean monthly</th>
<th>Mean monthly</th>
</tr>
</thead>
</table>

Figure 4.3 In-patient and deaths associated with malaria in Gucha District in 2003.
<table>
<thead>
<tr>
<th>Year</th>
<th>Temperature (°C)</th>
<th>Rainfall (mm)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>21.2 ± 1.8</td>
<td>182.4 ± 80.14</td>
<td>60 ± 8.14</td>
</tr>
<tr>
<td>2003</td>
<td>20.9 ± 0.86</td>
<td>182.4 ± 74.8</td>
<td>57.4 ± 5.6</td>
</tr>
<tr>
<td>2004</td>
<td>20.84 ± 0.6</td>
<td>173.9 ± 83.8</td>
<td>57.6 ± 7.4</td>
</tr>
<tr>
<td>2005</td>
<td>21.1 ± 1.03</td>
<td>138.7 ± 73.5</td>
<td>58.7 ± 6.5</td>
</tr>
<tr>
<td>2006</td>
<td>20.8 ± 0.83</td>
<td>183.5 ± 89.6</td>
<td>62.2 ± 9.4</td>
</tr>
</tbody>
</table>

4.12 Observed human activities important in malaria transmission in Gucha district

This study recorded human activities in Gucha district which may be associated with increased mosquito breeding and potential transmission of malaria. Stagnant water retained in brick making sites (Figure 4.4 and 4.5) may provide suitable mosquito breeding grounds, hence increased malaria transmission; poorly planned and constructed semi – permanent houses, which are poorly lit and maintained, with cracks and crevices and surrounded with long grass, flowers and shrubs, may provide suitable habitats for mosquitoes as they prefer such dark places as their hiding grounds. Agricultural activities like planting of bananas, sugarcane and other agricultural related activities near or around the homesteads, may all influence malaria transmission as they provide similar hiding grounds for the malaria vectors (Figures 4.6, 4.7 and 4.8).
Figure 4.4: Brick making site.
Figure 4.5: Stagnant water in depressions created at a brick making site.
Figure 4.6: A semi-permanent house (indicated by black arrow) surrounded with banana plants.
Figure 4.7: Grass thatched houses surrounded by trees and farm crops.
CHAPTER FIVE

5.0 DISCUSSION

Malaria is widespread in Kenya and varies from region to region due to diverse climatic and ecological conditions that range from semi-arid, deserts, to cold highlands. The disease undermines the growth of children who survive and the nations that depend on them. Although
the causes of malaria are known, there has been recent increase in incidence of highland malaria in Africa with current strategies of prevention and control being unsuccessful (WHO and UNICEF, 2003). This study was set out to assess the level of knowledge on factors contributing to increasing cases of highland malaria in Gucha Distric, Kisii County including causes, signs and symptoms of the disease, environmental factors facilitating increase in infections, and treatment and preventive options used by local communities to help control the disease.

The inclusion of a study population with ages ranging from 26 to 60 years old was a milestone contributing to the success of this study as this ensured involvement of people with a diversity of information on malaria gathered over a period of over 50 years before the time of undertaking this study. However, although the study was designed to include age groups from as young as 18 years, the study failed to recruit individuals aged from 18 to 25 years as these people either did not consent to participate or were not available for recruitment. This unavailability was not unexpected as the study was carried out during the day time and when schools were open and hence most of the individuals aged below 25 years may have been at school.

Gucha District residents are generally well educated people as found in this study that over 90% of the population studied were educated up to high school or beyond and with only less than 10 percent of the respondents ending their formal education at the primary school level. It was important for this study to a composition of people with formal education because the formal school curricula include science subjects which have aspects of diseases. Furthermore, it has been indicated that, people who have a high level of education have a better knowledge of malaria and therefore are better able to protect themselves (Guthmann et al., 2001).
Poor quality housing is generally accepted to be an important contributor to ill health (UNCHS, 1996). Previous studies in a malaria endemic community in Sri Lanka found a strong association between malaria incidence and the type of house construction (Gamage-Mendis et al., 1991). Most of the houses observed in the present study were mud walled with thatched roofs and these houses were associated with open eaves and other openings through the wall. The study carried out in Sri Lanka established that the risk of getting malaria was greater for inhabitants of the poorest type of houses, characterized by uncompleted construction with thatched roofs and walls made of mud or woven coconut palm leaves (Gamage-Mendis et al., 1991). One of the reasons for increased highland malaria infections in Gucha district and elsewhere may therefore be a result of poorly constructed houses in these areas. Poorly constructed houses are associated with a significantly higher number of indoor resting mosquitoes than better constructed houses (Gamage-Mendis et al., 1991; Guthmann et al., 2001). In another study in Sri Lanka, the risk of malaria was found to be 2.5-fold higher for people living in poorly constructed houses than those living in houses of good construction (Gunawardena et al., 1998). In Tanzania, houses built of bricks and zinc roofs are associated with lower levels of malaria-associated anaemia compared to poorly built mud-walled houses (Kahigwa et al., 2002). It is therefore clear that better housing can significantly reduce highland malaria (Atieli et al., 2009).

The study population was knowledgeable about the signs and symptoms of malaria infections. Fever was reported by majority of respondents as a common sign of the disease. Headache, aching joints, vomiting, lack of appetite and feeling chilly were reported as other symptoms of malaria. All these signs and symptoms are in agreement with documented literature on the common clinical symptoms and signs of *falciparum* malaria (Greenwood et al., 2008). This indicates that Gucha residents are generally aware of how malaria presents itself. However, fever is a symptom associated with many diseases and illnesses (Crosta, 2009) and it is likely
that without proper community education on specific symptoms for a particular disease, there could be a lot of misuse of drugs easily obtainable from local shops and chemists and this could be a contributing factor on the increasing cases of malaria infections as a result of drug resistance and disease relapses. Furthermore, misuse of malarial drugs can lead to high resistance rates (Bloland, 2001; Temu et al., 2006).

All the respondents were aware of the causes of malaria in humans. A half of the respondents reported that malaria is caused by *Plasmodium* and with one fifth of the respondents cited bites of female mosquitoes and existence of stagnant waters as the main causes of malaria, it would be valid to confirm that Gucha District residents are well aware of the causes of malaria and the factors associated with the disease transmission. These responses on the causes of malaria are in line with the causes described by Nayyar et al. (2012). This may be attributed to the level of education since over 90% of the respondents had completed high school education whose curriculum incorporates science where terms such as ‘*Plasmodium*’ in most cases could be learnt. It was also of great interest to learn that a number of the respondents studied were aware of the importance of climatic changes in malaria transmission. Furthermore, climatic changes have been reported to be partly responsible for increased malarial infections (Qader and Nabi, 2009).

When the local people became infected by *Plasmodium*, they sought treatment in two main ways depending on the severity of the disease. A very small percentage of the respondents visited hospital for treatments when they feel that they are infected with malaria. The treatment seeking behavior of the local residents involved ‘self medication’ by buying anti-malarial tablets (mainly Fansidar) from local sources. Almost the entire group that did not choose hospital as the first choice of treatment eventually visited the local hospitals for treatment due to failure of self-medication to clear the disease. All those attending hospital for treatment whether immediately following signs of the disease or as a result of failed self-
treatment, cited quinine as the injection that was given for cure of malaria, while those buying drugs from shops and local pharmacies reported fansidar tablets as the available drug for malaria treatment. It has been reported elsewhere that, self-medication which may also result to storage of drugs at home, may result in inadequate dosage administration (Temu et al., 2006). This may be one of the factors contributing to increased malaria in Gucha District and other places.

Low knowledge on malaria treatment guidelines and the irrational use of self medication with over-the counter-purchased antimalarials have been reported in Cameroon (Sayang et al., 2009). The high failure rate of self-medication in Gucha District could have been as a result of many factors which may include under-dosaging and drug resistance among others. In Tanzanian private pharmacies, drug stores and ordinary shops dispense antimalarials over the counter without prescription (Temu et al., 2006) and it is doubtful if they give appropriate dose, meaning that patients either do not take a required dose or might even be overdosed resulting in unwanted toxic effects. The effects of unguided self-medication may have far reaching detrimental consequences. Improvement in the self-treatment of malaria could be attained by providing clear information on choices of drugs for malaria treatment.

With an average number of respondents reporting the use of IRS and ITNs either singly or in combination as the sole strategy for control of malaria mosquito vector, effective methods of malaria control were not new to the local residents. In a recent study, it has been documented that, of the different strategies available for vector control, the most successful are ITNs and IRS (Beier et al., 2008). In Africa, sustained IRS has been used mainly in the southern part of the continent where it has been successful in controlling malaria and reducing transmission (Mabaso et al., 2004). This single method has been indicated to be both more effective and cheaper than ITNs in communities subjected to low, seasonal risks of infection and has been
recommended to form part of the control armamentarium for malaria prevention (Guyatt et al., 2002).

The present report established that, although most of the respondents were aware of better methods (including IRS and ITNs) for control of malaria, these methods are not commonly available in most of the homes due to their relatively high cost as compared to other less effective (traditional) methods. Use of mosquito nets, bush clearing and drainage of stagnant waters were more popular methods than IRS and/or ITNs and this again may reflect cost and ease of applicability of the method of choice used by this community. Furthermore, mosquito nets, bush clearing and drainage of stagnant waters are less costly mosquito control tools and are generally available methods compared to IRS or ITNs. However, these cheaper malaria prevention methods are also effective in checking the transmission of the disease. Draining of swamps has been indicated to control vector by larval habitat modifications (Beier et al., 2008). A small proportion of residents use mosquito repellants such as mosquito coils as a modern malaria prevention method but the sustainability of this method was not assessed. It should be noted that, most residents in Gucha District are generally poor and may not able to access adequate basic needs. It is clear that with the level of knowledge these residents have on malaria, the control of infection can be significantly improved if these effective vector control tools are supplied in adequacy.

An interesting finding is the use of traditional methods for control of malaria. The most common method mentioned was use of herbs in a like manner as mosquito coils. Indeed the highlands are rich in flora and it would be possible that most plants would act as insect repellants. It was not however established which particular plant species are used in this manner or how exactly these herbs are applied. Burning of cow dung was a method used by about half of the population and indicated to act in a similar manner like a mosquito coil. Burning of cow dung as a method for control of malaria vector has been reported elsewhere
(Ng’ang’a et al., 2008). About half of the residents apply a technique of burning Cypress leaves and these are believed to work in a similar manner to burning of pyrethrum flowers both methods of which are available and are used at comparable levels by these residents. A study carried out in Kericho, Kenya has indicated that most affected people have adapted the use of traditional curative measures including application of local herbs as insect repellants or antimalarial treatments (Wandiga et al., 2006). The study has indicated that residents use these methods due to high poverty levels in the area. It was an interesting finding in the present study that a third of the studied population considers eating of goats’ offal (Matumbo) as a method of choice that would control mosquito bites and hence prevention of malaria. It may be important to establish the scientific merit of use of traditional methods for control of malaria. Such methods if improved and validated can be cheaper and more widely used by the people.

The World Health Organization (WHO) has indicated that in some African countries, illness due to malaria has increased over the past decade and that no country in Africa south of the Sahara for which data are available shows a substantial decline (WHO and UNICEF, 2003). The present study sought to establish trends in malaria morbidity in Gucha District for the period from 1998 to 2006. This was done by interrogation of records on data on malaria infection gathered from the whole of the district and stored at the district hospital. The long term data used in this analysis indicate that clinical cases of malaria occur every month at each hospital in the district with seasonal peaks occurring between May and August each year. This finding concurs with results from a different study on clinical epidemiology of malaria carried out in several districts in the highlands of Western Kenya (Hay et al., 2002). However, our findings established infections in 1999 between May and August that were remarkably higher as compared to data obtained in similar months in other years. This was attributed to higher density rainfall reported to have occurred in this year prolonging to long rains as compared to
the other years studied. However, the lack of significant differences in the mean monthly morbidity statistics covering these years was an indication that statistically comparable malaria morbidity cases are recorded each month.

Data from district hospital records for the year 2003 on malaria infections by age structures indicated that all age-groups were vulnerable to malaria infections and that infections were reported throughout the year. The significantly higher infections associated with children aged five years and below are generally expected due to the susceptibility of the group to malaria partially due to lack of immunity build-up. This would be expected as young children’s immune system is not competent (Offit, 2002) as that of adult’s. This appears to be the case why the age group of 6-14 years was more vulnerable to malaria than the group aged 15 + years. Although significantly lower numbers of pregnant women were concluded to be infected, it is important to note that the proportion of pregnant mothers in any population is always lower compared to other categorized groups of the given population as only a few mothers would be pregnant at any given time. Pregnant mothers just like children under five years of age are considered to suffer more malarial infections than any other group in a given malarial endemic society. This has generally been attributed to lower immunity in these populations. Furthermore more malaria-associated deaths occur in pregnant mothers and infants due to incompetent immune response (Rogerson et al., 2007). It is correct to assume that adults have developed some degree of functional immunity to severe consequences of *Plasmodium falciparum* malaria (Hay et al., 2002).

Inpatient admissions and deaths associated with malaria infections indicated a similar trend in 2002 and 2003. However, the total number of cases of malaria was higher in 2002 and it has been indicated that, in 2002, exceptional rainfall during May in the western highlands of Kenya led to epidemics in some districts in June and July (Brooker et al., 2004). This may have affected the dynamics of malaria infections in Gucha district. Higher admissions and
deaths occurred in the months of January and February following the short rains of November to December in each year. The peaks of admissions and deaths were recorded between May and August of each year following the long rains of March to May. These recurring trends in admissions and deaths may suggest a lack of preparedness by the local population to control malaria infections in the months following short or long rains in each year despite knowledge on outbreak predisposing factors.

Changing climatic conditions have been blamed on the increased cases and outbreaks of diseases including highland malaria (Lindblade et al., 2000; Githeko and Ndegwa, 2001; Niringiye and Douglass, 2010). However, a comparative analysis of weather conditions between 2002 and 2006 in Kisii which hosts Gucha district did not yield any results that may assist in concluding a changing climatic situation. Furthermore mean annual temperatures, total annual rainfall and annual relative humidity levels did not change adversely and levels were comparable within each parameter for the period studied. It would be logical to consider a period of not less than fifteen years consecutively for analysis of changing weather patterns for a conclusive status of a climatic change.

Following claims by the studied population that increased malaria infections were being facilitated by human activities in the environment near homesteads, this study undertook investigations on possible human activities that may facilitate increased malaria outbreaks and infections. Indeed human activities were evident and these included bricks making which left trenches on the grounds which fill up with running waters during rains thereby creating stagnant water reservoirs. These in turn provide mosquito breeding sites leading to high malaria infections. Clearing of trees for brick baking fuel may also increase breeding areas for the malaria mosquitoes. A recent study has established that, tree clearing in the forest surrounding Kipsamoite in western Kenya highlands may create small soil depressions that retain water and could serve as breeding sites (Brooker et al., 2004). Houses located near a
drain or canals are associated with higher malaria mosquito human-biting rates. Studies have shown that the closer the proximity of the living place to a potential breeding site of the vector, the higher the risk of transmission. As shown by some authors in Dakar (Trape et al., 1992), this is probably due to high vector density in the area close to the breeding site, which decreases in areas located farthest away. Furthermore proximity to swammy areas has been associated with increased vector density (Ndenga et al., 2006).

Due to small pieces of land and prevalent poverty, the local people cultivate land and plant crops including bananas and sugarcanes near their houses. Most houses are also surrounded by flowers, shrubs and trees. These vegetations provide breeding and resting sites for mosquitoes near the homesteads thereby increasing chances of malaria infections and transmissions. Proximity of homesteads to forests has been associated with increased malaria risk in all years, including epidemic and non-epidemic years (Ernst et al., 2006). Most of the houses are poorly done with grass thatching and mud walling. Cracks in these house walls and darkness in these poorly constructed houses provide environments suitable for mosquito breeding and this may result in increased malaria infections.

Based on the above findings, it is clear that highland malaria cases are on the increase in Gucha district. The increasing cases of malaria cases may be attributed to the fact that most of the residents are not able to access control tools such as IRS and ITNs due to the high initial capital needed for acquisition of these tools. This leaves some of the residents with the option of using traditional malaria control methods such as burning of cow dung and eating of goats’ offal among other crude method which may not be effective. Furthermore most of the residents do not have access to these traditional methods. It would be correct to assume that, in the long run, the traditional methods are more expensive than the conventional ones bearing in mind the long time required to search for the vegetation/the plant material effective for use as
traditional mosquito control tools, the scarcity of land for propagation of these plants and the
daily expense required for some of these methods such as buying of goats’ offal.

Most of the houses are poorly built; with cracks and unclosed eaves that may facilitate easy
entry of mosquitoes into the sleeping rooms. Furthermore the ventilation in these houses is
poor given the nature of house thatching and this provides dark environment which is a
favorite for the malaria mosquitoes. It appeared evident that most of the increase in highland
malaria cases may be due to the poor immediate environment misuse and human activities
creating conducive mosquito breeding grounds and potential conditions for transmission of
malaria. The outside environment has been poorly used. The need to provide for daily needs
has pushed most of the residents into molding bricks for sale. This business has left many
trenches in the area which fill up with water during rains and this has created breeding
grounds for mosquitoes with potential increase in malaria transmission. The formal level of
education in this community cannot be blamed on the increased malaria cases in the area.
Most of the residents have attained basic and high school education and are knowledgeable on
the causes and signs of malaria. However, the most important remedy would be community
education on the importance of wise use of the environment and improved housing conditions.
Furthermore, health education has been found to be an important component in disease control
programme (Ghosh et al., 2006). A combination of these factors with use of modern mosquito
control tools would leave Gucha district and other areas malaria free zones.
CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results of this study, the following conclusions can be made:

i. The presence of stagnant water points and bushy environment contribute to outbreaks of highland malaria in the district.

ii. The community members in Gucha are knowledgeable about the causes of highland malaria and therefore they need to be supported and integrated in the malaria control programmes.

iii. Several methods (environmental, chemical and cultural) are applied in the prevention of highland malaria in the district.

6.2 Recommendations

i. There is need to carry out studies on high prevalence rates of highland malaria in the districts neighboring Gucha and the best way of controlling the disease.

ii. There is need to support community participation, collaboration and integration in the malaria control programmes in all stages and decentralization of malaria control operations.

iii. It would be imperative to continuously educate the local people on good environmental management, the need for good housing and the importance of using the conventional methods for control of malaria.

REFERENCES


APPENDICES

APPENDIX I: Gucha administrative units by division

<table>
<thead>
<tr>
<th>DIVISION</th>
<th>AREA (KM$^2$)</th>
<th>LOCATIONS</th>
<th>SUB LOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenyenia</td>
<td>11.6</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Ogembo</td>
<td>105.1</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Nyamache</td>
<td>81.4</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Nyacheki</td>
<td>79.9</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Sameta</td>
<td>78.0</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Nyamarambe</td>
<td>94.5</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Etago</td>
<td>105.7</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>660.8</strong></td>
<td><strong>30</strong></td>
<td><strong>78</strong></td>
</tr>
</tbody>
</table>

Source: DDP, Gucha, 2001
APPENDIX II: Study sites

APPENDIX III: Research authorization

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

JOGO HOUSE “B”
HARAMEEB AVENUE
P.O. Box 30040-00100
NAIROBI

7th June 2004

Peter Nyabuto Ondari
Kenyatta University
P.O. BOX 43844
NAIROBI

Dear Sir

RE: RESEARCH AUTHORIZATION

Please refer to your application for authority to conduct research on 'A study in courses and the Control Measures of Gucha District, I am pleased to inform you that you have been authorised to conduct research in Gucha District for a period ending 30th November, 2004.

You are advised to report to the District Commissioner and the District Education Officer, Gucha District before embarking on your research project.

You are further expected to avail two copies of your research report to this Office upon completion of your research project.

Yours faithfully

[Signature]

F: Permanent Secretary

CC:

The District Commissioner
Gucha

The District Education Officer
Gucha District
APPENDIX IV: Research permit

My name is Peter N. Ondari
From: Kenyatta University, School of zoological studies - A masters of Public Health and Epidemiology Student.

Purpose of the interview: Research work on ‘causes and control measures of highland malaria outbreaks, a case study of Gucha District.’

In signing this document, I am giving my consent to be a participant in a research study that is being conducted by Peter N. Ondari. I have been made to understand that the study is on “Causes and control measures of highland malaria outbreaks, a case study of Gucha District.” I have been told that participation in the study is voluntary and my refusal to participate will involve no penalty. Therefore, should I desire to withdraw from the study, I am free to do so.

Purpose of the study

I understand the information to be obtained from the study; will be used for the purpose of preventing and controlling malaria in Gucha District.

Research procedure

I will be interviewed to determine whether I have knowledge on causes, clinical features, treatment and control and prevention measures of highland malaria in Gucha District. I will be interviewed by use of open-ended structured questionnaires during the research period.

Risks/Benefits

I have been told that the study will not be harmful to me, but the benefit that I will derive from the research includes a possibility of knowing the causes, clinical features, and treatment, prevention and control measures of highland malaria. The information obtained from the research will be helpful in the prevention and control of highland malaria outbreaks in Gucha District.

Confidentiality

I have been assured that the information from this study will be kept confidential.
Costs

I have been told that I am not going to incur any cost for participating in this study.

Participants Name………………………………………………………………………………

Participant’s Signature………………………….Date………………………………………

Witness’s Name………………………………………………………………………………

Witness’s Signature …………………………………..Date……………………………………

APPENDIX VI: Questionnaire

A STUDY ON HIGHLAND MALARIA OUT BREAKS IN GUCHA DISTRICT

RESPONDENT’S BACKGROUND MOBILITY AND NEEDS

Q (1) In which year, month and date were you born?

Q (2) What is your level of education?

Q (3) Have you ever heard about malaria?
Q (4) have you ever been attacked by malaria? Yes or no. If yes how were you treated?
(a) ................................................ (b) ................................................
(c) ................................................ (d) ................................................

Q (5) Do you know what causes malaria? Yes (   ) or No (   )

Q (6) If yes, list all the probable causes of malaria:
(i) ...............................................................................................
(ii) ...............................................................................................
(iii) ...............................................................................................
(iv) ...............................................................................................

Q (7) List modern ways of preventing malaria from attacking you
(i) ........................................................................................................
(ii) ........................................................................................................
(iii) ........................................................................................................

Q (8) Suggest other malaria control and preventive measures which are not practiced locally?
(i) ........................................................................................................
(ii) ........................................................................................................
(iii) ........................................................................................................

Q (9) Give a list of the traditional methods of malaria control and preventive measures you know.
(i) ........................................................................................................
(ii) ........................................................................................................
(iii) ........................................................................................................

Q (10) Which one sign/symptom is always present when one has malaria?
........................................................................................................

Q (11) Name all the signs/symptoms of malaria
Q (12) What drugs are recommended for treatment of malaria?
(a) .................................................................
(b) .................................................................
(c) .................................................................
(d) .................................................................
(e) .................................................................
(f) .................................................................
(g) .................................................................

Q (13) Choose which type of house you live in?
(a) Block/Brick walled, tile/mabati roofing with ceiling.
(b) Block/Brick walled, tile/mabati roofing without ceiling.
(c) Mud walled, cracked wall/thatched/mabati roofing, and unclosed eaves.
(d) Mud walled, cracked wall/thatched/mabati roofing, open eaves.
Appendix VII: ANOVA table intermediate calculations

a) Malaria morbidity data (1998-2006)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments (between columns)</td>
<td>8</td>
<td>2.157E+08</td>
<td>2.696E+07</td>
</tr>
<tr>
<td>Residuals (within columns)</td>
<td>99</td>
<td>1.337E+09</td>
<td>1.350E+07</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>1.553E+09</td>
<td></td>
</tr>
</tbody>
</table>

F = 1.996  =\( \frac{\text{MS}_{\text{treatment}}}{\text{MS}_{\text{residual}}} \)  \( P = 0.0546 \)

b) Outpatient data on malaria per Age group (2003)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments (between columns)</td>
<td>3</td>
<td>1.858E+08</td>
<td>6.194E+07</td>
</tr>
<tr>
<td>Source of variation</td>
<td>Degrees of freedom</td>
<td>Sum of squares</td>
<td>Mean square</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>--------------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Treatments (between columns)</td>
<td>4</td>
<td>1.512</td>
<td>0.3781</td>
</tr>
<tr>
<td>Residuals (within columns)</td>
<td>55</td>
<td>65.764</td>
<td>1.196</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>59</strong></td>
<td><strong>67.276</strong></td>
<td></td>
</tr>
</tbody>
</table>

\[ F = 0.3162 = (\text{MS}_{\text{treatment}}/\text{MS}_{\text{residual}}) \quad P = 0.8659 \]

c) Data on Temperature (2002-2006)

d) Data on Rainfall (2002-2006)

e) Data on Humidity (2002-2006)
\[ F = 0.7971 = \frac{\text{MStreatment}}{\text{MSresidual}} \quad P = 0.5322 \]