COVERAGE AND FACTORS ASSOCIATED WITH THE UTILIZATION OF PYRETHROID-PIPERONYL BUTOXIDE TREATED NETS IN MATAYOS SUB-COUNTY, BUSIA COUNTY, KENYA.

BY

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF MASTER OF SCIENCE IN FIELD EPIDEMIOLOGY OF MOI UNIVERSITY

DECLARATION

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This work is dedicated to my family, parents and to all those who encouraged me to pursue this study to completion.

ABSTRACT

Background: Malaria is among the leading causes of morbidity and mortality in sub-Saharan Africa. Long-Lasting Insecticidal Nets (LLINs) use is key in the fight against malaria. Unfortunately, reports indicate a reduction in efficacy of the conventional LLINs due to insecticidal resistance, hence a recommendation by World Health Organization to deploy LLINs with Piperonyl Butoxide (PBO). Three Lake Endemic counties including Busia with a malaria prevalence of 39% piloted the new type of PBO nets before upscaling to the rest of the country. With limited resources and insufficient information on PBO nets, coverage and utilization may not be guaranteed.

Objectives: This study sought to establish the socio-demographic factors, coverage, and factors associated with underutilization of PBO bed nets in Matayos sub-County, Busia County.

Methods: A cross-sectional study was conducted from June through July 2022 in Matayos sub-County, Busia County. Multi-stage sampling was used to identify households and study participants. Data on the participants' socio-demographics, PBO bed net coverage, and factors associated with underutilization were collected using a structured questionnaire. Universal coverage was defined as possessing one LLIN (PBO) net for every two household members. Proper utilization of a bed net was defined as sleeping under a mosquito net the previous night, using the net on all seven days of the week, tucking and hanging the net adequately. Continuous variables were summarized using mean and standard deviations, while categorical variables were presented using frequencies and proportions. Associations were assessed using odds ratios and 95% confidence intervals, factors with $p<0.05$ were considered statistically significant.

Results: A total of 402 people took part in the study, with an average age of 41.2 years. Most of them, about 66.7% (268), lived in rural areas. The majority, 77.9% (313), were women, and 71.4% (287) were married. Almost half of them, 45% (181), had at least 8 years of schooling, and most, 86.6% (347), had jobs that weren't formal. When it comes to bed nets, 86.3% (347) of the people said they had them. Out of those, nearly all, 92.8% (322/347), were the special kind called PBO nets. About 64.9% (261) of households had enough bed nets for everyone, but that was below the target of 80%.The study found that households where the person in charge had informal jobs were less likely to use the PBO nets compared to those with formal jobs (adjusted odds ratio [aOR] = 0.29, 95% confidence interval [CI] = 0.11-0.78). Also, households that didn't have enough nets for everyone were much less likely to use the PBO-treated ones compared to those that did (aOR = 0.01, 95% CI = 0.01-0.03).

Conclusion: Low education, single parenting, religion and house hold size socio-demographic factors were not associated with utilization of PBO bed nets. Universal coverage of PBO bed nets was below the national target of 80%, less than what the country aimed for. Respondents with informal occupations and households that had not attained universal coverage were less likely to properly utilize the PBO bed nets in Matayos sub-County, Busia County.

Recommendation: Address barriers that influence utilization of PBO bed nets through alternative channels such as community engagement and targeted awareness campaigns, particularly among individuals in informal occupations. There is need for continuous PBO nets distribution through innovative channels like schools and upscale routine net distribution beyond targeted population (child and pregnant women) to supplement mass net distribution to improve universal coverage.

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OPERATIONAL DEFINITION OF TERMS

Malaria is a disease caused by a parasite. The parasite is spread to humans through bites of infected Anopheles species of mosquitoes.

Vector is an organism, typically a biting insect that transmits a disease or parasite from one animal to another.

Net is any bed net, whether treated or untreated

LLIN is a net that has a long-lasting insecticide treatment that is effective for up to 20 washes

Piperonyl butoxide is a man-made pesticide ingredient called a synergist. By itself, PBO does not harm insects. Instead, it works with insect killers to increase their effectiveness. PBO is low in toxicity to humans but is often combined with other pesticides like pyrethrins or Pyrethroids.

Universal Coverage is the proportion of a population who use an LLIN based on the assumption of one net per two people in a household.

Coverage is the proportion of LLINs to the number of households in the study population.

Utilization refers to proper utilization of LLINs where proper utilization implies proper installation of the nets, sleeping under a treated mosquito net daily, and tucking in the nets while poor utilization implies lack of either of the criteria for proper utilization.

Caseloads are the number of cases with which epidemiologists are concerned with at one time.

Resistance is the capacity of pathogens to withstand the effects of a harmful chemical agent.

ACRONYMS AND ABBREVIATIONS

ALMA	African Leaders Malaria Alliance
AOR	Adjusted Odds Ratio
CDC	Center for Disease Control
CI	Confidence Intervals
DNMP	Division of National Malaria Program
IPTp-SP	Intermittent preventive treatment with Sulfadoxine–pyrimethamine
IRS	Indoor Residual Spraying
IRR	Incidence Rate Ratio
IREC	Institutional Research and Ethics
KHIS	Kenya Health Information System
LLINs	Long-Lasting insecticide Nets
LSM	Larval Source Management
MCH	Mother Child and Clinic
MiP	Malaria in Pregnancy
NACOSTI	National Commission for Science, Technology and Innovation
NIAID	National Institute of Allergy and Infectious Diseases
ODK	Open Data kit
OR	Odds Ratio
PBO	Pyrethroid -piperonyl butoxide
SSA	Sub-Saharan Africa
WHO	World Health Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Malaria continues to be a major global health issue and is a cause of concern for numerous nations, including Kenya (Nyarko & Cobblah, 2014; Sultana *et al*., 2017). The disease is found in more than 100 countries, putting nearly about half of the world's population in danger of getting malaria, and roughly one million people die from it each year (G. S. WHO, 2014). Temperature significantly impacts the spread of malaria, alongside humidity and rainfall patterns. The highest transmission rates typically occur during the summer season with high temperatures and heavy rainfall, particularly in Africa (Chitunhu & Musenge, 2015; Patz & Olson, 2006; Sultana *et al*., 2017). Worldwide, there were approximately 249 million instances of malaria across 85 countries where the disease is prevalent. This marks an increase from 247 million cases reported in 2022, with most countries coming from Sub-Saharan Africa (WHO, 2023). The occurrence of malaria infections (measured as cases per 1000 population at risk) declined from 81 in 2000 to 59 in 2015 and further to 56 in 2019. However, it then rose to 59 in 2020, which was attributed to disruption of preventive services during the COVID-19 pandemic (WHO, 2020b, 2021). In 2020, the WHO African region reported approximately 228 million malaria cases, representing around 95% of the total global cases (WHO, 2021). Malaria kills a round 619,000 people every year, with most cases (96%) happening in Sub-Saharan Africa and having a disproportionately negative impact on children under the age of five (WHO, 2021). The giving out of bed nets, spraying homes to kill mosquitoes, and quickly diagnosing and treating malaria appeared to be making little progress in reducing caseloads in Sub-Saharan Africa in 2017 and 2018. As a result, the goals to reduce and get rid of malaria were not achieved, and there were about 219 million cases in 2018. In ten high-burden African countries, In 2020, the number of cases went up by 3 million compared to the year before (WHO, 2020b).

Malaria poses a major public health hazard and is the leading cause of sickness and mortality in Kenya. (Nairobi & Rockville, 2015). Kenya had 4.2 million malaria cases and around 10,700 deaths on average in 2021 (DHIS, 2021). According to KMIS reports, malaria prevalence rate decreased from 11% in 2010 to 8% in 2015 and 6% in 2020 nationally, with a reduction from 27% in 2015 to 19% in 2020 in the Lake endemic (DHS, 2020).

Malaria is recognized as a public concern, contributing to 438,000 deaths in 2015 (D. Roberts & G. Matthews, 2016). Malaria in pregnancy poses a significant risk to both the mother and the unborn baby. Worldwide, more than 125 million pregnant women are at risk of contracting malaria annually, resulting in approximately 200,000 infant deaths and 10,000 maternal deaths. (Lufele *et al*., 2017). Although the World Health Organization (WHO) has reported that malaria has not been the leading cause of death in children under 5 years old since 2000, it remains a significant source of illness in children in sub-Saharan Africa, contributing to 10% of all deaths in this age group. This means one kid in sub-Saharan Africa dies from malaria in every 2 minutes (D. Roberts & G. Matthews, 2016). Usually, pregnant women are more likely to get malaria compared to non-pregnant women. Particularly, young, first-time pregnant women are at the highest susceptibility, with a two to seven times greater chance of having babies with low birth weight, weighing less than 2500 grams, compared to women who have been pregnant multiple times. Additionally, associated adverse outcomes include maternal anemia and having a baby too early, before 37 weeks of pregnancy. In other parts of Africa, there has been a resurgence of malaria infections, leading to a greater burden among older children and adults. This resurgence is attributed to a prolonged period of infections (Anthony Kapesa *et al*., 2018; Trape *et al*., 2011). In Kenya, surveys have been conducted to assess malaria prevalence. These surveys revealed that adults develop a certain level of immunity to malaria over time, however, minors and expectant mothers remain at a higher chance of death from the disease. Usually, the surveys in Kenya look mainly at children (Jenkins *et al*., 2015), and 75% of the population is susceptible to malaria infection. (Homan *et al*., 2016). Currently, specific regions in western region of Kenya are going shifts in disease spread directions, however rise in using treated nets and other preventive measures. These changes are attributed to warmer temperatures, alterations in mosquito species, and the development of resistance among mosquito vectors to the chemicals used to eradicate them. (Anthony Kapesa *et al*, 2018; A. Kapesa *et al*., 2017). *Plasmodium falciparum* malaria is linked to these factors that lead to babies being born smaller, kids not getting enough food, and having ongoing swelling in the body, all of which are linked to high blood pressure. Additionally, children whose moms had malaria while pregnant often have higher blood pressure when they're 1 year old compared to kids whose moms didn't have malaria during pregnancy (Etyang *et al.*, 2016). Prior studies conducted have shown that things like how old the child is, how much money the family has, how educated the person in charge of the household is, what kind of house they live in, how the land is used, whether they live in the city or countryside, and where they get water from for everyday use are all linked to an increased risk of malaria parasitemia (Bannister-Tyrrell *et al*., 2017; Danielle Roberts & Glenda Matthews, 2016).

Insecticide-treated bed nets is being used in curbing malaria incidence. They are credited with contributing to approximately 80% of the decline in malaria cases in endemic countries between 2000 and 2015. However, recent efforts to combat malaria have faced challenges, including a slowdown in progress (Monroe *et al*., 2022). One contributing factor is the increasing resilience of mosquitoes to pyrethroids, the primary insect-killing chemical used on these nets (Richardson Choi, & Ranson, 2018). In Sub-Saharan Africa, the use of long-lasting insecticidal nets (LLINs) is critical in the battle against malaria. In 2020, of the 31 countries that had planned campaigns to distribute insecticide-treated mosquito nets, 18 (58%) successfully completed their campaigns by the year's end. By the end of 2020, 72% (which is equal to 159 million) of the planned bed nets had been given out, with over 63 million nets remaining for distribution in 2021 (CDC, 2020). These actions helped greatly reduce malaria morbidity and death, showing that the fight against malaria is working globally. However, progress slowed down between 2014 and 2018 (WHO, 2020a). Indoor residual spraying, employing pyrethroids, was initially implemented in Kenya between 2008 and 2012. However, due to widespread resistance to pesticides, this method was stopped from 2013 to 2016. To achieve universal coverage, the National Malaria Program in Kenya carries out mass net distribution campaigns every three years in places where malaria is endemic or outbreak prone (DNMP, 2020). To effectively control malaria in Kenya, it is crucial to assess malaria risks at the local level. This allows for the identification of vulnerable populations and the implementation of customized prevention methods that match the situation and target. Knowing what needs to be changed to lower the risk of malaria in this area is really important. It helps put actions in place to lessen these risks (Bashir *et al.,* 2019). Some ways to reach pregnant women and young children through bed nets through ANC/MCH clinics. Also, advertising at certain places and selling at regular stores (DNMP, 2020). Even though these modes of distribution have increased the LLIN coverage, reaching and maintaining universal coverage is still difficult since the nets are expensive, not available to the entire risk population, and gradually lose their physical integrity.

The goal of Kenya Malaria Strategy (KMS) 2019 - 2023 aims to decrease malaria cases and deaths by 75% of the 2016 levels as of the end of 2023. Achieving this ambitious goal requires implementing the six strategic objectives. These include preventing malaria in all individuals at risk, ensuring prompt diagnosis and effective treatment, promoting social behavior change and communication, strengthening performance monitoring, managing programs effectively, and establishing systems for malaria elimination in selected counties (DNMP, 2020; Ministry of Health, 2020). To attain this, WHO recommended interventions such as giving out LLINs that last for a long time and have insect-killing chemicals on them, spraying inside homes (indoor residual spraying) to kill mosquitoes, and larval source management (LSM) using a chemical called pyrethroid (WHO, 2019). However, a significant global challenge to their continued use in the battle against malaria has emerged with the recent emergence of malaria vector resistance to the pyrethroid pesticide class in use (Coelho *et al*., 2017). To avert the consequences caused by this resistance, the World Health Organization recommends adding a chemical synergist called Piperonyl butoxide (PBO) to the pyrethroid based bed nets. (WHO, 2019).

The WHO recommends that bed nets treated with insecticides are available in two varieties: long-lasting ones effective for up to three years and standard ones that require annual re-treatment. These nets are primarily distributed to high-risk groups, such as young children and pregnant women. However, many national malaria programs now provide nets to all individuals at risk. This widespread distribution and usage have contributed to averting 67% to 73% of the 663 million malaria cases in sub-Saharan Africa over the past 15 years (WHO, 2022). When the Vector Control Technical Expert Group (VC TEG) had its second meeting in 2014, they presented three main ideas to the Malaria Policy Advisory Committee (MPAC). One of these ideas was distribution of enough long-lasting insecticidal nets (G. S. WHO, 2014) and spraying inside houses with insecticide (IRS) (Taffese et al., 2018). One of the recommended interventions by the National Malaria Control Program (NCMP) for fighting malaria in Busia is the use LLINs (Kenya Ministry of Health, 2020). However, with mosquitoes developing resistance to the standard nets, PBO-treated nets were introduced in 2021 to curb the spread of malaria. (Hancock *et al.*, 2018). Before distributing the new PBO nets across Kenya, they were piloted in three Lake Endemic Counties: Busia, Bungoma, and Kakamega. Despite this initial trial, Busia, particularly Matayos sub-County, still reports a high number of malaria cases, according to the surveillance bulletin (DHS, 2020).

1.2 Problem statement

Preventing malaria is a top priority of Kenya's health plan. Malaria is one of the leading causes of incidence and mortality in under five years' old, where nearly 95% of the total population being vulnerable (Ministry of Health, 2020). A major challenge in controlling malaria disease in Africa is the rapid and widespread of mosquito withstanding to Pyrethroid -pesticides (WHO, 2020a). Resistance has been reported more frequently in Eastern African nations like Ethiopia, Tanzania, Sudan, Uganda, and Kenya, raising concerns that it could disrupt control initiatives and prevent them from accomplishing their intended objectives (WHO, 2020a). In western Kenya for example, about 80% of the resistance genotypes of mosquitoes reported, are Vgsc-1014S kdr mutation and Vgsc-1014F mutations. These mutations happen in the main mosquitoes that spread malaria, like Anopheles *gambiae s.s* and Anopheles *arabiensis*. (Kinya *et al*., 2022; Zhu *et al*., 2014). These genes discovered to be linked to Pyrethroid resistance and were as high as 13% and 39% at certain localities in Kenya in 2013 (Kinya *et al*., 2022; Zhu *et al.*, 2014). In malaria endemic areas, mosquito resistance to the pyrethroid insecticide may limit the progress so far gained in malaria prevention, management, and eradication (Oria *et al*., 2021). In the most recent mass net distribution, 1,160,792 persons in the entire Busia County were issued with LLINs, with 211,247 of those coming from Matayos sub-County. About 53,895 of the homes from Matayos, the area with the most residents, were served during distribution period (Ministry of Health, 2020). However, from previous studies, it was noted that availability of LLINs does not always correlate with the use of these nets (Tassew *et al.*, 2017). In addition, given the limited resources, the coverage might not be adequate. Consequently, there limited information on proper utilization of PBO nets among those who received them at the household level. It has also been reported that in some households, nets are reserved for guests, resold, given to family members, or used as garden fences (Ng'ang'a *et al.*, 2021). The practice was reported to likely reduce the maximum benefits that would be drawn from the very expensive LLINs, which could lead to increased malaria infections in the population resulting from failed intervention measures. The current study aimed to determine PBO net coverage and factors associated with their underutilization.

1.3 Justification of the study

Inaccessible rural communities do carry the biggest burden of malaria and have the greatest need for prevention and treatment measures. Even though the Kenyan government has devoted a lot of time and money to fighting malaria, complications associated to the disease still claim a lot of lives in the endemic rural areas. According to malaria surveillance data, Busia County has the second-highest national malaria incidence in the County (DHS, 2020). According to data reports there were about 401.4 confirmed cases of malaria for every 1,000 people, mostly from Matayos sub-County (DHS, 2020). For the implementing program and other stakeholders, a vector control intervention must be efficient and effective. However, data for decision making on this intervention is lacking and therefore there was need to investigate and document it. The coverage and possible contributing factors to LLIN improper utilization are discussed in this study. This has the effect of educating the community on malaria prevention and control, counseling people on how to properly use LLINs to protect everyone at risk, and saving resources used for the treatment of new cases in terms of drugs and costs associated with prolonged hospitalization. The Ministry of Health Management at the County and National Governments as well as other stakeholders would be informed by the findings of the intervention's strengths, flaws, and areas that require development.

It is anticipated that intervention measures undertaken to reduce malaria burden would contribute to achieving Sustainable Development Goals (SDGs) 3, which aim to make sure everyone is healthy and promote well-being for all at all ages (UNDP, 2022). The study's results will aid in promoting widespread LLINs use in Kenyan households to reduce malaria sickness and death. Additionally, the study findings would be helpful in making decisions on the design of interventions that involve community participation and educational initiatives. This is important because researching social behaviors is increasingly vital for designing and improving malaria control strategies, establishing baselines for understanding diseases and behaviors, and identifying ways to monitor and evaluate programs. This study focused on improving PBO nets distribution programs and developing effective communication strategies for using nets properly and for public health benefits.

1.4 Research Questions

1. What are the socio-demographic factors associated with the utilization of PBO nets in Matayos sub-County, Busia County?
2. What is the distribution coverage of PBO nets in Matayos sub-County, Busia County?
3. How is underutilization of PBO nets in preventing malaria infections in Matayos Sub-County, Busia County?

1.4.1 Broad objective

To determine the coverage and factors associated with the underutilization of PBO nets in the control of malaria cases in Matayos sub-County, Busia County, Kenya.

1.4.2 Specific objective

1. To establish the socio-demographic factors associated with the utilization on PBO nets in Matayos sub-County, Busia County.
2. To assess the coverage of PBO nets distribution in Matayos sub-County, Busia County.
3. To evaluate the factors associated with the underutilization of PBO nets in Matayos sub County, Busia County.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Numerous interventions have been put to combat malaria incidence in Kenya at the households' level including use of LLINs, however, malaria infection has remained endemic in the country particularly in the Lake Region and is seen as a significant barrier to the country's socioeconomic progress. (DHS, 2020). To tackle malaria in Kenya, the National Malaria Control Program was created in 2010 and tasked to distribute LLINs to households after every three years. Despite the achievement with LLINs distribution, malaria remains a significant public health issue and a disease endemic to the Lake Region of Kenya. Malaria accounts for 48% of outpatient cases in children under five, 40% of hospital admissions, and 18% of people who get it die (DHS, 2020). Some studies have reported that even though LLINs are available, not many people use them (Konlan *et al.*, 2017). According to the Kenya Malaria Strategy 2019-2023 report, the percentage of households using LLINs in Kenya has remained low, standing at just 45% nationwide.

2.2 Theoretical framework regarding human beliefs model of infections

The theoretical structure utilized in this study is the Human Belief Model (HBM), which was formulated in the 1950s by social psychologists Hochbaum, Rosenstock, and Kegels. This model was used to direct the research, indicating that people might not participate in disease prevention and detection efforts because of their beliefs (Siddiqui *et al.*, 2016). The HBM is a theoretical framework that can offer direction for programs aimed at promoting health and preventing diseases. (LaMorte, 2019; Siddiqui *et al.*, 2016). The Human Belief Model (HBM) is commonly used in studying health behaviors because it can predict and explain why people act the way they do (LaMorte, 2019; Siddiqui *et al*., 2016). The model describes the important things that affect how people behave when it comes to their health. This includes what someone thinks about their chances of getting sick (perceived susceptibility), how serious the consequences will be (perceived severity), the good things that will happen if they take action (perceived benefits), the things that might stop them from taking action (perceived barriers), things that remind them to take action (cues to action), and how confident they feel about doing what they need to (self-efficacy). In a study about communication research, Bancroft *et al.* (2022) the PI used the HBM as a guide to study parallel, serial, and moderated mediation. They suggested that messages could effectively change behavior if they targeted perceived barriers, benefits, self-efficacy, and threats. Despite being a useful framework for communication research, the HBM has some limitations in theory. One significant limitation is that it doesn't clearly explain the order of variables, making it unclear if constructs affect relationships at the same time, one after the other, or together with a moderator.

Using the HBM as the basis of this study would help me understand how people's health behaviors affect their use of PBO-treated LLINs for preventing malaria, and further to identify factors that might affect their use in households in Matayos sub-County. The HBM provides a structured framework for comprehending why individuals make decisions about their personal health. Behavior beliefs and social change backgrounds are shaped by elements such as cultural customs, traditions, societal dynamics, religious practices, gender expectations, institutional influences, and environmental aspects (Ruyange *et al*., 2016).

2.3 Epidemiology of malaria infections

The evaluation of malaria prevalence began with a survey in India in 1848, where they measured the proportion of people with enlarged spleens in certain age groups. This approach focused on looking at the symptoms of malaria. By looking at how many children aged 2 to 9 had enlarged spleens, they divided areas into four different levels of malaria prevalence: holo-endemic areas, where more than 75% of people had enlarged spleens; hyper-endemic areas, where 51 to 75% had enlarged spleens; meso-endemic areas, where 11 to 50% had enlarged spleens; and hypo-endemic areas, where less than 11% had enlarged spleens (Hay *et al.*, 2008). Malaria is triggered by a parasite called *Plasmodium*. Studies found that around 2.37 billion people worldwide could be at risk of getting *P. falciparum* infections, with 26% in Africa and 62% in the South East Asian and Western Pacific regions (Guerra *et al.*, 2008). Several studies in Africa show that *P. falciparum* is the most common species causing malaria. Blood samples were collected from nine different African countries from 1998 to 2006 and analyzed using PCR to identify each of the four malaria parasites found in humans (R. L. Culleton *et al*., 2008). In a study analyzing 2,588 samples, 1,737 exhibited indications of *Plasmodium* infection. Among these, 1,711 (98.5%) were confirmed to be positive for *P. falciparum*, comprising both single and mixed infections. In a separate investigation spanning four villages in Mulanda sub-County, located in eastern Uganda, the occurrence of *P. falciparum* infection was recorded at 94% during the rainy season spanning from July to December employing diagnostic methods based on thin film technology (Pullan *et al*., 2010). Consequently, some studies are reporting *P. vivax* malaria spread in West and Central Africa. In Congo, a study looked at 409 samples from patients at a health center on the western coast, where most people are expected to have the Duffy antigen. Out of these samples, 55 (13%) showed positive results for particular antibodies against P. *vivax* (R. Culleton *et al*., 2009).

An infectious form of the parasite is injected through the bite of a female Anopheles mosquito sporozoites into the bloodstream of a human host causing transmission of malaria infection. Malaria spreads more easily in areas where mosquitoes live longer, giving the parasite enough time to develop inside the mosquito, and where mosquitoes prefer to feed on humans are common. Out of the 512 Anopheles species, experts classify forty-one as "Dominant Vector Species" (DVS). These DVS are known as the main carriers of malaria worldwide, causing most cases of the disease in humans. Important traits of these dominant vector species include their preference for human blood, longer lifespans, high numbers, and increased ability to transmit the malaria parasite (Takken & Scott, 2003). When a female Anopheles mosquito bites, it injects sporozoites into the host. A person's bloodstream, it spreads malaria, symptoms experienced by the patient include nausea, vomiting, mild diarrhea, joint pain, chills, and fever. Effective treatment regimen involves prompt administration of a potent antimalarial medication therapy to relieve the acute symptoms and prevent the parasite from recurring (Ministry of Health & program, 1994).

Malaria can manifest with a mild or severe clinical course. Fever in the presence of peripheral parasitaemia is the primary symptom of uncomplicated malaria, although other symptoms including chills, excessive sweating, discomfort in the muscles, joints, or abdomen, nausea, vomiting, irritability, and anorexia nervosa may also be present alone or in combination (Ministry of Health & program, 1994). Severe malaria is extremely dangerous and is typically identified by the presence of *P. falciparum* in the blood along with any of the following clinical or laboratory signs (either alone or combined):

experiencing multiple generalized convulsions (two or more within a 24-hour period), having trouble breathing (acidotic breathing), struggling to sit up, stand, or walk without assistance, showing changes in consciousness level (from drowsiness to deep coma), exhibiting signs of cerebral malaria (unresponsive coma not linked to any other cause in a patient with falciparum malaria), encountering respiratory distress (acidotic breathing), experiencing circulatory collapse (shock, septicemia), developing pulmonary edema, facing abnormal bleeding (disseminated intravascular coagulopathy), showing jaundice, experiencing hemoglobinuria (black water fever), encountering acute renal failure (presenting as reduced urine output or no urine output), suffering from severe anemia (hemoglobin less than 5g/dL or hematocrit less than 15%), experiencing low blood sugar levels (blood glucose level less than 2.2mmol/L), dealing with high parasite levels (parasitemia of more than 200,000/μL in areas with high transmission or 100,000/μL in areas with low transmission), and facing elevated lactate levels (Ministry of Health & program, 1994).

Environmental factors significantly influence the spread of malaria and the various mosquito species that carry changes in climate, like different seasons, how rain falls, temperature changes, and how humid it is, can directly affect how malaria spreads. Having plants and water on the ground is also really important for the malaria cycle. Plus, things people do, like farming, changing forests, building cities, moving around, making dams and roads, and having wars, all affect how much malaria spreads and how many people get sick (Machault *et al*., 2011).

2.4 Overview of Malaria Disease Burden

With more than 200 million people affected every year and causing around one million deaths annually, Malaria is a significant global health issue (WHO, 2023). According to the WHO, (2022), Malaria is a significant global health issue of concern in Africa and South East Asia, despite a notable decline in its global impact. The disease predominantly impacts pregnant women and children under five years old, contributing significantly to illness and death worldwide (WHO, 2019). Between 2010 and 2018, the global incidence of malaria decreased from 69 to 56 cases per 1,000 individuals at risk. However, the rate of decline slowed between 2014 and 2018, in 2018 alone, around 228 million malaria cases were reported worldwide, with the WHO South East Asia region bearing 3.4% of this burden. Approximately 85% of all malaria cases are concentrated in 18 African nations and India, which also holds nearly half (47%) of all *Plasmodium vivax* cases globally (WHO, 2019). The efforts to control malaria in the America face significant hurdles, posing a threat to the region's goal of eradicating malaria by 2030. The progress made in reducing malaria cases and deaths between 2000 and 2015 stalled in 2016 when cases malaria surged to over 1 million per year in both 2017 and 2018. The WHO (2019) furthermore, asserted that following Venezuela's economic collapse since 2014, along with the breakdown of its healthcare system, has played a crucial role in this upsurge of malaria infection in that country. Venezuela reported the highest number of malaria cases in Latin America from 2015 to 2018, experiencing one of the most significant increases in malaria cases globally in 2017 (WHO, 2019).

Despite its importance, there is a notable lack of comprehensive understanding regarding the characteristics and factors influencing the changing endemicity of malaria in sub-

Saharan Africa. The health records of 32 highly malaria-endemic nations, collectively representing about 90% of the global malaria burden, are considered insufficient for assessing trends in malaria cases (WHO, 2015b). This issue stems from several factors: low rates of seeking medical care (many malaria cases go unreported at official healthcare centers), inadequate record-keeping and management (numerous documented cases are not included in surveillance databases), and historically limited access to accurate parasitological diagnosis (malaria cases often diagnosed based on presumption, lacking specificity). However, improvements have started to emerge with the enhancement of systems, such as increased utilization of rapid diagnostic testing in healthcare facilities (WHO, 2015b). In the past, the WHO used a "cartographic" approach to gauge the malaria burden in these countries. This method involves using a map of climatic suitability for malaria transmission to predict expected incidence rates across the continent. These rates are then adjusted downwards as intervention coverage increases, based on the effectiveness observed in randomized control trials. One recognized limitation of this approach is its reliance on the central assumption that the outcomes seen in a limited number of short-term trials can be applied to sustained implementation across the continent. This assumption has not been validated beyond local or national-level analyses (Chizema-Kawesha *et al*., 2010). Close to 88% of global malaria cases and approximately 90% of global malaria-related deaths happen in sub-Saharan Africa (DHS, 2020). *Plasmodium falciparum* continues to infect millions of individuals annually in sub-Saharan Africa (SSA), as indicated by a recent study (Kamau, *et al*., 2020). The extent to which malaria infection directly and indirectly contributes to mortality remains uncertain. Identifying malaria as the sole cause of death in a community presents challenges, given that many fatalities occur outside medical settings where parasitological diagnoses are unavailable, often relying on symptom descriptions from bereaved relatives. With over 70% of the population exposed to the risk, malaria remains a significant cause of sickness and death in Kenya (DHS, 2020). Around 70% of the population in Kenya exceeding 50 million individuals face the risk of malaria infection (WHO, 2019). In Kenya, the malaria infection is responsible for 30 to 50% of all outpatient hospital visits, 20% of all hospital hospitalizations, and 5% of all patient fatalities (DHS, 2020). In 2019, malaria ranked as the second most burdensome disease after HIV/AIDS, particularly affecting mortality rates among children under five years old. The pattern of fever linked to malaria in Kenya shows a trend that increases with age during childhood, peaks around the age of 10, and then gradually decreases into adulthood, remaining consistently lower thereafter. The higher risk observed among children aged 5–14 years corresponds to the prevalent infection rates in the community, suggesting that fevers in this age group may be more coincidental rather than directly caused by malaria infection. (Kamau *et al*., 2020). However, more than half (52.6%) of all individuals presenting with fever and positive rapid diagnostic tests (RDT) at healthcare facilities are aged between 5 and 14 years. This places a substantial burden on the healthcare system and underscores the importance of following malaria treatment protocols as outlined in national guidelines (Githinji *et al*., 2016).

A survey in Kilifi, Kenya, found that compared to children aged 6 months to 4 years, those aged 5 to 14 years had a higher prevalence of malaria infection (PR = 13.4%; aOR = 1.28; 95% CI 1.01, 1.63; $p < 0.001$), even after adjusting for factors such as site, month of enrollment, LLIN usage, and gender. Conversely, malaria parasite prevalence decreased in older age groups compared to children aged 6 months to 4 years (15–49 years—PR = 7.1%;

aOR = 0.63; 95% CI 0.48, 0.82), with the lowest risk observed among participants aged 50 years and above (PR = 4.3%; aOR = 0.38; 95% CI 0.23, 0.64). Malaria results in more than 100 million workdays lost for each individual affected, and over 20 million schooldays are missed by children due to this disease (Kenya Ministry of Health, 2020). Addressing the control of malaria is considered a primary concern, as the Kenyan government recognizes it as not only a health issue but also a significant socioeconomic burden (Kenya Ministry of Health, 2020). Economic investment in the disease's control is a top priority because the Kenyan government views it as both a health problem and a socioeconomic burden (DHS, 2020). When used and maintained correctly, insecticides and LLINs prove highly effective in reducing malaria-related illnesses and deaths. Kenya has reached the Roll Back Malaria target of 60%, but utilization remains below the desired 80%. Consequently, PBO nets still suffer from low coverage and inadequate usage. Scaling up indoor residual spraying (IRS) in high malaria transmission areas can lead to increased costs due to the need for multiple spray cycles for full population protection. Additionally, IRS poses greater health and environmental risks compared to other intervention methods. Some insecticides like dichlorodiphenyltrichloroethane (DDT), while effective against mosquitoes, are banned in certain countries due to environmental concerns, and the World Health Organization (WHO) recommends their restricted use. Like insecticide-treated nets (ITNs), the rise of insecticide resistance poses a significant obstacle in IRS implementation, particularly with concerns about pyrethroid resistance (Tizifa *et al.*, 2018).

2.5 Prevention of malaria

Malaria-affected nations need to provide protection to vulnerable groups from the disease. These include pregnant women, children under five, nomadic communities, and people traveling to malaria-prone areas. In African regions where malaria is common, the disease remains a major health concern during pregnancy, impacting around 25–30 million expectant mothers who are at risk of *P. falciparum* infection and its negative impact on pregnancy results (Steketee *et al.*, 2001).

The fact that the parasite and its vector are both extremely adaptive to the environment makes malaria a challenging disease to control. The plasmodium parasite and mosquito vectors would counteract certain preventive techniques if employed ineffectively. A combination of novel strategies and instruments would be required to effectively manage malaria (Coelho *et al*., 2017). Changes in malaria prevalence closely followed the expansion of insecticide-treated bed net (ITN) coverage, with ITNs being the main intervention in Africa. They were estimated to have caused about 68% (ranging from 62-72%) of the reductions in *Plasmodium falciparum* parasite rate (PfPR) by 2015. Artemisinin-based combination therapies (ACTs) and indoor residual spraying (IRS) were estimated to have contributed 19% (ranging from 15-24%) and 13% (ranging from 11-16%), respectively, although their impact was more pronounced in areas with high coverage rates. It's important to note that these proportional contributions do not necessarily indicate the comparative effectiveness of different intervention strategies but are primarily influenced by the timing and scale of deployment. In total, malaria control interventions were estimated to have prevented 663 million clinical cases since 2000, with ITNs contributing approximately 68%, ACTs 22%, and IRS 10% (Bhatt *et al.*, 2015).

Research assessing chemoprophylaxis has shown its effectiveness in reducing both malaria and anemia incidence. The global malaria control plan emphasizes the targeted application of preventive interventions where they can have long-lasting effects. Selective vector control, which involves the targeted application of vector control technologies alone or in combination, is recommended to prevent or limit human-vector contact while addressing sustainability concerns. A number of intervention measures have been put in place, which include indoor residual spraying, the use of insecticide-treated materials, the use of gametocytocidal medications, chemotherapy to the infected individuals, health promotion, malaria prevention in pregnancy through prophylaxis or intermittent treatment, and LLIN use. Other methods might include access to early diagnosis and effective treatment for anemia and clinical malaria (Coelho *et al*., 2017). Intermittent preventive treatment (IPT), although the term may not fully capture its nature as it includes elements of prophylaxis, involves administering a full therapeutic dose of an antimalarial or antimalarial combination at predetermined intervals, regardless of the individual's infection status. Unlike chemoprophylaxis, IPT allows drug levels to decrease below protective thresholds between doses. Therefore, while IPT may have lower efficacy compared to chemoprophylaxis, it is expected to have a lesser impact on the development of naturally acquired immunity by allowing intermittent exposure to parasites and exerting reduced drug pressure. Initially explored as a strategy for malaria control during pregnancy, IPT has been extended to include the prevention of malaria in infants, young children, and school-aged children *(*Kalanda *et al*, 2006).

Intermittent preventive treatment (IPT) using a single administration of sulphadoxine/pyrimethamine (SP) emerged as a strategy for malaria control during pregnancy due to the declining favor of chloroquine chemoprophylaxis (CQ) and increasing resistance to CQ. Initial studies showed that IPT, administered biweekly or triweekly throughout the second and third trimesters of gestation, had comparable efficacy in preventing maternal anemia and low birth weight compared to CQ chemoprophylaxis, while being significantly more palatable *(*Kalanda *et al*, 2006). In areas with high and persistent malaria transmission, infants constitute a considerable proportion of both malaria-related deaths and severe illnesses. In such epidemiological settings, infants become a vital focus for tailored malaria control efforts, including preventive measures. Following the discontinuation of chemoprophylaxis, Tanzanian infants encountered a notable increase in both malaria cases and instances of anemia, a phenomenon often termed as rebound malaria (Menendez *et al*., 1997). During the Global Malaria Eradication Campaign, the main strategy employed was indoor residual spraying, which resulted in the elimination of malaria from many countries and notably reducing its impact in others (WHO, 2015a).

Stepped-wedge randomized cluster trials were conducted in central regions, covering fifty-four health posts, to evaluate the implementation of seasonal malaria chemoprevention (SMC). SMC, usually administered by community health workers, involves giving sulfadoxine-pyrimethamine (SP) along with amodiaquine (AQ) monthly to children aged 3 to 59 months in areas with acute seasonal malaria transmission. This strategy has been widely adopted by countries in the Sahel sub-region. In Senegal, from 2008 to 2010, a study involving children aged 3–59 months showed a 60% decrease in malaria cases confirmed by rapid diagnostic testing (RDT), along with a 69% reduction in the administration of malaria treatment. Additionally, there were declines observed in the prevalence of parasitemia at the end of the transmission season in areas implementing seasonal malaria chemoprevention (SMC) 68% in 2008, 84% in 2009, and 30% in 2010 (Cissé *et al.*, 2016). Indoor residual spraying (IRS) has been utilized in various countries to combat malaria outbreaks and achieve eradication. Numerous studies, including a randomized controlled trial (RCT) in Tanzania targeting areas with stable malaria transmission (entomological inoculation rate (EIR) > 1), demonstrate its effectiveness. After treatment, IRS notably reduced reinfection with malaria parasites detected through active surveillance in children, showing a protective efficacy (PE) of 54%. Moreover, in the same setting, there was a slight decrease in malaria case incidence among children aged 1 to 5 years based on passive surveillance, with a PE of 14%. However, this reduction was not observed in children older than 5 years, where the PE was −2% (Pluess *et al*, 2010). In a trial conducted within various districts in Northern Uganda, focusing on children under five, there was an increase in malaria cases after indoor residual spraying (IRS) was stopped. The incidence rate ratio among children under five rose from 0.77 in December 2014 to 1.74 in June 2015 after spraying operations ceased (Okullo *et al.*, 2017). The most effective way to prevent malaria remains sleeping under insecticide-treated mosquito nets. Despite significant progress made by the international community in the last 15 years, many regions in Africa are now considering strategies for malaria elimination. However, in 2015, numerous individuals in Africa still faced the threat of malaria-related illness and death. This evaluation highlights the considerable effectiveness of current malaria interventions in reducing both prevalence and incidence across the continent. It strongly emphasizes the importance of maintaining and expanding access to these interventions as essential components of post-2015 control strategies. These efforts should be accompanied by intensified measures to combat drug and insecticide resistance. Additionally, innovative approaches are needed to address residual transmission in certain areas, even with extensive vector control coverage. Finally, localized initiatives to systematically identify and eliminate remaining parasites are crucial (Bhatt *et al*., 2015).

2.6 Long-Lasting Insecticide-treated Nets (LLINs) with Pyrethroid-piperonyl butoxide (PBO)

Kenya implements various interventions and goals to combat malaria, including improving access to prompt and effective medical treatment, ensuring the availability of preventive measures such as long-lasting insecticidal nets (LLINs) and indoor residual spraying, and implementing programs to reduce malaria among pregnant women (Kenya Ministry of Health, 2020).

The World Health Organization recommended the use of long-lasting insecticidal nets (LLINs) as the primary intervention to prevent malaria transmission in endemic areas (WHO, 2010). The evolution of LLINs has been a significant milestone in the fight against malaria infections. In the early 1980s, the initial LLINs were created by treating regular nets with pyrethroids like permethrin and deltamethrin. While these nets effectively reduced mosquito bites and malaria transmission, their insecticidal effectiveness declined quickly with repeated washing. To tackle this issue, second-generation LLINs were developed, integrating a polyethylene-based material for longer insecticidal activity. These type of nets were infused with a combintion of pyrethroids and binders to enhance durability and insecticidal efficacy. Third-generation LLINs introduced a slow-release mechanism, allowing gradual insecticide release over an extended period. This innovation improved net durability and boosted effectiveness in killing and reducing mosquito bites and consequently malaria transmission (Gonahasa *et al*., 2018). A study conducted by (Wotodjo *et al*., 2015) showed a consistent trend in LLIN usage, with 55%, 65%, 52%, 50%, 63%, and 79% of observations indicating individuals who consistently used LLINs across various time periods. A study conducted by (E. H. Diouf *et al*., 2022) examined 3,012 Long-Lasting Insecticidal Nets (LLINs) distributed across two distinct epidemiological regions of Senegal, indicate a retention rate of only 12.5% over a period of three years. This relatively low retention rate could lead to a resurgence of malaria in the studied areas if additional nets are not distributed before the next transmission season. The reduced retention rate of LLINs in the study may be due to the large-scale distribution initiative conducted in the region during the fifth semester or the practice of giving nets to acquaintances or family members observed within the initial six-month period. Research in Senegal has identified relocation as the primary cause of net loss, especially within the first month after distribution (M. Diouf *et al.*, 2022)

At present, there are two varieties of LLINs accessible in the market: pyrethroid-only impregnated nets and those treated with PBO. Pyrethroid-only impregnated nets have been the primary choice for malaria control initiatives worldwide and have significantly contributed to the decline in malaria morbidity and mortality. In a randomized trial conducted in Tanzania, it was discovered that over a span of two years, the utilization of LLINs infused with a blend of chlorfenapyr and pyrethroid led to a nearly 50% reduction in malaria infection rates and clinical cases compared to nets treated solely with pyrethroid (Mosha *et al*., 2022). However, the effectiveness of pyrethroid-only nets has diminished due to a rise in insecticide-resistant mosquito populations. To address this issue, PBO-treated nets were developed, containing a synergist that boosts the potency of the pyrethroid insecticide by inhibiting the mosquito's metabolic resistance mechanisms. This reduces the likelihood of resistance and enhances the insecticide's effectiveness (Mosha *et al.*, 2021).

Data have shown that PBO-treated LLINs are highly effective in reducing mosquito bites and malaria transmission, particularly in areas where insecticide resistance is prevalent. In a randomized controlled trial conducted in Burkina Faso, PBO-treated LLINs were found to be significantly more effective in preventing malaria infection than pyrethroid-only impregnated nets (Mosha *et al.*, 2021). Another study conducted in Tanzania showed that PBO-treated nets were effective in reducing the density of insecticide-resistant mosquito populations, thereby reducing malaria transmission (Mosha *et al*., 2021).

2.7 Socio-demographic characteristics associated with PBO nets usage

One of the key strategies for preventing malaria at the household level is the use of insecticide-treated nets (ITNs), and therefore, the possession of long-lasting insecticide-treated nets (LLINs) significantly influences their usage. The promotion of LLIN ownership has been emphasized in various African countries due to its pivotal role in malaria prevention. Having an LLIN directly affects its utilization and coverage in a population. Studies have demonstrated that LLINs can reduce the incidence of severe malaria infections by 45%, leading to a 42% decline in premature births and a decrease in overall child mortality ranging from 17% to 63%. (Pryce *et al*., 2018). For every 1000 LLINs distributed to a risk population, approximately five and a half children's lives are preserved. Efficacy trials indicate that employing insecticide-treated nets (LLINs) can reduce malaria transmission by as much as 90*%* (Pryce *et al.,* 2018*)*.

More than half of those using LLINs were female, and the age group with the highest proportion of users was 18-30 years old, while the lowest proportion was aged 50 and above. A significant majority identified as Christians, with the Yoruba ethnicity being the most common. The largest occupational groups were civil servants and students, with a majority reporting a monthly income of at least $57 (Omonijo & Omonijo, 2019).

Among Nigerian urban families, Alawode, *et al.*, (2019) a study examining household characteristics as predictors of mosquito net ownership found that socio-demographic factors influenced ownership. The Alawode team recommended that in order to enhance ownership and usage of mosquito nets, there is a need for increased education emphasizing their value and fair distribution campaigns bridging the rural-urban gap. These efforts are particularly crucial for pregnant women in Nigeria (Iyanda *et al*., 2020). Another study investigated geographic differences and demographic factors associated with awareness of malaria risks and prevention methods, and concluded that urban women with at least a secondary school education possessed greater knowledge of malaria risk. Additionally, urban women in the South-West and South-East part of Nigeria were more inclined to utilize treated mosquito nets during pregnancy. Moreover, women in the urban South-West part of Nigeria exhibited higher likelihood of employing malaria medications during pregnancy compared to those in the North-Central region (Iyanda *et al*., 2020).

In Budondo sub-County, Uganda, Moscibrodzki *et al.*, (2018) in a comparison between the possession and utilization of free and purchased mosquito nets, findings indicated that the median proportion of households equipped with adequate LLINs (long-lasting insecticidal nets) differed across counties, ranging from 8.5% to 62.0%, with a median of 30.7%. Initial examination of Moscibrodzki data revealed disparities in LLIN usage across various age groups within households, peaking among individuals aged 0–4 years and 30–40 years, and decreasing among those aged 5–14 years and 50 years and older. Meta-regression analysis conducted in the same study indicated that, across all counties, mean adjusted odds ratio (aOR) for LLIN usage was notably higher among children under 5 years, pregnant women, non-pregnant women aged 15–49 years, and individuals aged 50 years and above compared to men aged 15–49 years (Kanyangarara *et al.*, 2018). The study explored malaria awareness and bed net utilization in three transmission settings across southern Africa. Among the 3836 adult participants, the majority correctly associated mosquito bites with malaria (85.0%), identified at least one malaria symptom (95.5%), and recognized the advantages of sleeping under LLINs. The LLIN usage was demographically influenced by age, gender, education level, socioeconomic status, and household size. Okafor and Odeyemi (2012) examined the utilization of insecticide-treated mosquito nets among children under five years old in an urban region of Lagos State, Nigeria, and found a substantial LLINs usage rate in their investigation (61.8%). The study observed that the outcome was notably influenced by the marital status of the caregivers and the quantity of children under 5 years residing in the household. However, factors such as the educational level of caregivers and the occupation of the household head did not significantly influence LLIN usage.

A study conducted by E. H. Diouf *et al.*, (2022) in Senegal included a total of 1,249 households across study regions. On average, around 92.7% (with a 95% CI of 90–94) of household heads were men, with an average age of 53 years. In the Mbagame area, this proportion was 78.2%, with an average age of 52 years, while in the villages near Thies, it was 94.8%, with a mean age of 53 years ($P < 0.001$). The average percentage of household heads with any schooling was 38.4% (with a 95% CI of 34–42). Gender-wise, 96% were men and 4% were women. Among 604 households, 37.7% (228 out of 604) had some means of transportation, with 68% using carts and only 14% owning cars. The overall average percentage of households with electricity was 31% (with a 95% CI of 27–35). In Mbagame village, 87.2% of households had electricity, compared to an average of 22.6% in the study villages near Thies ($\chi 2 = 132.4377$, df = 1, $P < 0.0001$). Wood remained the primary fuel for cooking in 97.7% of households in the study areas. Another study conducted by *(*Wotodjo *et al.*, 2015*)* in a population on whether they experienced malaria attacks or not, a variance in the proportion of women between the two groups was observed. Precisely, the group with malaria attacks had a smaller percentage of women compared to the group without malaria (37% versus 50%). Univariate analysis revealed that being female was linked to a protective effect against malaria attacks, with an odds ratio of 0.59 [95% CI: 0.39–0.90].

Inungu *et al. (*2017*)* study highlighted certain socio-demographic factors that play a significant role in the utilization of LLINs. Out of the 5,138 individuals surveyed, the vast majority (96.6%) were women, with 2,008 of them being pregnant during the study period. Most participants (68.8%) were married, and a significant portion (35.5%) identified as housewives. Additionally, around 74.3% had attained at least a primary level of education, with the majority (54.3%) falling within the age range of 15 to 29 years. The most commonly reported religious affiliations were Catholic, Protestant, and charismatic churches but had no any association with use of PBO bed nets.

A study conducted by Bashir *et al.*, (2019) uncovered a link between malaria parasitemia and households involved in agricultural activities. In the Lake endemic region of Kenya, where large-scale farming of crops like cane and rice, as well as small-scale farming of corn and other plants, is common, the favorable breeding conditions for mosquito vectors contribute to increased risk. This heightened risk among farmers is consistent with previous findings. Parasitemia prevalence was lowest in the youngest age group, at 14%, and increased with age, peaking at 35% among 13–14-year-olds. Children from the Lake endemic region had notably higher parasitemia prevalence across all age groups compared to the national average. Univariate analysis identified the child's age as the primary risk factor associated with parasitemia.

2.8 The PBO bed Net coverage and utilization

According to the World Health Organization 2022, universal coverage is defined as having one net for every two individuals in a household. Utilization of nets on the other hand refers to those who effectively use PBO nets, which includes correctly installing them, sleeping under a treated mosquito net every night, and properly tucking them in. A study conducted in Brazil revealed that, when comparing access to long-lasting insecticidal nets (LLINs) with their actual usage, it was found that in the intervention group, although 85.1% of individuals had access to an LLIN in 2014, only a remarkably low 14.9% actually used one the previous night. Similarly, among individuals in the control group, despite 63.8% having access, only 30.8% used them the previous night. These findings demonstrate that while access to LLINs was higher in the intervention area compared to the control area, there was also a wider gap between access and usage in this group. This suggests that the lack of mosquito net usage the previous night was not due to a lack of access to nets. Rather, it appears to be influenced by cultural or psychological factors. In both cases, the percentage of usage was lower than the ownership rate, indicating a significant disparity between owning nets and actually using them (Alvarado *et al*., 2011). A study conducted by Wotodjo et al., (2015) have shown that PBO impregnated nets have contributed to reducing malaria incidence by around 24% to 39% in regions with stable malaria transmission. Furthermore, compared to areas without nets, impregnated nets have been found to lower malaria incidence by up to 50%.

Tassew *et al*., (2017), explored on factors affecting the possession and utilization of long-lasting insecticidal nets (LLINs) for preventing malaria in Ethiopia, and discovered that more households had LLINs and used them. Furthermore, the study concluded that there was a deficiency in knowledge about how malaria spreads and the strategies for controlling mosquitoes to prevent malaria among the study residents. Njumkeng *et al.,* (2019) study in the Mount Cameroon region examined how many households had long-lasting insecticidal nets (LLINs) and how often they were used, along with factors influencing this and their effect on the rate of malaria infection. The findings showed that LLIN ownership was not widespread, and boosting ownership while ensuring regular replacement of nets could notably decrease the rate of malaria infection in the country. Aung *et al*., (2022), investigated the usage of insecticide-treated bed nets by pregnant women in Myanmar using data from the 2015–2016 Demographic and Health Survey and found that pregnant women living in delta and lowland regions or plains and hilly areas were more inclined to report not using long-lasting insecticidal nets (LLINs) compared to those living in coastal regions of Burma.

A study conducted by E. H. Diouf *et al*., (2022) found variations in the regular usage of mosquito nets across different types. At the end of the observation period, usage rates were recorded as 23.3%, 38.5%, 7.3%, 78.3%, and 16.1% for Dawa Plus 2.0, Life Net, NetProtect Olyset Net, and PermaNet 2.0, respectively. Notably, NetProtect had a significantly lower usage rate compared to Life Net and Olyset Net, as indicated by Fisher's exact test with odds ratios of 0.13 (95% CI: 0.017–0.83, P = 0.014) and 0.022 (95% CI: 0.017–0.83, P < 0.001), respectively. Dawa Plus 2.0 and PermaNet 2.0 consistently maintained usage rates exceeding 50% during the initial four semesters. Olyset Net sustained a usage rate above 60% throughout the three-year follow-up period. Conversely, NetProtect and Life Net were less frequently utilized in households. Their usage rates were satisfactory only in the first two semesters post LLIN distribution, with rates of 52.6% (95% CI: 47.7–57.5) for NetProtect in the first semester and 53% (95% CI: 46–59.6) for Life Net® in the second. Solomon *et al.,* (2019) conducted a community-based cohort study in south-central Ethiopia and explored the reasons behind the limited use of long-lasting insecticidal nets (LLINs) for malaria prevention. Initially, all households possessed LLINs. Nevertheless, throughout the study, the average proportion of LLIN usage per person remained low, with a median of merely 14%.

A cross-sectional study conducted by Perkins *et al.,* (2019) in rural Uganda delved into social norms, misconceptions, and the utilization of mosquito nets. It discovered that although the majority of respondents stated that they slept under a mosquito net every night, a significant portion, about one-quarter, believed that most adults in their community did not. Moreover, 8% expressed uncertainty regarding how often most adults in their community used a mosquito net per week. Individuals who viewed daily mosquito net usage as the standard were nearly three times more inclined to personally sleeping under a mosquito net every night compared to those who did not perceive it as the norm, even after adjusting for other variables. Admasie *et al*., (2018) in their research on the utilization of insecticide-treated nets (ITNs) and the factors influencing it among children under five years old in Mirab-Abaya District, Gamo-Gofa Zone, Ethiopia, found that while most of the children in this age group had access to ITNs, only 37.2% of them actually used them on the night preceding the survey. The study identified that households with mothers of middle age and those with fewer than five members were significantly associated with the proper utilization of ITNs among children under five. Overall, the study concluded that despite a considerable number of children having access to ITNs, only a third of them were using them as intended. Tapera, (2019) study examined factors influencing the ownership and usage of long-lasting insecticidal nets (LLINs) in regions affected by malaria transmission, using data from the Zimbabwe Demographic and Health Surveys. It reported that there were no significant changes associated with the demographic characteristics of surveyed households between the 2010 and 2015 survey cycles. However, LLIN ownership notably increased by 42 percentage points from 2010 to 2015, indicating a substantial enhancement in universal coverage. Despite this rise in ownership, the overall utilization rates of LLINs among children under 5 years old declined by 11 percentage points during the same period. Additionally, the study observed that LLIN usage among households mirrored the trend seen in children under five years old.

Ng’ang’a *et al.,* (2021), study conducted in the Lake Victoria basin of Western Kenya examined the ownership, usage, and coverage of long-lasting insecticidal mosquito nets (LLINs) following a mass distribution campaign. About 31% of study participants reported at least one household member being sick with malaria in the week before the interview. Common signs and symptoms of malaria included fever (24.1%), headache (17.7%), vomiting (14.5%), feeling cold (12.6%), and loss of appetite (10%). Among the 160 households surveyed, there were a total of 382 reported LLINs among the 753 occupants. On average, each household owned 2.4 nets, with 1.97 persons per LLIN in Ng’ang’as study. Almost all households (96.9%) owned at least one LLIN, and 64.1% had at least one LLIN for every two people. Among LLIN owners, 98.1% reported using them the previous night. LLINs per household ranged from 0 to 6, averaging 2.39. More than three-quarters of the nets were obtained through free mass distribution campaigns, and 80% were acquired less than 6 months before the survey. Another study in Tanzania by Mboma *et al*., (2018) on mosquito net coverage found that only three out of eight districts had household LLIN ownership exceeding 80%. Earlier in 2013, less than a quarter of households had one LLIN for every two people, and only half of the population had access to an LLIN. Wealthier quintiles achieved ownership and access levels above 80%, mainly through untreated nets (UTNs). Overall net usage in Tanzania population in 2018 was low, with 32.8% using LLINs and 9.5% using UTNs. The net use-to-access ratio fell below the target level, with values of 0.66 for LLINs and 0.50 for UTNs, varying significantly in district by district.

The World Health Organization predicts an annual requirement for more than 32,000,000 LLINs among the groups at risk (WHO, 2016). The public sector should concentrate its limited resources on those who are most at danger, who cannot afford to pay, and who need free nets by creating commercial markets for high quality and reasonably priced LLINs to serve those who can pay and prefer the convenience and choice of the marketplace. To increase the range of choices and the efficiency of subsidy methods, it's important to expand the market. Since 2003, the Ministry of Health's National Malaria Control Program Division has been giving out free mosquito nets to pregnant women and kids under five years, aiding the progress of the Millennium Development Goals, which later became the Sustainable Development Goals, and the Abuja targets (Amin *et al*., 2007; Aung *et al*., 2022). Despite the ample supply of nets, the initiative fell short. Presently, less than 10%

of the intended recipients have received the distributed nets, which is expected to have a positive effect on reducing illness and fatalities. The desired outcomes of reducing poverty linked to the disease and boosting school attendance for students affected by malaria have not been achieved in districts where the disease is prevalent (Amin *et al.*, 2007; Aung *et al.*, 2022).

In 2006, the country's 46 high-malaria district received 3.4 million LLINs from the Ministry of Health. This resulted in the greatest single distribution of nets ever carried out internationally. As a result of this activity, net ownership among households increased significantly to 51%, while current usage among vulnerable populations increased to 70%. In terms of the cost of the net and the distance to the source of the net, this increased accessibility for the majority of rural families. Additionally, pro-poor, this free distribution of durable LLINs in 2006 was focused on them. LLINs were also provided by the public and non-governmental organizations in Kenya, although no persistent, sizable interventions took place (Ng'ang'a *et al.*, 2021).

2.10 Factors associated with the coverage and utilization of PBO treated Nets against malaria vectors

In a study on LLIN Evaluation in a Ugandan Project (LLINEUP), Gonahasa *et al.*, (2018) examined factors linked to the ownership and usage of long-lasting insecticidal nets (LLINs) across 48 districts in Uganda. Their findings revealed that 65% of households possessed at least one LLIN. Notably, sufficient coverage was strongly correlated with wealth status and smaller household sizes. Moreover, children under five years old and individuals residing in the area for over 15 years were more inclined to use nets.

To explore the impacts of long-lasting insecticidal nets with and without piperonyl butoxide on pregnancy outcomes, Roh *et al.,* (2022) had carried out a quasi-experimental, and found out that pregnant women were the most consistent users of the nets. It was observed that their utilization of treated mosquito nets stemmed from the belief that preventing malaria early in pregnancy could offer substantial benefits beyond what antenatal malaria care typically provides. The broad confidence intervals, which extended across the null hypothesis, significantly contributed to the inconclusive nature of the findings from exploratory studies comparing PBO and traditional LLINs on pregnancy outcomes.

According to a 2007 study by García-Basteiro *et al.,* (2011) that was done on the island of Bioko in Equatorial Guinea found that household usage of mosquito nets increased in homes with greater coverage. However, the coverage of PBO nets was reported to have decreased by 32% the subsequent year. This decrease was attributed to the country's expanding population and housing stock. In a bid to enhance coverage and reduce the incidence of malaria infections, nearly 3 million LLINs were distributed to homes in Sierra Leone (Bennett *et al.*, 2012). Following the distribution, the utilization and coverage surged from 37% to 87.6%. Factors such as area of residence, understanding of malaria transmission, age, gender, education level, occupation of the household head, and household size were among the factors identified as key determinants of usage in regions where coverage was enhanced (Bennett *et al*., 2012). For example, a study in Ethiopia had found that the probability of owning a mosquito net had doubled for each additional unit increase in household size (Watiro & Awoke., 2016). The Watiro & Awoke’s research also showed that households with at least one child under five were almost 60% more inclined to possess a net compared to those with older children (Watiro & Awoke., 2016).

In Ghana, a study employed logistic regression to explore mothers' tendencies toward preventive healthcare for children under the age of five. The investigation highlighted various factors linked to mothers' acceptance and utilization of long-lasting insecticidal nets (LLINs), such as household income, child's age, neighborhood, proximity to the nearest hospital facility, and proximity to the nearest grocery store (Nketiah-Amponsah., 2010). The findings of the Ghanas study also indicated a negative association between age and the probability of a child sleeping under a net, and further demonstrated a positive correlation between low income and LLIN utilization. This might be attributed to higher-income families being able to afford other methods of malaria prevention or residing in areas with lower mosquito exposure. Conversely, a study in Nigeria found a positive relationship between income and LLIN usage (Orji *et al* ., 2018). The results revealed that people from households with greater incomes were more likely to sleep with a treated mosquito net. The results are corroborated by Kendie *et al*., (2021), who discovered a link between LLIN use and income in Ethiopia. Kendie's team revealed that media usage among any household member was influenced by factors such as gender, household head income, and the presence of media devices in the home. Additionally, media utilization among vulnerable groups like young children and expectant mothers was predicted by the educational attainment of the household head and the location of the home. This was part of efforts to prevent malaria during pregnancy in two regions of Ghana. Aberese-Ako *et al.*, (2019) explored various factors affecting the utilization of bed nets, including health system, sociocultural, economic, environmental, and personal aspects. The findings indicated that the availability of LLINs in health facilities significantly impacted their ownership and usage. Additionally, receiving accurate information from healthcare providers and endorsement from community leaders positively influenced LLIN utilization. Women who had prior experience with LLINs, especially before pregnancy, and those with young children, tended to consistently use them.

The LLINs use decreased as a result of the irritating effects of LLINs and a preference for conventional means of repelling insects. The LLIN use was favorably influenced in pregnant women whose homes and families already utilized them. Women's use of LLINs was influenced by husbands and wives' gender power dynamics. Babalola *et al*., (2018), investigated the factors linked to caregivers' consistent use of bed nets in Nigeria, employing multilevel multinomial analysis of survey data. It found that various factors such as age, gender, religion, household size, net density, household wealth, socio-demographic characteristics, and ideational factors like perceptions of bed net severity, susceptibility, self-efficacy, and response-efficacy, awareness of purchase sources, willingness to pay for bed nets, attitudes toward net use, and descriptive norms influenced the choice of using a bed net every night rather than occasionally or never. In southern Rwanda, pregnant women were evaluated for their knowledge of and attitudes towards the use of long-lasting pesticide nets by Uwimana *et al*., (2021), all study participants knew that sleeping under LLINs could help to avoid mosquito bites, but however, although LLINs coverage was high, its utilization was low.

Tapera, (2019) A research investigation was undertaken to examine the factors influencing ownership and usage of long-lasting insecticidal nets (LLINs) in regions where malaria transmission occurs, utilizing information from the Zimbabwe Demographic and Health

Surveys. By employing logistic regression techniques on data from 2015, the study (LLINs). Kanmiki *et al*., (2019) study examined socio-economic and demographic disparities in the ownership and usage of insecticide-treated bed nets among rural women of reproductive age in northern Ghana, and revealed that a significant portion, up to 79%, of the study participants possessed LLINs, while 62% of LLIN owners reported using them the night before the survey. Disparities were observed in both ownership and utilization of LLINs in regard to wealth status, occupation, religion, and district of residence of the respodents. The kanmiki's study reported that the participants in the wealthiest wealth quintile were 74% more likely to own LLINs compared to those in the poorest quintile (p-value< 0.001, CI = 1.29–2.34), yet they were 33% less likely to use LLINs compared to the poorest (p-value = 0.01, CI = 0.50–0.91).

Yitayew *et al*., (2018) in their study found out that among a total of 226 subjects (mothers), 160(70.8%) of them had good utilization of LLINs. In Yitayew's study mothers who had an educational level up to of college and above were 2.8 times more likely to utilize insecticide-treated bed nets than those who could not read and write (AOR; 28: CI; 1.9-6.5). Mothers whose age was >30 were 70% times less likely utilized insecticide-treated bed net than mothers whose age was 30 and less (AOR;.3: CI;.2,.6). Alemu *et al* (2018), A study conducted in Kola Diba town, North Gondar, Amhara region, Ethiopia, investigated the usage of insecticide-treated bed nets and its related factors among households. Among the 260 households surveyed, 239 (91.9%) reported using insecticide-treated bed nets on the night before the interview, with a confidence interval of 95% (CI = 88.5–95%). Additionally, within the same study, it was found that 242 (93.1%) households did not regularly treat their bed nets with chemicals, while 18 (6.9%) did. The type of household structure and the participants' knowledge about malaria transmission were identified as factors associated with the utilization of insecticide-treated bed nets in Alemu's research.

Malede *et al.,* (2019), A qualitative investigation was carried out to examine the obstacles hindering the consistent use of long-lasting insecticidal nets (LLINs) in villages surrounding Lake Tana, Northwest Ethiopia. The study revealed that although LLINs lose effectiveness against mosquitoes after three months, their efficacy in eliminating other arthropods rendered them a favored choice for malaria prevention. Participants showed a preference for conical net types due to their adaptability to different sleeping bedding structures (Malende *et al*., 2019) Several factors influenced the inconsistent use of LLINs, including misconceptions about LLINs, reduction in malaria cases and mosquitoes; bedbug infestations; inconvenience; unintended uses; distribution issues; and socio-cultural and economic factors. Unintended uses were often driven by local needs and were rarely related to social issues or inadequate information about malaria and LLINs.

Kwalar-Toh *et al*., (2018), had conducted a study on the factors associated with the use or non-use of long-lasting insecticidal nets (LLINs) in rural Cameroon. The study identified several potential social, cultural, and demographic variables that are important for promoting effective LLIN utilization. Individuals aged 26-40 years were found to be the most likely to use LLINs (75.00%), while those in the 18-25 age group had lower utilization rates (32.26%). Interestingly, there was no progressive relationship between net use and educational level; but those with no formal education and those who had attended secondary school had the highest rates of net usage (76.9% and 77.78% respectively), Conversely, individuals with higher education levels demonstrated lower rates of LLIN usage (26.32% for first-degree holders and 33.33% for master's degree holders). Among the 35.88% of LLIN non-users, prevalent reasons included engagement in night work, residing in traditional homes, and experiencing symptoms like facial and body swelling, coughing, and discomfort. The study did not identify any cultural factors acting as barriers to LLIN utilization.

Ernst *et al.,* (2016), In Western Kenya, a study was conducted to discern the factors linked with bed net ownership. The results showed disparities depending on the location. In the highlands, possession of higher education levels, a perceived risk of malaria, and awareness of individuals who had succumbed to malaria were correlated with increased bed net ownership. Conversely, in the lowlands, individuals who perceived acquiring a bed net as easy were more inclined to own one. An analysis encompassing both regions indicated that non-usage of available bed nets was associated with attitudes such as considering malaria medication easier than bed net usage and doubting the effectiveness of bed nets in preventing malaria (Ernst *et al.,* 2016). Furthermore, households with unused bed nets were more likely to perceive bed nets as cumbersome to use, believe that purchased nets are superior to freely distributed ones, and consider bed nets necessary only during the rainy season. The Kenya Malaria Indicator Survey showed that LLIN use decreases with age, with households with children under five having a usage rate of 24%.

However, it did not identify intra-household factors affecting LLIN use. Interestingly, there is no consensus on some factors affecting LLIN use. For example, Eisele *et al.,* (2012) in Equatorial Guinea, there is a reported low utilization of long-lasting insecticidal nets (LLINs) in rural areas compared to urban areas, while in Sierra Leone, the opposite trend is observed, with higher usage in rural settings than urban ones. Despite significant efforts to enhance LLIN coverage in Sub-Saharan African nations like Kenya, actual usage rates still fall short of national, regional, and global targets. Numerous factors affect LLIN utilization, including socio-demographic characteristics, coverage levels, knowledge, wealth, attitudes, and practices. Unintended uses of LLINs often stem from local needs and are rarely linked to misconceptions or insufficient information about malaria and prevention. The readiness of health facilities to stock adequate LLINs also plays a role in ownership and use of the nets. Receiving accurate information from healthcare providers and encouragement from public figures positively impacts LLIN utilization. Before pregnancy, as well as those with young children, tend to be consistent users. Factors such as experiencing discomfort from LLINs and preferring traditional mosquito repellent methods can decrease LLIN use. Pregnant women are positively influenced to use LLINs when other household members also utilize them. Gender dynamics within households can also affect women's utilization of LLINs.

2.11 Knowledge Gap in the utilization of LLINs

The central question arising from the various studies that have focused on the utilization of LLINs is whether there are factors that can improve the utilization of the malaria preventive nets in an endemic. Efforts and resources to promote coverage and utilization of PBO nets in the country has typically focused on the reduced risk of malaria prevention methods. Previous researches have shown that the use of Long-Lasting insecticidal nets incorporating Piperonyl- Butoxide have contributed remarkebly to a reduced malaria infection rate. In Kenya, the number of households indicating ownership of LLINs has increased over the past years, but utilization of the free nets has remained low. The effects of this country’s non-use and low coverage of free nets continued to be felt with the surge in malaria infections in endemic areas. This implies that the country cannot achieve the national and international targets of LLINs use to prevent malaria infection unless the factors that hinder utilization of the nets are identified and appropriate policy solutions found. In view of the foregoing, this study sought to establish the socio-demographic factors, coverage and factors associated with underutilization of PBO nets in Matayos sub-County and provide possible recommendations that could help in mitigating some of the associated factors in the control and prevention of malaria. This will contribute widely in the fight against malaria infections and deaths caused by malaria in this endemic area, nationally and to a large extend globally.

2.12 Conceptual framework

Independent Variable **Dependent Variable**

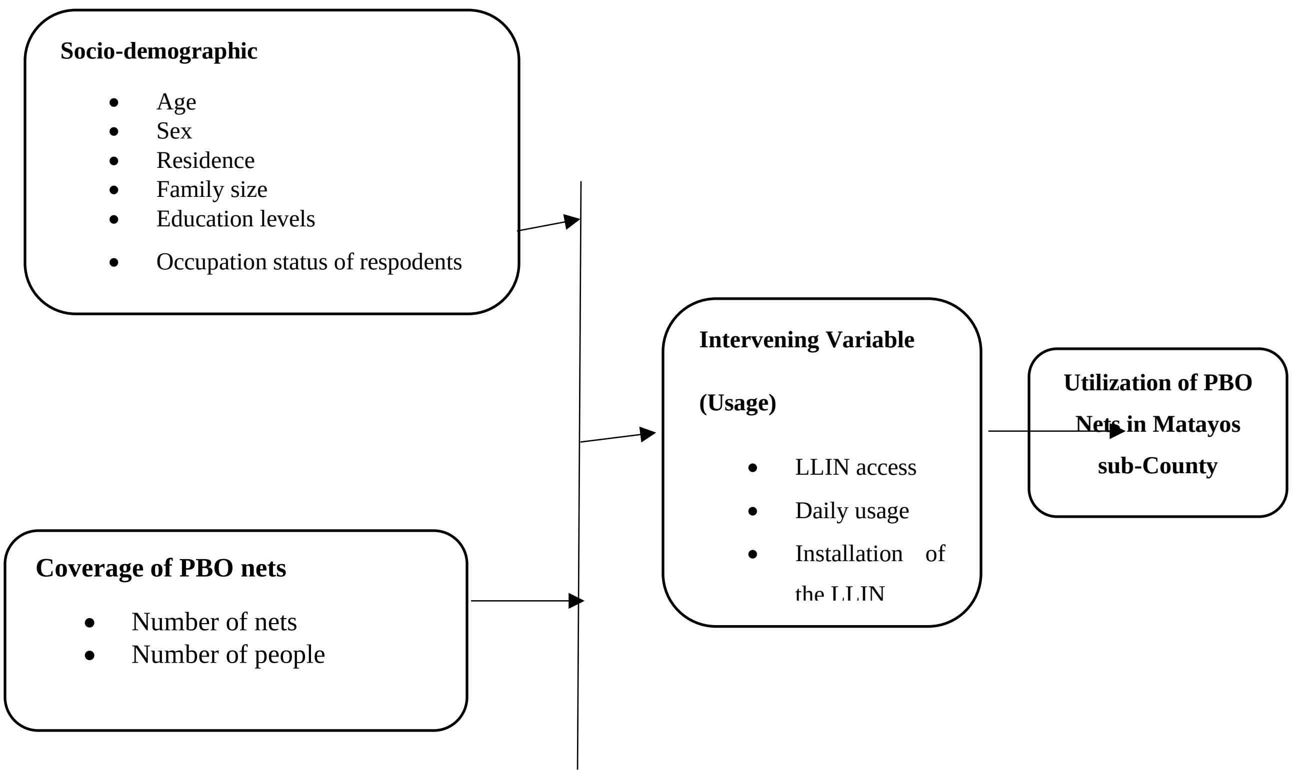

Figure 1: Conceptual Framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Location

The study took place in Matayos sub-County, located in Busia County, western Kenya. Matayos is the most densely populated sub-County in the lower part of Busia County and serves as the county's administrative headquarters. It comprises five wards: Mayenje, Burumba, Matayos South, Busibwabo, and Bukhayo West, primarily inhabited by the Bakhayo, Teso, and Luo tribes. Positioned as a border sub-County, Matayos is a vital hub for East and Central Africa, notably due to its proximity to the Kenya-Uganda border, fostering cross-border trade as the primary economic activity. Other economic activities taking place in the sub-County include agriculture and hospitality. With an area spanning 1,628 square kilometers, the region is estimated to have a population at malaria risk of approximately 893,681 individuals, as per the 2019 Kenya Population and Housing Census data (KNBS, 2019). The region's altitude averages 1208 meters above sea level. The mean annual rainfall typically falls between 800 and 1700 mm in the majority of sub-Counties, although some areas of the County may receive up to 2000 mm. Temperatures remain consistent, with mean maximum temperatures ranging from 26°C to 30 °C and mean minimum temperatures ranging from 14°C to 22 °C annually. The study area is situated within the lake endemic region, characterized by high levels of malaria transmission throughout the year, peaking after the long and short rainy seasons from May to July and October to December. These conditions are suitable for the breeding of mosquito vectors and the transmission of malaria. Data from DHIS2, 2022 records the malaria incidence rate of 567.3 per 1000 population in Matayos sub-County. The structure of Matayos health care system includes health care facilities such as Matayos Health Center, Kaka health clinic, China dispensary, Mmangani dispensary and other private health care facilities. Trained community health promoters (CHPs) play a critical role in the fight against malaria in Matayos sub- County by not only testing, treating, and referring malaria related cases, but also conducting health education on malaria prevention within their communities.

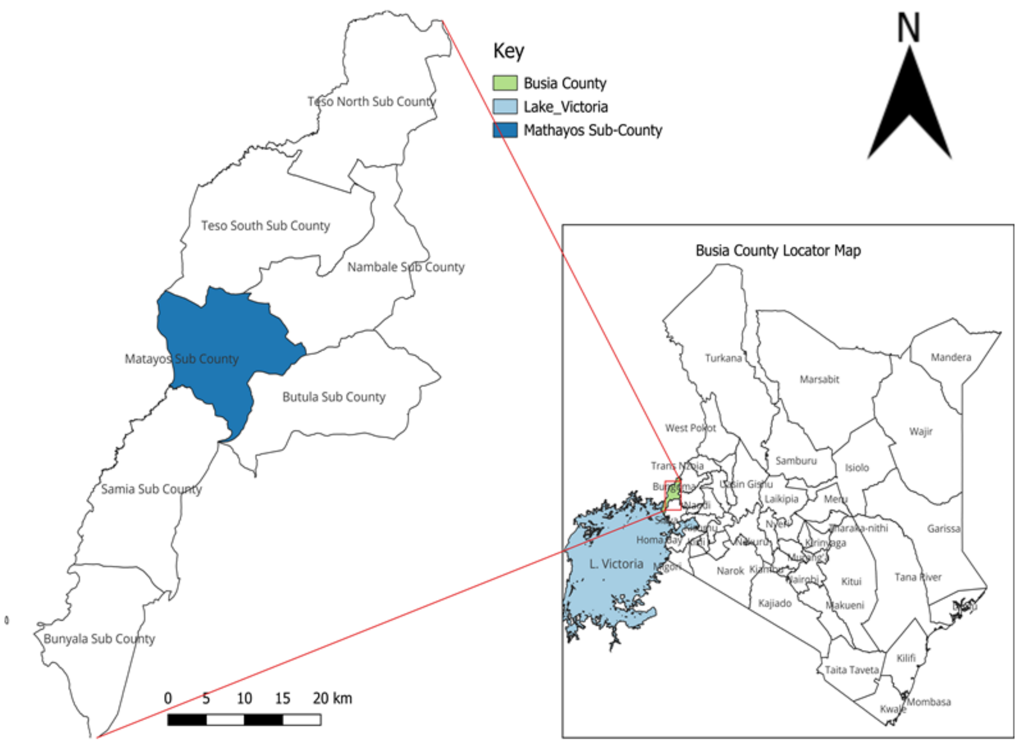

Figure 2: Map of Matayos sub-County, Busia County

Source: (KNBS, 2019)

3.2 Research Design

This research employed a cross-sectional descriptive study design, characterized by the observation and simultaneous measurement of both the outcome and the exposures among the study participants (Setia, 2016). This type of design aided the principal investigator in developing a fuller picture of the socio-demographics, coverage and factors associated with the underutilization of Pyrethroid-PBO treated nets in the area. The method also was best suited for this study because of its ability to elicit a wide variety of baseline data according to Mugenda, (2008).

3.3 Variables

A variable is a measurable trait that takes on various values among individuals (Mugenda, 2008), and the current study focused on the following variables;

3.3.1 Dependent variable

This is a variable that indicates the total influence arising from the effect of the independent variables. The dependent variable in this study was utilization of PBO treated nets by the respondents and was measured by the number of study participants who were effectively using LLINs.

3.3.2 Independent variables

The independent variable is that which the PI can manipulate to determine the impact of various factors on the underutilization of PBO-treated nets, including the coverage scope and socio-demographic factors.

3.4 Target Population

The study targeted all households in Matayos sub-County.

3.5 Study Population

The study population was household heads in randomly selected households that benefited from the recent mass 2021 net distribution campaigns and had received at least one PBO nets and who may have lived in the area for at least 6 months in Matayos sub-County prior to the commencement of the study.

3.6 Selection criteria

3.6.1 Inclusion criteria

All household heads in Matayos South and Burumba wards who were residents in the areas for not less than six months prior to the study.

3.6.2 Exclusion Criteria

Mentally unstable household heads were excluded from the study due to the possible incoherent status.

3.7 Sample Size and Sampling Procedures

3.7.1 Sample size determination

A sample size was required to ensure a 95% level of confidence in estimating the true proportion of individuals using PBO-treated LLINs, with a margin of error of 0.05. The estimated percentage of LLIN coverage and utilization in Matayos sub-County was 70.5% (Zhou *et al.*, 2014).

The following Cochran's formula of 1977 was used to calculate the sample size:

$$N = Z^2 P\ (1-P)/d^2$$

Where:

N = sample size

Z= Statistic for a level of confidence

P= Expected prevalence

d= Allowed error

Z=1.96 for the level of confidence of 95%

P= 70.5% Overall LLINS coverage in western Kenya (G. Zhou *et al*., 2014)

d= 5% (0.05)

$$N = Z^2P\ (1-P)/d^2 = 1.96^2 \times 0.705(1-0.705)/0.05^2$$

$$= 320$$

An additional 10% of the household heads was added to the final sample size to adjust for non-response making a total sample size of 352. Hence, 352 household heads were the minimum sample size in this study. An extra 1.14 design effect was added to take care of the clustering effect in the sub-County wards adjusting the number of households sampled to 402.

3.7.2 Sampling Procedure

A multi-stage sampling approach was utilized, beginning with the random selection of two wards. A comprehensive list of all sub-Locations within these wards was compiled to facilitate the selection of households for inclusion in the study. The allocation of households per sub-Location was determined using proportionate sampling. Working alongside community leaders, a comprehensive list of households within the study area was created, and a simple random sampling technique was applied to select the final households for inclusion.To execute this, the total number of households within each sub-Locations was divided by the required number of households, yielding the sampling interval (n). Every nth household was then systematically selected. A directional indicator was determined by spinning a bottle, with the top indicating the chosen direction. Household heads within the selected sub-Locations were subsequently interviewed using structured questionnaires focusing on socio-demographic factors, coverage, and aspects associated with the underutilization of the free PBO nets. The starting point for household selection was identified from the central point of the sub-Locations, often utilizing landmarks such as shopping centers or public institutions for directional guidance.

Table 1: Sample Population

Ward	**Population (National census 2019)**	**sub-Location**	**Population**	**Households**	**HH sampled**
Matayos South	36, 552	Lung'a	3936	838	18
		Lwanya	10541	2352	50
		Murende	4763	1008	21
		Nangoma	9927	2172	46
		Nasewa	7385	1540	33
Burumba	46, 414	Bulanda	5655	1435	30
		Mabale	3906	1014	21
		Mjini	32,908	8659	183
Totals	**82,966**		**82,966**	**19,018**	**402**

3.8 Data collection instruments

Structured questionnaires served as the primary tool for data collection, with the principal investigator (PI) offering guidance as needed. To ensure the validity and suitability of responses from study participants, the PI adhered to several principles in constructing the questionnaires. Firstly, recognizing the potential sensitivity of certain questions, the PI provided multiple-choice options to allow participants to choose answers they felt comfortable with. Secondly, great care was taken to formulate questions that were precise, concise, and easily understandable, ensuring that participants could respond accurately. Additionally, meticulous attention was paid to eliminating any errors in grammar, spelling, or punctuation within the questionnaire to maintain clarity and professionalism. Moreover, the questions were crafted to be unbiased, avoiding any language or phrasing that might lead participants towards specific responses.

Both open-ended and closed-ended questions were incorporated into the questionnaire, with each serving a specific purpose in aligning with the three main objectives of the study. Closed-ended questions proved to be particularly valuable in situations where participants may have found it challenging to articulate their responses or where specific answers were required. By providing structured options for responses, the closed-ended questions facilitated a more streamlined data collection process compared to open-ended questions, which could potentially yield less focused or less informative responses. Overall, the careful construction of the questionnaire, along with the strategic use of both question types, contributed to the effectiveness and efficiency of the data collection process and uniformity.

The questionnaires were designed, pre-tested and administered using ODK collect application. The study data were collected from June 2022 through July 2022 by trained research assistants and were supervised by the Principal Investigator. Data were double-entered into a Microsoft Excel data abstraction tool for cleaning prior to analysis. The Information collected from the study participants included their socio-demographic characteristics, PBO coverage, and utilization of LLINs. To confirm and evaluate the quality of the questionnaire, a pilot test was conducted to verify its validity and reliability

3.9 Pilot testing of the instruments for data collection

A pilot test is defined as a small-scale preliminary study conducted to evaluate feasibility, time constraints, expenses, and statistical variations. Its aim is to anticipate the necessary sample size and improve the research design before embarking on a larger-scale project. (Kothari, 2004; Mugenda, 2008). Performing a pilot test is essential for enhancing the precision and reliability of the research instrument prior to commencement of a study. Therefore, the PI pilot-tested the questionnaire instrument of the study before the actual study and administered the questionnaire following the intended research methodology. To gather adequate feedback, the pilot study included a minimum of 10% of the total sample size (Kothari, 2004; Mugenda, 2008). The PI therefore issued the questionnaire forms to 40 household heads who were from Mayenje and Bukhayo wards in Matayos sub-County. The pilot test group was requested to provide input on the difficulties encountered while completing the questionnaires so that any necessary adjustments could be made. The PI also aimed to evaluate the duration taken by each respondent to complete the questionnaire. Typically, respondents spent approximately 20-30 minutes on questionnaire completion. This timeframe was deemed satisfactory, considering the PI's required data in the sample size.

3.10 Data Collection Procedures

Before initiating the research, the PI crafted a comprehensive research proposal, serving as a roadmap for data collection. The proposal underwent evaluation by the Institutional Research and Ethics Committee (IREC) and the supervisors as well as other lecturers to ensure it provided clear guidelines for both data collection and analysis. Subsequently, five research assistants were trained by the PI to aid in data collection. A pilot study was conducted to evaluate the effectiveness of the research instruments, and adjustments were made based on identified limitations. Data collection occurred at the household level, with the PI and assistants visiting each house to gather relevant information. This approach aimed not only to enhance the return rates of questionnaires, but also to encourage study participants to provide genuine and thoughtful responses.

In case the household head was absent or was mentally unstable, an adult in the same household who was above 18 years of age, of sound mind and has been a resident in the area for not less than six months at the time of the visit and was willing to consent to participate was included to participate in the study.

3.11 Data Management and Analysis Techniques

Meetings were convened with research assistants every morning prior to the commencement of data collection, allowing for the identification and resolution of any challenges encountered in the previous day's fieldwork. Upon receiving the completed questionnaires, the Principal Investigator (PI) meticulously reviewed the responses for inaccuracies, omissions, exaggerated claims, or biases. The data were stored in digital format and securely managed by the principal investigator, who, along with supervisors, had exclusive access to them.Additionally, all collected information was entered into computers using only the research identification numbers, ensuring anonymity and confidentiality. Unauthorized individuals were prevented from accessing the data to maintain its integrity and privacy. As the study employed quantitative methodologies, the analysis was conducted quantitatively. This structured approach involves the conversion of observed information into numerical data, providing insights into various aspects of the research, typically addressing questions related to "what" or "how many." about a particular phenomenon. (Bryman, 2006). First, the process involves reducing the collected data to a manageable size. Then, the PI creates summaries, detects patterns, and finally utilizes statistical methods to help understand the findings in relation to the research questions. (Kennedy *et al*., 2011).

In this study, the Principal Investigator (PI) employed both descriptive and inferential analysis methods. Descriptive statistics such as means, standard deviations, frequencies, and percentages were utilized to illustrate the characteristics of the variables under investigation. This involved a thorough examination of the data to succinctly outline its fundamental attributes and associations. The primary aim of this process was to assist the PI in identifying behavioral patterns and specific outcomes. Subsequently, the data was transferred to Stata version 16 software for analysis. Univariate analysis was conducted to summarize continuous variables using measures of central tendency and dispersion, while categorical variables were summarized using frequencies and proportions.

Bivariate analysis was performed to identify factors potentially associated with the utilization of PBO bed nets. Odds ratios with corresponding p-values were utilized as measures of association. Variables with a p-value of less than 0.2 in the bivariate analysis were further analyzed using multivariable binary logistic regression. This technique aimed to account for confounding variables and effect modifiers, with a backward elimination approach used to identify independent predictors of PBO net utilization. A significance level of p-value less than 0.05 and a 95% confidence interval were employed for all statistical analyses.

1. Data collection

2. Reviewed the formulated research questions based on the study objectives

3. Identification of a statistical software for analysis

4. Statistical methods adopted

5. Generation of output and interpretations for the results

6. Preparation of the analyzed results report

Figure 3: Data management and analysis plan

3.11 Ethical consideration

Ethics refer to professional standards of behavior that differentiate between acceptable and unacceptable behaviors of a practice. Ethical considerations involve an essential part of research. Ethical approval for this study was sought and obtained from Moi Teaching and Referral Hospital/Moi University Institutional Research and Ethics Committee (IREC), Approval No. **FAN: 0004142 (Appendix IX)**. A study permit was obtained from NACOSTI, License No. **NACOSTI/P/22/18175 (Appendix VIII)**. Authorization to carry out the study was sought from the Department of Health and County Commissioner of Busia County. In addition, informed verbal consent was granted from each household head or their equivalent before interviews at the household level. Each household interviewed received a unique identification number consisting of the household number to ensure confidentiality. The PI furnished the study participants with contact details should they desire to request a copy of the research findings or had any other inquiries with regards to the study.

3.12 Operational definition of the variable

Operationalizing variables means precisely defining them into measurable factors. This helps ensure that the research methodology can be accurately replicated. Operationalization simplifies the study, analysis, and drawing of conclusions from the defined variables. In this study, independent variables included socio-demographic factors such as age group, gender, occupation, place of residence, marital status, income, family size, and educational level. "Coverage" was defined as the ownership of nets by households, while "universal coverage" was defined as the proportion of households with at least one net for every two people (Zhou *et al.*, 2014). The dependent variable in this study was the usage of PBO treated nets, categorized as either proper or poor. Proper utilization was defined as sleeping under a mosquito net the night before, consistently using the net every day of the week, ensuring the net is properly tucked and hung, and meeting the coverage criteria (Tesfazghi *et al.*, 2016).

Table 2: Operationalization of Variables

VARIABLES	INDICATORS	LEVEL OF MEASUREMENT	STATISTICAL MEASURE
Dependent variables			
Utilization of PBO treated nets	Number of days slept under treated mosquito net	Interval	Odds ratio
Independent variables			
Socio-demographic factors	Age group	Ratio	Mean and standard deviation
	Sex	Nominal	Frequencies and Proportions
	Occupation	Nominal	Frequencies and Proportions
	Residence	Ordinal	Frequencies and Proportions
	Marital status	Nominal	Frequencies and Proportions
	Family size	Nominal	Frequencies and Proportions
	Education level	Interval	Frequencies and Proportions
Coverage	Proportion of household with at least one treated net for two individuals.	Nominal	Frequencies and Proportions

CHAPTER FOUR

4.0 RESULTS

4.1 Socio-demographic characteristics of the respondents

A total of 402 participants were surveyed, with 234 (58.21%) from Burumba Ward and 168 (41.79%) from Matayos South Ward. Among them, 259 (64.43%) were household heads, while 143 (35.57%) were other household members who responded in the absence of the head. Among those who responded on behalf of the household heads, 103 (72.03%) were spouses, 32 (22.38%) were adult children, 4 (2.80%) were sons or daughters-in-law, and 4 (2.80%) had no relation to the head. The average age of participants was 41.23 years, with a standard deviation of 16.72 years. The youngest respondent was 18 years old, and the oldest was 90 years old. The most common age group was 30-49, with 159 participants (39.55%), followed by 18-29 with 121 participants (30.10%), and 50–69 with 92 participants (22.89%). Only 30 individuals (7.46%) were 70 years and older. Females accounted for 313 (77.9%) of the participants, while males were 89 (22.1%). In terms of education, 181 participants (45%) had primary education, 139 (34.6%) had secondary education, and only 26 (6.5%) had tertiary education. The majority lived in rural areas (268, 66.7%), with 134 (33.3%) in urban areas. Approximately 86.6% had informal occupations, 287 (71.39%) were married, and 393 (97.8%) were Christians. Regarding household size, 218 (54.23%) had 1–5 members, 167 (41.54%) had 6–10 members, and 17 (4.23%) had over 10 members. These details are summarized in Table 4.1.

Table 3: Socio-demographic characteristics of the study population

Variable	Frequency	Percentage
Age		
18–29	121	30.10
30–49	159	39.55
50–69	92	22.89
70 and above	30	7.46
Sex		
Male	89	22.10
Female	313	77.90
Education Level		
No formal education	56	13.90
Primary	181	45.00
Secondary	139	34.60
Tertiary	26	6.50
Occupation		
Formal	54	13.40
Informal	348	86.60
Residence		
Rural	268	66.70
Urban	134	33.30
Marital Status		
Married	287	71.39
Single	105	26.12
Divorced	10	2.49
Religion		
Christian	393	97.80
Islam	6	1.50
Other	3	0.80

Household size		
Between 1–5	218	54.23
Between 6–10	167	41.54
Over 10	17	4.23

4.2 Coverage of PBO nets distribution in Matayos sub-County, Busia County.

Ownership was defined as having at least one PBO net in a household. During the study, 347 participants (86.32%) owned LLINs, while 55 (13.68%) did not. The majority of households, 183 (52.74%), owned 3–5 LLINs, 139 (40.06%) owned at most two LLINs, and 25 (7.20%) owned over 5 LLINs. Of the LLINs, 124 (35.73%) were torn, while 223 (64.27%) were intact and suitable for use. Out of all LLINs, 322 (92.80%) were PBO nets, and 25 (7.2%) were non-PBO nets. Among households with PBO nets, 129 (37.18%) had at most two, 175 (50.43%) had between 3 and 5, and 18 (5.19%) had over 5. The sources of PBO nets included mass net distribution (279; 86.65%), ANC visits (48; 14.91%), purchase from vendors (38; 11.80%), and receiving nets from friends or relatives (15; 4.66%). Universal coverage, defined as owning one net per two people in a household, was met by only 261 participants (64.93%). These results are summarized in Table 4.2.

Table 4: Respondents' access, coverage and universal coverage of PBO nets

Variable	Frequency	Percent
Access to LLINs (n=402)		
Yes	347	86.32
No	55	13.68
Number of LLINs in household (n=347)		
Two or less	139	40.06
Between 3–5	183	52.74
Over 5	25	7.20

LLINs condition (n=347)		
Torn	124	35.73
Intact	223	64.27
Type of LLINs in use (n=347)		
PBO'	322	92.80
Non PBO	25	7.20
Number of PBO nets in use (n=322)		
Two or less	129	37.18
Between 3–5	175	50.43
Over 5	18	5.19
Source of PBOs (n=322)		
Mass net distribution	279	86.65
ANC clinic	48	14.91
Market/Shop/Pharmacy	38	11.80
Friend/Relatives	15	4.66
Universal Coverage (n=402)		
Yes	261	64.93
No	141	35.07

4.3 Household utilization of PBO treated nets

Utilization was classified as either poor or proper. Proper utilization entailed sleeping under a mosquito net the previous night, correct installation, daily use of a treated net, tucking in the net, ensuring full body coverage, and meeting coverage criteria. According to these standards, 280 participants (69.65%) properly utilized the PBO nets, while 122 participants (30.35%) did not. In terms of household utilization, 329 household members (94.81%) slept under a mosquito net the night before the study, whereas 18 (5.19%) did not. Among the households that used mosquito nets the previous night, 60 (18.24%) had fewer than two members, 164 (49.85%) had 3-5 members, 100 (30.40%) had 6-10 members, and five (1.52%) had more than 10 members. Of those who slept under LLINs, 279 (84.80%) used

PBO nets, 25 (7.60%) used non-PBO nets, and 25 (7.60%) used both PBO and non-PBO nets. The primary reasons cited for sleeping under LLINs were protection against mosquitoes (45.24%), prevention of malaria (92.54%), availability of LLINs as the only nets (13.55%), and the long-lasting nature of LLINs (15.27%). Only 124 participants (35.73%) properly met all the utilization criteria. installed and tucked in the LLINs to cover their whole bodies. Reasons for not tucking in LLINs included perceiving them as a source of bed insects (65.47%), believing they had negative health effects (21.97%), finding the routine discouraging (8.08%), and thinking they trap mosquitoes (4.48%). The results are as tabulated in table 4.3

Table 5: Household utilization of PBO nets

Variable	Frequency	Percent
Household members slept under mosquito net last night (n=347)		
Yes	329	94.81
No	18	5.19
Number of household members who slept under LLINs last night (n=329)		
Two or less	60	18.24
Between 3–5	164	49.85
Between 6–10	100	30.40
Over 10	5	1.52
Type of LLINs in use in household (n=329)		
PBO	279	84.80
Non PBO	25	7.60
Both PBO and non PBO	25	7.60
Reasons for sleeping under LLINs (n=347)		
Get protection against mosquitoes	157	45.24
Prevents malaria	90	25.94
Only net available	47	13.55

LLINs are long lasting	53	15.27
No of days in the last week did you (self) use the LLIN? (n=347)		
None	17	4.90
1–2 days	1	0.29
3–5 days	8	2.31
6–7 days	321	92.51
No of days in the last week did family members use the LLINs? (n=347)		
None	22	6.34
1–2 days	1	0.29
3–5 days	6	1.73
6–7 days	318	91.64
Reasons for not using LLINs		
Bedbugs (n=402)		
Yes	319	79.35
No	83	20.65
Tucking in of LLINs (n=347)		
Yes	124	35.73
No	223	64.27
Covering the body (n=347)		
Yes	124	35.73
No	223	64.27
Reasons for not tucking in the LLINs (223)		
It traps mosquitoes	10	4.48
Brings bedinsects	146	65.47
Have a negative health effect	49	21.97
Discouraged by routine raising every	18	8.08
Morning after use		
Utilization (n=402)		
Proper	280	69.65
Poor	122	30.35

4.4 Associations between underutilization of PBO nets and explanatory factors (Bivariate analysis).

Household and individual variables presumed to be associated with the utilization of PBO-treated LLINs were assessed using a logistic regression model. Table 4.5 below presents the results of the bivariate analysis of PBO-treated LLIN utilization. The analysis revealed that household heads aged 30-49 years had a crude Odds Ratio (cOR) of 1.40 (95% CI 0.84-2.32). Households with heads in informal occupations had a cOR of 0.55 (95% CI 0.27-1.10), and households in urban Household and individual variables thought to be associated with the utilization of PBO-treated LLINs were evaluated using a logistic regression model. Table 4.5 below displays the bivariate analysis results for PBO-treated LLIN utilization. The analysis indicated that household heads aged 30-49 years had a crude Odds Ratio (cOR) of 1.40 (95% CI 0.84-2.32), while those with heads in informal occupations had a cOR of 0.55 (95% CI 0.27-1.10). Households located in urban areas had a cOR of 0.68 (95% CI 0.44-1.06).

Table 6: Associations between underutilization of PBO treated nets (Bivariate analysis)

Variable	**Utilized PBO (%)**	**No PBO utilized (%)**	**cOR (95% CI)**	**p-value**
Age				
18-29	23 (31.5)	50 (68.5)	Ref	
30-49	23 (25)	69 (75)	1.40 (0.84-2.32)	0.197
50-69	44 (26.2)	124 (73.8)	1.33 (0.74-2.38)	0.341
70 and above	15 (21.7)	54 (78.3)	1.81 (0.72-4.56)	**0.208**
Sex				
Male	23 (25.8)	66 (74.2)	Ref	
Female	82 (26.2)	231 (73.8)	1.14 (0.69-1.89)	0.603

Education Level				
Primary	13 (23.2)	43 (76.8)	Ref	
Secondary	48 (26.5)	133 (73.5)	1.13 (0.70-1.82)	0.625
Tertiary	38 (27.3)	101 (72.7)	1.28 (0.51-3.22)	0.599
No formal education	6 (23.1)	20 (76.92)	1.18 (0.61-2.28)	0.624
Occupation				
Formal	9 (16.8)	45 (83.3)	Ref	
Informal	96 (27.6)	252 (72.4)	0.55 (0.27-1.10)	**0.090**
Residence				
Rural	64 (23.9)	204 (76.1)	Ref	
Urban	41 (30.6)	93 (69.4)	0.68 (0.44-1.06)	**0.092**
Marital Status				
Married	76 (26.4)	211 (73.5)	Ref	
Single	2 (20)	8 (80)	1.07 (0.66-1.75)	0.777
Divorced	27 (25.7)	78 (74.3)	1.80 (0.37-8.64)	0.464
Religion				
Christian	104 (26.5)	289 (73.6)	Ref	
Islam	1 (16.7)	5 (83.3)	2.2 (0.25-19.01)	0.474
Other	0 (0)	3 (100)	0.88 (0.08-9.79)	0.917
Household Size				
1-5	45 (20.6)	173 (79.4)	Ref	
"6-10	53 (31.7)	114 (68.3)	0.66 (0.43-1.03)	**0.069**
Over 10	7 (41.2)	10 (58.8)	0.51 (0.18-1.39)	**0.187**
Coverage				
Yes	90 (77.6)	26 (22.4)	Ref	
No	15 (5.2)	271 (94.8)	0.02 (0.01-0.03)	**0.001**

4.5 Factors linked to the underutilization of PBO nets within the community of Matayos sub-County (multivariate analysis)

The variables significantly associated with the utilization of PBO nets, identified through bivariate analysis with a p-value < 0.2, included age, household size, occupation, residence, and coverage. These factors were then analyzed together in a multivariate logistic regression model to determine their predictive power for PBO net utilization, detailed in Table 4.5 below.

The findings of the multivariable logistic regression highlight occupation and coverage as significantly linked with the utilization of PBO-treated nets. Specifically, households where the head holds an informal occupation exhibit the following odds: (aOR = 0.29, 95% CI = 0.11–0.78). This suggests that households with heads in informal occupations are significantly less inclined to use PBO nets compared to those with heads in formal occupations. The 95% confidence interval (0.11-0.78) indicates the likely range of the true odds ratio with 95% probability. The p-value of 0.014 confirms that this association is statistically significant and not a random occurrence.Likewise, households that have not achieved universal coverage show the following odds: (aOR = 0.01; 95% CI = 0.01–0.03). This indicates that households lacking universal coverage are significantly less likely to utilize PBO nets compared to those with universal coverage. The 95% confidence interval (0.01-0.03) provides a range within which the true odds ratio likely falls with 95% probability. true value of the odds ratio is likely to fall within this range with a 95% probability. The p-value of 0.001 indicates that the association is statistically significant and unlikely to have occurred by chance.

Table 4.5: Multivariable logistic regression analysis of association between utilization of PBO nets and explanatory factors linked to usage of PBO nets within the community of Matayos Sub-county.

Table 7: Factors linked to the usage of PBO nets within the community of Matayos sub-County (Multivariate analysis)

Variable	**Utilized PBO net (%)**	**No PBO utilized (%)**	**cOR (95% CI)**	**aOR (95% CI)**	**p-value**
Age					
18-29	23 (31.5)	50 (68.5)	Ref	Ref	
30-49	23 (25)	69 (75)	1.40 (0.84-2.32)	1.29 (0.57-2.91)	0.539
50-69	44 (26.2)	124 (73.8)	1.33 (0.74-2.38)	1.35 (0.50-3.66)	0.559
70 and above	15 (21.7)	54 (78.3)	1.81 (0.72-4.56)	0.85 (0.20-3.71)	0.834
Occupation					
Formal	9 (16.8)	45 (83.3)	Ref	Ref	
Informal	96 (27.6)	252 (72.4)	0.55 (0.27-1.10)	0.29 (0.11-0.78)	**0.014**
Residence					
Rural	64 (23.9)	204 (76.1)	Ref	Ref	
Urban	41 (30.6)	93 (69.4)	0.68 (0.44-1.06)	1.69 (0.80-3.60)	0.171
Household Size					
"1-5"	45 (20.6)	173 (79.4)	Ref	Ref	
"6-10"	53 (31.7)	114 (68.3)	0.66 (0.43-1.03)	1.44 (0.68-3.06)	0.345
Over 10	7 (41.2)	10 (58.8)	0.51 (0.18-1.39)	0.87 (0.16-4.64)	0.875
Coverage					
Yes	90 (77.6)	26 (22.4)	Ref	Ref	
No	15 (5.2)	271 (94.8)	0.02 (0.01-0.03)	0.01 (0.01-0.03)	**0.001**

4.6 Reasons for underutilization of PBO-treated nets

In this study, participants who did not use PBO-treated nets the night before cited various reasons, including torn nets (44.4%), fear of bedbug infestations (33.3%), high indoor temperatures (5.56%), insufficient nets for the family (5.56%), nets inhibited by bedbugs

(5.56%), and 5.56% reported that the nets had been washed. These results are illustrated in the figure 4.6 below.

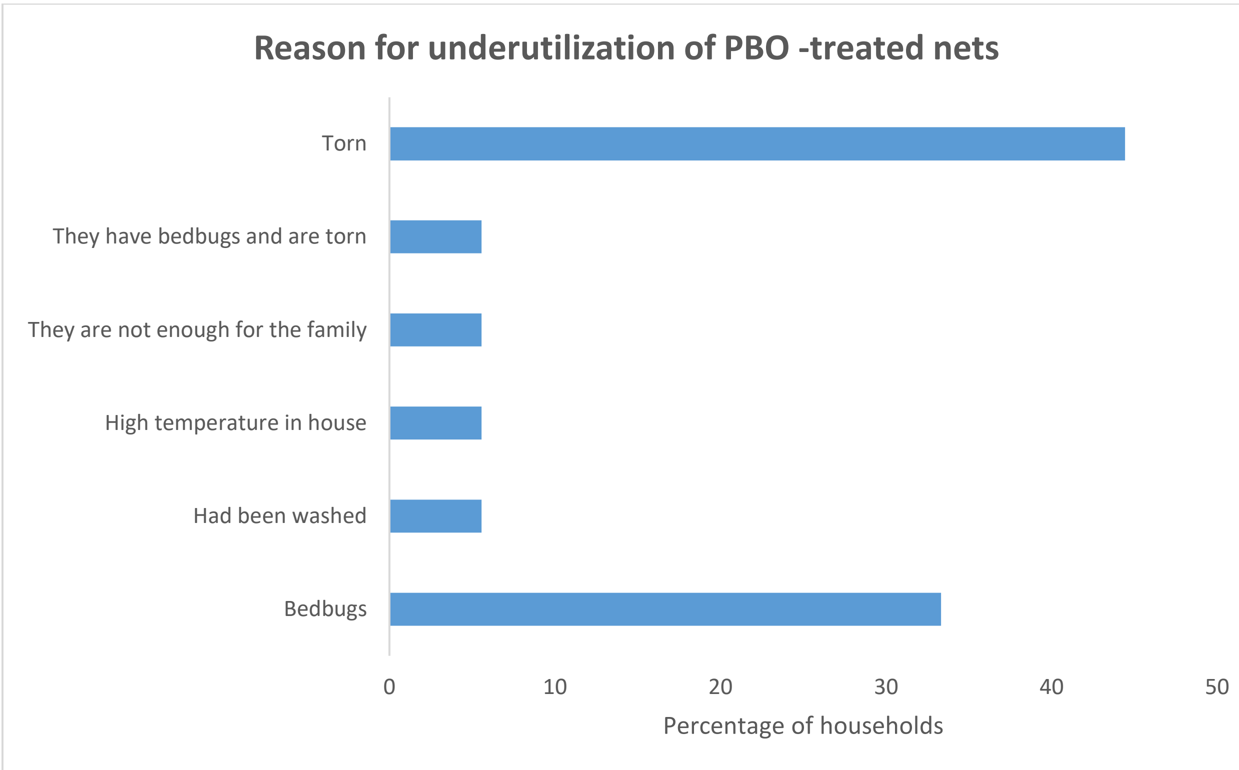

Figure 4: Reasons for underutilization of PBO-treated nets

4.7 Reasons behind the utility of PBO-treated nets among the respondents

The majority of study participants (46.34%) reported using PBO-treated nets because they were the only nets available within reach. Additionally, 30.49% used them to prevent malaria, 13.72% because the nets were still in good condition, and 4.88% because they were freely distributed by the national government. Other reasons cited included government policy (0.30%), adequate size (0.91%), durability (2.13%), lack of negative side effects (0.61%), and prevention of bedbug infestations (0.61%).

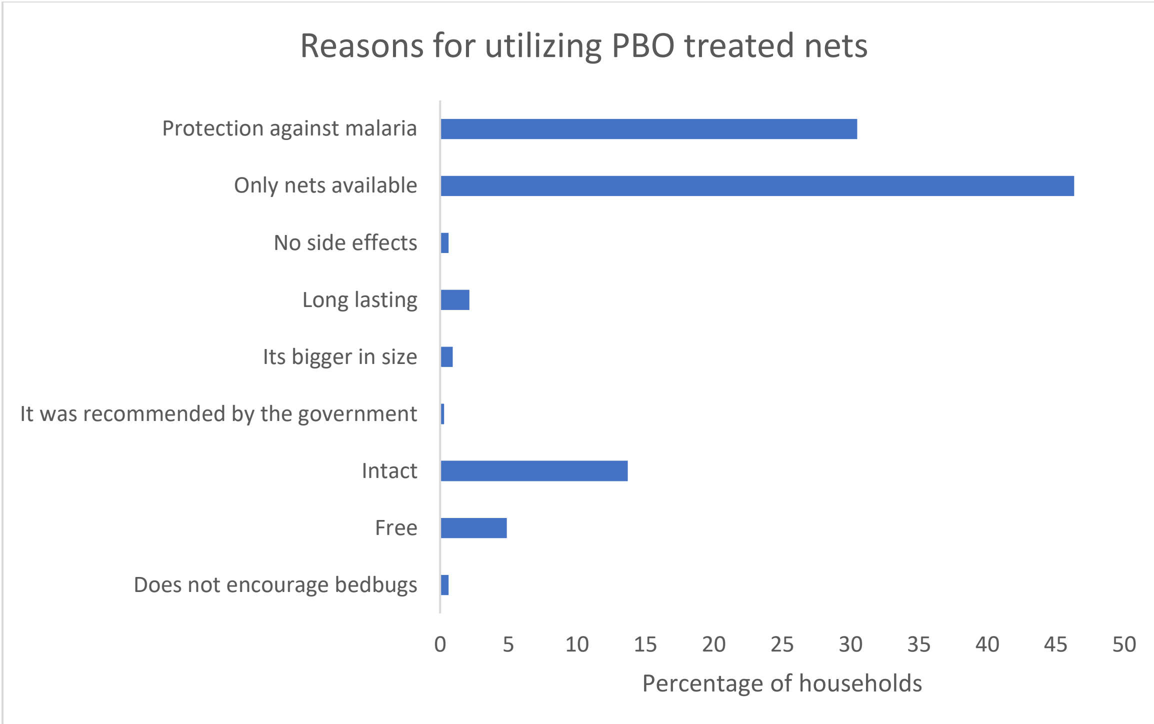

Figure 5: Reasons behind the utility of PBO-treated nets among the respondents

The study participants proposed several recommendations to boost the adoption of PBO-treated LLINs. These recommendations include supplying larger nets with extended hanging ropes or hooks, incorporating additional chemicals into the nets, enhancing their quality, expanding net distribution in villages through government programs, adding chemicals that also kill bedbugs, providing continuous education on the benefits of LLINs, offering nets in various shapes, and increasing the frequency of government distribution cycles.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Summary of Findings

This section summarizes the research findings. The study sought to determine the socio-demographics, coverage and factors associated with the underutilization of PBO nets in the control of malaria cases in Matayos sub-County, Busia County. The summary has been arranged according to the sequence of the research objectives.

5.1.1 Socio-demographic factors associated with the utilization of PBO treated nets

The study revealed that the demographic makeup of the surveyed population played a crucial role in predicting the coverage and utilization of LLINs. It was observed that participants spanned from 18 to 90 years in age, with an average age of 41.23 years. Notably, a substantial portion of the participants belonged to the 30 to 49 age group, suggesting that older individuals predominantly led households. Consequently, younger households constituted only 18.2% of the overall study population. This led to a clear association between the age of the household head and the utilization of LLINs, with older individuals showing higher rates of usage. These findings are consistent with prior research, underscoring the significance of age as a key factor influencing the utilization of bed nets (Hoynes *et al*., 2016; Orinda *et al*., 2005). This could be due to the perception that younger individuals like youths are at a lower risk of getting infected with malaria (Hoynes *et al*., 2016; Orinda *et al*., 2005). People aged 18 and older generally have more access to information about preventing malaria and using LLINs correctly. Previous research has stressed the necessity of ensuring extensive LLIN coverage across all age groups (Tassew *et al*., 2017; Teklehaimanot *et al*., 2007) since sustained use is not associated with rebound mortality among older children (Eisele *et al*., 2012).

Religion plays a significant role in shaping individuals' perspectives and behaviors, including their approach to seeking healthcare. While many Christians, particularly traditionalists, tend to prioritize accessing professional medical services, certain Christian sects believe in divine healing and may not seek medical attention when ill. In this study, the majority of participants (97.8%) identified as Christians, with only 1.5% identifying as Muslims. When it came to the utilization of PBO treated nets, 91% of the Christians demonstrated proper usage, while the utilization rate among Muslims, comprising 1.5% of the sample, was not reported. Residents in the study area, all of them reported a higher PBO net coverage ratio. Religion was, however, not associated with PBO treated net use, which was inconsistent with a study by (Ndugga Patricia, 2013) which found that religious affiliation influenced the prevention (use of a treated net) and treatment of malaria especially among children, our study did not focus on malaria treatment.

Majority 71.39% of the study participants did indicate that they were married, while only 2.49% of the sample population were divorced. In most of the studied households, married individuals had reported proper utilization and a higher coverage ratio of PBO treated nets as opposed to single study participants. These were consistent with findings of studies by Tapera (2019) where married women were more likely to own and effectively utilize a LLIN compared to single women. Also, children who lived with both parents were four times more likely to use LLINs compared to children from single parents (Imaledo, 2021), due to parental influence.

Of the study participants, 86.1% had at least some level of education with a majority having attained primary education. This implied that at least 86% of the total population had read and had knowledge of malaria infection and possible control measures that could be taken as this was a widely taught concept from primary school level (basic level of education in Kenya). Two studies, one in Sierra Leone one and another in Ghana had found out that the level of education has influenced in the use of PBO treated bed nets, and that knowledge levels have been associated with better coverage ratios and proper utilization of LLINs (Aberese-Ako *et al*., 2019; Bennett *et al*., 2012). Education is one of the reasons that has promoted campaigns to fight malaria infection among communities in the country. Household education level in terms of awareness, has brought preventive measures of malaria and ways to effectively utilize LLINs that has contributed significantly to a reduction in malaria infection rates in disease endemic areas.

The households that averaged 1–5 members, as reported by 54.23% of the sample population, were the most participants who properly utilized the PBO treated nets and were employed, either formally or informally.

5.1.2 The coverage of PBO treated nets distribution in Matayos sub-County, Busia County

In general, the utilization of PBO treated nets is closely linked to their coverage within households. Analysis of household sizes in the study indicated that each household was anticipated to possess at least one PBO treated mosquito net. Those households with a ratio of one net per two individuals were observed to demonstrate more effective utilization of PBO treated nets compared to households with fewer nets relative to their population size. Adequacy of nets was attributed to the number of people sharing a bed per household. A study done in Cameroon indicated that societies with households having fewer individuals, tend to have a better coverage ratio of PBO treated nets as opposed to societies with larger households (Njumkeng *et al.*, 2019).

Households with men as the household heads in this study reported a high proportion of coverage for PBO nets, which was contrary to study findings by Inungus which reported more coverage in women-headed households in the Democratic Republic of Congo on the use of LLIN (Inungu *et al.,* 2017). Inungu indicated that this might have been attributed to the reproductive nature of women and sharing information on the importance of LLINs, hence boosting up the coverage of LLINs. The effects of malaria on pregnant women and their infants places them at a vulnerable position, consequently, they take appropriate caution by exploring ways of preventing infection hence boosting their coverage and utilization of PBO treated nets (Eisele *et al.*, 2012). During ANC visits, women are usually given PBO treated nets to help them minimize the rate of getting infected with malaria which is known to greatly affect pregnancy outcomes. After birth, they are also given a PBO treated nets and are encouraged to consistently and properly use them. Women have also been known to be very active when it comes to participation in community activities like mass distribution of nets country-wide as opposed to men who view themselves as too busy to go for such services. Such measures have been reported to have a great effect when it comes to increased knowledge of net use and coverage.

Universal coverage of PBO treated nets was found to be 64.93% in this study, which was consistent with a study in Cameroon (Njumkeng *et al.*, 2019). A similar study in Myanmar reported a high coverage of PBO treated nets (Dunning *et al.*, 2022). Another study in Ethiopia had recorded an even higher coverage (Lunde *et al.*, 2013*).* In Mozambique a study reported a moderate coverage of PBO treated nets (Van Voorhis *et al.*, 2016*)*. Similar impressive results were demonstrated in Nigeria (Iyanda *et al.*, 2020). Proper coverage tend to have a positive impact on utilization of PBO treated nets while inadequate coverage has a negative impact on their utilization. This means that households with adequate coverage would most likely properly utilize the PBO treated nets compared to households with inadequate coverage. A Ugandan study reported a higher percentage of participants who utilized a mosquito net during the preceding night (participants who properly utilized LLIN) from households with sufficient coverage (Gonahasa *et al.,* 2018)*.* Similar studies from Mozambique (Quive *et al.*, 2015) and Ethiopia (Tassew *et al.,* 2017) supported this studys finding that people who own LLINs were more likely to utilize them compared to those who did not own one. However, adequate coverage in most cases does not directly translate to proper utilization of the PBO treated nets (Inungu *et al.,* 2017). There were also other factors that influenced utilization of PBO treated nets in households with proper coverage, which include; presence of a child under-five, age and gender of the participant and the size of the households (Gonahasa *et al.,* 2018*)*.

5.1.3 Factors associated with the underutilization of PBO treated nets in Matayos sub-County, Busia County

Recognizing the precise factors that impact the consistent use of PBO treated nets is crucial for maintaining malaria control and ultimately advancing towards the elimination of the disease. Through multivariate analysis, it was found that informal occupation and universal coverage emerged as statistically significant indicators strongly linked to the utilization of PBO nets. Conversely, socio-demographic traits such as age, gender, education, marital status, household size, and religion did not demonstrate significant associations with the utilization of PBO treated nets.

The utilization of PBO treated bed nets was lower in households with heads in informal occupation sector compared to those in formal occupations (aOR = 0.29, 95% CI = 0.11-0.78). This result was in agreement with the findings by (Gonahasa *et al*., 2018) which found that occupation significantly influenced utilization of PBO treated nets. In contrary outcome, individuals with formal occupations were most likely to prefer other prevention methods, like the use of insecticides other than the nets (Iyanda *et al*., 2020). The PBO treated bed nets have also been reported to be small in size (WHO, 2020a) and individuals with formal occupation could afford big sized beds, and therefore would prefer larger LLINs *(*Iyanda *et al.,* 2020). It has also been shown that expenditure on health care and on all forms of malaria prevention strategies often depends on the type of infrastructure available at the community level, including the quality of roads and proximity to access market centers *(*Iyanda *et al.,* 2020*;* Kanmiki *et al.,* 2019). Such amenities are more available in urban areas and have been proven to have more impact in the utilization of PBO treated nets than in rural settings as supported by this study.

In this study households without universal coverage for PBO treated bed nets had significantly lower odds of utilizing a PBO-treated LLIN as compared to those with universal coverage (aOR = 0.01, 95% CI = 0.01-0.03). Our findings were contrary to a study by (Raghavendra *et al.,* 2017) which found that the proportion of households that met the universal coverage criteria was only 39%. The Raghavendra study concluded that universal coverage of bed nets was inadequate in the study clusters making it difficult for all household members to share the available PBO treated bed net.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions of the study

The research found that low education, single parenting, religion and house hold size socio-demographic factors were not associated with utilization of PBO bed nets, only informal employment showed a significant connection to the use of PBO (pyrethroid-piperonyl butoxide) treated nets.

The universal coverage of PBO bed nets fall short of the national target of 80%, indicating a need to increase efforts in distributing through innovative channels to supplement the routine ones

The low usage of PBO-treated nets is linked to factors like informal occupation and the universal coverage. This highlights the necessity to address both occupational differences and improve overall coverage to ensure wider access and awareness for better net utilization.

6.2 Recommendations of the study

The study makes the following recommendations:

- Given that informal occupation is the sole socio-demographic factor significantly linked to PBO-treated net utilization, it is advised to concentrate efforts on raising awareness and distributing PBO nets among individuals in informal occupations. This could involve community-based educational programs, partnering with local leaders, and leveraging informal networks to spread information about the benefits and proper use of PBO nets.

- There is need for continuous PBO nets distribution through innovative channels like schools and upscale routine net distribution beyond targeted population (child and pregnant women) to supplement mass net distribution to improve universal coverage.
- Targeted interventions are necessary to boost awareness and distribution of PBO bed nets among various occupational groups and to increase overall coverage to achieve national targets.

6.3 Suggested area for further research

A follow up study should be carried out, and similar studies conducted in other regions where there is low coverage of PBOs to establish effective methods to improve on PBO treated nets utilization and also the misconceptions on bedbug infestations.

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APPENDICES

Appendix I: Household consent form

Ward

Name………………………………………………………………………………………….

Village

Number/Name……………………………………………………………………………

Household Number

………………………………………………………………………………

Interviewer's

Name………………………………………………………………………………

Title of Study: Coverage and factors associated with the utilization of Pyrethroid-piperonyl butoxide treated nets in Matayos Sub-County, Busia County.

Introduction:

My name is Aricha Stephen I am from the Division of Field Epidemiology and Laboratory Training/DNMP. We are conducting a survey about malaria on the recently distributed mosquito nets in Matayos Sub-County.

Purpose of the study:

An efficient and effective vector control intervention is important to the implementing program and other stakeholders. The research will provide information on the coverage and factors associated with utilization of LLINs. This has an impact of advising individuals on the proper utilization of LLINs with the aim of protecting all that are at risk, community sensitization on malaria prevention and control, thus, saving resources spent on the treatment of new cases in terms of drugs and expenses as a result of prolonged hospitalization. The findings will inform the Ministry of health management at the National and County governments and other stakeholders on the intervention's strengths and weaknesses and areas that need improvement.

Expectations of the study:

If you agree to participate in the study, I wish to ask you some questions using a standardized questionnaire. This will take between 30 to 45 minutes to complete. Whatever information you provide will be kept confidential and will not be shown to anyone other than members of our survey team. Your participation in this survey is voluntary, and if we should come to any question you don't want to answer, just let me know and i will go on to the next question; or you can stop the interview altogether at any time.

Risks:

There are no envisaged risks to you as a participant in this study since there is no collection of human sample, names and geo-coordinates. Through coding any risks associated with potential loss of confidentiality will be minimized.

Benefits:

The information we collect will help the government to plan health services especially on malaria prevention and control. The results of this study will be communicated and disseminated to the people concerned for them to take action on the recommendations that will come out from the study results.

Confidentiality:

Any information obtained from you will be kept confidential and used solely for purposes of this research only. The results of this research may be published in scientific journals or presented at scientific conferences, but your identity will not be disclosed.

Compensation:

If you accept to take part in this study, there will be no payment for participation.

Alternatives:

You have a choice to agree or not to agree to participate in this study. If you agree to participate in study you are allowed to withdraw from the study at any time if you so wish without any consequences whatsoever.

Approval of the study: This study will be approved by the Moi Teaching and Referral Hospital Ethics and Research Committee and the Board of Post graduate studies Moi university P.O. Box 4600, Eldoret, Kenya

In case of any further questions or concerns, you can address them to the directors of the above institutions.

Verbal Consenting:

I have been fully informed about the study, its risks and benefits. I had the opportunity to ask questions which have been answered satisfactorily. I also understand that I am free to choose not to take part in this survey at any time and that if I decline, it will not affect my rights, position or privileges or my family in any way. I therefore verbally consent to voluntarily participate in this study.

Date…………………………………………………………………………………………..

Contact information

If you have any questions regarding this study you may contact my supervisors:

1. Dr. Judith Mangeni
   Department of Epidemiology and Medical Statistics
   Moi University
   Phone No. 0722647415
2. Dr. Elvis Oyugi
   Department of Epidemiology and Medical Statistics
   Moi University
   Phone No. 0720483652

Appendix II: Household Questionnaire

Ward Name………………………………… Village Number/Name…………..……………

Household Number ……………………………………………………………………..……..

Respondent: Household head (If not state the relationship to the respondent)

- Wife or Husband
- Son or Daughter
- Parent in law
- Son or Daughter in law
- Parent
- Parent in law
- Not related

Interviewer's Name……………………………………Contact…………..…………………

Date……………………………………………………………………..……..……… …..

PART I: SOCIO-DEMOGRAPHIC FACTORS OF THE RESPODENT

1. Age (Years) ____________
2. Gender

   [ ] Male

   [ ] Female
3. Highest level of education attained

   [ ] No formal education

   [ ] Primary

   [ ] Secondary school

   [ ] Tertiary
4. Occupation

   [ ] Formal

   [ ] Informal
5. Residence

[ ] Rural (if residence is more than 20 km from the Sub-County headquarters and Matayos Semi-Urban town)

[ ] Urban (if residence is within 20 km from the Sub-County headquarters and Matayos Semi-Urban town)

6. Marital status

   [ ] Married

   [ ] Single

   [ ] Student

7. Religion

   [ ] Christian

   [ ] Islam

   [ ] Traditional worshiper

   Others ………………………………

8. Number of people in the house__________

PART II: COVERAGE AND ACCESSIBILITY OF LLINs NETS (PBO)

1. Does your household have any LLINs?

   [ ] Yes

   [ ] No

2. How many mosquito nets does your household have? ____________

3. How many are PBOs [ ] (observe for a PBO tag and color) and non PBOs [ ] …………..

4. How many are in use? PBOs [ ] and non PBOs [ ]

5. What is the source of your LLIN?

   [ ] Mass net distribution [ ]

   [ ] Antenatal clinic [ ]

   [ ] Market/Shop/Pharmacy

   [ ] Friend/Relative

   [ ] Others? __________________

6. Were the LLINs readily available

   [ ] Yes

   [ ] No

7. What is the condition of the LLIN?

    [ ] Intact

    [ ] Torn

PART III: UTILIZATION OF LLINs

1. Did anyone in the family sleep under this mosquito net last night?

    [ ] Yes

    [ ] No

2. If yes, how many people in the household slept under the net last night?
3. Which net was used?

    [ ] PBO net

    [ ] non-PBO net

4. If yes or no to question 3, please explain why you or your family member slept under the net.
5. How many days in the last week did you use the net? …………………………………...
6. How many days in the last week did your family members sleep under a net?
7. What was the main reason why this net was not used last night?
8. How do use your LLINs?
    - Tucking in
    - Hangs loose over the bed
    - Covering the body
    - Hanging at one corner of the room
    - Hanging it over the window or door
    - Others (Specify)
9. Why don't you tuck in the LLINs
    - It traps mosquitoes
    - Brings bedinsects
    - Have a negative health effect
    - Discouraged by routine raising every morning after use
    - Others (Specify)

10. What do you think should be done to enhance correct use of LLINs (Provide adequate information on how to hang LLINs, they should be made readily available, they should be given freely of charge, and the price should be reduced).

Appendix III: Observation Checklist

List	**Remarks**
Condition of the net	
How the net is hanged	
What is the brand of the net observed?	
Is the net covering the whole bed?	

Appendix IV: Scoring criteria on PBO net utilization

	Variable	Score (Yes=1 and No=0)
1	Did anyone in the family sleep under this mosquito net last night?	
2	How many days in the last week did you use all the nets (7 days=1, 0-6=0)?	
3	Tucking in	
4	Hangs loose over the bed	
5	Covering the whole body	
6	Number of people vs. nets (one net for two people)	
7	Average score (1) Greater than 1=proper utilization Less than 1 =poor	

Appendix V: Data analysis dummy table

PBO net indicator	**Number(n/N)**	**Percentage**	**Mean**	**CI**
Number of sleeping places per household				
Number of people per household				
Mean number of LLIN per household				
Households with any type of mosquito net				
Households with at least one LLIN				
Households with net to sleeping space ratio				
Households with persons to net ratio of				
Percent of nets correctly hung through demonstration				

Appendix VI: Work plan

Objective	**To determine the coverage, knowledge, attitude, practices and factors associated with utilization of PBO nets**					
Activities		**2021**	**2022**			
		10-12	**1-4**	**5**	**6**	**7**
1.1	Protocol writing and approval by supervisors					
1.2	Protocol submission to IREC for approval					
1.3	Data collection and analysis					
1.4	Thesis writing					
1.5	Mock defense Thesis submission for marking					

Appendix VII: Budget

s/n	Item	Unit	No. of days	Cost per item	Total
1	**Study personnel**				
	Supervision	2 person	2 visits	15,000	60,000
	Research Assistants(5 people)	5 person	30 days	2,000	300,000
2	**Supplies and equipment**				
	Notebook	5 pieces	-	200	1,000
	Biro pen	1 box	-	500	500
	Questionnaires	1000	-	10	10,000
	Files	5 pieces	-	300	1,500
	Sanitizers	15 pieces	-	450	6,750
	Masks	10 boxes	-	400	4,000
3	**Travel and accommodation**				
	Interviewer	5 person	30 days	500	75,000
	Investigator	1 person	30 days	8,000	240,000
4	**Miscellaneous**				
	Training	10 person	2 days	10,000	20,000
	Grand total				**718,750**

Appendix VIII: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 341845

Date of Issue: 22/June/2022

RESEARCH LICENSE

This is to Certify that Mr.. Stephen Akuma Aricha of Moi University, has been licensed to conduct research in Busia on the topic: Coverage and factors associated with the utilization of Pyrethroid Piperonyl butoxide treated nets in Matayos Sub- County, Busia County for the period ending : 22/June/2023.

License No: NACOSTI/P/22/18175

341845

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix IX: Ethical Approval

MTRH/MU-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
Tel: 33471/2/3

Reference: IREC/164/2022
Approval Number: 0004142

26th May, 2022

Aricha Stephen,
Moi University,
School of Public Health,
P.O. Box 4606-30100,
ELDORET-KENYA.

Dear Mr. Aricha,

COVERAGE AND FACTORS ASSOCIATED WITH THE UTILIZATION OF PYRETHROID-PIPERONYL BUTOXIDE TREATED NETS IN MATAYOS SUB-COUNTY, BUSIA COUNTY

This is to inform you that ***MTRH/MU-IREC*** has reviewed and approved the above referenced research proposal. Your application approval number is ***FAN: 0004142.*** The approval period is **26th May, *2022- 25th May, 2023.***
This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, Material Transfer Agreements (MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***MTRH/MU-IREC***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***MTRH/MU-IREC*** within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***MTRH/MU-IREC*** within 72 hours.
v. Clearance for export of biological specimens must be obtained from ***MOH at the recommendation of NACOSTI*** for each batch of shipment.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***MTRH/ MU-IREC.***

Prior to commencing your study; you will be required to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and other relevant clearances from study sites including a written approval from the CEO-MTRH which is mandatory for studies to be undertaken within the jurisdiction of Moi Teaching & Referral Hospital (MTRH) and its satellites sites.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
26 MAY 2022
APPROVED
P.O. Box 4606-30100 ELDORET

Sincerely,

PROF. E. WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD