EFFECTIVENESS OF COMBINED USE OF NON-PYRETHROID INDOOR RESIDUAL SPRAY AND LONG-LASTING INSECTICIDALNETS AND THEIR ACCEPTABILITY AMONG THE RESIDENTS OF WESTERN KENYA

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented to any other university/institution. No part of this research proposal may be reproduced without the prior permission of the author or Moi University

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DEDICATION

To my loving wife Diramu Dika and my daughter Lelo Diba for their encouragement, understanding and support during the long periods of time I was away from home. I also dedicate this thesis to my mother Taditi Dulacha for her prayers and encouragement.

ABSTRACT

Background: Kenya employed combination of long lasting insecticidal nets (LLINs) and non-pyrethroid indoor residual spray (IRS) in 2017 and 2018 as a strategy to address the widespread pyrethroid resistance which is threatening to affect the progress towards malaria elimination.

Objectives: To evaluate the effectiveness of combined use of non-pyrethroid IRS and LLINs on malaria indicators and assess awareness and acceptability of the two interventions among the residents of Nyatike and Suba sub-Counties in Western Kenya.

Methods: Record review and tally of monthly aggregates of outpatient attendance, suspected malaria cases and number tested for malaria and number positive for malaria at Karungu

Sub-county Hospital in Nyatike (intervention area) and Suba Sub-county Hospital in Suba (comparison area) was done for pre-intervention (1 February 2016 to 31 January 2017) and post-intervention periods (1 April 2017 to 31 March 2018). Interviews and screening for malaria was done among febrile clients at outpatient departments of the two health facilities. Data analyses were done using Epi Info 7 and Stata. Poisson regression was used to determine the effectiveness of the intervention in the presence of confounders. Descriptive statistics was used to evaluate awareness and level of acceptability for LLINs and IRS by the residents.

Results: Annual malaria incidences among all ages reduced by 89% from 360 per 1000 in pre-intervention to 38 per 1000 in post-intervention in intervention area and reduced by 52% from 131 per 1000 to 78 per 1000 in the comparison area. Among the under 5 children, the net change in annual malaria incidence was 308 per 1000 population (RR=0.25, 95CI 0.24-0.29 $p<0.001$).Test positivity rate among the febrile clients was 8% (15/187) and 12% (22/187) in Nyatike and Suba sub-Counties respectively. The majority of the clients had heard about free mass net distribution and IRS campaigns. The level of acceptability for LLINs was 94% in Nyatike and 93% in Suba while the level of acceptability for IRS was 61% in Nyatike and 65% in Suba.

Conclusion: Combination of non-pyrethroid IRS and LLINs provided greater protection against malaria. The TPR was lower in Nyatike than in Suba sub-County. The level of awareness was high for both LLINs and IRS. The level of acceptability was high for LLINs but considerably lower for IRS in both sub-counties.

Recommendations: Scale up of combined use of LLINs and non-pyrethroid IRS in all malaria endemic areas and address factors contributing to low acceptability for IRS through adequate community sensitization and health education.

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ABBREVIATIONS AND ACRONYMS

Acronym	Meaning
ACT	Artemisinin-based Combined Therapy
ANC/MCH	Antenatal Clinic/Maternal and Child Health
AIRS	Africa Indoor Residual Spray
CDC	The US Centers for Disease Control and Prevention
CHV	Community Health Volunteers
CI	Confidence Interval
CIDP	County Integrated Development Plan
DDT	Dichlorodiphenyltrichloroethane
DHIS2	District Health Information System 2
GPIRM	Global Plan for Insecticide Resistance Management
HIV	Human Immunodeficiency Virus
IDSR	Integrated Disease Surveillance and Response
IPTp	Intermittent Preventive Therapy in Pregnancy
IRS	Indoor Residual Spray
ITNs	Insecticide-Treated Nets
KDR	Knockdown resistance
KMIS	Kenya Malaria Indicator Survey
KNBS	Kenya National Bureau of Statistics
LLINs	Long-Lasting Insecticidal nets
MIS	Malaria Indicator Survey
MOH	Ministry of Health
NMCP	National Malaria Control Program
OPD	Outpatient Department

OR	Odds Ratio
PMI	The US President's Malaria Initiative
RDT	Rapid Diagnostic Test
SOP	Standard Operating Procedure
TDR	WHO Special Programme for Research and Training in Tropical Disease
WHO	World Health Organization

DEFINITIONS OF KEY TERMS

Acceptability - is the process of allowing spraying of a house or agreeing to sleep under a mosquito net

Effectiveness - Ability to produce desired effect or outcome

Gametocytes - The form of malaria parasite which is infectious to the *Anopheles* mosquito vector

Household - All family members or group who lives together and eats from one pot

Impact - A positive or negative effect on health status, usually referring to disease or death

Ownership - Possession of a mosquito net

Spraying operators - Officials who undertake the act of spraying

Sporozoites - Infectious forms of malaria parasites which are injected into bloodstream during a blood meal by the *Anopheles* mosquito vector.

Universal coverage - Possession of at least one net for every two people in the household

Use of ITNs/LLINs - Sleeping under a mosquito net the night before the interview

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CHAPTER ONE

INTRODUCTION

1.1 Background

In Kenya, malaria is a major public health and socio-economic problem with three-quarters of the population at risk of the disease (MOH, 2014). Malaria contributed 20% of all the outpatient visits and caused 1.6% of all hospital deaths countrywide in 2016(KDHIS2, 2016). The national prevalence of malaria was 8% in 2015 but varies widely across different regions depending on altitude, rainfall, and urbanization (MoH, 2015).

Kenya has four malaria epidemiological zones which are targeted by different combinations of prevention and control measures. The risk and prevalence of malaria varies greatly between the four epidemiological zones based on climatic factors like altitude, rainfall patterns and temperature (MoH, 2015). In 2015, the prevalence of malaria among children aged 6 months to 14 years was 3.1% in highland epidemic areas, 0.5% in seasonal malaria transmission areas and 0.3% in low risk malaria areas. The prevalence was much higher in malaria endemic areas where it was 8.1% in coastal endemic counties and 27% in lake endemic counties (MoH, 2015). Other studies that estimated the prevalence of malaria in lake endemic counties showed much higher estimates. For instance, a study done among school-going children (mean age of 9.6 years) in 2014estimated the prevalence to be 51.8% in Homa Bay and 29.6% in Migori (Okoyo *et al*., 2015).

As part of its Kenya Malaria Strategy, the National Malaria Control Program (NMCP) has been implementing the two key vector intervention measures, LLINs and IRS, in targeted malaria epidemiological zones. The program's objective has been to ensure

80% of the target population use LLINs and be protected by IRS. The two main channels of net distribution used in Kenya include free mass net distribution, and continuous routine distribution to pregnant women in antenatal clinics (ANC) and to children less than one year of age in child health clinics. Four free mass mosquito net distribution campaigns have been in conducted in Kenya, in 2006, 2011/2012, 2014/2015, and 2017/2018.Migori and Homa Bay counties received their nets in June 2017 as part of the last free mass net distribution.

As a result of these distributions, in 2015 the majority of the nets found in the households were LLINs and that 40% of the households owned at least one LLIN for every two persons (universal coverage) (MoH, 2015). Net usage in the country improved from 24% of children under 5 sleeping under a net the night before the surveying 2005 to 58% in 2015. An analysis combining data from DHS 2014 and KMIS 2015 and re-analyzing to give results at county level estimated that the proportion of the population sleeping under LLIN the night before the survey was conducted was 51% in Migori County and 53% in Homa Bay County. The proportion of households with universal ITNs coverage in 2015 was 39% in Homa Bay and 32% in Migori (Noor, 2016).

In sub-Saharan Africa, insecticide treated nets were believed to have contributed the most in malaria burden reduction between 2000 and 2015, with 68% of averted cases of malaria being attributed to the use of ITNs(Bhatt *et al.*, 2015). Other studies done to assess the impact of use of ITNs have shown a significant reduction of malaria incidence rates by 50% and malaria mortality rates by 55% among children under 5 year of age in sub-Saharan Africa (Eisele, Larsen, & Steketee, 2010).

In Kenya, use of IRS in malaria endemic districts commenced in 2009 after the adoption of the new Kenya Malaria Strategy (2009-2018) following WHO's recommendation to use IRS as a malaria reduction tool in malaria endemic regions. Indoor residual spraying activities in the country were later stopped in 2013, when widespread pyrethroids resistance was reported, and re-introduced in 2017 in Migori County using a newly-approved organophosphate insecticide, following the country's insecticide resistance management strategy(MOH, 2015a).

The impact of IRS has been demonstrated outside of Kenya through reduced morbidity and mortality, although data on IRS are not as comprehensive as those on ITNs (Pluess *et al.*, 2010). A review of previous studies done in the continents of Africa and Asia in an attempt to examine effectiveness of combined use of LLINs and IRS found mixed results while analysis of malaria indicator survey (MIS) data between 2006 and 2008 from Bioko in Equatorial Guinea and Zambezi in Mozambique showed lower malaria prevalence among children protected by both IRS and use of LLINs compared to those protected by a single intervention (Kleinschmidt *et al*., 2009).

The combination of LLINs and IRS is now being deployed as a strategy for management of insecticide resistance. Pyrethroids are the only recommended class of insecticide for use in LLINs. However, pyrethroid resistance is now rapidly spreading, particularly in West and East Africa, jeopardizing the progress so far made in malaria burden reduction (WHO, 2015). Approximately 67% of countries with ongoing malaria transmission, including Kenya, have reported insecticide resistance among its major vector populations (MOH, 2015a). Therefore, to reduce development of resistance and protect pyrethroids, WHO recommends the class of insecticide for IRS

should be different than the one used in nets. Non-pyrethroid IRS and pyrethroid LLINs are currently being combined in areas of high malaria transmission where resistance to pyrethroids have been identified in order to protect the effectiveness of LLINs (WHO, 2015).

1.2 Problem Statement

In Kenya, the prevalence of malaria in malaria endemic counties in the Lake Victoria region in Western Kenya is 27%, higher than the national prevalence of 8% (MoH, 2015). In 2015, 74% of Homa Bay County and 65% of Migori County population were at risk of malaria. During the same period four sub-counties in Migori County and six sub-counties in Homa Bay County were reported to have malaria prevalence estimated to be 20-50% (Noor, 2016). Malaria and anemia, a complication resulting from malaria, were identified as the commonest causes of childhood mortality in Western Kenya from 2003 to 2009 (Hamel, *et al*., 2011). The burden of this entirely preventable disease still remains high.

Pyrethroid resistance had been reported in anopheline mosquitos from all malaria-endemic counties in Kenya (MOH, 2015a), including high resistance in anopheline mosquitoes from Migori and Homa Bay counties (Kawada *et al*, 2011; MOH, 2015a). Efficacy of these pyrethroid-treated LLINs, which are critical component of malaria control strategy in the country, is being threatened by the development of resistance to pyrethroids by major malaria vectors. Pyrethroid resistance is likely to jeopardize the gains already made in malaria burden reduction as it compromises effectiveness of LLINs being used in mass campaigns and routine distribution in health facilities.

The Kenya Insecticide Resistance Management Plan, in line with WHO recommendations, advocates for the use of non-pyrethroid IRS in areas with high

coverage of nets and pyrethroid resistance as part of the pyrethroid resistance management strategy(WHO, 2015). Accordingly, Kenya launched the use of an organophosphate insecticide, pirimiphos-methyl (Actellic 300CS), in IRS in Migori County in 2017 with the aim of protecting the effectiveness of the LLINs. However, the effect of the combined use of the non-pyrethroid IRS and LLINs in this setting is poorly understood.

The IRS and LLINs are community-based vector control measures whose success depends on their acceptability and, for LLINs, their proper usage by the targeted population. When used correctly and consistently, LLINs provide both individual and community level protection as demonstrated through reductions of malaria burden and deaths among net users and non-users residing within communities with high ITN coverage (Atieli *et al*., 2011; Klinkenberg *et al*., 2010). IRS, with its potential to further reduce malaria burden and to mitigate the risk of mosquito resistance to the pyrethroids being used in the LLINs, can also give a "community effect", with increased effectiveness with high household coverage (Pluess *et al*., 2010; WHO, 2015). High IRS coverage and community buy-in are achieved through proper community mobilization and involvement in planning and implementation of IRS campaign(MOH, 2015b). The local communities' acceptance of LLINs and the new insecticide used in IRS, Actellic 300CS®, have not been examined in the communities residing in Western Kenya.

1.3 Justification

It was expected that the combination of non-pyrethroid IRS and LLINs in Migori County would result in marked reduction in malaria transmission and therefore lower malaria burden in the county. In some African countries with high pyrethroid

resistance, the combined use of non-pyrethroid IRS and LLINs has been shown to be effective to reduce malaria incidence (Kanyangarara *et al*., 2016; Katureebe *et al*., 2016). Information on additional protection afforded by use of organophosphates (e.g. Actellic 300CS®) in IRS in combination with LLINs in Western Kenya is limited. Several reports have found an impact of the combination of IRS and LLINs on anopheline populations(PMI, 2018b), but results are also needed on the epidemiological impact. Understanding whether this combination reduces malaria burden more than LLINs alone, in areas with high pyrethroid resistance, would be critical to guide national malaria control program Kenya to decide where and how to deploy IRS and LLINs as vector control measures. Understanding local communities' acceptability of the two major vector control interventions would also be vital.

1.4 Research Questions

1. How does combination of non-pyrethroid indoor residual spray (IRS) and use of LLINs provide additional protection against malaria compared with use of LLINs alone in Western Kenya?
2. What is the acceptability of LLINs alone or LLINs and IRS in combination among residents of Nyatike and Suba sub-counties?

1.5 Broad Objective

To evaluate the effectiveness of combined use of non-pyrethroid IRS and LLINs on malaria indicators and assess knowledge and acceptability of the two interventions among the residents of Nyatike and Suba sub-Counties in Western Kenya, 2016 to 2018.

1.5.1 Specific objectives

1. To compare changes in malaria indicators between pre-intervention and post-intervention period in Nyatike (intervention area) and Suba (comparison area) sub-counties from 2016 to 2018
2. To compare test positivity rate among febrile outpatient clients in Nyatike and Suba sub-counties in 2018
3. To assess awareness and level of acceptability of LLINs and IRS among residents of Nyatike and Suba sub-counties in 2018

CHAPTER TWO

LITERATURE REVIEW

2.1 Etiology and Transmission of Malaria

Malaria is an acute febrile disease caused by parasites of genus *Plasmodium* which can be fatal when untreated or treatment is delayed (WHO, 2016a). Transmission occurs through bites of infectious female *Anopheles* mosquitoes, with most biting occurring between dusk and dawn . In humans, malaria is caused by one or more of the four species of plasmodia: *Plasmodium falciparum, P. vivax, P. ovale* and *P. malariae* . Recently, a new species of *Plasmodium* that causes malaria has been identified; *P. knowlesi* (Bronner *et al*., 2009). The presentation of malaria diseases caused by each species differs in their response to medication, severity and their clinical manifestation in human. *P. falciparum* causes the most fulminant disease while *P. vivax* causes a more prolonged illness and the two cause the greatest health problem (WHO, 2016c). *P. falciparum* is the most dominant species in Africa and contributes the most to malaria-related deaths globally (WHO, 2017b). In Kenya, *P. falciparum* is the predominant species causing infection, accounting for 96% of malaria cases in 2015 (MoH, 2015). Most human malaria is transmitted by female mosquitoes of the genus *Anopheles* (Raghavendra *et al*., 2011). Over 400 species of anopheles mosquitoes have been found and about 30 of them are of major public health importance in malaria transmission (WHO, 2016c). Three anopheles species - *Anopheles gambiae, Anopheles arabiensis* and *Anopheles funestus* - are the most important malaria vectors in Africa (Tonnang *et al*., 2010). The first two species belong to *An. gambiae* complex, a group that is very efficient at transmitting malaria. In Kenya, malaria is transmitted by *An. gambiae* s.l. and *An. funestus* (MoH, 2015b).

Malaria transmission is affected by several environmental factors such as climate and altitude. The environmental factors of considerable importance in malaria transmission are precipitation, temperature, altitude and humidity. Climatic factors influence the density of *Anopheles* mosquito populations and the length of the extrinsic development cycle of *Plasmodium* inside the mosquito (Krefis *et al*., 2011). Higher temperature strongly influences malaria transmission by facilitating parasite infection and increasing the rate of development in the vector (Paaijmans *etal*., 2010).Precipitation is another important meteorological factor influencing malaria transmission with malaria incidence higher during or after a rainy season (Krefis *et al*., 2011; WHO, 2016c). The ongoing changes in the global climate and its effect on human health are thought to have a considerable potential impact on malaria as its transmission is climate sensitive.

2.2 Malaria Lifecycle

The *Plasmodium* parasite is transmitted via a bite of an infected *Anopheles* mosquito during a blood meal. Upon entry into the circulation, sporozoites multiply in the liver and then release merozoites that infect red blood cells and feed on hemoglobin. Merozoites replicate within the red cells, causing their destruction and the release of successive broods of parasites which infect other red blood cells (Goldberg & Sigala, 2017). Some parasites differentiate into sexual erythrocyte stages (gametocytes) that are taken up by mosquitoes during a blood meal. Inside the gut of the mosquito, the gametocytes start a different cycle of growth where they undergo fusion into zygotes that in turn develop into oocyts. Within 10-18 days, the oocysts rupture, releasing sporozoites that make their way to the mosquito's salivary glands from where they will be injected into the next person during a blood meal (Aly, Vaughan, & Kappe, 2009).

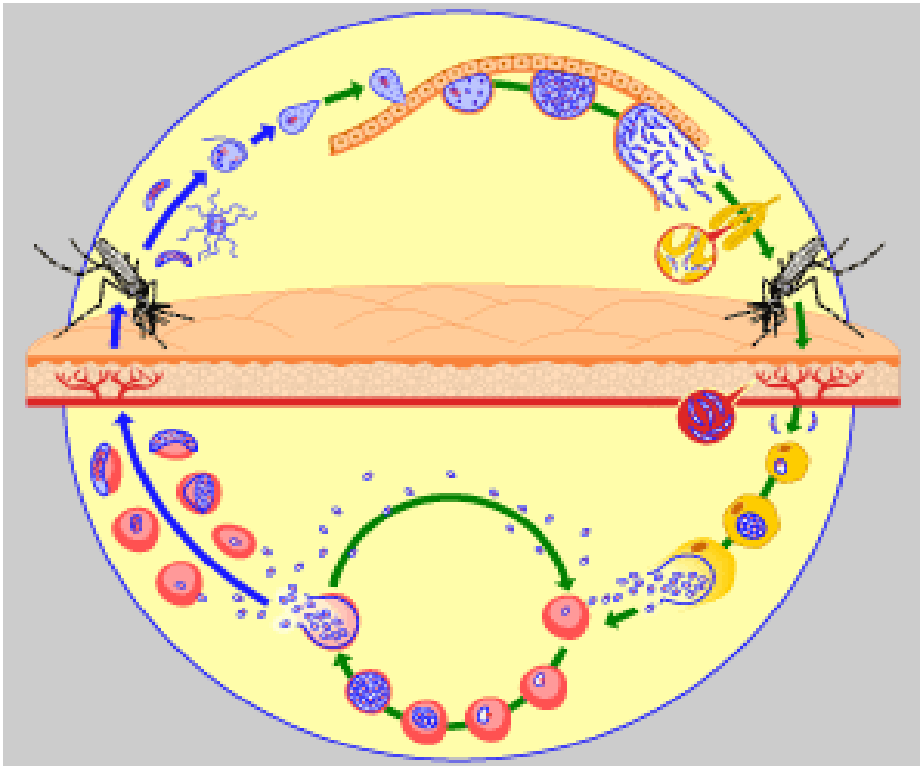

Figure 2.1: The Lifecycle of malaria in the human and the vector hosts

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2.3 Epidemiology of Malaria

Malaria is a global public health problem with an estimated 3.2 billion people at risk worldwide, and 212 million cases with 429,000 deaths being reported in 2015. Children under the age of 5 years represent 86% of the cases (WHO, 2016b). Sub-Saharan African countries accounted for 90% of malaria cases and 92% of malaria deaths in 2015 (WHO, 2016c). Between 2015 and 2010, estimated malaria incidence had fallen by 21% globally (WHO, 2016e). During the same period, estimated rates of mortality due to malaria were reduced by 29% globally and by 31% in African region. In 2015, 429,000 malaria deaths were reported globally, out of which 70% were among the children under 5 years of age (WHO, 2016e). Recent reviews of progresses indicate that remarkable transformations have been made in malaria programme financing and intervention coverage contributing to reduction of the disease burden,

however reductions in morbidity and mortality need to be accelerated in countries with the highest burden to achieve future malaria targets (Cibulskis *et al*., 2016).In Kenya, malaria had been prioritized for elimination in the revised Kenya malaria strategy plan 2009-2018 as it is still considered a disease of public health and socio-economic problem (MoH, 2014). Almost half of the country's population (48%) was estimated to live in areas with prevalence of 5-10% and about 18% in areas with parasite prevalence of 20-40% (MoH, 2014).The prevalence of malaria has reduced from 11% in KMIS 2010 to 8% in KMIS 2015. By age group, the prevalence was highest at 11% among children aged 10-14 years (MoH, 2015).

2.3.1 Malaria Endemic Zones in Kenya

The risk of malaria transmission in Kenya is dependent on altitude, precipitation and temperature. Based on this risk, and the underlying climatic and altitude variation, the country was divided into four eco-epidemiological regions. The four eco-epidemiological regions include endemic region, seasonal malaria transmission areas, low risk transmission areas and epidemic prone areas of Western Highlands of Kenya(PMI, 2016). Endemic zones include the lake endemic zone, located around Lake Victoria in Western Kenya, and the coast endemic zone along the Indian Ocean coast. Presence of suitable climatic conditions favoured vector's survival and their lifecycle. These zones are hyper-holoendemic areas with altitude ranging from 0 to 1300 metres above sea level. Estimated malaria parasite prevalence is 8.1% in the coastal endemic areas and 26.7% in lake endemic zone(MoH, 2015). Malaria endemic counties drive the malaria burden in Kenya as the burden is heavily concentrated there, with much lower burden in the rest of the country(Noor *et al*., 2009). While the burden of malaria in other regions of the country has gone down, the Western part of

the country continue to experience high mortalities and morbidities secondary to malaria. About 26% of the country's population live in this region (MoH, 2014).

2.4 Malaria Prevention Strategies

Measures to prevent malaria infections, at both community and individual levels, have received renewed emphasis since 2000, with a widespread scaling up of LLIN possession and IRS in the last decade (Gimnig *et al*., 2016). Vector control measures, used in conjunction with case management and intermittent preventive therapy in pregnant women, are critical for the reduction and interruption of malaria transmission. The two most commonly-used vector control strategies in malarious areas are the use of LLINs and IRS (WHO, 2015).

The production of LLINs involves impregnating netting materials with long-lasting insecticidal chemicals of pyrethroid class which can offer protection against malaria for at least three years. The LLINs have insecticide incorporated into the netting material, protecting people sleeping under them through a physical barrier, a repulsive effect to mosquitoes, and, to mosquitoes landing on the net, a lethal dose of insecticide. These different mechanisms mean sleeping under a LLIN in a region without high net coverage is still protective, but when usage is high (>80% of the population) community effects start to emerge, where mosquito populations decrease and even people not sleeping under a net are protected (WHO, 2015).

The use of IRS as a vector control intervention involves spraying of a long-lasting, residual insecticide to malaria resting areas e.g. internal walls of all dwellings to increase the chances of the vectors coming into contact with the insecticide. The five classes of insecticide recommended by WHO are: pyrethroids, organochlorines (dichlorodiphenyltrichloroethane, DDT), organophosphates, carbamates and

neonicotinoids (MOH, 2015, WHO, 2018). The IRS is usually targeted at and most effective against indoor resting (endophilic) and indoor feeding (endophagic) vectors (WHO, 2015). These vectors usually rest indoors on the wall after a blood meal and therefore get exposed to a lethal dose of insecticide. Effective insecticides used in IRS work by reducing the lifespan of the adult mosquitoes to less than the duration required for development of sporozoites. This early mortality results in overall reduction of the vector density and longevity, reducing transmission of the sporozoites in the region (WHO, 2015). Insecticides used in IRS also have a repellant effect, reducing contact between the humans and the vectors. Some pesticides, for example pyrethroids, have a greater repellant effect than others. For IRS to be effective, high coverage of 85% or more of all the structures in a region is required in order to benefit from the 'mass effect' on the mosquito population (WHO, 2015).

Use of LLINs and IRS are effective and highly recommended for use in sub-Saharan African countries(WHO, 2016d, 2017a). These two control measures have made major contribution to reduction of morbidities and mortalities secondary to malaria (WHO, 2016e). Successful eradication of malaria in some parts of the world during mid-1990's was majorly attributed to the use of vector control interventions (Raghavendra *et al*., 2011).

Efficacy and cost-effectiveness of use of LLINs which is the most commonly used vector control intervention has long been proven (Karunamoorthi, 2011; Kleinschmidt *et al*., 2009). In addition to reducing morbidity, sleeping under an ITN has been shown to reduce mortality rates by 55% among children less than 5 years age in sub-Saharan countries (Eisele *et al*., 2010). Attaining and maintaining the required rates of LLINs ownership and use is often thought to be logistically easier than achieving the

same coverage with IRS. Scaling up of ownership of LLINs by governments and stakeholders through use of various avenues like free mass net distribution and continuous distribution of nets in health facilities has resulted into improved rates of ownership, though in few countries do an adequate proportion of households have the recommended one LLIN for every two residents. Following the scaling up of vector control interventions in all the regions of the world since early 2000s, the number of ITNs delivered to malaria-endemic countries increased from 6 million in 2004 to 178 million in 2015. Consequently, the proportion of people at risk who had access to one or more ITN in their household increased from 7% in 2005 to 67% in 2015 in sub-Saharan African countries (Cibulskis *et al*., 2016). As ownership rates have increased, so has usage. For instance in sub-Saharan countries, the proportion of population at risk of malaria who slept under LLINs increased from 30% in 2010 to 53% in 2015 (WHO, 2016e). In Kenya, use of ITNs as a vector control has a long history and some of the first large-scale trials of ITNs/LLINs were done in Western Kenya. A plan to scale up access to ITNs was first emphasized in national malaria strategy 2001-2010. During this period, various channels of nets distribution were adopted, including social marketing in 2001/2002 and to pregnant mothers and children under 5 years attending ANC or MCH clinics in 2004. In 2005 and 2006, use of LLINs was introduced and distributed through free mass distribution to children under five with support from Global Fund. By 2011 the strategy changed to target universal coverage, defined as one LLIN for every two people sleeping in a household. Three mass net distributions targeting universal coverage have been done since, in 23 high-risk counties (in the lake endemic, coast endemic, and highland epidemic zones), in 2011-12, 2014-15 and 2017.Routine continuous distribution of nets to pregnant mothers and children <1 year occurs in ANC/MCH clinics in order to supplement the free mass net

distribution campaigns. In Kenya, net use had increased since 2010 to 67% in Lake Endemic, 59% in coast endemic, 54% in highland epidemic and 34% in low risk zone during the 2015 indicator survey. It is important to note that these proportions of populations sleeping under nets remain well below the target of 80% of the population sleeping under an LLIN.

Despite limited randomized studies examining its effectiveness, IRS is believed to have an efficacy comparable to ITNs (Pluess *et al*., 2010). Dichlorodiphenyltrichloroethane (DDT) was the primary insecticide used during Global Malaria Eradication Program and resulted in elimination of malaria in many regions and reduction of malaria burden in many others (Nájera *et al*., 2011). After the abandonment of the first malaria eradication efforts, IRS use was low for several decades. In the early 2000s vector control activities again had international attention and strategies for scale-up were adopted (WHO, 2016a). Currently, the use of IRS is increasing in African countries although it declined in 2017 as countries switched from pyrethroid insecticides to more expensive alternatives as part of strategies to combat pyrethroid resistance (WHO, 2019). Following this increased use of IRS, the number of people that had been protected by IRS in WHO African region had increased from 10 million in 2005 to 78 million in 2010 (WHO, 2015). In 2015, 49 million people had been protected by IRS in the WHO African region(WHO, 2015).

In Kenya, IRS activities were initially focused on epidemic-prone districts, in response to malaria epidemics in the late 1990s. After WHO revised its guidelines in 2006 and recommended the use of IRS as a vector-control measure in all the malaria epidemiological zones, including areas with intense year-round transmission, Kenya amended its strategy in 2009 and included IRS as an intervention measure meant for

malaria burden reduction in endemic regions (MOH, 2015b). Afterwards several rounds of IRS were undertaken between 2008 and 2012 targeting districts that are now part of Kisumu, Migori and Homa Bay Counties(Noor, 2016). Indoor residual spraying campaigns stopped in the country in 2013 following discovery of high resistance to pyrethroids in *Anopheles* mosquitoes and the lack of an alternative insecticides from different insecticide classes that had been registered in the country(MOH, 2015a). Indoor residual spraying activities were then re-introduced in 2017 and Migori County was selected for spraying using a new organophosphate formulation, Actellic 300CS®.

This recent increase in the use of IRS has necessitated the need to collect quantitative data to determine the impact of IRS on malaria indicators. When compared against use of ITNS, the limited data suggest that ITNs gave a better protection than IRS in malaria unstable areas; an insignificant difference was found in malaria stable setting (Pluess *et al*., 2010). An analysis of malaria indicator surveys and demographic health surveys data from six sub-Saharan African countries conducted with aim of quantifying effects of malaria intervention in the region showed that despite variations of reduction in parasitemia across different regions, a significant effect of ITNs and IRS was detected in all the countries (Giardina *et al*., 2014). And in a cross-sectional study conducted in Malawi in an area of intense malaria transmission to assess impact of IRS alone on parasitemia and anemia among under 5 year children showed a 46% reduction in parasite prevalence and a 30% reduction in anemia prevalence(Skarbinski *et al*., 2012). A significant reduction in parasite prevalence in the same study was also noted among children living in households which did not receive IRS but were within the IRS area, highlighting the protective mass effect of IRS when adequate coverage was achieved(Skarbinski *et al*., 2012). Another study done in Uganda also showed a

significant reduction in malaria burden in areas after few episodes of IRS campaign was done in the area (Kigozi *et al*., 2012).

The WHO currently recommends using a combination of IRS and LLINs as a response to insecticide resistance in areas where LLINs had been the dominant vector control strategy(WHO, 2015). This combination is aimed at protecting pyrethroid group of insecticides, the only class currently used in LLINs. The practice of integration of LLINs and IRS as vector control measures is mainly being seen in holoendemic and hyperendemic areas although different countries have differing strategies emphasizing one intervention over the other or both (Okumu & Moore, 2011). The additional protection from the combined use of IRS and LLINs, though widespread, is still poorly understood. WHO has recommended that the insecticides used in LLINs and IRS should be of different class of insecticides, for instance use of carbamates or organophosphate in IRS in areas with pyrethroid-impregnated LLINs. Studies evaluating different national malaria control programs have shown different results. In a prospective cohort study conducted in Kenya by Hamel and team in 2011, a greater protection against malaria was afforded by a combination of IRS and ITNs as compared to ITNs alone, with an adjusted protective efficacy of 62% (95% CI=0.50-0.72) (Hamel *et al.*, 2011).Some household surveys done to evaluate the BIMCP in Equatorial Guinea and through a malaria decision support system project in Zambezia, Mozambique, showed that a protective effect of IRS against malaria when combined with ITNs/LLINs relative to when IRS was used alone (OR=0.71, 95% CI=0.59-0.86, P=0.001 in Bioko, and OR=0.63, 95% CI=0.50-0.79, P<0.001 in Zambezia) (Kleinschmidt *et al*., 2009). In addition, a study in Tororo district in Uganda compared the incidence of malaria in children under five years of age before and after the scale-up of vector control interventions. The results showed an

insignificant reduction in incidences of malaria among under five year old children, from 130 to 100 cases per 1000 (odds ratio (OR) =0.98, 95% confidence interval (CI) 0.97-1.00, P=0.08) in 2014 when LLINs were used alone; when IRS was combined with LLINs, malaria incidences significantly declined to 45 cases per 1000 in 2015 when (OR=0.94, 95% CI 0.91-0.996, P< 0.001) (Oguttu *et al*., 2017). And in a non-randomized prospective study comparing impact of combined use of ITNs and IRS against use of ITNs alone showed a lower incidence of *P. falciparum* (18 per 100 persons-years at risk) among the group with both ITNs and IRS as compared to the group with ITNs only (44 per 100 persons-year at risk) with an adjusted rate ratio of 0.41 (95% CI 0.31-0.56)(Hamel *et al*., 2011). On the other hand, despite widespread implementation of use of LLINs and ITNs concurrently and the expected interactions between the two interventions; little is known about the impact of the two interventions when used together indicating the existence of inconclusive evidence to either support or refute the combination strategy (Okumu & Moore, 2011).

2.4.1 Insecticide Resistance

Resistance of malaria vectors to insecticides used in LLINs and IRS is posing a growing threat to the gains made in reducing malaria morbidity and mortality since the turn of millennium (WHO, 2018b). With aim of effective management of this emerging global problem, WHO and stakeholders in 2012 developed the Global Plan for Insecticide Resistance Management to guide countries on use of vector control measures and monitoring of insecticide resistance(WHO 2012). Sixty countries out of the 70 malaria endemic countries have reported resistance to at least one insecticide in one malaria vector. Resistance to pyrethroids was reported as the commonest in 2015 with over three quarters of the countries monitoring the insecticide reporting some

resistance(WHO, 2016e). Resistance to pyrethroids by major malaria vectors is now widespread and continues to spread (Ranson *et al*., 2011).

Pyrethroids resistance through target site (kdr) and metabolic resistance are the main mechanisms of insecticide resistance found among vectors in Kenya (MOH, 2015a). Pyrethroid resistance via target site insensitivity, also called knockdown resistance (*kdr*), has been identified in *An. gambiae s.s* in Western Kenya (Ranson *et al*., 2011). By 2014, pyrethroid resistance among the major vectors in the country was believed to be widespread in the Western part of the country (Noor, 2016). However, vectors were sensitive to carbamates and organophosphates(Noor, 2016).

In a study done in Western Kenya with the aim of determining insecticide susceptibility among the major malaria vectors in the region, it detected high levels of metabolic resistance caused by point mutations in *An. gambiae* s.s and P450-related resistance in *An. funestus* and *An. arabiensis* s.s. It also found that *An. gambiae* s.s was resistant to both DDT and permethrin while *An. funestus* and *An. arabiensis* s.s lacked this cross-resistance(Kawada *et al*., 2011). Ochomo *et al* in 2013 found resistance to permethrin, deltamethrin and bendiocarb through metabolic, phenotypic and target site insensitivity. Among *An. gambiae s.s* in Bungoma District, Ahero Division in Nyando District and Budalangi Division in Busia District in Western Kenya, reduced mortality and prolonged time to knock-down 50% (KDT_{50}) was found in the tested mosquitoes. This pattern of resistance through either of mechanism was absent among *An. arabiensis* population from all the three sites(Ochomo *et al*., 2013). A multicenter, WHO-coordinated observational cohort study done in Benin, Cameroon, Kenya, Indian and Sudan which followed up 40 000 children for clinical incidence of malaria, found lower malaria prevalence and incidence among LLINs

users compared to non-users regardless of presence of pyrethroid resistance as determined by a standard WHO bioassay (Kleinschmidt *et al*., 2018).

2.4.2 Knowledge and Acceptability of LLINs and IRS

Community based vector control measures, LLINs and IRS, rely on how the benefiting communities view and embrace it. The rapid scale up of LLINs as a key vector control measure has resulted in increased ITN coverage and significantly reduced malaria burden in Africa (CDC, 2019; Kyu *et al*, 2013). About 294 million nets were distributed in sub-Saharan Africa between 2008 and 2010 (CDC, 2019).Consistent use of ITNs is required to for maximum protection from malaria infections. Studies have found factors associated with consistent ITN use include positive experiences with net use, awareness about the health and non-health benefits of net use, ability to replace worn out nets and residing in 'settled' urban and rural settings (Strachan *et al*., 2016). A study done in Eastern Ethiopia reported low level of education of the caretakers, low awareness on malaria prevention, preferences of particular colors, and unavailability of adequate nets for the household members as some of the main barriers to net (Gobena, Berhane, & Worku, 2012). A similar study done in Kenya highlighted access as the main barrier to net use in addition to perceptions that children are at more risk of malaria than adults, purchased bed nets are more effective than the freely distributed bed nets, bed nets are used only during rainy season, no benefit in using bed nets as they were going to get malaria anyway, taking antimalarial drugs is easier than using the bed nets and that using the bed nets was difficult (Ernst *et al*., 2016). Increase in bedbugs and associated irritability, and discomfort or warmness particularly during dry season were reported to decrease net use in Rwanda (Ingabire *etal*., 2015). Seasonal use of ITNs instead of consistent use has also been reported with better consistency being reported during rainy season

when there are perceived increase in mosquito population and malaria cases (Strachan *et al*., 2016).

World Health Organization advocates for IRS as an effective vector control measure (WHO, 2016d; 2017a). However, low IRS coverage has been reported in many campaigns in Africa limiting the ability of the campaigns to deliver the maximum protection for the benefitting communities(Bridges *et al*., 2018; Larsen *et al*, 2017).In a study done in a malaria endemic region in Mozambique, the main factors that influenced communities' decisions on whether to accept or refuse to have their households sprayed with IRS included having an understanding of IRS, involvement of community leadership in planning and implementation, level of education, experiences with past IRS campaigns, difficulty in removing heavy and bulky household assets, and preferences for LLINs over IRS (Magaço *et al*., 2019). Other studies also identified various individual and household factors influencing acceptance of IRS, including age, level of education of the head of the household, type of the housing structure, socioeconomic status of the household, knowledge about use of IRS and fear about harmful effects of IRS (Ediau *et al*., 2013; Kyokusingura *et al*, 2011; Munguambe *et al*., 2011; Wandawa, 2011). No study has yet documented Kenyan communities' experiences with the newly introduced organophosphate, pirimiphos-methyl (Actellic 300CS®) as a primary insecticide for IRS.

2.5 Conceptual Framework Diagram of Malaria in Kenya

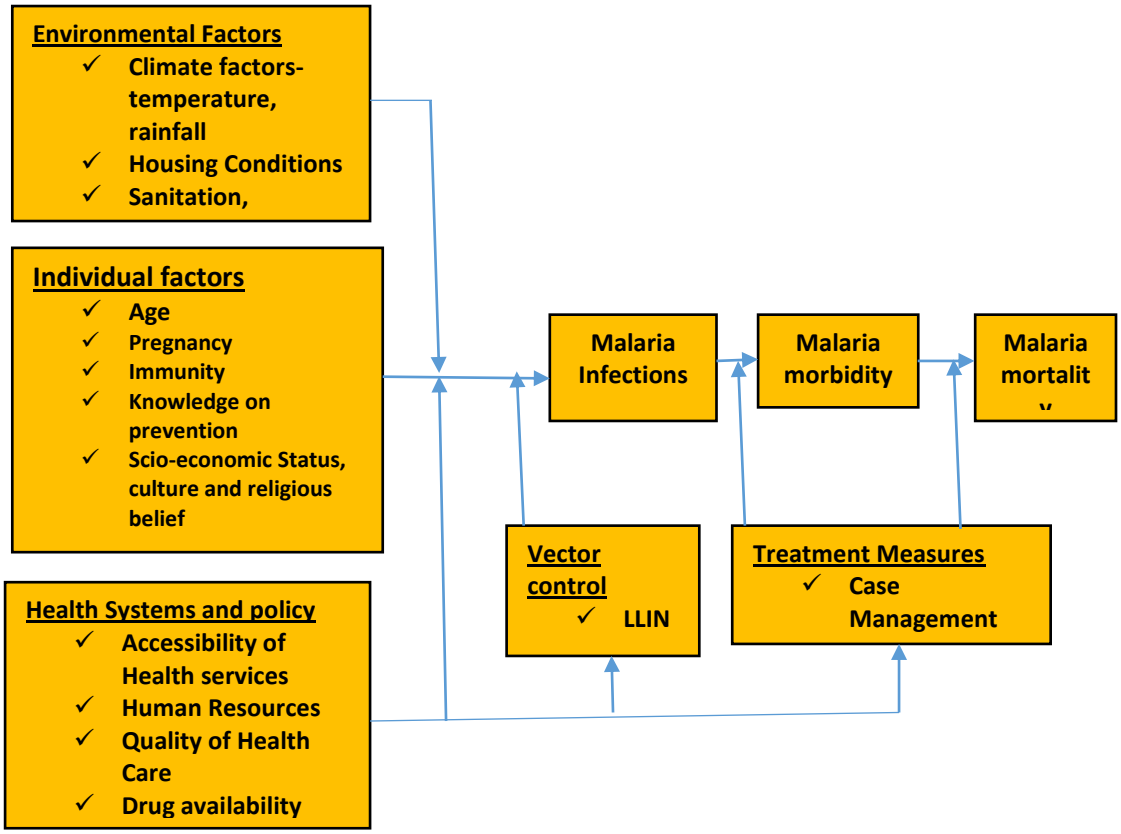

Figure 2.2: Malaria Conceptual Framework

(Adapted from measure evaluation, 2018)

Malaria and its effect on an individual or a community are influenced by various individual, environmental, climatic and health system factors. The climatic factors such as temperature, rainfall and altitude influence malaria transmission through its effect on vector population. Social economic factors are associated with malaria risk, poverty and poor health seeking behavior of patients. Demographic factors age, gender and geographical residence increase susceptibility to malaria infection with pregnant women and children below 5 years of age at most risk especially in the endemic malaria zones of Kenya. Health care system and program factors determine implementation of strategies to reduce malaria burden. The key vector control measures, IRS and LLINs, contribute to malaria burden reduction by preventing transmission of malaria infection to susceptible persons.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Site

The study was conducted in Migori and Homa Bay counties two of the forty-seven counties in Kenya. The two counties border each other and Lake Victoria to the west. Migori borders Tanzania to the south and south west while Homa bay borders Uganda to the west. Migori County is inhabited by a diverse population of communities including Luo, Luhya, Kuria, Abagusii and Somali with the total population of 917,170 according to 2009 National census (KNBS, 2009). Nyatike sub-County one of the 8 sub-counties in Migori County had a population of 144,625 people in 2009 . The major economic activities of the residents in the county include fishing and small-scale agriculture. Migori County is located between latitude 0° 24’ south and 0° 40’ south and longitude 34° east and 34° 50’ east, and lies roughly 1500m above sea level, with annual rainfall of 700-1800 mm. The area has two rainy seasons with long rains being in March to May while short rains coming between September and November. Dry seasons are experienced in the months of December through February, and June to September. Temperatures here range between mean minimum of 24 degrees Celsius and maximum of 31 degrees Celsius. Nyatike sub-County and adjacent areas do experience harsher climatic conditions than the rest of the county (CIDP, 2013b).

Homa bay has a population of 1,038,858 people with Luo and Abasuba community accounting for about 95% of the population(KNBS, 2009). Suba sub-County has a population of 103,054 .Homa Bay County lies between latitude 0°15’ south and 0°52’south, and between longitudes 34° east and 35° east. The county has an inland equatorial climate which is influenced by altitude and proximity to Lake Victoria.

Rainfall pattern in the county is seasonal with 250-1000mm of rainfall usually received during long rains in March to June and 500-700mm received in short rains which usually come in the months of August to November. The annual rainfall ranges between 700mm to 800mm. The mean temperatures range from 17.1 degrees Celsius to 18.6 degrees Celsius(CIDP, 2013a).

Malaria, along with other infectious diseases like respiratory tract infections and diarrheal diseases are the most prevalent diseases in the two counties (CIDP, 2013a, 2013b). Nyatike sub-County in Migori County was selected as one of the study sites since the first round of IRS campaign with organophosphate (Actellic 300CS®) had been conducted in the sub-county in 2017. Suba sub-County in Homa Bay County was selected to provide comparison, since IRS campaign was not conducted in Suba during the first round of IRS in 2017. Both sub-counties had received LLINs through free mass net distribution campaigns and other channels of nets distribution. Both sub-counties are endemic for malaria and have similar weather patterns and environmental settings. These sub-counties are mostly rural and are the settings where IRS campaigns usually target. One major health facility was selected each sub-county i.e. Karungu Sub County Hospital in Nyatike Sub County in Migori County and Suba Sub County Hospital in Suba Sub County in Homa Bay County.

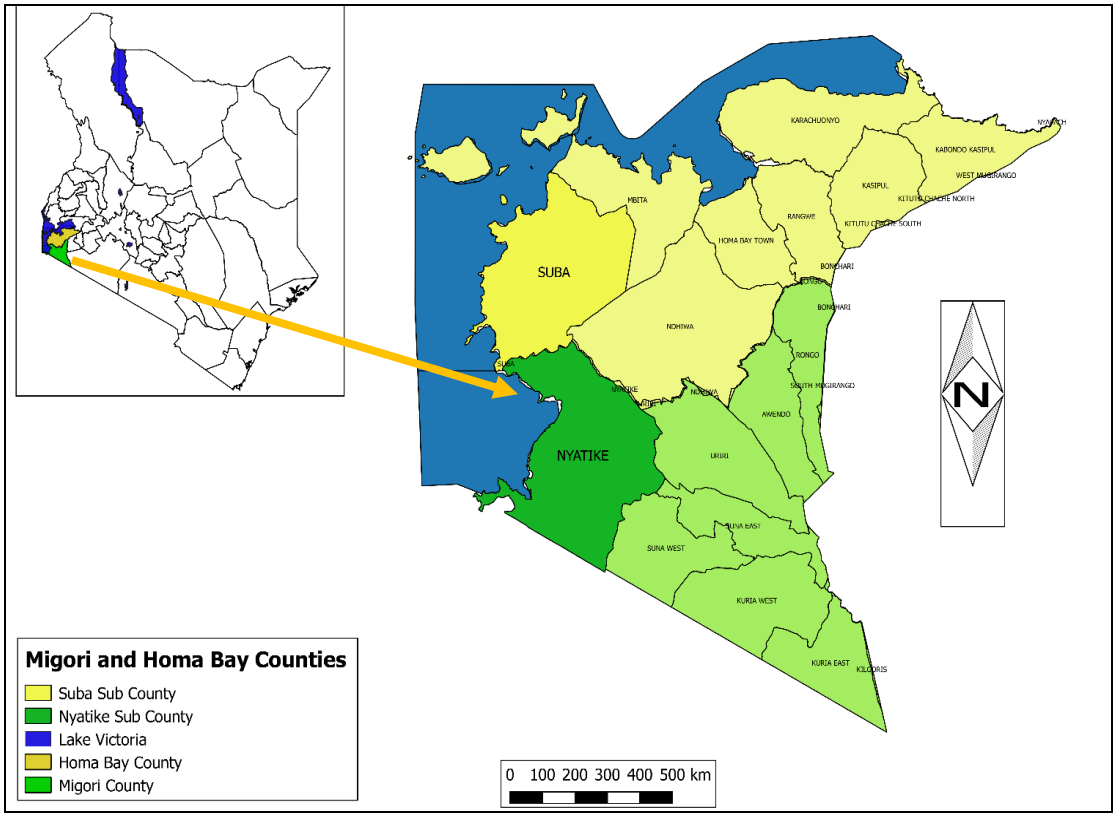

Figure 3.1: A map of Migori and Homa Bay Counties in Western Kenya, 2017

The first round of IRS campaign in 2017 was implemented in Migori County while the second round of IRS in 2018 was done in both Migori and Homa Bay counties. The insecticide used for the two campaign was an organophosphate, pirimiphos-methyl (Actellic 300CS), rather than the pyrethroids used earlier, in response to increasing pyrethroid resistance in western Kenya. The campaign was implemented through the funding of The Presidential Malaria Initiative Africa Indoor Residual Spraying project. The program started with macro-planning activities at the national level followed by micro-planning at the county and sub-county levels. The actual spraying activities started on 13th February2017 and 12th February 2018 for round 1 and round 2 respectively. The first round of IRS was done in Migori County alone while the second round of IRS covered both Migori and Homa Bay counties(PMI, 2017, 2018a).

By the end of the round 1 IRS campaign on 18 March 2017,212,029 structures had been sprayed with spray coverage of 98%, protecting 906,388 people including 16,932 pregnant women and 127,157 <5 children in Migori. In Nyatike sub-County, 47,648 structures were sprayed; attaining a high coverage of 98%, giving protection to 195,696 people. A post-spray data quality audit was done to validate data reported by PMI AIRS project using visits to a sample of 500 households for observation and interviews showed a spray coverage of 83% . At the end of the second round of IRS campaign, some 251,741 (94.7%) structures were sprayed in Homa Bay County and 189,228 (93.3%) structures were sprayed in Migori County (PMI, 2017, 2018a).

3.2 Study Design

The study design was mixed methods with two components. The first one was a quasi-experimental study utilizing retrospective review of records for pre-intervention and post-intervention periods to compare changes in malaria indicators between intervention and comparison areas. The malaria indicators of interest were number of confirmed outpatient malaria cases per 1000 persons per month, proportion of suspected malaria cases in OPD, testing rate and test positivity rate. The intervention was the combination of IRS (the first round) and LLINs which took place in Nyatike sub-County (intervention area) in Migori County in 2017. The comparison area (Suba sub-County) received LLINs alone when the intervention area received IRS (first round) in addition to the LLINs. The pre-intervention period (year 1) was from 1 February 2016 to 31 January 2017, and the post-intervention period (year 2) was from 1 April 2017 to 31 March 2018. Data in the intervention area were collected from Karungu sub-County hospital in Nyatike sub-County and data from the comparison area were collected from Suba sub-County Hospital in Suba sub-County. Data records for months of February and March 2017, during the IRS campaign in Migori County,

were also collected to help complete graphs describing the seasonal trends in malaria. Data from these months showed the expected seasonal increase in malaria in Suba in Homa Bay versus a decline in Nyatike in Migori.

The second component of the study was a facility-based, prospective cross-sectional study to determine malaria test positivity rate (TPR) of febrile patients presenting to the outpatient departments (OPD) of Karungu sub-County Hospital in Nyatike sub-County and Suba sub-County Hospital in Suba sub-County (the same facilities where medical record review was undertaken). In addition, the interviews were conducted to assess awareness and acceptability of these vector control measures among individuals from communities residing within the catchment area for the two health facilities. Semi-structured questionnaires were administered at the OPDs of these selected facilities to collect demographic and household information, use of vector control measures, knowledge and acceptability of these vector control measures among the participants. A facility-based study was chosen over a household cross-sectional survey because of ease of implementation and fewer required logistics. The test positivity rate of patients seen in each health facility was used as a proxy for measuring malaria risk and prevalence in the community as had been done in a past study (Githinji *et al.*, 2016). An earlier study had demonstrated that the TPR from a health facility survey could reliably predict malaria prevalence from a community based survey (Oduro *et al.*, 2011). The cross-sectional study was conducted from 18 May 2018 through 30 June 2018 during the high transmission season for malaria.

3.3 Study Population

In retrospective record review, all the records available between 1st February 2016 and 31st March 2018 were included in the study. The two facilities were chosen for the study after permission from County Health Management Teams had been

received. No individual consents were required from the patients whose records were extracted from their files once permission was obtained since only monthly summaries were collected.

For the prospective study (facility based interview), all the patients > 6 months of age in the outpatient departments who met the national case definition for a suspected malaria (any person with history of fever in the last 48 hours or axillary temperature of ≥ 37.5°C with or without presence of other non-specific symptoms)were eligible for the study (MoH, 2016).

3.3.1 Criteria for selection of health facilities

The two health facilities were selected based on the following factors, namely; 1) Availability of health records over the study period, 2) Availability of malaria diagnostics i.e. microscopy and/or malaria rapid diagnostic tests, 3) Permission from the facility or county management to access the health records and, 4) A sub-county hospital within Nyatike or Suba sub-Counties.

The selected facilities were expected to be comparable by choosing facilities at the same tier/level.

3.3.2 Inclusion Criteria

a) **For the interviews the inclusion criteria were:**
    - Presence of fever for the last 48 hours or temperature of >37.5°c
    - Must be a resident of Nyatike or Suba sub-Counties
    - Must be 6 months and above in age

3.3.3 Exclusion criteria

a) **For interviews the exclusion criteria were**:

- Being on any antimalarial medications or treated for malaria 2 weeks before the visit
- Possess signs or symptoms of a severe malaria and requires hospitalization

3.4 Sample Size Calculation

Sample size required for the prospective study was calculated to determine the number of patients to be interviewed at both health facilities.

The following assumptions were made during sample size calculation

a) The sample size was determined to detect a 15% change in malaria test positivity rate (TPR) of OPD visits between Nyatike and Suba sub-Counties.
b) The average weekly TPR in 2016 in intervention area (Nyatike sub-County) was 59.6% and 56% in comparison area (Suba sub-County) .
c) The power of the study was 80%, level of precision 5% and significance level of 95%

The sample size was determined using the formula by (Demidenko, 2008).

$$n = \frac{2(\bar{p})(1-\bar{p})(Z_{\beta} + Z_{\alpha/2})^2}{(p_1 - p_2)^2}$$

Where Z_{β}=power of 80%; $Z_{\alpha/2}$=Significance level (1.96 for α=0.5), Ṗ=ratio of smaller to larger group; P= (0.596+0.56)/2=0.578; P_1-P_2=15% (0.15)

n = [2*0.578*(1-0.587)*(1.96+0.84) ^2]/0.15^2=170

Based on the formulae shown above and adjusting for 10% non-response rate, the sample size that was adequate to detect 15% difference in TPR between the two study sites was 187 clients at each study site.

Sample sizes: intervention area (Nyatike) =187

Comparison area (Suba) =187

3.5 Sampling Procedure

a) Prospective study

A sample of patients attending the OPD of Karungu and Suba sub-County Hospitals from Monday to Friday between 8.00 am to 5.00 pm was enrolled into the study using a systematic random sampling technique. A review of DHIS2 2016 data to get a daily workload at outpatient departments of both facilities was conducted and an average of 40 patients per day was established. The average daily workload at OPD per day was multiplied by the proposed number of days in the field and divided by the sample size to get the sampling interval, K^{th}, which were 9. The first patient was selected by simple random sampling method using Microsoft Excel generated random numbers. Then every 9^{th} patient who met the case definition of suspected malaria was selected and enrolled until the required number for the day was obtained. Every patient who refused to consent or for a child without a responsible adult to give consent was replaced until the required number was attained. Replacement was done by moving to the next patient. In case patients came in so quickly that while interviewing the n^{th} patient, the $(n^{th} +9)^{th}$ patient came in, the subsequent patient was enrolled and interviewed conducted later while the patient continued receiving the services in the department.

3.6 Data collection and Variables

3.6.1 Retrospective review

Data collection from the health facility registers was done at two selected health facilities; Karungu sub-County Hospital in Nyatike sub-County in Migori County, and

Suba sub-County Hospital in Suba sub-County in Homa Bay County. The retrospective review tallied for each facility the monthly aggregate totals of all variables listed below and broken down into two categories (<5 and >5). Various registers in different departments in the facilities were utilized. Outpatient register (OPD), MOH 405 A and B, provided information on everyone who visited the outpatient department for consultation, their clinical diagnosis, the malaria tests they were requested to do and the antimalarial treatment given. The laboratory registers provided data on all the malaria tests performed in the laboratory and their results during the study period. It was not possible to link OPD entries with laboratory entries. Monthly aggregates from these registers were used to generate malaria indicators that were compared between pre- and post-intervention period and between intervention and comparison areas.

The indicators from pre-intervention period acted as a baseline for the study and established trends of indicators before IRS campaign took place and was compared with the indicators from the post-intervention period.

A standard data collection form was used to collect monthly aggregates of the required variables from the OPD and laboratory registers (categorized into two age groups, <5 years and 5years and older). The following monthly variables were collected.

- Total number of all OPD visits
- Number suspected of malaria (met suspected case definition)
- Number tested through microscopy or RDT
- Number tested positive for malaria through microscopy or RDT

3.6.2 Cross-sectional study

The cross-sectional study was undertaken at outpatient departments of the two selected facilities. Patients seeking care at outpatient departments of the two health facilities, and meeting the case definition of suspected malaria, were recruited into the study after written informed consent were obtained. The consent was obtained from the patients or the parents/guardians or a responsible adult present in case of young children. For children 7-17 years of age, an assent was also obtained from the parent or guardian. Recruitment was done at the general outpatient clinics and the under 5 clinics of the two health facilities. After consent had been obtained, a standard questionnaire was administered to the respondent or the guardian (for children <15 years) by an interviewer.

Community health volunteers (CHVs) who were familiar with the local community of the study were recruited and trained on standard operating procedures (SOPs) to assist in collection of information on use of the nets and spraying of households with insecticide. The CHVs visited the clients at their homes and verified their responses related to the characteristics of their houses, net use and spraying of their houses with IRS. The variables obtained through the interviews were:

- Identifying Information
- Demographic Information
- Clinical manifestations
- RDT results
- Housing structure- Materials used for building-flooring, roofing and the walls
- Malaria control intervention received/used i.e. IRS,LLINs or both
- Information on awareness and acceptability of malaria control measures-IRS and LLINs

3.6.3 Laboratory Sampling and Testing

All the consenting clients were screened for malaria using *Carestart HRP2 P. Falciparum RDT*. Tests were performed by a qualified laboratory technologist. The RDT test was carried out and read according to manufacturer's instructions. The kit was readied by labelling with the patient's unique number/name. The 4th finger on the patient's left hand was cleaned with alcohol swab, allowed to dry and then pricked using a lancet to get a drop of blood. The lancet was discarded immediately. Then a blood sample was collected into the provided pipette by gently squeezing the bulb and then released to draw blood up to the first line of the pipette. The blood sample was transferred to the test by touching the pipette to the sample hole marked "S" on the kit. Two drops of buffer were added into the opening marked "A" and test result read after 20 minutes in a well-lit room. A positive test result had a line in both "C" and "T" while a negative test result had a line in "C" only. An invalid test which was repeated using a new RDT kit had no line in "C" and a line or no line in "T" on the kit. The test results were shared with the clinician for use in patient management or for further testing using a standard microscopy depending on hospitals policy.

3.7 Data Management and Analysis

For the retrospective review, the data was entered into MS Excel for cleaning and consistency check. Data entry and double checking was done by the principal investigator. In accordance with the study SOP, for the months with missing monthly variables imputing was done using the averaging of the values in the preceding month and the month that follows the month with a missing value. Data was then uploaded into STATA (STATA Corp., College Station, TX, USA) for analysis. The following indicators were computed:

- Annual incidence of confirmed malaria cases in the outpatient department per 1000 catchment population. Calculating the rate per 1000 population adjusted the incidence to the catchment population of the health facility and made the data more comparable when facilities had significant difference in catchment population. The catchment population for the facilities was adjusted for population growth by assuming linear growth during the monthly intervals totaling up to an annual population growth of2.5% for the years under study (KNBS, 2009). The catchment population for the facilities was obtained from the respective facilities.
- Proportion of OPD patients with diagnosis of suspected malaria(number of patients suspected of having malaria by clinician/total number of all OPD visits)
- Testing rate (number tested for malaria with microscopy or RDT/total number clinically diagnosed with suspected malaria)
- Test positivity rate (number of slides or RDTs positive for malaria/total number of malaria test done)

Descriptive analysis of the monthly data was done to estimate changes in malaria morbidity using the four indicators i.e. annual incidence of confirmed outpatient malaria cases per 1000 catchment area population, proportion of OPD patients with diagnosis of suspected malaria and test positivity rate. To compare malaria indicators between the pre-intervention period or Year 1 (from February 1, 2016 through January 31, 2017) and the post-intervention period or Year 2 (from April 1, 2017 through March 31, 2018) and between intervention area (Nyatike) and comparison area (Suba), two categorical variables were created: Time period indicating Year 1vsYear 2, and spray status indicating whether catchment area received IRS in

February-March 2017 (IRS round 1) or not. Time period variable was used to estimate the differences in malaria indicators between Year 1 and Year 2 while spray status variable to compare changes in malaria indicators between intervention and comparison areas. The difference-in-differences (DID) approach, frequently used in impact evaluation of interventions in before-after studies(Gertler *et al*., 2016; Wing *et al*, 2018),was used to estimate the difference between Year 1 and Year 2 and between intervention area and comparison areas to determine the net effect of the intervention. Mixed-effect Poisson regression model was used to measure the effect of the intervention on the malaria indicators where the coefficient of interaction term between spray status variable and period of study (Year 1 vs Year 2) represented the net effect of the intervention. The comparison of monthly test positivity rates was done by calculating the relative rate (RR) using Poisson regression model to assess presence of significant differences in temporal trends of the indicators over the period of interest. Month-to-month comparison was done at various intervals after IRS campaign (at 3 months, 8 months and 12 months) to attempt to identify the point at which effect of IRS would begin to decrease. For the Poisson regression model, relative rate (RR) of <1 was considered protective and P-value of <0.05 statistically significant.

For the cross-sectional study, the questionnaires were manually checked for completeness by the principal investigator and double entered into Epi info version 7 (CDC Atlanta, GA, USA) for cleaning and consistency check and analysis. Socio-demographic characteristics of the participants were tabulated. Malaria cases were defined as febrile patients with positive results on RDT testing while malaria negative cases were febrile patients meeting suspected malaria case definition but with a negative RDT result. Test positivity rate (TPR) for the cross-sectional study was

calculated as proportion RDT positive cases. Awareness about LLINs and IRS was determined by asking respondents whether they had ever heard of an IRS or free mass net distribution campaign (a channel of LLIN distribution), their knowledge of the purposes of LLIN distribution campaigns and spraying of houses with IRS, and whether they had registered and collected nets during free mass net distribution campaign, and whether their house had been sprayed during an IRS campaign. The level of acceptability for LLINs was categorized as high or low, and determined by scoring responses to questions on whether or not they would be willing to agree to participate in future free mass net distributions (register and collect LLINs during campaign) or IRS campaigns (allow houses to be accessed and sprayed), and whether they have had any concerns with LLINs and IRS. The responses to questions on attitudes towards participating in free net distribution or IRS campaigns were scored as two if they agreed to participate and a zero if they had not agreed to participate. The responses on concerns with LLINs and IRS were scored as zero for a 'Yes' response and a one for a 'No' response. The scores were added to obtain a total score for each respondent and a median score was calculated for all the respondents. High level of acceptability was defined as a total score above or equal to the median score and low level of acceptability as a score below the median score.

3.8 Ethical Consideration

The study protocol approval was obtained from Moi Teaching and Referral Hospital/Moi University's Institution for Research and Ethics Committee (IREC). The study staff complied with the protocol, good clinical practice guidelines and all other applicable requirements. The permission to access the records was obtained from the County Health Management Teams. The data collected were monthly aggregate summaries lacking patient's names or any other direct identifiers.

For the prospective study, all the clients were required to give an informed written consent. Children 7-17 years of age were asked to give their assent in addition to the consent of their parents/guardians. Consent was also sought from the participants to allow the CHVs to visit the clients' households and verify their responses concerning the housing characteristics and use of vector control measures.

All the filled questionnaires were held in a locked file cabinet with limited access while the laptop with the information was locked down and password protected.

3.9 Risks and Benefits

Risks to the study participants were minimal. Minor pain was expected during blood sampling for malaria testing but this pain was temporary and expected to fade away in a few minutes. The blood collection procedure used was part of standard procedure in patient care. No adverse effects were anticipated from oral interviews or visual verification at the households.

The persons whose records were collected did not have any direct benefits. However, the findings of the study were to be utilized by MOH and malaria program to make decisions concerning malaria vector control strategies. All the participants in interviews benefited from access to accurate and rapid diagnosis of malaria through RDTs.

CHAPTER FOUR

RESULTS

4.1 Retrospective Review

4.1.1 Changes in annual malaria indicators

The total number of OPD visits in the intervention area reduced from 12,460 encounters in year 1 to 6948 OPD encounters during the year 2. Year 1 (pre-intervention) was from 1 February 2016 to 31 January 2017, and year 2 (post-Intervention) was from 1 April 2017 to 31 March 2018. This reduction in overall number of OPD visits was accompanied by a reduction in the proportion of OPD visits due to suspected malaria from 32% in year 1 to 10% in year 2. Testing positivity rate among all ages decreased from 39% in year 1 to 14%in year 2. In comparison area, overall OPD visits reduced from 19,823 in year 1 to 15,160 in year 2, while TPR among all ages reduced from 19% to 16%.

The annual malaria incidences among all ages was 360 per 1000 population in intervention area and 131 per 1000 population in comparison area during year 1. In year 2, the annual malaria incidences in intervention area reduced by 89% to 38 per 1000 population. In the comparison area, malaria incidence fell by 52% to 78 per 1000 population (Table 4.1).

Table 4.1: Changes in annual malaria indicators in intervention and comparison areas before and after introduction of first round of IRS, 2016-2018

		Intervention area		Comparison area	
Characteristics	Age groups	Year 1	Year 2	Year 1	Year 2
Total OPD visits*	All ages	12460	6948	19823	15160
	<5	2741	1848	8621	3502
	≥5	9719	5100	11202	11658
Suspected cases (% OPD visits**)	All ages	3966 (31.8)	746 (10.7)	7284 (36.7)	4780 (31.5)
	<5	1026 (37.4)	184 (10.0)	2607 (30.2)	801 (22.9)
	≥5	2940 (30.3)	562 (11.0)	4677 (41.8)	3979 (34.1)
Tested (% suspected cases)	All ages	9981 (251.7)	3135 (420.2)	15460 (212.2)	7341 (153.6)
(Microscopy/RDT)	<5	4220 (411.3)	1086 (590.2)	5862 (224.9)	2746 (342.8)
	≥5	5761 (196.0)	2049 (364.6)	9598 (205.2)	4595 (115.5)
Tested positive (% tested)	All ages	3847 (38.5)	436 (13.9)	2929 (19.0)	1147 (15.6)
	<5	1144 (27.1)	172 (15.8)	1331 (22.7)	469 (17.1)
	≥5	2703 (46.9)	264 (12.9)	1598 (16.6)	678 (14.8)
Malaria incidences/1000***	All ages	359.8	38.4	130.6	78.2
	<5	551.6	78	359.7	194
	≥5	313.7	28.8	85.3	55.3

**All outpatient visits as recorded in the registers; **Proportion of all outpatient visits contributed by suspected malaria cases; ***Mid-year population estimates for the two facilities was used as denominators*

4.1.2 Changes in mean monthly malaria incidences

In children <5 years old, the mean monthly incidence was 46 per 1000 population in the intervention area in year 1, falling by 88% to 5.4 per 1000 population in year 2. In the comparison area, the mean monthly incidence dropped from 31 per 1000 population in year 1 to 16 per 1000 population in year 2, representing a 49% decrease (Figure 4.1).

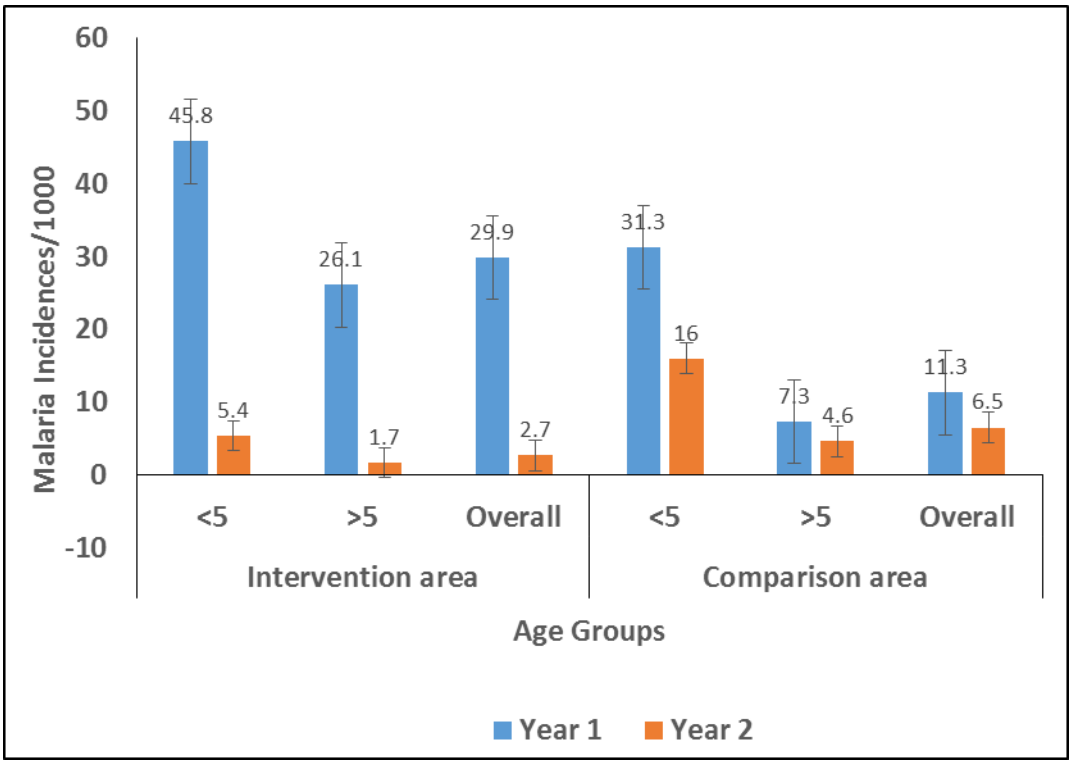

Figure 4.1: Changes in mean monthly malaria incidences in intervention area (Nyatike) and comparison area (Suba), 2016-2018

4.1.3 Net effect of combined use of IRS and LLINS

The net effect of combined use of IRS and LLINs was estimated by the difference in differences observed in intervention areas and the differences observed in comparison area. Among children <5 years of age, the observed difference in annual malaria incidence between year 1 and year 2 was -474 per 1000 population in the intervention area and -166 per 1000 population in the comparison area, leading to a significant difference in differences (DiD) in annual malaria incidence of -308 per 1000 (RR=0.25, 95% CI 0.24-0.29 p<0.001). For children under five years of age, the DiD for the TPR was -5.7% (RR=0.70, 95%CI 0.55-0.91, P=0.006) and for the proportion of OPD visits due to suspected malaria was -20% (RR=0.29, 95%CI 0.24-0.36, p<0.001) (Table4.2).

Table 4.2. Net effect of combined use of IRS and LLINs on malaria indicators compared with use of LLINs alone in intervention area and comparison area, 2016-2018

Malaria indicators	Age group	Intervention Area			Comparison Area			Net effect			
		Year 1[A]	Year 2[B]	Change[C=B-A]	Year 1[D]	Year 2[E]	Change[F=E-D]	DID[G=C-F]	RR*	95%CI	P value
Test positivity rate (%)	<5	27.1	15.8	-11.3	22.7	17.1	-5.6	-5.7	0.70	0.55-0.91	0.006
	>5	46.9	12.9	-34	16.7	14.8	-1.9	-32.1	0.37	0.28-0.48	<0.001
	All ages	38.5	13.9	-24.6	18.9	15.6	-3.3	-21.3	0.47	0.36-0.62	<0.001
Suspected malaria as a % of all OPD visits	<5	37.4	10	-27.4	30.2	22.9	-7.3	-20.1	0.29	0.24-0.36	<0.001
	>5	30.3	11	-19.3	41.8	34.1	-7.7	-11.6	0.59	0.47-0.74	<0.001
	All ages	31.8	45.1	13.3	36.7	31.5	-5.2	18.5	0.45	0.35-0.57	<0.001
Incidences/1000	<5	551.6	78	-473.6	359.7	194	-165.7	-307.9	0.26	0.24-0.29	<0.001
	>5	313.7	28.8	-284.9	85.3	55.3	-30	-254.9	0.14	0.12-0.16	<0.001
	All ages	359.8	38.4	-321.4	130.6	78.2	-52.4	-269	0.19	0.16-0.20	<0.001

*C is change observed in malaria indicators between year 1 and year 2 in intervention area while F is the observed change in the comparison area. G denotes the net effect of the intervention (IRS plus LLINs). *RR (relative risk is) generated using the mixed effect Poisson regression model and RR <1 was considered protective. DID is the net effect of the intervention derived by difference between differences observed in intervention area and differences observed in comparison area.*

4.1.4 Temporal trends in malaria indicators

Generally, the TPR was higher in intervention area than comparison area in 2016, with a marked decrease in intervention area in 2017 but no major change in comparison area. There are a few unexplained spikes noted.

In the intervention area, where IRS was implemented in February and March 2017, the monthly test positivity rate reduced from 46% in February 2016 (start of review period) to 11% in February 2018 (end of review period), representing a 76% absolute decrease in TPR among all ages (RR=0.24, 95% CI 0.12-0.46, P<0.001). In the comparison area, TPR was 16% in both February 2016 and February 2018 (RR=1.0, 95% CI 0.52-2.09, p=0.9). At 3 months (June 2017) after introduction of IRS in intervention area, TPR among all ages reduced by 80%, from 41% in June 2016 to 8.2% in June 2017 (RR=0.20, 95% CI 0.10-0.43, P=<0.001) in the intervention area, and slightly increased from 17% in June 2016 to 19% in June, 2017 in the comparison area (RR=1.1, 95%CI 0.59-2.18, P=0.7). At 8 months (November, 2017) after the first round of IRS campaign, the overall TPR decreased to 10% compared with 23% in same month in the year preceding IRS(RR=0.46, 95%CI 0.22-0.95, p=0.037) in intervention area, and decreased from 30% to 10% (RR=0.30,95%CI 0.14-0.63, p=0.001) in the same time period in comparison area. (Figure4.2).

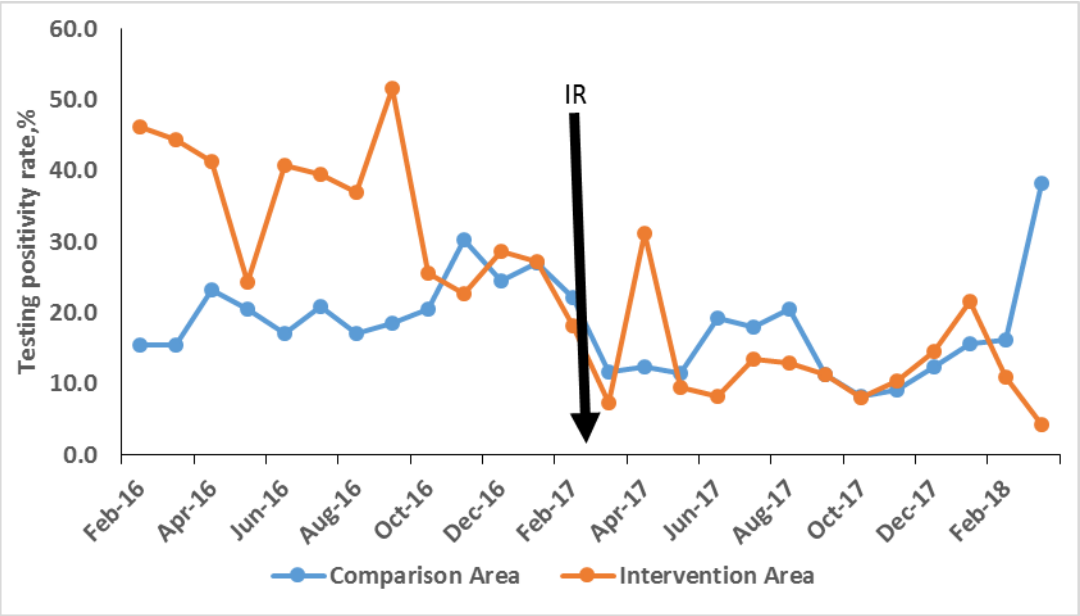

Figure 4.2: Trend of monthly malaria test positivity rates among all ages in intervention area and comparison area, 2016-2018

4.2 Prospective Study

4.2.1 Socio-demographic characteristics of the study participants

Between May 18, 2018 and June 30, 2018, a total of 374 febrile clients were recruited at the OPD of Karungu sub-County Hospital (intervention area) and Suba sub-County Hospital (comparison area).Of all clients recruited, females comprised55% (207) while children <5 years of age accounted for 47% (177). The median age of participants was 5.4 years (interquartile range, IQR 1.8, 23.4 years). About43% (76) of the adult patients had educational level above secondary education. (Table 4.3).

Table 4.3. Socio-demographic characteristics of febrile patients recruited in Nyatike and Suba sub-Counties in Western Kenya from May 18, 2018 to June 30, 2018

Characteristics	Nyatike, n (%)	Suba, n (%)	Total, n (%)
Sex of participants (n=374)			
Male	84 (44.9)	83 (44.3)	167 (44.7)
Female	103 (55.1)	104 (55.6)	207 (55.4)
Age, median age (Interquartile range, IQR) in years	5.4 (1.4, 24.4)	5.0 (2.0,23.0)	5.4 (1.8,23.4)
Age groups (n=374)			
<5	89 (47.6)	88 (47.1)	177 (47.3)
5-14	27 (14.4)	29 (15.5)	56 (15.0)
≥15	71 (38.0)	70 (37.4)	141 (37.7)
Marital status of participants (n=373)			
Child	123 (66.1)	118 (63.4)	242 (64.7)
Single	17 (9.1)	19 (10.2)	36 (9.6)
Married	40 (21.5)	45 (24.2)	85 (22.7)
Widowed	6 (3.2)	4 (2.2)	10 (2.7)
Level of education of participants (n=374)			
Primary education complete	30 (16.0)	22 (11.8)	52 (13.9)
Primary education incomplete	28 (15.0)	22 (11.8)	50 (13.4)
Secondary education complete	15 (8.0)	25 (13.4)	40 (10.7)
Secondary education incomplete	10 (5.4)	5 (2.7)	15 (4.0)
Tertiary education	6 (3.2)	15 (8.0)	21 (5.6)
Child	98 (52.4)	98 (52.4)	196 (52.4)
Main occupation of participant (n=374)			
Fishing	10 (5.4)	12 (6.4)	22 (5.9)
Farming	11 (5.9)	10 (5.4)	21 (5.6)
Unemployed	9 (4.8)	22 (11.8)	31 (8.3)
Salaried worker	3 (1.6)	10 (5.4)	13 (3.5)
Business-trader/boda boda	17 (9.1)	12 (6.4)	29 (7.8)
Casual laborers	12 (6.4)	10 (5.4)	22 (5.9)
Child	121 (64.7)	110 (58.8)	231 (61.8)
Student	4 (2.1)	1 (0.5)	5 (1.3)

4.2.2 Test positivity rate by demographic characteristics

RDT test positivity rate in Nyatike was 8% (15/187) and 12% (22/187) in Suba. Among the school-going children (5-14 years) who presented with recent history of fever, malaria infection was detected in 7% (2/27) of the children in that age group in Nyatike sub-County and 35% (10/29) in Suba sub-County. Test positivity rate among the female clients was 8% in Nyatike and 14% in Suba (Table 4.4).

Table 4.4: RDT positivity rate among febrile outpatient clients in intervention and comparison areas in Western Kenya from May 18, 2018 to June 30, 2018

Variables	Nyatike			Suba		
RDT Results	Positive	Negative	TPR (%)	Positive	Negative	TPR (%)
Overall	15	172	8.0	22	165	11.8
Age Groups						
<5y	3	86	3.4	7	81	8.0
5-14y	2	25	7.4	10	19	34.5
>=15y	10	61	14.1	5	65	7.1
Sex						
Male	7	77	8.3	8	75	9.6
Female	8	95	7.8	14	90	13.5

4.2.3 Awareness and acceptability of LLINs

The areas around both health facilities have benefited from three mass distribution campaigns, with last being done in June 2017. Awareness about mosquito nets and free mass nets distribution campaign, one of the major channels of distribution of ITNs/LLINs, was high among the clients. The majority of febrile patients or care givers of young children, 162/187 (87%) in Nyatike and 180/187 (96%) in Suba, were aware of the free mass net distribution campaign and an equally high proportion of clients or care givers of young children, 124 (83%) in Nyatike and 137 (83%) in Suba, were aware that their households registered for the distribution campaign in 2017. In addition, the majority of the clients or care givers of young children,155/158 (98%) in

Nyatike and 179/180 (99%) in Suba had reported that they would be willing to register and collect mosquito nets in the next rounds of free mass nets distribution campaigns.

Majority, 94% (153/162) in Nyatike and 91% (164/180) in Suba, of the respondents or their care givers had high level of acceptability for LLINs. (Table 4.5)

Table 4.5. Awareness and acceptability of LLINS by participants and caretakers in Nyatike and Suba sub-Counties, Western Kenya from May 18, 2018 to June 30, 2018

Variable	Nyatike, n (%)	Suba, n (%)
Heard of free mass net campaign(n=374)		
Yes	162 (86.6)	180 (96.3)
No	25 (13.4)	7 (3.7)
Registration for free mass net campaign (n=316)		
Yes	124 (82.7)	137 (82.5)
No	26 (17.3)	29 (17.5)
Reasons for registration for free mass net campaign*		
Nets are free	10 (7.4)	5 (3.3)
Protect my family against malaria	125 (92.6)	144 (96.6)
Reasons for not registering for free mass net campaign*		
Absent during household visit	15 (62.5)	18 (72.0)
Not visited by the registration team	9 (37.5)	4 (16.0)
Didn't know about the registration	0 (0.0)	3 (12.0)
Collected nets from distribution posts in 2017 free mass net campaign (n=342)		
Yes	137 (84.6)	143 (79.4)
No	25 (15.4)	37 (20.6)
Reasons for not collecting nets from distribution posts*		
No time	0(0.0)	1 (4.0)
Nets not available when I visited the post	2(13.3)	1 (4.0)
Missed or forgot the dates	8 (53.3)	17 (68.0)
They refused to give us nets	5 (33.3)	6 (24.0)
Agree to register for next campaign (n=338)		
Yes	155 (98.1)	179 (99.4)
No	3 (1.9)	1 (0.6)
Concerns about ITNs/LLINs (n=367)		
Yes	2 (1.1)	9 (5.0)
No	183 (98.9)	173 (95.1)
Level of acceptability of LLINs (n=342)		
Low	9 (5.6)	16 (8.9)
High	153 (94.4)	164 (91.1)

**More than one response was allowed*

4.2.4 Awareness and acceptance of IRS

As the interviews were done in May and June 2018 after the second round of IRS was conducted in Migori and Homa Bay Counties all participants from both Nyatike and Suba sub-Counties were asked about IRS. Majority of the clients, 84% (157/187) in Nyatike and 98% (184/187) in Suba reported having heard about IRS. Among the clients who were aware of IRS, 58% (91/157) in Nyatike and 61% (112/184) in Suba reported having had their households sprayed with IRS during the campaigns.

Over 61% (95/155) of clients in Nyatike and 68% (123/180) in Suba had high level of acceptability for IRS. Among the clients whose households were sprayed with insecticide, 62% (56/91) in Nyatike and 35% (39/112) in Suba reported staining or discoloration of their walls as a concern about IRS (Table 4.6).

Table 4.6. Awareness and acceptability of IRS by participants or their caretakers in Nyatike and Suba sub-Counties from Western Kenya, May 18, 2018 to June 30, 2018

Variable	Nyatike, n (%)	Suba, n (%)
Heard of IRS (n=374)		
Yes	157 (84.0)	184 (98.4)
No	30 (16.0)	3 (1.6)
Household sprayed with IRS (n=341)		
Yes	91 (58.0)	112 (60.9)
No	66 (42.0)	72 (39.1)
All rooms accessed and sprayed with IRS (n=203)		
Yes	70 (76.9)	99 (88.4)
No	21 (23.1)	13 (11.6)
Reasons why agree to IRS*		
To kill mosquitoes	61 (36.3)	3 (2.8)
To kill mosquitoes and other insects	17 (10.1)	57 (53.8)
To kill other household insects	10 (6.0)	0 (0.0)
To protect family from malaria	79 (47.0)	46 (43.4)
Afraid of officials or health workers	1 (0.6)	0 (0.0)
Reasons house not sprayed*		
My house not visited	8 (12.9)	17 (26.6)
Refused to give consent	8 (12.9)	8 (12.5)
House made of iron sheets	4 (6.5)	2 (3.1)
Absent during household visit	42 (67.7)	37 (57.8)
Agree to next IRS campaign (n=335)		
Yes	152 (98.1)	172 (95.6)
No	3 (1.9)	8 (4.4)
No	90 (98.9)	110 (98.2)
Problem with smell (n=203)		
Yes	8 (8.8)	19 (17.0)
No	83 (91.2)	93 (84.0)
Chemical discolors/stains walls (n=203)		
Yes	56 (61.5)	39 (34.8)
No	35 (38.5)	73 (65.2)
Repainted or re-plastered house after IRS (n=203)		
Yes	2 (2.2)	6 (5.4)
No	89 (97.8)	106 (94.6)
Level of acceptability of IRS (n=335)		
Low	60 (38.7)	57 (31.7)
High	95 (61.3)	123 (68.3)

CHAPTER FIVE

DISCUSSION

5.1 Comparison of Malaria Burden between Pre- and Post-Introduction of Non-Pyrethroid IRS

The findings from the retrospective review of records attempting to establish the effect of combined used of non-pyrethroid IRS and LLINs on malaria indicators showed marked reduction in all the malaria all indicators. For the three malaria indicators that were measured i.e. malaria incidence, TPR and proportion of OPD visits due to suspected malaria, the net effect of the combination of non-pyrethroid IRS and LLINs was greater protection against malaria infection than when only LLINs were deployed in the community. The findings suggest that adding IRS with non-pyrethroid insecticide to pyrethroid impregnated LLINs was effective in further reducing malaria burden. The TPR from the prospective study supported the impact of IRS seen in the routine data, with a TPR of 8%-12%. These findings add to growing body of evidence showing additional benefits afforded by combination of non-pyrethroid IRS and LLINs in malaria endemic areas.

The findings were consistent with several observational studies attempting to evaluate effectiveness of IRS when used in combination with LLINs or insecticide treated nets (ITNs). A similar study utilizing enhanced routine surveillance data at an outpatient facility in Uganda demonstrated a dramatic decline in malaria morbidity after initiation of IRS with bendiocarb and resurgence in malaria cases three months after discontinuation of IRS (Raouf *et al*., 2017). In addition, a pre-post comparison study done in Tororo district in Uganda using secondary facility data for period between 2013 to 2015had noted an significant reduction in incidences of malaria among <5 year old children from 130 to 100 cases per in 2014 when LLINs were used alone

and a further significant decline to 45 cases per 1000 in 2015 when IRS was combined with LLINs (Oguttu *et al*., 2017). A non-randomized prospective study comparing impact of combined use of ITNs and IRS against use of ITNs alone also showed a lower incidence of *P. falciparum* (18 per 100 persons-years at risk) among the group with both ITNs and IRS than the group with ITNs only (44 per 100 persons-year at risk) with an adjusted rate ratio of 0.41 (95%

CI 0.31-0.56)(Hamel *et al*., 2011). Another study done in 2008-2009 in Rachuonyo and Nyando former districts in Western Kenya looked at repeat household surveys among randomly selected households which were visited on monthly basis showed a lower malaria prevalence in a district with IRS compared with another district where only ITNs were provided (6.4% vs 16.7%, OR=0.36, 95%CI 0.22-0.59, p>0.001) (Gimnig *et al*., 2016). A review of data from 6 countries in Africa examining the effect of combining IRS and LLINs had found mixed results, with possibly additional benefits from the combination in a setting with low-medium LLIN usage (Lines & Kleinschmidt, 2015). Indoor residual spraying is associated with rapid reduction in vector population and affords protection to in individuals in the community not sleeping under mosquito nets and additional protection to those who sleep under LLINs/ITNs which explains the greater reduction among those in houses covered by IRS who were also using LLINs(West *et al*., 2015).

5.2 Test Positivity Rate (TPR)

The test positivity rate from the cross-sectional study was comparable to findings from the retrospective review of records. The TPR among the febrile clients who were interviewed was lower in Nyatike sub-County than in Suba sub-County and the difference could be programmatically significant. This finding was consistent with findings from the retrospective data, where the TPR was lower in Nyatike sub-County

than in Suba sub-County for most months after the re-introduction of IRS with an organophosphate insecticide.

In Nyatike the highest frequency of malaria infection was found among the children older than 15 years and adults while in Suba school-going children carried the highest burden. Children less than five years of age had the least risk of malaria in Nyatike sub-County. The shift in peak in malaria prevalence from younger to older children and adults has been observed in other studies (Färnert *et al*., 2014; Githinji *et al*., 2016; Oduro *et al*., 2013). The higher prevalence of malaria among the school-going children has been attributed to slower development of immunity because of enhanced malaria prevention efforts, and the focus of malaria control efforts on younger children and their mothers, overlooking the school-going population (Gitonga *et al*., 2012; Nankabirwa *et al*., 2014). As countries continue to scale vector control measures towards achieving malaria burden reduction or malaria elimination, attention needs to be paid to interventions targeting older children and adults as important groups at risk of malaria. The frequency of malaria infection was much higher among females in Suba than in Nyatike suggesting that IRS could be more protective for women, and therefore counterbalancing any gender inequalities in access to the LLINs.

5.3 Awareness and Acceptability of LLINs and IRS

The findings from the prospective component of the study suggests that a majority of the respondents were knowledgeable about ITNs/LLINs and free mass net distribution campaign which is one of the main channels of net distribution in the country. In addition, high level of acceptability for ITNs/LLINs was demonstrated by a majority of the respondents who showed willingness to register and participate in future nets distribution campaigns. This high rate of acceptability among the respondents could

be attributed to the previous successes and experiences with ITNs/LLINs distribution and the health education that had been happening in covered the area. However, the use of LLINs could not be assessed in a manner consistent to other studies as interviews were conducted in a clinic where the patients were presenting for possible malaria disease.

The respondents demonstrated high level of knowledge about the intended purposes of ITNs/LLINs as evidenced by almost all of them having reported that they registered and collected mosquito nets from distribution points to protect their families against malaria. However, in Migori County fewer clients had heard about the free mass net distribution campaigns and more clients reported that their households had not been visited during the registration exercise; while in Homa Bay County fewer people had actually collected their mosquito nets during the distribution campaign with most of them saying that they had forgotten about the announced days for collection of the mosquito nets. These differences may have been related to operational differences in the two counties that could have affected various stages of the distribution campaign. The finding of high level of knowledge on the intended purpose of LLINs was consistent with findings from studies done in Tanzania and Nigeria (Akinleye & Ajayi, 2011; Mazigo *et al*., 2010). Insecticide treated nets and LLINs are among the most recognized measures of malaria prevention and their benefits have been demonstrated by research findings(Bhatt *et al*., 2015). It has been noted that knowledge on intended purposes of ITNs/LLINs to prevent malaria has not been always enough to convince communities to use them regularly (Taremwa *et* al., 2017). However, a re-analysis of 41 DHS and MIS surveys conducted in 2005-2012 in sub-Saharan Africa had indicated that non-use of LLINs by household members was primarily driven by intra-household access to LLINs rather than lack of

behavioral change to consistently use LLINs (Koenker & Kilian, 2014). The few respondents who expressed concerns about ITNs/LLINs had reported side effects associated with nets that included allergies and skin irritations. These side effects usually associated with new mosquito nets are transient and mild. This finding was also found in studies conducted in Kenya and Tanzania where these side effects were reported as among the reasons for ITN non-use(Atieli *et al*., 2011;Taremwa *et al*., 2017).

The current study demonstrated that majority of the respondents were aware about IRS and its intended purposes but much lower level of acceptability was observed amongst respondents from both Nyatike and Suba sub-Counties. While majority of the respondents showed willingness to accept to have their households sprayed in future IRS campaigns, concerns related to smell of and staining of the walls by the insecticides were reported by many respondents. Although the proportion of clients who had reported having received IRS was lower in Migori County compared to Homa Bay County both sites fell below the target of >85% of all sprayable structures set by the Ministry of Health. More clients from Homa Bay reported that their houses had not been visited as one of the reasons for missing IRS. The low IRS coverage in both Nyatike in Migori County, which received IRS twice (2017 and 2018) and Suba in Homa Bay County (IRS in 2018 only) could be associated with low acceptability of IRS or failure of the spray teams to visit all the households during the campaign period. However, majority of the respondents believed IRS was effective in reducing numbers of mosquitoes and other household insects in their households. Some concerns were reported by respondents whose households were sprayed with the insecticide during the campaigns and they included bad smell, discoloration or staining of the walls and interference with families' privacy. Migori County had more

clients with concerns about the smell of the insecticide and staining of their walls. The reasons given by the respondents whose households missed IRS during the recent campaigns are varied and few related to refusals to accept IRS as vector control strategy. Indoor residual spray as a vector control measure is believed to be highly dependent on its acceptance by local communities as an effective measure of malaria prevention (Munga et al., 2017). Acceptance of IRS by the benefitting communities is particularly more critical when more expensive insecticide like organophosphates is used. The finding of the concerns related to smell and discoloration of the walls was consistent with other studies done in Kenya, Tanzania and Benin (Aïkpon *et al*., 2013; Kaufman *et al*., 2012; Mazigo *et al*., 2010; Munga *et al*., 2017).

5.4 Limitations

The current study had some limitations. The retrospective data used in the first component of the study was affected by data quality issues that are usually associated with routine facility data. For instance, testing rate was consistently higher than 100% which was likely occasioned by the fact that it was not possible to track outpatient clients from the OPD to the laboratory using their IP numbers as the laboratory registers did not capture the IP numbers issued at OPD. Therefore the study ended up including clients who came from other parts of the hospital like ANC and inpatient wards when abstracting data from laboratory registers. In addition, some RDT tests done outside the laboratory or by non-laboratory personnel in different parts of the facilities might not have been recorded in the lab registers. Secondly, the respondents in the prospective study and the patients whose records were reviewed were people seeking care at the particular health facilities and might have come from outside the health facilities' catchment area. The results presented therefore could have been influenced by factors related to facility attendance. The results were also subject to

selection bias for testing and the accuracy of laboratory testing. The other limitation for the study was the absence of climatic and environmental factors that could have influenced risks and transmissions of malaria. However, the design of the study which incorporated a comparable control site would assist in controlling for unobserved factors that could have affected our findings. Therefore it's likely that the observed changes in malaria indicators were related to combination of non-pyrethroid IRS with LLINs. The cross-sectional study used TPR using RDT as a proxy for prevalence of malaria in the community and therefore could be affected by false positives due to longer period of persistent histidine-rich protein 2 (HRP2) antigenaemia as had been reported in other studies (Grandesso *et al*., 2016). The cross-sectional study was also limited in that it was restricted to only one time of the year and, therefore, not representative of periods of low transmission.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The conclusions of the study are as follow:

1. The combination of non-pyrethroid IRS with pyrethroid impregnated LLINs provided greater protection against malaria infection than when LLINs are used alone. More marked reduction in the three malaria indicators (annual malaria incidences, TPR and proportion of OPD attendance due to suspected malaria) was observed in the intervention area than in the comparison area indicating additional protection provided by the intervention.
2. Lower TPR among febrile outpatient clients in Nyatike sub-County than in Suba sub-County with the highest risk of infections among the school-going children in Suba and among the ≥ 15 years in Nyatike sub-County.
3. Equally high level of awareness about LLINs and IRS and its intended purposes by the majority of the respondents from both Nyatike and Suba sub-Counties.
    i. High level of acceptability for LLINs as a major malaria vector control intervention in both Nyatike and Suba sub-Counties
    ii. Low level of acceptability of IRS by residents from both sub-counties with slightly higher level of acceptability in Suba sub-County than in Nyatike sub-County
    iii. Important concerns about IRS were raised by the respondents. The concern relating to discoloration of the walls and smell by Actellic 300CSwas the most outstanding and more prevalent in Nyatike sub-County than in Suba sub-County.

6.2 Recommendations

Based on the drawn conclusions, the followings are the recommendations of the study:

Policy Recommendations

1. Adopt and scale up combination of non-pyrethroid IRS and pyrethroid LLINs in malaria endemic areas as a tool of malaria burden reduction. The high level of knowledge and acceptability rate for IRS and ITNs/LLINs among the local communities suggests that the communities are ready for up scaling of these interventions.
2. Formulate targeted malaria prevention interventions for school-going children and those older than 15 years of ages to both reduce the burden of the disease and remove them as a source clinical infection for the other community members

Implementation recommendations

1. Address the concerns related to IRS through proper, well planned and community-driven health education and sensitization exercises before and during the mosquito net and IRS campaigns

Further Research

1. A study on cost-effectiveness of deploying non-pyrethroid IRS in combination with pyrethroid LLINs
2. Randomized control trial to compare effectiveness of non-pyrethroid IRS in combination with LLINs versus when LLINs is alone, and when non-pyrethroid IRS is used alone

3. A qualitative study to assess factors hampering acceptance of IRS among the local communities

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APPENDICES

Appendix I: Informed consent

Study Title: Effectiveness of combined use of indoor residual spraying (IRS) and long lasting insecticidal nets (LLINs) in malaria endemic zone in Western Kenya, 2016 to 2018

Name of Principal Investigator(s): Diba Dulacha

Co Investigators: Not Applicable

Name of Organization: Moi University

Name of Sponsors: Ministry Of Health, Kenya Field Epidemiology and Laboratory Training Program (FELTP)

Informed consent form

Effectiveness of combined use of indoor residual spraying (IRS) and long lasting insecticidal nets (LLINs) in malaria endemic zone in Western Kenya, 2016 to 2018

Informed Consent Form for: Patients above 18 years (=>18 years)

Introduction

Moi University and Ministry of Health (NMCP/FELTP) are doing evaluation of effectiveness of malaria vector control measures in your community. We want to know how effective the combined use of insecticide treated bed nets and spraying of houses with insecticide in prevention and control of malaria, and your experience with these mosquito control measures in your household.

Purpose

The government needs to know this information to determine how best to utilize these mosquito control measures in this region.

Procedures

If you agree to take part in the study, the study staff will ask you about your current illness, ownership and use of nets and spraying of your houses with insecticide. They will also ask you about features of your houses and your experience with use of nets and spraying of your houses by the spraying operators. In addition, a small drop of blood will be obtained from your finger tip through a prick for malaria testing. Also, a community health volunteer who works in your village will visit your house after the interview and have a look at your nets.

Risks and benefits

There will be minor pain expected during blood sampling for malaria testing but this is temporary and expected to fade away in a few minutes. No adverse effects are anticipated from oral interviews or visual verification at the households.

The test results will be used as part of routine patient care. In addition, the findings of the study will be utilized by MOH and malaria program to make decisions concerning mosquito control strategies.

Alternatives

You are free to choose to be part of this study or not to be a part of this study. You have the right to refuse.

Confidentiality

The information collected in this study and the results of the laboratory test will be kept confidential. Your name or any direct identifiers will not be used on any of the reports we generate.

Persons to Contact:

If you have any questions about this study, you can contact Dr. Diba Dulacha at Moi University, School of Public health- FELTP, P.O BOX 4606-30100 ELDORET. Or FELTP P.O BOX 225, KNH Post Office NAIROBI. Or 0721848710 email diba8088@gmail.com. If you have any questions about your rights as a study participant, or if you want to talk about the study with someone who is not part of this research project, please contact The Secretary, or the Chairman of Institutional Review Ethics Committee (IREC) 053 33471 Ext.3008IREC.

Declaration of verbal consent

This form has been read to me/I have read this form. I have had the chance to ask questions. By giving verbal consent, I agree to be part of this study.

Study Participant

Signature _____ Date _____

Study staff consenting participant

Name …… Signature …… Date ……. /……../……

Principal Investigator

Diba Dulacha Signature……. Date……./……./……

Informed Consent Form for: Children <18 years old, care-giver consent

Introduction

Moi University and Ministry of Health (NMCP/FELTP) are doing evaluation of effectiveness of malaria vector control measures in your community. We want to know how effective the combined use of insecticide treated nets and spraying of houses with insecticide in prevention and control of malaria, and your experience with these mosquito control measures in your household.

Purpose

The government needs to know this information to determine how best to utilize these vector control measures in this region.

Procedures

If you agree for your child to take part in the study, the study staff will ask your child or you on his/her behalf about his/her current illness, use of nets and spraying of your houses with insecticide. They will also ask your child or you about features of your houses and your experience with use of nets and spraying of your houses by the spraying operators. In addition, a small drop of blood will be obtained from your child's fingertip through a prick for malaria testing. Also, a community health volunteer who works in your village will visit your house after the interview and have a look at your nets.

Risks and benefits

There will be minor pain expected during blood sampling for malaria testing but this is temporary and expected to fade away in a few minutes. No adverse effects are anticipated from oral interviews or visual verification at the households.

The test results will be used as part of routine patient care for your child. In addition, the findings of the study will be utilized by MOH and malaria program to make decisions concerning mosquito control strategies.

Alternatives

You are free to choose to allow your child to be part of this study or not to be a part of this study. You have the right to refuse.

Confidentiality

The information collected in this study and the results of the laboratory test will be kept confidential. Your child's name or any direct identifiers will not be used on any of the reports we will generate.

Persons to Contact:

If you have any questions about this study, you can contact Dr. Diba Dulacha at Moi University, School of Public health- FELTP, P.O BOX 4606-30100 ELDORET. Or FELTP P.O BOX 225, KNH Post Office NAIROBI. Or 0721848710 email diba8088@gmail.com. If you have any questions about your rights as a study participant, or if you want to talk about the study with someone who is not part of this research project, please contact The Secretary, or the Chairman of Institutional Review Ethics Committee (IREC) 053 33471 Ext.3008IREC.

Declaration of verbal consent

This form has been read to me/I have read this form. I have had the chance to ask questions. By giving verbal consent, I agree to be part of this study.

Responsible Adult (Parent/Guardian)

Signature _____ Date _____

Study staff consenting participant

Name …… Signature …… Date ……. /……../……

Principal Investigator

Diba Dulacha Signature……. Date……./……./…

Appendix Ⅱ: Assent Form for: Participants aged 7-17 years

Purpose

My name is Diba Dulacha from Ministry of health/Moi University. I am doing a study to find out whether combined use of insecticide treated nets and spraying of houses with insecticide is effective in control and prevention of malaria, and your experience with these mosquito control measures in your household. We would like to invite you to take part in our study.

If you agree to take part in the study, the study staff will ask you or your mother/father/guardian about your current illness, ownership and use of nets and spraying of your houses with insecticide. They will also ask you or your mother/father/guardian about features of your houses and your experience with use of nets and spraying of your houses by the spraying operators. In addition, a small drop of blood will be obtained from your fingertip through a prick for malaria testing. We will also visit your house to have a look at your nets.

It may hurt when we prick your finger or some bleeding may occur. The persons doing the collection of blood are very well trained. They will use a safe method for taking blood.

You can choose if you want to be part of our study or not. It is okay if you do not want to join. You can also change your mind at any time of the study.

You can ask your mother or father if you have any questions. You can also ask questions to any of the researchers.

Do you have any questions?

Your mom, dad or guardian said that it is all right to be in the study. Please let me know if you would like to join our study.

Signature of the responsible adult present……Date…….

Study staff consenting participant

Name …… Signature …… Date ……. /……../……

Principal Investigator

Diba Dulacha Signature……. Date……./……./……

Appendix Ⅲ: Questionnaire

Questionnaire number _____

County: _____ Sub-County: _____ Health Facility_____

Date of interview: _____

Section A: Participant Information

1. Sex Female □ Male □
2. Date of Birth (dd/m/y)_____ (If don't know DoB, indicate age in years)
3. Residence (Ward) _____
4. Residence (Village) _____
5. Marital status □ Married □ Single □ Divorced
   □ Widowed □ Child □ Declined to answer
6. Religious affiliations? □ Christian □ Islam □ Traditionalist □ Others_____
7. In case of a child below 15 years, what is the relationship of the respondent with the child?

□ Mother □ Father □ Grandparent □ Sister/brother □ Uncle/auntie □ Others____

Section B: Clinical information

8. What are the signs and symptoms that you are experiencing or brought you to the hospital?

□ Fever □ Headache □ Vomiting □ Loss of appetite

□ Joint pains □ Muscle pains □ General body weakness □ Diarrhea □ Cough

9. Did you travel outside your usual village of residence in the last 2 weeks?

□ Yes □ No

10. If yes, where? _____

11. RDT result? □ Positive □ Negative

12. Have taken any medication before coming to the hospital for this illness?

□ Yes □ No

13. If yes, which medicine?

□ Antibiotic □ Pain killer □ Cough syrup □ others _____

Section C: Household characteristics and socio-demographic information

14. What is the educational level of the participant

□ Primary incomplete □ Primary complete □ Secondary complete

□ Secondary incomplete □ Tertiary □ None □ Child

15. What is the main occupation of the participant?

□ Fishing □ Farming □ Unemployed □ Salaried worker

□ Trader/Boda boda □ Casual laborer □ skilled laborer □ Mining □ Child

16. Is the participant head of the family? □ Yes □ No

If answer is yes, move to 21. Otherwise, continue.

17. Who is the head of the family?

□ Father □ Mother □ Emancipated child □ others _____

18. What is the sex of the head of the family? □ Male □ Female

19. What is the educational level of the head of the family?

□ Primary incomplete □ Primary complete □ Secondary complete

□ Secondary incomplete □ Tertiary □ None

20. What is the main occupation of the head of the family?

□ Fishing □ Farming □ Unemployed □ Salaried worker

□ Trader/Boda boda □ Casual laborer □ skilled laborer □ Mining □ Child

21. Does your household own/have?

□	Agricultural land	Yes/No
□	Electricity	Yes/No
□	Radio	Yes/No
□	TV	Yes/No
□	Mobile phone	Yes/No
□	Refrigerator	Yes/No
□	Table/chair	Yes/No
□	Bed	Yes/No
□	Bicycle	Yes/No
□	Motor cycle	Yes/No
□	Cart	Yes/No
□	Car/truck	Yes/No
□	Boat with motor	Yes/no

22. What is the type of walls of the room where the participant slept the night before the hospital visit or the night before she became unwell?

□ Stone with mud □ Cane/wood/trunks with mud

□ Cane/wood/trunks unplastered □ Concrete/cement/bricks/block

23. What is the type of roof of the room where the patient slept the night before the hospital visit or the night before she became unwell?

□ Corrugated iron □ Grass thatched/makuti/cane □ Polythene

□ Dung/mud/soil □ Tin

24. What is the type of floor of room where the patient slept the night before the hospital visit or the night before she became unwell?

□ Cement □ Earthen/sand □ Earthen covered with gravel

□ Mixture based from mud and animal dung □ Carpet/PVC

25. What is the type of windows of the room where the patient slept the night before the hospital visit or the night before she became unwell?

□ No windows □ Open space, not protected □ Wooden

□ Glass □ Windows with screen/curtains

26. Do the house where the patient slept the night before the hospital visit have a space between the roof and the wall that extends around most part of the house?

□ Yes □ No

27. What time do you usually get home in the evening?

□ Before sunset □ At sunset □ After sunset

□ Variable from day to day □ Not applicable, small child

28. Do you sometimes spend time outdoors for whatever reasons between sunset and going to sleep? □ Yes □ No

29. Do you sometimes sleep outside a house at night for whatever reason?

□ Yes □ No

30. How many nights did you spend outside in the last 3 months? _____

Section D: Malaria Control Practices of the participants

Net use

31. How many people are in your household? ____

32. How many sleeping spaces are present in your house? _____

33. Do you have insecticide treated nets (ITNs) in your house? □ Yes □ No

34. If yes, how many ITNs do you have in your house?

□Total _____

35. How did you get your most recently acquired net?

□Purchased □ Through antenatal and child clinic

□Relatives, friends, neighbors □ Mass net distribution campaign

□Others, specify____ □ don't know

36. When did you purchase or receive your most recently acquired net?

□Less than 1 year ago

□1-3 years ago □>3 years

37. How is your most recently acquired net used?

□ Every night Olyset net □ irregular but more than half of all nights last week

□ Irregular less than half of all nights last week Duranet

□ Don't know □ not used

38. If the net is in use, how is it hanged? Don't ask if net is not used.

□ Hanged permanently □ hanged but taken down every morning

39. Did you sleep under a mosquito net last night?

□ Yes □ No

40. If no, why?

□ It was too hot □ there were no mosquitoes □ my house was sprayed recently

□ Net was being washed □ I did not spend last night in my usual residence

□ I never sleep under a mosquito net □ others _____-

41. Does the nets used by the patient the night before the interview have holes?

□ Yes □ No

42. If yes, how many holes _____

Questions 36-47 to be answered by the head of household/father/mother/guardian/ responsible adult present.

43. Did you hear about free mass net distribution in 2017? □ Yes □ No

44. If yes, where did you get the information on free mass net distribution?

□ Brochures/flyers/posters □ Radio □ TV □ Chief's barazas

□ Home visits by registration team □ Community leaders □ Newspaper

□ Friends/neighbors □ Health care workers

45. Did your household register to collect nets? □ Yes □ No

46. If yes, why did your household agree to be registered for free mass net distribution?

□ Nets are free □ Protect my family from malaria

□ Afraid of the health workers or the village elders

□ I can't buy one myself □ Others_____

47. If no why was your household not registered?

□ Absent □ Refused □ didn't know about the registration

□ Not visited by the registering team

48. Did anyone from your household collect any nets from distribution points during the 2017 free mass net distribution? □ Yes □ No

49. If no, why? □ No time/means □ Waiting time too long □ Not interested

□ Missed or forgot the date □ Not nets available at the time

□ They refused to give us nets

50. Will you agree to register your household and collect nets for your household during next free mass net distribution? □ Yes □ No

51. Do you have any concerns about ITNs? □ Yes □ No

52. If yes, what are your concerns?

□ ITNs causes allergy e.g. itching of skin □ ITNs causes diseases e.g. cancer, asthma

□ ITNs causes infertility □ ITNs makes me hot at night and interferes with my sleep

□ Don't like the shape and color of the nets □ Others_____

53. Have you obtained any nets any time in the last 1 year that you no longer have, for whatever reasons? □ Yes □ No □ Don't know

54. If yes, what happened to the net(s)?

□ Net was stolen □ Net was destroyed accidentally □ Net was sold

□ Net was given away to relative/friends □ Net was thrown away

□ Use by family members elsewhere □ Used for other purposes

□ Don't know

55. If used for other purposes, what was the net used for?

□ Fishing □ Drying fish □ To cover window/door/eave

□ Protecting plants, seedlings □ Patch other nets □ Bedding/padding

□ Around latrine □ Cut up and used for various purposes

□ Don't know □Others_____

IRS use (for participants from Migori County only) to be answered by head of the household/father/mother/guardian/responsible adult accompanying.

56. Have you heard of indoor residual spraying (IRS)? □ Yes □ No

57. Did the spraying operators spray your house during the last IRS exercise in Migori County? □ Yes □ No

58. If answer to 55 is yes, were all the rooms in your house accessed and sprayed?

□ Yes □ No

59. If answer to 55 is yes, why did you agree to have you house sprayed?

□ To kill mosquito □ To kill other household insect

□ To kill both mosquitoes and other household insects □ Forced to accept

□ To protect my family from malaria □ Everyone is doing it

□ Afraid of the government officials or health workers

60. If answer to 55 is no, why did they not spray your house?

□ I was absent during their visit □ They did not come to my home stead

□ They ran out of the spraying chemicals when they reached my house

□ I refused to give consent □ The spray operators were rude so I refused

□ I was not informed about the exercise beforehand so I refused

61. Did the spraying operators spray your immediate neighbor's house? □ Yes □ No

62. Will you agree to have your house sprayed again in the next IRS exercise?

□ Yes □ No

63. Do you have any concerns about IRS program? □ Yes □ No

64. If yes, what are your concerns?

□ Interference with privacy by spray operators

□ Interruption of their normal activities by moving household items

□ Smell of the insecticide □ Staining of the walls

□ Insecticide is not effective against mosquitoes □ Insecticide has side effects

65. Did the spraying operators interfere with your privacy during the exercise?

□ Yes □ No

66. Did you have any problems with the smell of the chemical sprayed on your walls?

□ Yes □ No

67. Did the chemical stain/discolor your walls/ceilings? □ Yes □ No

68. Did your household re-plaster or repaint the walls of its house during the one year after the spraying was done? □ Yes □ No

69. If yes, how many months after the spraying was the re-plastering or repainting done?

□ Less than 3 months □ 3-6 months □ More than 6 months

70. If answer to 64 is yes, was re-plastering or painting done because of the insecticide sprayed on the walls? □ Yes □ No
71. Do you still sleep under a mosquito net even after your house was sprayed during the IRS exercise? □ Yes □ No
72. If no, why?

□ I don't need a mosquito net since my house was sprayed

□ I never sleep under mosquito net □ Others _____

Assessment of implementation of IRS exercise

73. Did you get any information about IRS before the actual spraying exercise?

□ Yes □ No

74. How did you get information about IRS?

□ Through radio □ Through TV □ Through chief barazas

□ Through health care workers □ Through friends and neighbors □ Others____

75. Were you or head of your family informed about effect of the insecticide on humans and domestic animals? □ Yes □ No
76. Were you or head of your family given instructions on when to enter the house after spraying? □ Yes □ No
77. What was the relationship between spray operators and the household members during the exercise? □ Very good □ Good □ Not good
78. Was your community involved preparation and mobilization for the of IRS program?

□ Yes □ No

79. Does the chemical kill all kind of insects including mosquitoes? □ Yes □ No

80. Has the chemical reduced the number of mosquitoes in your household?

□ Yes □ No

Appendix Ⅳ:CHV Checklist

Questionnaire number _____

County: _____ Sub-County: _____ Health Facility_____

Date of interview/visit: _____

Housing Characteristics

1. Type of walls of the room where the participant slept the night before the interview

□ Stone with mud □ Cane/wood/trunks with mud

□ Cane/wood/trunks un-plastered □ Concrete/cement/bricks/block

2. Type of roof of the room where the participant slept the night before the interview

□ Corrugated iron □ Grass thatched/makuti/cane □ Polythene

□ Dung/mud/soil □ Tin

3. Type of windows of the room where the participant slept the night before the interview

□ No windows □ Open space, not protected □ Wooden

□ Glass □ Windows with screen/curtains

4. Type of floor of the room where the participant slept the night before the interview

□ Cement □ Earthen/sand □ Earthen covered with gravel

□ Mixture based from mud and animal dung □ Carpet/PVC

5. The space between the roof and the walls of the sleeping area.

□ Yes □ No

6. Number of sleeping spaces _____

Vector Control Measures

7. Number of nets owned by the household
    i. PermaNet (Supa Net Extra)_____
    ii. Olyset net_____
    iii. Netprotect____
    iv. Duranet
    v. Unbranded____
    vi. Other_____
8. How is the net hanged? (1-hanged permanently, 2-hanged but taken down every morning)
    vii. PermaNet (Supa Net Extra)_____
    viii. Olyset net_____
    ix. Netprotect____
    x. Duranet
    xi. Unbranded____
    xii. Other_____
9. How many holes in the net being used by the participant the night before the interview __

Appendix Ⅴ: Data collection Tool for Retrospective Record Review

Table 7: Data collection tool for retrospective record review

Health facility Name	Year	Month	Age group (<5 or =>5)	Total OPD visits	Total suspected malaria cases	Total tested for malaria	Total positive for malaria

Appendix VI: IREC Approval

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET

Reference: IREC/2017/189
Approval Number: 0002048

15th February, 2018

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
15 FEB 2018
APPROVED
P. O. Box 4606 - 30100 ELDORET

Dr. Diba Dulacha,
Moi University,
School of Public Health,
P.O. Box 4606-30100,
ELDORET-KENYA.

Dear Dr. Diba,

RE: FORMAL APPROVAL

The Institutional Research and Ethics Committee has reviewed your research proposal titled:-

"Effectiveness of Combine Use of Indoor Residual Spraying (IRS) and Long Lasting Insecticidal Nets (LLINs) to Reduce Malaria Burden in Malaria Endemic Zone in Western Kenya, 2016 to 2017".

Your proposal has been granted a Formal Approval Number: ***FAN: IREC 2048*** on 15th February, 2018. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; it will thus expire on 14th February, 2019. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Sincerely,

DR. S. NYABERA
DEPUTY-CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE