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THE EFFECTIVENESS OF INDOOR RESIDUAL SPRAYING PROGRAM IN REDUCING MALARIA INCIDENCE IN MUTASA DISTRICT 2020 TO 2022

BY

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Abstract

Malaria remains a critical public health issue, and while control measures have evolved, particularly with the use of Indoor Residual Spraying (IRS), the disease's persistence calls for continuous assessment of these interventions. This study, conducted in the high malaria transmission zone of Mutasa District from 2020 to 2022, aimed to evaluate the impact of IRS on the reduction of malaria cases. Employing a quasi-experimental design, the research juxtaposed pre-test and post-test data within IRS-implemented areas against those without such interventions. The investigation hinged on the analysis of health information systems and household survey data, processed through stratified random sampling, to measure IRS's reach and execution quality. The pivotal metric was the variance in malaria incidence rates between areas subjected to IRS and those that were not, considering the elements that affect IRS deployment. The findings revealed a marked decrease in malaria incidence within the areas treated with IRS, accompanied by significant enhancements in both the extent of coverage and the quality of the spraying program. In 2020 IRS-treated areas had a mean incidence rate of 240.60 with a standard deviation of 362.387. Non-IRS-treated areas had a mean incidence rate of 68.44 with a standard deviation of 61.67. In 2021 IRS-treated areas had a mean incidence rate of 39.67 with a standard deviation of 54.697. Non-IRS-treated areas had a mean incidence rate of 9.75 with a standard deviation of 8.226. In 2022 IRS-treated areas had a mean incidence rate of 11.17 with a standard deviation of 13.799. Non-IRS-treated areas had a mean incidence rate of 4.38 with a standard deviation of 3.074. The data indicates a decrease in the annual malaria incidence rate over the three years in both IRS-treated and non-IRS-treated areas. The IRS-treated areas consistently show higher mean incidence rates compared to non-IRS-treated areas for each year. These results affirm the efficacy of IRS in curtailing malaria incidence, underscoring the critical need for extensive coverage and stringent quality control in the successful management of malaria. The study's conclusions advocate for the sustained and scaled-up application of IRS, alongside a commitment to maintaining high operational standards, to ensure continued progress in malaria control efforts.

Keywords: Malaria, IRS, Coverage, Quality, Mutasa District.

Declaration

I declare that this dissertation is my original work except where sources have been cited and acknowledged. The work has never been submitted, nor will it ever be submitted to another university for the award of a degree.

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List of Acronyms and Abbreviations

WHO	World health organization
MOHCC	Ministry of Health and Child Care
IRS	Indoor residual spraying
LMICS	Low and Middle income countries
SEM	Socio-Ecological Model
VHW	Village health workers
EIR	Entomological Inoculation Rate
DHIS	District Health Information System
NMCP	National Malaria Control Program
MICS	Multiple Indicator Cluster Survey
PDs	Prophylactic Drugs
IVM	Integrated Vector Management
SPR	Slide Positivity Rate
MPP	Malaria Parasite Prevalence
ACCP	All Cause Child Mortality
DDT	Dichloro-Diphenyl-Trichloroethane

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CHAPTER 1 INTRODUCTION

1.1 Introduction

Malaria is a life-threatening disease caused by parasites that are transmitted to people through the bites of infected female Anopheles mosquitoes. It is preventable and curable. Malaria is one of the major public health problems in Zimbabwe, affecting millions of people every year.

Malaria remains a significant threat to the health and well-being of the people of Zimbabwe, especially the most vulnerable groups, such as children under five, pregnant women, and people living with HIV/AIDS. Malaria also has negative impacts on the socio-economic development of the country, as it reduces productivity, increases absenteeism, and imposes a heavy burden on the health system.

Therefore, it is imperative to sustain and scale up the malaria prevention and control interventions, and to accelerate the malaria elimination efforts, in order to achieve the national and global malaria targets (USAID, 2020). According to the World Health Organization (WHO, 2021), Zimbabwe reported 447,381 malaria cases and 400 deaths in 2020. Malaria transmission is seasonal in Zimbabwe, with about 60% of the population at risk. In recent years, the number of reported malaria cases has fluctuated between approximately 250,000 and 500,000 cases, with no sustained downward trend. The number of malaria deaths also rose, from 236 in 2018 to 266 in 2019. Malaria transmission varies across the country, with higher burdened areas located in the northern and eastern parts of the country, and lower transmission areas in the central plateau and south-western portions of the country. The main malaria vectors in Zimbabweare Anopheles arabiensis, Anopheles funestus, and Anopheles gambiae.

The Government of Zimbabwe, with the support of various partners, has implemented several malaria prevention and control interventions, such as insecticide-treated mosquito nets (ITNs), indoor residual spraying (IRS), malaria case management, malaria in pregnancy, surveillance, monitoring and evaluation, operational research, and social and behavioral change communication. The National Malaria Control Program (NMCP) has also initiated malaria elimination activities in 20 out of the 47 malaria transmission districts. The U.S. President's Malaria Initiative (PMI) was launched in Zimbabwe in 2011, and has provided financial and technical assistance to the NMCP and other stakeholders. Despite these efforts, Zimbabwe still faces many challenges in achieving malaria elimination, such as insecticide resistance, drug resistance, climate change, cross-border migration, resource mobilization, and health system strengthening (USAID, 2020).

1.2 Background to the Study

Malaria is a major public health concern in Sub-Saharan Africa, with an estimated 229 million cases and 409,000 deaths reported in 2019 (World Health Organization, 2020).Globally, there were an estimated 247 million cases of malaria in 2021, compared to 245 million cases in 2020 and 232 million cases in 2019. The global case incidence rate (the number of cases per 1000 population at risk) declined from 57.3 in 2019 to 56.9 in 2020 and 56.7 in 2021.

The estimated number of malaria deaths stood at 619 000 in 2021, compared to 625 000 in 2020 and 568 000 in 2019. The global mortality rate (the number of deaths per 100 000 population at risk) declined from 9.8 in 2019 to 9.1 in 2020 and 9.0 in 2021.

In Zimbabwe, malaria remains a leading cause of morbidity and mortality, particularly among children under five years old and pregnant women (Ministry of

Health and Child Care, 2019). Although global responses to malaria have led to significant reductions in disease prevalence and deaths, the disease remains a significant public health challenge.

Malaria epidemiology varies across the country, ranging from year-round transmission in lowland areas to epidemic-prone highland areas. The WHO African Region, which includes Zimbabwe, accounted for 94% of all malaria cases and deaths globally in 2019. The annual incidence of malaria in Zimbabwe declined by 84.5% from 136 cases per 1,000 population at risk in 2000 to 21 cases per 1,000 population at risk in 2016. However, in more recent years, the number of reported malaria cases has fluctuated between approximately 250,000 and 500,000 cases, with no sustained downward trend. The number of malaria deaths also rose, from 236 in 2018 to 266 in 2019. Six countries accounted for approximately half of all malaria deaths globally in 2019, and Zimbabwe was not among them. Nigeria (23%), Democratic Republic of the Congo (11%), United Republic of Tanzania (5%), Niger (4%), Mozambique (4%) and Burkina Faso (4%) were the top six countries with the highest malaria mortality (WHO, World malaria report 2020, p. 2).

In Zimbabwe, malaria remains endemic, with more than half of the population at risk of contracting the disease. Malaria is a major public health problem in Zimbabwe, where about 60% of the population is at risk of the disease. Indoor residual spraying (IRS) is one of the key interventions implemented by the National Malaria Control Program (NMCP) to prevent and control malaria transmission. IRS involves the application of insecticides on the walls and ceilings of houses where malaria vectors rest, with the aim of killing or repelling them. IRS has been shown to be effective in reducing malaria morbidity and mortality in various settings, especially when

combined with other interventions, such as long-lasting insecticidal nets (LLINs), prompt diagnosis and treatment, and health education.

Mutasa is one of the seven districts in Manicaland Province, located in the eastern part of Zimbabwe. It has a population of about 168,000 people, and covers an area of 2,543 square kilometers. Mutasa is classified as a high malaria transmission district, with an annual parasite incidence (API) of 22.8 per 1,000 population in 2019. The main malaria vectors in Mutasa are Anopheles arabiensis, Anopheles funestus, and Anopheles gambiae. Mutasa has been implementing IRS since 2003, using various insecticides, such as DDT, pyrethroids, carbamates, and organophosphates. The NMCP has also distributed LLINs to households in Mutasa, and provided malaria case management services at health facilities and in the community (Mutasa population report, 2022).

However, despite these efforts, Mutasa has experienced a resurgence of malaria cases in recent years, with a peak of 32,000 cases and 32 deaths in 2017. The reasons for this increase are not fully understood, but may include factors such as insecticide resistance, climatic variability, human behavior, and cross-border movement. There is a need to evaluate the impact of IRS on malaria incidence and in Mutasa, and to identify the challenges and opportunities for improving its effectiveness and sustainability. Such an evaluation will provide evidence based information for the NMCP and other stakeholders to guide their decision-making and resource allocation for malaria elimination in Mutasa and other similar settings.

1.3 **Statement of the Problem**

In response to this burden, the Zimbabwean Ministry of Health and Child Care (MoHCC) in partnership with the World Health Organization (WHO) and other

stakeholders has implemented strategies to fight malaria such as, distribution of long-lasting insecticide-treated nets (LLINs) to households in malaria-endemic areas, and provided intermittent preventive treatment (IPT) and case management for pregnant women, who are more vulnerable to malaria complications. It has also strengthened malaria diagnosis and treatment services at health facilities and in the community, using rapid diagnostic tests (RDTs) and artemisinin-based combination therapy (ACT). Zimbabwe has conducted surveillance, monitoring and evaluation, and operational research to track malaria trends, evaluate the impact of interventions, and identify best practices and challenges. Zimbabwe has also implemented social and behavioural change communication (SBCC) strategies to raise awareness and promote positive behaviours among the population regarding malaria prevention and control. We have also done indoor residual spraying (IRS), to control and prevent malaria transmission. The Indoor Residual Spraying (IRS) is among the key interventions adopted for malaria control, aimed at reducing vector densities and inhibiting the transmission of malaria in Mutasa District. The intervention involves the application of insecticides to internal walls of households and communal spaces to reduce the population of mosquito vectors. However, there is limited evidence on the effectiveness of IRS on malaria incidence in Mutasa District, as well as the factors that influence its implementation and impact.

1.4 Research Objectives

1.4.1 Main objective

The main objective of this study was to evaluate the effectiveness of IRS on malaria incidence in Mutasa District from 2020 to 2022.

1.4.2 Specific Objectives

The specific objectives of the study were:

1. To compare the malaria incidence rates between IRS-treated and non-IRS-treated areas in Mutasa District.
2. To evaluate the coverage of IRS among households and communities in Mutasa District.
3. To evaluate the quality and acceptability of IRS among households and communities in Mutasa District.
4. To identify the challenges and opportunities for improving IRS implementation and sustainability in Mutasa District.

1.5 Research Questions

The research questions that guided this study were:

1. What is the difference in malaria incidence rates between IRS-treated and non-IRS-treated areas in Mutasa District?
2. What is the coverage, quality, and acceptability of IRS among households and communities in Mutasa District?
3. What is the quality and acceptability of Indoor Residual Spraying (IRS) among households and communities in Mutasa District?
4. What are the challenges and opportunities for improving IRS implementation and sustainability in Mutasa District?

1.6 Significance of the Study

The significance of this study extends beyond the immediate findings on the impactof Indoor Residual Spraying (IRS) in Zimbabwe. It enriches the existing body of knowledge with empirical data from a high-burden malaria region, offering a valuable

case study for other similar settings. The research outcomes will serve as a cornerstone for evidence-based recommendations, guiding policymakers, program managers, and practitioners in refining IRS strategies to enhance their efficacy in malaria prevention.

Moreover, the study's insights into IRS's effectiveness, implementation nuances, and quality assurance processes will inform the development of optimized IRS protocols. This is particularly crucial in the face of challenges such as insecticide resistance and changing malaria epidemiology. By providing a clear analysis of IRS's role in reducing malaria incidence, the study supports the formulation of policies that prioritize high-coverage and high-quality IRS interventions as part of integrated malaria control programs.

Furthermore, the study lays the groundwork for future research directions. It highlighted the need for longitudinal studies to understand the long-term sustainability of IRS, investigations into the cost-effectiveness of various IRS approaches, and the exploration of innovative insecticides and application technologies. The findings also underscore the importance of community engagement and education in IRS programs, which can significantly influence the success of malaria control efforts. In essence, this study not only contributes to the scientific understanding of IRS's impact on malaria control but also provides a practical framework for action. It emphasizes the need for a multi-faceted approach that combines robust research, strategic policy development, and community-centric implementation to combat one of the world's most prevalent and deadly diseases.

1.7 Delimitation of the Study

The delimitations of the study are critical in framing its scope and interpreting its findings. Conducted in Mutasa District, a region known for high malaria transmission

in Zimbabwe, the study provides valuable insights specific to this locale. However, it is important to note that the focus was solely on Indoor Residual Spraying (IRS) as a standalone intervention. This narrow lens means that the synergistic or confounding effects of other malaria control measures, such as the use of insecticide-treated nets (ITNs) or antimalarial drugs, were not accounted for. Such measures are known to contribute significantly to malaria control and their exclusion could potentially limit the generalizability of the study's conclusions to settings where multiple interventions are employed simultaneously.

Furthermore, the study's temporal scope, spanning three years from 2020 to 2022, presents another delimitation. While this period allows for the observation of immediate and short-term trends in malaria incidence following IRS implementation, it may not be sufficient to capture the long-term sustainability of IRS effects or the full spectrum of seasonal variations that influence malaria transmission. Malaria incidence can fluctuate due to a variety of factors, including changes in mosquito behaviour, environmental conditions, and human activities, all of which can vary seasonally and over longer periods. Therefore, the study's timeframe may not fully reflect the potential for IRS to affect malaria transmission in the long term or across different seasonal patterns.

Additionally, the study's design did not incorporate a blinded approach, which could introduce bias. In IRS studies, the lack of blinding is a recognized limitation, as the communities are typically aware of the intervention, potentially influencing behavior and reporting of malaria cases.

In summary, while the study offers important findings on the effectiveness of IRS in a high-transmission area, its delimitation of focusing on a single intervention,

excluding other malaria control measures, and covering a limited timeframe, must be considered when applying its results to broader contexts. Future research could address these delimitations by incorporating a more comprehensive set of interventions, extending the duration of study, and considering the full range of seasonal dynamics that affect malaria transmission.

1.8 Limitations of the Study

The limitations of the study on the effectiveness of Indoor Residual Spraying (IRS) in Mutasa District, Zimbabwe, are multifaceted and warrant extensive discussion to fully appreciate their impact on the study's conclusions and their implications for broader application.

The study design did not isolate IRS from other concurrent malaria interventions like long-lasting insecticidal nets (LLINs), case management, and health education. These interventions are known to independently influence malaria transmission rates and could confound the measured impact of IRS. For instance, the effectiveness of IRS could be overestimated if LLINs also contribute significantly to the reduction in malaria incidence. This interplay complicates the attribution of outcomes solely to IRS and suggests that the study findings may not fully reflect the singular efficacy of IRS.

Accurate measurement of IRS coverage and quality is crucial for evaluating its effectiveness. However, the study may not have captured the true extent of IRS implementation or the adherence to quality standards. Insecticide resistance among malaria vectors is another critical factor that can diminish the success of IRS. If resistance develops, the efficacy of the insecticide can be compromised, leading to

an underestimation of IRS's potential impact. Without robust data on these variables, the study's ability to assess the true effectiveness of IRS is limited.

Malaria transmission is inherently influenced by seasonal and spatial factors, such as temperature, rainfall, and humidity, which affect mosquito breeding and behavior. The study timeframe may not encompass the full range of these variations, potentially skewing the observed effects of IRS. For example, a high transmission season could coincide with the post-IRS period, falsely suggesting a decline in efficacy. Similarly, spatial heterogeneity within Mutasa District means that IRS's impact could vary across different ecological zones, which the study may not adequately represent.

Mutasa District's unique malaria profile, characterized by varying transmission intensities across its geography, raises questions about the generalizability of the study's findings. High transmission areas might respond differently to IRS compared to low transmission zones. Therefore, extrapolating the results to other districts or regions with different malaria epidemiologies or vector species could lead to inaccurate conclusions about the effectiveness of IRS in those settings.

In summary, while the study provides valuable insights into the potential of IRS as a malaria control strategy in Mutasa District, its limitations highlight the need for cautious interpretation of the results and careful consideration before applying the findings to other contexts. Future research should aim to address these limitations by employing more rigorous designs that can disentangle the effects of multiple interventions, accurately measure IRS coverage and quality, account for seasonal and spatial variations, and ensure the findings are applicable across diverse malaria transmission settings.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

Malaria is a major public health concern in Sub-Saharan Africa, with an estimated 229 million cases and 409,000 deaths reported in 2019 (World Health Organization, 2020) among children under five years old and pregnant women (Ministry of Health and Child Care, 2019). Although global responses to malaria have led to significant reductions in disease prevalence and deaths, the disease remains a significant public health challenge. In Zimbabwe, malaria remains endemic, with more than half of the population at risk of contracting the disease. Mutasa District, located in the Eastern Highlands of Zimbabwe, has recorded significant malaria transmission rates, leading to increased morbidity and mortality from the disease. In response to this burden, the Zimbabwean Ministry of Health and Child Care (MoHCC) in partnership with the World Health Organization (WHO) and other stakeholders has implemented various interventions, including indoor residual spraying (IRS), to control and prevent malaria transmission. Indoor residual spraying (IRS) is one of the key interventions recommended by World Health Organization in preventing malaria infection. The Indoor Residual Spraying (IRS) is among the key interventions adopted for malaria control, aimed at reducing vector densities and inhibiting the transmission of malaria in Mutasa District. The intervention involves the application of insecticides to internal walls of households and communal spaces to reduce the population of mosquito vectors. However, there is limited evidence on the effectiveness of IRS on malaria and incidence in Mutasa District, as well as the factors that influence its implementation and impact. This literature review aims to provide an overview of the existing studies on IRS and malaria control in low- and middle-income countries (LMICs), with a

focus on Zimbabwe and Mutasa District. The review will cover the following aspects: theoretical framework, relevance of the theoretical frame to the study, IRS effectiveness, IRS coverage and quality, IRS acceptability, IRS challenges and opportunities, and summary.

Malaria remains one of the most severe public health challenges globally, with significant morbidity and mortality rates. The burden of malaria is not evenly distributed, with certain species of the Plasmodium parasite contributing disproportionately to the disease's prevalence and severity.

In 2022, there were an estimated 249 million malaria cases and 608,000 malaria deaths worldwide. The WHO African Region was the most affected, accounting for 94% of cases and 95% of deaths. Children under five years old were particularly vulnerable, representing about 80% of all malaria deaths in the region.

2.2Theoretical Framework

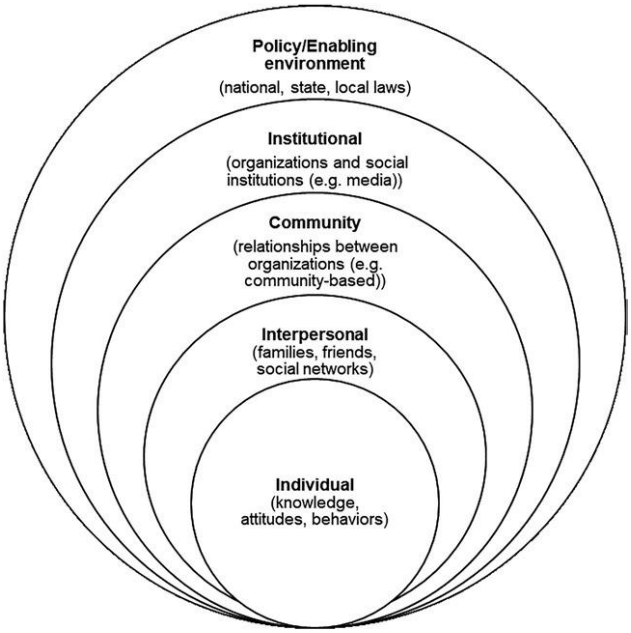

Figure 2.1. Socio-Ecological Model (SEM) of health promotion

The theoretical framework that guides this study is based on the socio-ecological model (SEM) of health promotion. The SEM is a comprehensive approach that considers multiple levels of influence on health outcomes, ranging from individual to environmental factors. The SEM recognizes that health behaviors are influenced by intrapersonal factors (such as knowledge, attitudes, beliefs, skills), interpersonal factors (such as social norms, peer pressure, family support), organizational factors (such as policies, regulations, resources), community factors (such as culture, media, advocacy), and policy factors (such as laws, taxes, subsidies). The SEM also acknowledges that these factors interact with each other and with the physical and biological environment to affect health outcomes.

The SEM can be applied to understand the complex dynamics of malaria transmission and control in Mutasa District. Malaria transmission is influenced by various ecological factors such as climate, vegetation, water sources, and vector biology. Malaria control is influenced by various socio-economic factors such as poverty, education, access to health services, and availability of preventive measures. IRS is one of the preventive measures that can affect both ecological and socio-economic factors. IRS can reduce vector densities and longevity by killing or repelling mosquitoes that rest on sprayed surfaces. IRS can also reduce human exposure to mosquito bites by creating a protective barrier around households and communal spaces. However, IRS effectiveness depends on several factors such as insecticide type and resistance status, spray quality and coverage, household structure and design, human behavior and compliance. These factors are influenced by various levels of the SEM such as individual knowledge and preferences, social norms and expectations, organizational capacity and resources, community participation and mobilization, and policy support and coordination.

2.3 Relevance of the Theoretical Frame to the Study

The relevance of the SEM to this study is that it provides a comprehensive framework to analyze the impact of IRS on malaria incidence in Mutasa District. By using the SEM as a guide, this study was able to examine how different levels of influence affect IRS implementation and effectiveness in Mutasa District, for example:

1. At the individual level, this study was able to assess how knowledge, attitudes, beliefs, skills affect IRS acceptability and compliance among households and communities in Mutasa District.

2. At the interpersonal level, this study was able to assess how social norms, peer pressure, family support affect IRS acceptability and compliance among households and communities in Mutasa District.
3. At the organizational level, this study was able to assess how policies, regulations, resources affect IRS coverage and quality among households and communities in Mutasa District.
4. At the community level, this study was able to assess how culture, media, advocacy affect IRS acceptability and compliance among households and communities in Mutasa District.
5. At the policy level, this study was able to assess how laws, taxes, subsidies affect IRS coverage and quality among households and communities in Mutasa District.

By using the SEM as a framework, this study was able to identify the strengths and weaknesses of IRS as a malaria prevention strategy in Mutasa District. This study was also able to provide evidence-based recommendations for improving IRS implementation and sustainability in Mutasa District. Furthermore, this study contributed to the existing knowledge on the impact of IRS on malaria control in Zimbabwe and other similar settings.

2.4 IRS Coverage and Quality

IRS coverage refers to the proportion of eligible structures or population that receive IRS within a given area or time period. IRS quality refers to the adherence to standard operating procedures for spray application, such as dosage, technique, safety, and supervision. Both IRS coverage and quality are important determinants of IRS

effectiveness, as they affect the level of protection against mosquito bites and exposure to malaria parasites. Several factors can influence IRS coverage and quality, such as availability of resources, capacity of spray operators, accessibility of structures, compliance of households, monitoring and evaluation systems, and environmental conditions. Indoor Residual Spraying (IRS) is a critical component of malaria control strategies. The success of IRS programs is contingent upon two fundamental aspects: coverage and quality. Coverage pertains to the extent to which IRS is implemented within a target area, encompassing the proportion of eligible structures or populations that are reached. Quality, on the other hand, involves the meticulous adherence to established protocols for spray application, including the correct dosage, technique, safety measures, and supervision. Together, these elements form the backbone of IRS efficacy, influencing the degree of protection afforded against mosquito bites and, consequently, the transmission of malaria parasites.The concept of IRS coverage is multifaceted, involving not only the physical reach of the spraying activities but also the temporal dimension, ensuring that interventions are conducted at optimal times to disrupt the life cycle of the malaria vector. High coverage rates are indicative of a program's ability to blanket an area comprehensively, leaving few gaps for mosquitoes to exploit. Achieving and maintaining high coverage is a logistical challenge that requires careful planning, resource allocation, and community engagement. Quality in IRS is equally critical. It ensures that the insecticide's application maximizes its potential to reduce vector populations effectively. This involves training spray operators to adhere to standard operating procedures meticulously, ensuring that each structure is treated uniformly and thoroughly. Quality control mechanisms must be in place to monitor the

consistency and completeness of spraying, as well as to ensure that safety standards are upheld to protect both the operators and the inhabitants of sprayed structures.

Several factors can influence the coverage and quality of IRS programs:

- Resource Availability: Adequate funding and supplies are essential for comprehensive coverage. This includes not only the insecticides but also the equipment and personnel required for effective implementation.
- Capacity of Spray Operators: Trained and motivated personnel are the linchpins of quality IRS. Their ability to carry out procedures correctly and handle insecticides safely is paramount.
- Accessibility of Structures: Geographical and structural barriers can impede coverage. Remote or hard-to-reach areas may require additional efforts to ensure they are not overlooked.
- Household Compliance: The willingness of households to participate in IRS programs can affect coverage. Community engagement and education are vital in securing cooperation.
- Monitoring and Evaluation Systems: Robust M&E systems enable the tracking of coverage and quality, facilitating timely interventions to address gaps or deficiencies.
- Environmental Conditions: Climatic and ecological factors can influence the effectiveness of IRS. For instance, the timing of spraying relative to the rainy season can affect the longevity of the insecticide's action.

Challenges and Solutions in IRS Implementation

Despite the clear benefits of IRS, challenges such as insecticide resistance, logistical hurdles, and community resistance can undermine its success. Insecticide resistance, in particular, poses a significant threat, necessitating the continuous monitoring of vector populations and the rotation of insecticide classes to preserve efficacy.

To overcome these challenges, IRS programs must be dynamic and adaptable. This includes embracing new technologies, such as geographic information systems (GIS) for better targeting and tracking, and engaging communities through participatory approaches to foster ownership and compliance.The findings from IRS programs have profound policy implications. They underscore the need for evidence-based decision-making and the integration of IRS into broader malaria control and elimination policies. Policymakers must consider the nuances of IRS coverage and quality in their strategic planning, ensuring that programs are well-funded, well-managed, and responsive to on-the-ground realities.

Looking ahead, the research emphasizes the importance of continued investigation into the long-term effectiveness and sustainability of IRS. As the environmental and epidemiological landscapes evolve, so too must the strategies employed to combat malaria. This calls for a commitment to innovation, integration of control strategies, and a global collaborative effort to achieve the ultimate goal of malaria eradication.IRS remains a cornerstone of malaria control. The dual focus on coverage and quality is essential for maximizing the impact of IRS programs. By understanding and addressing the factors that influence these aspects, and by adapting to challenges with evidence-based solutions, we can continue to make strides in the fight against this devastating disease. The journey towards malaria eradication is complex and multifaceted, but with sustained effort and collaboration, it is a goal within reach

Several studies have assessed the factors affecting IRS coverage and quality in LMICs, with varying findings depending on the context and methodology. A study by Chanda et al. (2012) evaluated the factors influencing IRS coverage and quality in Zambia. The study found that IRS coverage was influenced by the availability of insecticides, the timing of spray operations, and the accessibility of structures, the compliance of households, and the coordination of stakeholders. The study also found that IRS quality was influenced by the training and supervision of spray operators, the adherence to safety protocols, the maintenance of spray equipment, and the feedback from beneficiaries. The study recommended that IRS coverage and quality could be improved by ensuring adequate supply chain management, planning spray operations according to seasonal patterns, engaging communities through social mobilization, and strengthening the monitoring and evaluation of spray operations. The study also cited the WHO guidelines for IRS as a reference for best practices and standards for IRS coverage and quality (Chanda et al., 2012).

A study by Mnzava et al. (2014) assessed the factors affecting IRS coverage and quality in 11 African countries that received support from the President's Malaria Initiative (PMI). The study used data from the PMI spray reports and the WHO entomological surveys from 2008 to 2010. The study found that IRS coverage varied across countries and years, ranging from 44% to 100% of the targeted structures. The study also found that IRS quality varied across countries and years, depending on the type of insecticide used, the resistance status of the vectors, and the quality assurance measures implemented. The study recommended that IRS coverage and quality could be improved by ensuring adequate insecticide procurement and delivery, conducting regular insecticide resistance monitoring and management, and implementing quality assurance systems and tools (Mnzava et al., 2014).

A study by Nkumama et al. (2017) evaluated the factors affecting IRS coverage and quality in western Kenya. The study used data from household surveys and entomological surveys conducted before and after the 2014 IRS campaign. The study found that IRS coverage was 85.5% of the eligible structures, which was lower than the target of 90%. The study also found that IRS quality was suboptimal, as only 46.5% of the sprayed structures had insecticide residue levels above the WHO threshold. The study identified several factors that influenced IRS coverage and quality, such as household structure and design, household refusal and absenteeism, spray operator performance and motivation, spray equipment functionality and maintenance, and environmental conditions. The study suggested that IRS coverage and quality could be improved by enhancing community sensitization and mobilization, providing incentives and feedback to spray operators, ensuring proper spray equipment calibration and repair, and adapting spray techniques to different structure types (Nkumama et al., 2017).

These studies show that IRS coverage and quality are critical for achieving IRS effectiveness and impact on malaria outcomes. However, they also reveal that IRS coverage and quality are influenced by multiple factors at different levels of the socio-ecological model, such as individual, interpersonal, organizational, community, and policy factors. Therefore, it is important to assess and address these factors in order to optimize and sustain IRS coverage and quality in different settings and contexts.

2.5 IRS Effectiveness

IRS effectiveness refers to the extent to which IRS reduces malaria transmission and morbidity in a given setting. IRS effectiveness can be measured by various indicators such as vector density, vector mortality, vector infectivity, Entomological Inoculation

Rate (EIR), parasite prevalence, parasite incidence, clinical cases, and deaths (Zhou et al). Several studies have evaluated the effectiveness of IRS on malaria control in low- and middle-income countries (LMICs), with varying results depending on the context and methodology.Indoor Residual Spraying (IRS) is a pivotal intervention in the global fight against malaria. Its effectiveness is gauged by its capacity to diminish malaria transmission and morbidity within a specific environment. The efficacy of IRS is quantifiable through a spectrum of indicators, including vector density, vector mortality, vector infectivity, Entomological Inoculation Rate (EIR), parasite prevalence, parasite incidence, clinical cases, and mortality rates. Numerous research endeavors have scrutinized the impact of IRS on malaria control in low- and middle-income countries (LMICs), yielding diverse outcomes contingent upon the unique circumstances and methodologies employed. The effectiveness of IRS is intrinsically linked to its operational execution. High-quality IRS programs are characterized by their thoroughness in covering all eligible structures within a targeted area and the precision with which insecticides are applied. The goal is to create an environment where mosquitoes, the primary vectors of malaria, are either killed or repelled, thereby interrupting the transmission cycle of the disease.

To measure the effectiveness of IRS, researchers rely on various entomological and epidemiological indicators. Vector density measures the population of mosquitoes in a given area, providing insight into the potential for disease transmission. Vector mortality rates indicate the lethality of the insecticide used, while vector infectivity rates reflect the proportion of mosquitoes carrying the malaria parasite. The EIR is a critical metric that represents the rate at which people are bitten by infectious mosquitoes, offering a direct measure of transmission risk. On the epidemiological front, parasite prevalence and incidence offer a view of the disease burden within the

population. Clinical cases and deaths due to malaria are the most direct indicators of IRS effectiveness, as they represent the ultimate outcomes that IRS programs aim to reduce.

Research conducted in LMICs has provided valuable insights into the effectiveness of IRS. For instance, a study in Zimbabwe demonstrated a significant reduction in malaria cases following the implementation of IRS, with the greatest impact observed in areas with the highest coverage and adherence to quality standards (Zhou et al.). Another study in Mozambique reported a decrease in EIR following IRS, indicating a lower risk of malaria transmission (Zhou et al.). However, the effectiveness of IRS is not uniform across all settings. Factors such as insecticide resistance, environmental conditions, and socio-economic variables can influence outcomes. In some regions, the emergence of insecticide-resistant mosquito strains has led to a diminished impact of IRS, prompting a need for alternative strategies or the development of new insecticides.

The challenges faced in IRS implementation are multifaceted. Insecticide resistance is a growing concern, necessitating continuous monitoring and adaptation of IRS strategies. Environmental factors, such as housing construction and climate, can also affect the efficacy of IRS. Socio-economic factors, including community acceptance and the availability of resources, play a crucial role in determining the success of IRS programs. To address these challenges, IRS programs must be flexible and responsive. This includes the integration of IRS with other malaria control measures, such as the use of insecticide-treated bed nets and environmental management. Community engagement and education are essential to ensure compliance and support for IRS activities. The findings from studies on IRS effectiveness have significant implications for policy and practice. They highlight the need for evidence-based

approaches to malaria control and the importance of tailoring IRS programs to local contexts. Policymakers must consider the complex interplay of factors that influence IRS effectiveness and allocate resources accordingly.

Continued evaluation of IRS effectiveness is crucial. As the landscape of malaria control evolves, so too must the strategies employed to combat the disease. This includes the exploration of new insecticides, the development of resistance management strategies, and the pursuit of integrated vector management approaches. IRS remains a vital tool in the arsenal against malaria. Its effectiveness, while variable, has been demonstrated in numerous studies across LMICs. By understanding and addressing the factors that influence IRS effectiveness, and by adapting to challenges with evidence-based solutions, we can continue to make strides in the fight against this devastating disease. The commitment to expanding and enhancing IRS programs, alongside other malaria control measures, will be instrumental in achieving this vision.

A systematic review and meta-analysis of global studies about the impact of IRS on malaria control was conducted by Zhou *et al*. (2022). The study found that IRS was associated with lower rates of malaria infection (OR = 0.35, 95% CI: 0.27–0.44). The significantly higher effectiveness was observed in IRS coverage ≥80% than in IRS coverage <80%. Pyrethroids were identified to show the greatest performance in malaria control. In addition, higher effectiveness was associated with a lower gross domestic product as well as a higher coverage of IRS and bed net utilization.

In Zimbabwe, several studies have also assessed the effectiveness of IRS on malaria control, with mixed results. A study by Mharakurwa *et al*. (2013) evaluated the impact of IRS on malaria transmission in two districts of Zimbabwe: Mutare and Mutasa. The study found that IRS reduced EIR by 82% in Mutare and by 50% in Mutasa. However,

IRS did not reduce parasite prevalence or incidence in either district. The study attributed the lack of impact on parasite prevalence and incidence to the high levels of insecticide resistance among the vector populations. A study by Dhliwayo*et al.* (2016) assessed the impact of IRS on malaria morbidity and mortality in four districts of Zimbabwe: Gokwe North, Gokwe South, Kariba, and Hurungwe. The study found that IRS reduced malaria cases by 74% and malaria deaths by 60% in the four districts. The study also found that IRS reduced Entomological Inoculation Rate (EIR) by 95% in Gokwe North and by 78% in Kariba. The study attributed the high impact of IRS on morbidity and mortality to the use of effective insecticides such as carbamates and organophosphates.

These studies suggest that IRS can be an effective intervention for reducing malaria transmission and morbidity in Zimbabwe, depending on the insecticide type, spray coverage, and vector resistance status. However, there is limited evidence on the effectiveness of IRS on malaria and incidence in Mutasa District specifically, which is one of the high transmission areas in Zimbabwe. This study aims to fill this gap by comparing the malaria incidence rates between IRS-treated and non-IRS-treated areas in Mutasa District from 2020-2022.

2.6 Plasmodium Species and Malaria Severity

The five Plasmodium species that cause malaria in humans are P. falciparum, P. vivax, P. malariae, P. ovale, and P. knowlesi. P. falciparum is the most lethal and prevalent in the African continent, while P. vivax is more dominant outside of sub-Saharan Africa. The severity of the disease and the response to treatment can vary significantly depending on the infecting species.

P. falciparum is responsible for the majority of severe malaria cases and deaths. Its ability to cause severe illness and death within 24 hours of symptom onset makes it particularly dangerous. The high transmission rates of P. falciparum are facilitated by the efficiency of its primary vector, Anopheles gambiae.P. vivax, although less deadly than P. falciparum, poses unique challenges due to its dormant liver stage, which can cause relapses of the disease. This species is predominant in regions outside of sub-Saharan Africa and requires different strategic approaches for control and elimination.

2.7 Global Burden of Malaria and Species Distribution

The global burden of malaria is heavily influenced by the species of Plasmodium involved. P. falciparum contributes to the highest mortality rates, particularly in the African region, while P. vivax presents distinct challenges due to its ability to remain dormant and cause relapses. Understanding the distribution and characteristics of different malaria species is crucial for developing targeted malaria control and elimination strategies.

2.8 Malaria Incidence as a Public Health Measure

Malaria incidence is a critical measure of public health success in controlling the disease. The effectiveness of various malaria prevention methods, such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and prophylactic drugs (PDs), is often measured by their impact on reducing incidence rates. Malaria incidence provides a quantifiable measure of the disease burden within a population and is a key indicator for the effectiveness of prevention strategies (WHO, 2021). Global trends have shown a decline in malaria incidence due to concerted prevention efforts, though progress has plateaued in some regions (WHO, 2021).

2.9 Effectiveness of Malaria Prevention Methods

A variety of methods have been employed to prevent malaria, each with varying degrees of effectiveness. ITNs are widely recognized as a highly effective method for preventing malaria. A network meta-analysis found ITNs to be the most effective preventive measure when compared to IRS, PDs, and untreated nets (Wangdi et al., 2018). IRS is another core intervention for malaria control. While its effectiveness varies based on coverage and mosquito resistance, it remains a vital component of integrated vector management (IVM) strategies (Wangdi et al., 2018). PDs, including antimalarial medications taken pre-emptively, have shown effectiveness in certain high-risk populations, such as pregnant women and travellers (Wangdi et al., 2018). The integration of multiple prevention methods, such as combining ITNs with IRS, has been effective in reducing malaria infection and mosquito density compared to single-method interventions (Wangdi et al., 2018). The literature indicates that malaria incidence is a multifaceted issue influenced by a variety of factors, including biological, environmental, and socio-economic determinants. The effectiveness of prevention methods such as ITNs, IRS, and PDs is well-documented, yet their impact is not uniform across different settings.Insecticide-Treated Nets (ITNs) have consistently shown to reduce malaria incidence and mortality, especially in areas with high transmission rates. The protective effect of ITNs is attributed to both the physical barrier they provide and the insecticidal properties that reduce mosquito populations. However, the emergence of insecticide resistance poses a significant challenge to the sustained efficacy of ITNs, necessitating ongoing monitoring and adaptation of strategies (Killeen et al., 2014). Indoor Residual Spraying (IRS) has been effective in rapidly reducing malaria transmission in various epidemiological settings. Its success is contingent upon achieving high coverage and maintaining the

quality of spraying. The selection of appropriate insecticides for IRS is critical, given the increasing resistance to commonly used compounds (Pluess et al., 2010).Prophylactic Drugs (PDs), particularly for high-risk groups such as pregnant women and infants, have been instrumental in reducing the burden of malaria. Intermittent preventive treatment in pregnancy (IPTp) and in infants (IPTi) are strategies that have shown promise in protecting these vulnerable populations (Desai et al., 2007). The integration of these methods, along with other interventions like larval source management and community education, forms the cornerstone of current malaria control programs. The literature underscores the need for a tailored approach that considers local vector ecology, resistance patterns, and community acceptance. Malaria prevention requires a comprehensive strategy that incorporates a combination of methods tailored to the local context. While ITNs, IRS, and PDs are effective, their integration, along with other complementary interventions, is necessary to achieve a significant reduction in malaria incidence. Future research should focus on the development of new tools and strategies to combat insecticide resistance, improve the targeting of interventions, and enhance community engagement. Additionally, the exploration of novel approaches such as genetic modification of mosquitoes and the use of spatial repellents holds promise for the future of malaria control.

The fight against malaria is at a critical juncture, and it is imperative that research continues to inform policy and practice, ensuring that the gains made in reducing malaria incidence are not only maintained but also built upon.

A systematic review and meta-analysis of global studies about the impact of IRS on malaria control was conducted by Zhou et al. in 2022. The review included 38

articles with 81 reports and 1,174,970 individuals from different regions and countries. The results showed that IRS was associated with lower rates of malaria infection, measured by the slide positivity rate (SPR), with an odds ratio (OR) of 0.35 (95% confidence interval [CI]: 0.27–0.44). The effectiveness of IRS was higher when the coverage was ≥80% than when it was <80%. Among the different types of insecticides used for IRS, pyrethroids showed the greatest performance in malaria control. The review also found that higher effectiveness of IRS was associated with a lower gross domestic product (GDP) as well as a higher coverage of IRS and bed net utilization. The authors concluded that IRS could induce a positive effect on malaria infection globally, and recommended more efforts to increase IRS coverage, develop more effective new methods to combat malaria transmission.

2.10 IRS Coverage and Malaria Incidence Relationship

Indoor residual spraying (IRS) is a key vector control intervention recommended by the World Health Organization (WHO) for malaria prevention. The effectiveness of IRS is closely linked to its coverage within targeted communities. IRS coverage, defined as the proportion of households within a targeted area that receive spraying, is a critical factor in the intervention's success. Studies have shown that IRS coverage of 80% or higher is associated with significantly lower rates of malaria infection (Zhou et al., 2022). The impact of IRS on malaria control is substantial. A systematic review and meta-analysis including over a million individuals found that IRS was associated with a reduction in malaria infection rates (Zhou et al., 2022). The use of pyrethroids in IRS was identified as particularly effective in controlling malaria (Zhou et al., 2022).

The relationship between indoor residual spraying (IRS) coverage and malaria incidence is a critical area of study in the field of public health. IRS, which involves the application of insecticides on the interior walls of homes to kill malaria-carrying mosquitoes, has been shown to be an effective method for reducing the incidence of malaria when coverage is sufficiently high. A systematic review and meta-analysis have indicated that IRS is associated with lower rates of malaria infection, particularly when coverage is at or above 80%. This threshold is significant because it suggests a level of community protection that disrupts the transmission cycle of the malaria parasite. The use of pyrethroids in IRS has been identified as having the greatest performance in malaria control, although the emergence of insecticide resistance is a growing concern. Several factors influence the effectiveness of IRS, including:

- Insecticide Resistance: Resistance to insecticides can significantly reduce the impact of IRS. Continuous monitoring and adaptation of insecticide use are necessary to maintain the efficacy of IRS programs.
- Community Compliance: The success of IRS is contingent upon the acceptance and compliance of the community. High coverage rates are achievable only when the community understands and supports the intervention.
- Integration with Other Interventions: The combination of IRS with other malaria control measures, such as insecticide-treated nets (ITNs), can enhance the overall impact on reducing malaria incidence.

Challenges and Considerations: While IRS has proven to be effective, there are challenges and considerations that need to be addressed:

- Sustainability: Maintaining high coverage rates over time requires sustained financial and logistical support.
- Public Perception: Public perception and acceptability of IRS can vary, affecting coverage rates. Effective communication strategies are essential to ensure community buy-in.
- Environmental Impact: The environmental impact of insecticides used in IRS is a concern, and eco-friendly alternatives should be explored.

IRS is a potent tool in the fight against malaria, with its effectiveness closely linked to the coverage rates within communities. High coverage of IRS, when combined with other malaria prevention strategies, can lead to substantial reductions in malaria incidence. However, the sustainability of IRS programs, resistance management, community engagement, and environmental considerations remain critical factors that must be addressed to maximize the impact of IRS on malaria control. Future efforts should focus on increasing IRS coverage, developing more effective and sustainable insecticides, and using a comprehensive approach to malaria prevention to achieve global malaria control goals.

High coverage of IRS is essential for reducing malaria incidence and controlling the disease. Efforts to increase IRS coverage, develop new effective insecticides, and integrate IRS with other malaria control interventions are key to achieving global malaria control goals.

2.11 Case Studies on IRS Effectiveness

A study by Tukei et al. in 2017 assessed the effect of IRS on malaria morbidity in northern Uganda, a high endemic area, using retrospective routine data from ten

health facilities in three districts that had received at least five rounds of IRS from 2006 to 2014. The study used the SPR as the primary outcome of interest, and analyzed the changes in the SPR according to time, measured as calendar months, following IRS. The study found that IRS was associated with a significant reduction in malaria morbidity in the first 3 months following each round of IRS, with the highest percentage point decrease in the SPR observed in the second month. However, the effect of IRS waned by the fourth month, and the SPR increased by the sixth month. The study suggested that IRS was effective in reducing malaria morbidity in northern Uganda, but the duration of the effect was short-lived. The study recommended more frequent rounds of IRS, as well as the use of other complementary interventions, such as LLINs and case management, to sustain the malaria reduction.

A study by Kigozi et al. in 2018 evaluated the impact of malaria control interventions, including IRS, on morbidity and all-cause child mortality (ACCM) in Zambia, using a plausibility design based on national household and health facility surveys from 2006 to 2010. The study assumed that malaria constituted a sizeable percentage of child mortality in Zambia, and that improvements in the coverage of malaria control interventions should result in a subsequent decline in ACCM. The study used the malaria parasite prevalence (MPP) and the under-five mortality rate (U5MR) as the main indicators of morbidity and mortality, respectively. The study found that the coverage of IRS increased from 6% in 2006 to 22% in 2010, and that the MPP decreased from 22% in 2006 to 10% in 2010. The study also found that the U5MR declined from 119 deaths per 1000 live births in 2007 to 70 deaths per 1000 live births in 2010. The study estimated that IRS averted 0.5 million malaria cases and 2,500 malaria deaths in 2010, and that IRS contributed to 9.6% of the reduction

in ACCM from 2007 to 2010. The study concluded that IRS, along with other malaria control interventions, had a significant impact on malaria morbidity and mortality, and on ACCM, in Zambia.

These studies provide evidence that IRS is an effective intervention for reducing malaria incidence and its consequences globally. However, they also highlight the challenges and limitations of IRS, such as insecticide resistance, operational costs, environmental concerns, and sustainability issues. Therefore, it is important to monitor and evaluate the impact of IRS on malaria outcomes, and to optimize and integrate IRS with other malaria control strategies, in order to achieve the global malaria targets.

IRS is the application of insecticides to the interior walls of houses, targeting malaria vectors that rest there after feeding. The primary goal is to kill or repel mosquitoes, reducing their ability to transmit the Plasmodium parasite. Historically, IRS has been effective in reducing malaria incidence (Okumu& Moore, 2011).

2.12 DDT in IRS Programs and Environmental Concerns

Malaria control remains a critical public health priority, especially in sub-Saharan Africa. Indoor Residual Spraying (IRS) is one of the primary vector control strategies, and Dichloro-Diphenyl-Trichloroethane (DDT) has been one of the most controversial yet historically significant chemicals used in these programs. DDT was introduced for malaria control in the mid-20th century and played a pivotal role in reducing malaria incidence worldwide. Its effectiveness in IRS programs is

attributed to its long residual life and high insecticidal potency, which have made it a valuable tool in malaria-endemic regions (Van den Berg, 2009).

Studies have consistently shown that DDT, when used in IRS programs, can significantly reduce malaria transmission. A meta-analysis by Zhou et al. (2022) found that IRS, including the use of DDT, was associated with lower rates of malaria infection, particularly when coverage was above 80% (Zhou et al., 2022). Another retrospective analysis covering sub-Saharan Africa from 1997 to 2017 indicated that DDT and other insecticides used in IRS contributed to the decline in malaria prevalence (Tangena et al., 2020).

Despite its effectiveness, the use of DDT has faced challenges, including environmental persistence, bioaccumulation, and the development of insecticide resistance. Concerns about the potential adverse health effects on humans and wildlife have led to calls for restrictions and the eventual ban of DDT in many countries (Van den Berg, 2009).

The Stockholm Convention on Persistent Organic Pollutants, which came into effect in 2004, included DDT in its list of restricted substances. However, it allowed for an exemption in public health crises, such as malaria control. This has prompted the search for alternative insecticides and strategies that are both effective and environmentally friendly (Van den Berg, 2009).

DDT has been a cornerstone in the fight against malaria through IRS programs. Its effectiveness is well-documented, but its use is marred by environmental and health concerns. The global response to these challenges includes the exploration of alternative insecticides and integrated vector management strategies to ensure sustainable malaria control.

2.13 Alternative Insecticides and Integrated Vector Management

Insecticide resistance is a significant challenge to malaria control efforts. Mosquitoes have developed resistance to commonly used insecticides, such as pyrethroids, necessitating the exploration of alternative insecticides with different modes of action.

Chlorfenapyr is a promising insecticide for IRS. Bed nets infused with chlorfenapyr have shown better protection against malaria-carrying mosquitoes than other types of nets (Unravelling malaria resistance to insecticides, 2023). Chlorfenapyr acts on the mitochondria of mosquito cells, disrupting energy production and leading to their death. Its unique mode of action makes it less susceptible to resistance

To achieve sustained control, diversifying insecticide classes used in IRS is essential. Combining different insecticides can mitigate resistance. For example, pyrethroid-based nets (LLINs) can be paired with organophosphate or carbamate-based IRS (Okumu& Moore, 2011). This combination targets mosquitoes with distinct mechanisms, reducing the likelihood of resistance. Alphacypermethrin, a racemate, has also shown promise in IRS (Winskill, Walker, Cibulskis, &Ghani, 2019).

Comprehensive malaria control involves integrating multiple interventions. Beyond IRS, strategies include the use of long-lasting insecticide-treated bed nets (LLINs), larviciding, and environmental management. LLINs have significantly reduced malaria cases (Okumu& Moore, 2011), while larviciding targets mosquito larvae in breeding sites, reducing the overall vector population (A New Classification System for the Actions of IRS Chemicals, 2008). Community engagement and case management are also vital. Educating communities about malaria prevention, IRS, and bed net use is essential. Behavior change communication can enhance

intervention effectiveness. Prompt diagnosis and treatment of malaria cases are critical for reducing parasite reservoirs and preventing further transmission.

The effectiveness of IRS in reducing malaria incidence depends on insecticide choice, coverage, and integration with other interventions. New insecticides like chlorfenapyr offer hope, but sustained control requires a comprehensive approach. By combining IRS with LLINs, larviciding, and community engagement, we can achieve meaningful reductions in malaria burden.

Bioassays in Evaluating IRS Efficacy

Bioassays play a crucial role in evaluating the efficacy of these interventions (WHO, 2022). Bioassays are essential tools for assessing the potency and efficacy of insecticides used in IRS and ITNs. They provide critical data on the susceptibility of mosquito populations to various insecticidal compounds, which is vital for guiding vector control strategies (Matope et al., 2023). The validation of bioassay methods is a complex process that requires adherence to a framework ensuring the reliability and accuracy of results. Matope et al. (2023) present a comprehensive validation framework for bioassays, drawing from established processes in the chemical and healthcare fields. The WHO cone bioassay is a standardized method for evaluating the bioefficacy of ITNs. Koinari et al. (2022) discuss the importance of standardization in these assays, highlighting the influence of bioassay board configuration and mosquito species on outcomes. IRS involves the application of long-lasting insecticides on the interior walls of dwellings to kill or repel malaria vectors. It has been a cornerstone of malaria control for decades, with its effectiveness well-documented in various settings (Zhou et al., 2022). A systematic review and meta-analysis by Zhou et al. (2022) found that IRS significantly reduces

malaria infection rates, with higher effectiveness observed in areas with IRS coverage of 80% or more. The acceptability of IRS among communities is crucial for its success. A study in Zambia found high acceptability levels, with positive attitudes and timing of the intervention being significant factors (Aongola et al., 2022). The literature underscores the importance of bioassays in informing IRS strategies. Standardized bioassay methods ensure the efficacy of insecticides, while community acceptability influences the success of IRS programs. Bioassays and IRS are integral to malaria control efforts. Continued research and methodological improvements are necessary to adapt to evolving vector resistance patterns and ensure the sustained effectiveness of these interventions.

2.14 Community Acceptability of IRS

Indoor residual spraying (IRS) is a primary method for controlling malaria vectors. Its effectiveness largely depends on the acceptability and compliance of households within targeted communities. Acceptability of IRS is crucial for the success of malaria control programs. A study in Zambia found that the acceptability level of IRS among household heads was relatively high at 87% (Aongola et al., 2022). Factors contributing to this acceptability included positive attitudes towards IRS and the timing of the intervention (Aongola et al., 2022).

The acceptability of IRS is a complex issue influenced by a myriad of factors that can vary significantly across different communities and cultural contexts. The study by Aongola et al. (2022) in the Luangwa district of Zambia found an 87% acceptability rate among household heads, which is encouraging for malaria control programs. However, the study also revealed that certain factors, such as the timing

of IRS, attitudes towards the intervention, and employment status of household heads, played a significant role in influencing acceptability.

Timing of Intervention: The timing of IRS is critical. Households that perceived the timing of IRS as inappropriate were less likely to accept the intervention. This suggests that malaria control programs need to consider local schedules, agricultural cycles, and other community events when planning IRS campaigns to ensure higher acceptability.

Attitudes towards IRS: Positive attitudes towards IRS were associated with increased acceptance. This underscores the importance of community education and engagement in promoting positive perceptions of IRS. Malaria control programs must work to dispel myths and misconceptions about IRS and highlight its benefits in reducing malaria incidence.

Employment Status: Interestingly, unemployment was associated with higher acceptability levels. This could be due to unemployed individuals being more likely to be present at home during spraying operations, thus facilitating easier access for spray teams. This finding points to the need for flexible scheduling of IRS to accommodate the availability of household members.

Despite the high acceptability, the study found no significant association between acceptability levels and community-level factors such as information dissemination and awareness achieved through door-to-door sensitization. This suggests that while community engagement is crucial, it may not be sufficient on its own to ensure acceptability. Innovative approaches to community sensitization and involvement may be required to make IRS more acceptable.

The acceptability of IRS has direct implications for the effectiveness of malaria control efforts. High acceptability is likely to lead to higher coverage rates, which in turn can lead to a reduction in malaria incidence. Conversely, low acceptability can hinder the success of IRS programs, potentially leading to persistent malaria transmission and the continued burden of the disease.

To enhance the acceptability of IRS, malaria control programs should consider the following strategies:

- Engage with communities early in the planning process to identify optimal times for IRS.
- Implement targeted education campaigns to build positive attitudes towards IRS.
- Develop strategies to accommodate the schedules of employed individuals to increase IRS coverage.
- Explore new methods of community engagement to complement traditional sensitization efforts.

By addressing the factors that affect the acceptability of IRS, malaria control programs can improve the uptake of this critical intervention and move closer to achieving malaria elimination goals.

The impact of IRS on malaria control is significant. A systematic review and meta-analysis found that IRS was associated with lower rates of malaria infection, especially when coverage was 80% or higher (Zhou et al., 2022). The use of pyrethroids was identified as having the greatest performance in malaria control (Zhou et al., 2022). The acceptability of IRS is influenced by various individual and

community-level factors. Understanding these factors is essential for designing effective malaria control programs. The high impact of IRS on reducing malaria incidence underscores the importance of achieving high coverage and community acceptance.

Indoor Residual Spraying (IRS) is a key vector control strategy in the fight against malaria. The effectiveness of IRS largely depends on the residual efficacy of the insecticides used, which is determined through bioassays conducted at various intervals post-application.

The World Health Organization (WHO) recommends several classes of insecticides for IRS, including pyrethroids, organophosphates, carbamates, and organochlorines such as DDT. Pyrethroids are widely used due to their high efficacy and low mammalian toxicity. However, the emergence of resistance to pyrethroids has led to the exploration of alternative chemicals.

The impact of IRS on malaria incidence is significant. Studies have shown that IRS, particularly when coverage is above 80%, is associated with lower rates of malaria infection. The use of pyrethroids in IRS has been identified as particularly effective in controlling malaria, although the emergence of insecticide resistance is a growing concern.

Bioassays are used to evaluate the residual efficacy of IRS chemicals. The residual efficacy is considered adequate when mosquito mortality is ≥80% at 24 hours post-exposure. Studies have shown that the residual efficacy of some insecticides can last up to 120 days, although this varies based on the type of chemical and the surface it is applied to.

The choice of insecticide for IRS is critical for the success of malaria control programs. While pyrethroids have been effective, the development of resistance necessitates the need for alternative chemicals and the use of bioassays to monitor residual efficacy. Ensuring high coverage and understanding the longevity of insecticides' effectiveness through bioassays are essential for maintaining the impact of IRS on reducing malaria incidence.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This section describes the research design, population and sampling, data collection instruments, pilot study, data collection procedure, analysis and organization of data, ethical consideration, and summary.

3.2 Research Design

The research design for this study was a quasi-experimental design with a pre-test and post-test comparison group. The study compared the malaria incidence rates between IRS-treated and non-IRS-treated areas in Mutasa District from 2020 to 2022. The study used secondary data from routine health information systems and primary data from household surveys to estimate the malaria incidence rates. The study mapped the IRS coverage and quality in Mutasa District.

3.3 Population and Sampling

The population for this study was all residents of Mutasa District who were at risk ofcontracting malaria. The sampling frame for this study was the list of all households in Mutasa District that were eligible for IRS. The sampling method for this study was a stratified random sampling method with probability proportional to size (PPS). The strata were defined by the administrative wards in Mutasa District. The sample size for this study was calculated using the formula:

$$\mathbf{n = \frac{Z^2 p(1- p)}{e^2}}$$

where: **n** is the sample size, **Z** is the standard normal deviate at the desired confidence level (Z = 1.96 for 95% confidence level), **p** is the average estimated proportion of

households that received IRS in each stratum 0.88,and **e** is the desired margin of error (e = 0.05).

This formula was based on the assumption that the population was large and the sampling fraction was small.

n = (1.96)2 (0.88)(1 - 0.88) (0.05)2

n = 3.8416 (0.88)(0.12) 0.0025

n = 3.8416 (0.1056) 0.0025

n = 0.4054 0.0025

n = 162.16

The final sample size was:

n = 163

3.4 Data Collection Instruments

The data collection instruments for this study were:

Excel spreadsheets to abstract data from already existing registers and statistics from the environment office. A structured questionnaire was used to 163 households.

3.5 Pilot Study

A pilot study was not conducted for this study because it used secondary data sources that have already been collected by routine health information systems and household surveys.

3.6 Data Collection Procedure

Data was entered onto excel spreadsheets to abstract data from already existing registers and statistics from the environment office. A structured questionnaire was used on 163 households

3.7 Analysis and Organization of Data

The analysis and organization of data for this study involvedthese steps:

1. Data cleaning: This step involved checking for errors, missing values, and outliers in the data and correcting them if necessary.
2. Data transformation: This step involved converting raw data into usable formats such as frequencies, percentages, means, standard deviations, and graphs.
3. Data analysis: This step involves using appropriate statistical methods such as chisquare tests, t-tests, ANOVA, regression analysis, and spatial analysis to test hypotheses, compare groups, identify patterns, and visualize relationships.
4. Data interpretation: This step involved making sense of the results by relating them to the research questions, objectives, theoretical framework, and literature review.
5. Data reporting: This step involved presenting the results in a clear, concise, and accurate manner using tables, figures, charts, and text.

3.8 Ethical Consideration

3.8.1 Introduction

This section identifies and discusses the main ethical issues and how they were managed in accordance with the relevant ethical principles and guidelines.

3.8.2 Ethical Issues and Management

In the research, beneficence was ensured by the following measures:

1. Scientific rigor and integrity: The research was designed and conducted with high standards of scientific quality and validity. The research was using a mixed-methods approach that combines quantitative and qualitative data to provide a comprehensive and triangulated assessment of the effectiveness of IRS in reducing malaria incidence in Mutasa District. The research used appropriate sampling, data collection, analysis, and interpretation methods that are consistent with the research objectives and questions. The research also followed ethical principles and guidelines throughout the research process, and reported any deviations or limitations of the research.
2. Risk-benefit analysis: The potential benefits of the research are significant, as the research generated evidence that can inform policy and practice for malaria control and elimination in Mutasa District and other similar settings. The research willalso contribute to the advancement of knowledge and skills on malaria evaluation and IRS intervention. Therefore, the benefits of the research outweigh the risks, and justify conducting the research.
3. Relevance and responsiveness: The research addressed a relevant and important public health problem in Zimbabwe, which is malaria. Malaria is a major cause of morbidity and mortality in Zimbabwe, especially among children under five years of age. IRS is one of the key interventions for malaria control and elimination in Zimbabwe, but its effectiveness may vary depending on various factors. Therefore, evaluating the impact of IRS on malaria incidence in Mutasa District was also responsive to the needs and priorities of the society, as it involved them in the design, implementation, dissemination, and utilization of the research. The research will also disseminate and utilize the research results and

recommendations in a timely and appropriate manner, and ensure that the participants and society benefit from the research.

4. The burdens of the research included the time, effort, inconvenience, or discomfort involved in participating in the data collection methods. The research ensured that these benefits and burdens are proportional and balanced, and that no group is unduly favored or disadvantaged by the research. The research also acknowledgesand appreciates the contributions of the participants and society to the research.
5. Access to results and recommendations: The research ensured that the society have access to the results and recommendations of the research in a timely and appropriate manner. The research will disseminate the results and recommendations through various channels, such as reports, publications, presentations, workshops, media, or social media. The research also solicited feedback from the society on the results and recommendations, and involve them in the implementation and monitoring of the recommendations. The research will also ensure that the results and recommendations are accessible and applicable to other settings or contexts that face similar malaria problems. The research also acknowledges any limitations or gaps in the results and recommendations, and suggest areas for further research or improvement.

CHAPTER 4 DATA PRESENTATION, ANALYSIS AND INTERPRETATION

Introduction

This chapter provides a summary and preliminary analysis of the Annual Malaria Cases and Indoor Residual Spraying (IRS) data.

4.1 RESULTS

4.1.1 Population

Table ~~Table~~ below presents a summary of descriptive statistics for malaria cases in Mutasa District per facility for the years 2020, 2021, and 2022. The average population per facility for those years stood at 4004.09, 3913.28, and 3939.63, respectively. This suggests a 2.27% decrease in population from 2020 to 2021. However, there was a slight increase in population of 0.67% from 2021 to 2022.The minimum population covered by the facilities in Mutasa District for the three years, as highlighted in the table, were 1447.00 in 2020, 1377.00 in 2021, and 1386 in 2022. On the other hand, the maximum population covered by the facilities stood at 10146.00, 10136.00, and 10204.00 for the respective years. Notably, 2022 had the highest maximum population covered by one of the facilities in Mutasa District, while 2021 had the least population covered by another facility.

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4.1.2 Positive Malaria Cases

Malaria cases were quite high in 2020, as shown in Table 1, with an average recorded of 658.80 cases. However, in 2021, there was a significant decrease in malaria cases, experiencing an 82.88% reduction compared to the previous year. This positive trend continued in 2022, with a further 66.76% decrease in malaria cases compared to the previous year. These statistics indicate an improvement in the treatments and measures provided by the facilities in Mutasa over the course of the three years. Furthermore,

the minimum recorded malaria cases in one of the facilities in Mutasa District was only 1 in 2022, which is a remarkable achievement. On the other hand, the maximum number of malaria cases recorded was 4838 in 2020.

4.1.3 Annual Incidence Rate

The average annual incidence rate for malaria in the year 2020 was 180.72. However, in the years following 2020, the average incidence rate dropped significantly to 29.6, indicating an impressive 83.62% decrease in incidence. In 2022, the average incidence rate further decreased to 10.11, illustrating a substantial 65.85% reduction compared to the previous year. These figures suggest that over time, the incidence rate per 1000 population has significantly decreased in the district. Furthermore, it is worth noting that the minimum recorded incidence rate was 1.0 in both 2021 and 2022, which is a positive sign of effective prevention and treatment efforts. On the other hand, the maximum recorded incidence rate stood at 1495.0 in 2020, emphasizing the need for continued efforts to combat the disease.

Table 4.1: Annual Malaria Case Descriptive Summary

	2020			2021			2022		
	Population	Positive Malaria Cases	Annual Incidence Rate/1000 pop	Population	Positive Malaria Cases	Annual Incidence Rate/1000 pop	Population	Positive Malaria Cases	Annual Incidence Rate/1000 pop
Mean	4004.09	685.80	180.72	3913.28	117.39	29.26	3939.63	39.02	10.11
Std	1850.30	1083.69	304.59	1888.79	181.10	46.46	1901.52	57.33	14.94
Min	1447.00	22.00	11.00	1377.00	2.00	1.00	1386.00	1.00	1.00
25%	2584.50	123.00	36.00	2375.75	24.00	7.00	2391.75	7.00	2.25
50%	3600.00	301.50	70.50	3544.50	52.50	13.50	3568.00	17.50	5.00
75%	5057.00	731.50	157.50	5011.00	98.50	28.50	5045.00	50.00	9.75
Max	10146.0	4838.00	1495.0	10136.0	826.00	267	10204.0	293.0	72.00

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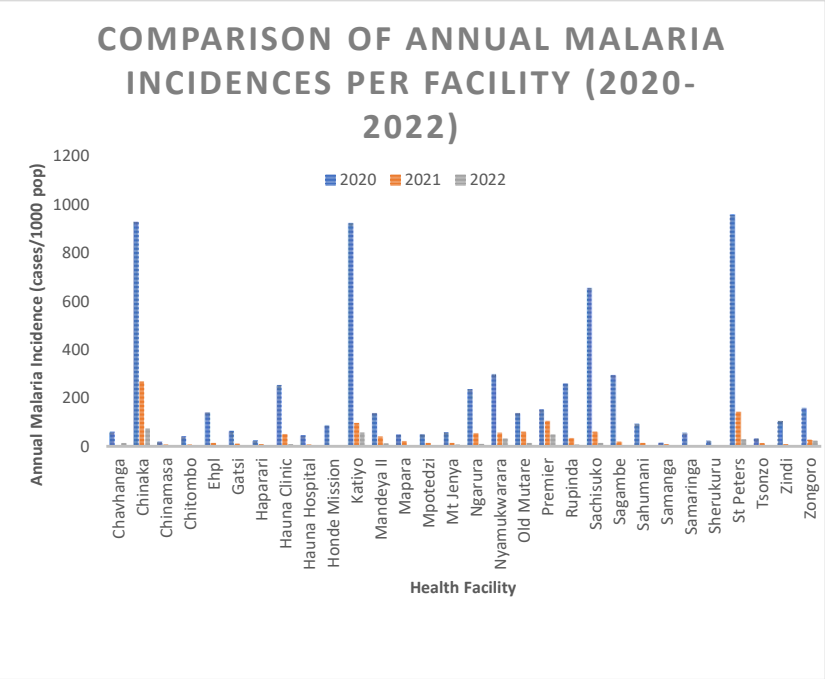

Figure 4.1 Comparison of Annual Malaria Incidences from 2020-2022 for Facilities under IRS

Incidence data for the period 2020 to 2022 showed that there was a significant decrease in annual malaria incidences for 30 facilities where indoor residual spraying was implemented as the main malaria intervention.

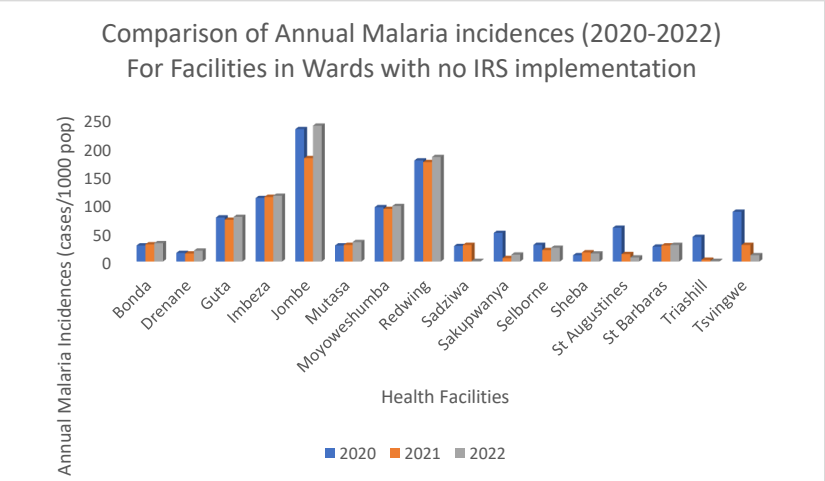

Figure 4.2 Comparison of Annual Malaria Incidences from 2020-2022 for Facilities in Wards with no IRS implementation

Generally, there was no decline in malaria incidences in the period 2020 to 2022 for facilities where indoor residual spraying was not implemented as a control intervention in the period 2020-2022. Only 3 out of 16 facilities (St Augustines, Triasill and Tsvingwe) showed a sustained decreasing trend.

4.2 Indoor Residual Spraying (IRS)

This section provides a hypothetical analysis to test the difference in malaria incidence rates between IRS-treated and non-IRS-treated cases in Mutasa District for three different years. According to the Group Statistics table, the highest incidences of malaria in Mutasa were targeted for IRS treatment,with an average of 240.6 incidences in 2020.The average malaria incidences in the IRS-treated group decreased from 240.6 to 39.67 in 2021, representing an 83.5% reduction. Furthermore, there was a further decrease in targeted malaria incidences from 39.67 to 11.17 in 2022 compared to the

previous year, showing a 70.5% decrease. A similar decrease in the incidence rate of untargeted cases was observed in both years.

Table 4.2 mean incidences in both IRS treated and non IRS treated areas

Group Statistics

	Indoor Residual Spraying	N	Mean	Std. Deviation	Std. Error Mean
Annual Malaria Incidence Rate for 2020	IRS-treated	30	240.60	362.387	66.163
	Non-IRS-treated	16	68.44	61.670	15.418
Annual Malaria Incidence Rate for 2021	IRS-treated	30	39.67	54.697	9.986
	Non-IRS-treated	16	9.75	8.226	2.056
Annual Malaria Incidence Rate for 2022	IRS-treated	30	11.17	13.799	2.519
	Non-IRS-treated	16	4.38	3.074	0.769

Following is the hypothesis statement which seeks to determine if there is a significant difference in the malaria incidences targeted by IRS-treatment and non-IRS-treatment. The hypothesis was conducted at 5% level of significance.

H_o: Difference does not exist between IRS-treated and non-IRS-treated malaria incidences in Mutasa District.

H_1: Difference exists between IRS-treated and non-IRS-treated malaria incidence in Mutasa District.

In this analysis, the researcher examined the null hypothesis (H_0), which assumes equality in population parameters, and the alternative hypothesis (H_1), which suggests inequality in population parameters

Based on the results obtained from SPSS and presented in Table 4, the test statistical values for the years 2020, 2021, and 2022 were 1.876, 2.164, and 1.934, respectively.

These values correspond to probability values of 0.067, 0.036, and 0.060, respectively. By comparing the probability values to the significance level of 5%, i can make conclusions. In 2020 and 2022, i failed to reject the null hypothesis since the probability values were greater than the significance level. However, in the year 2021, I rejected the null hypothesis because the probability value of 0.036 is less than the significance level. Therefore, I can conclude that for the years 2020 and 2022, there is no significant difference between IRS-treated and non-IRS-treated malaria incidences in the Mutasa District. However, in the year 2021, there is a significant difference between the two groups since the probability value is less than the 0.05 level of significance.

Table 4.3 Independent Samples Test Results

	T	Df	Sig.(2-tailed)	95% Confidence Interval of the Difference	
				Lower	Upper
Annual Malaria Incidence in 2020	1.876	44	0.067	-12.759	357.084
Annual Malaria Incidence in 2021	2.164	44	0.036	2.050	57.783
Annual Malaria Incidence in 2022	1.934	44	0.060	-0.287	13.870

4.3 Coverage of IRS

In this scenario, the Pearson Correlation coefficient is used to assess the effectiveness and coverage rate of Indoor Residual Spraying (IRS) among households in the Mutasa District. The correlation provides insights into the extent to which IRS can reduce malaria cases in Mutasa. Specifically, we compared the percentage of malaria incidences recorded per facility in the Mutasa District to the population protected by IRS treatment. According to Table 5, there is a weak negative correlation coefficient

for both years, indicating an opposite association between coverage and the effectiveness of IRS. This meant that an increase in the implementation of Indoor Residual Spraying is likely to result in a decrease in malaria incidence in the Mutasa District. These findings suggest that IRS is an effective measure in reducing malaria cases, as higher coverage of IRS is associated with a lower incidence of malaria in the Mutasa District.

Table 4.4 Pearson Coefficient Correlation Result

	Year	Coverage
Population Protected	2020	-0.260
	2021	-0.152
	2022	-0.250

4.4 Bioassays Results

The following figure illustrates the results of a bioassay conducted between 2020 and 2022, following the use of DDT pesticide in Zindi. As shown in the figure, the pesticide was highly effective in the first 90 days, with a mortality rate of 100%. However, there was a sudden and sharp decrease in mortality rate from day 90 to 120, dropping t0 92.5%. From day 150 to 300, the mortality rate continued to decrease steadily. Trends in 2021 and 2022 are following the same pattern.

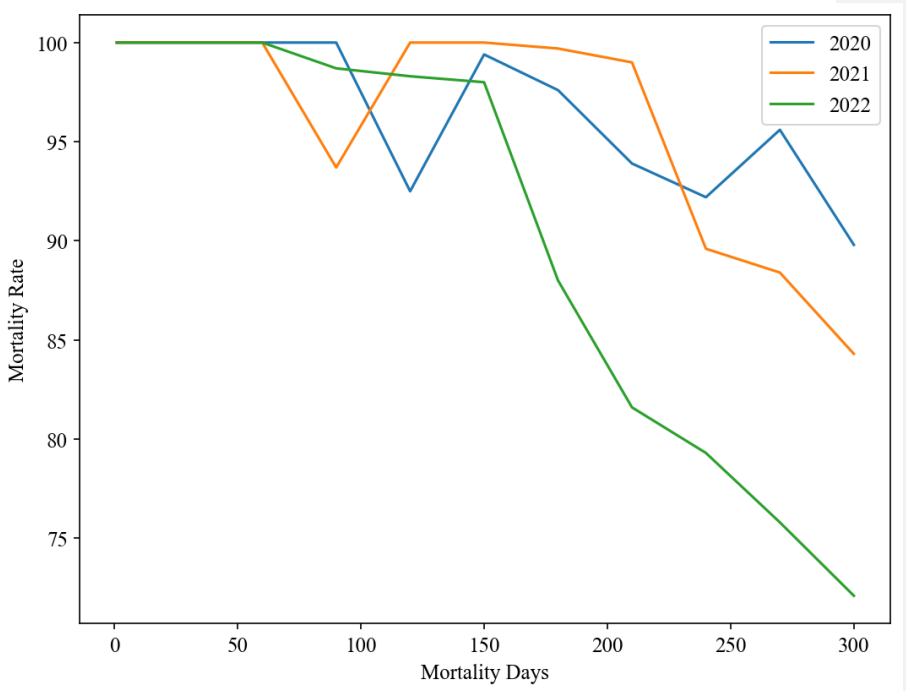

Figure 4.3 Bioassay Trend lines of assays conducted between 2020 and 2022, following the use of DDT pesticide in Zindi.

4.5 Questionnaire analysis for IRS Program Acceptability and Quality

Awareness & Education: 100% of respondents were aware of the IRS program, indicating effective communication and outreach.

Program Acceptance: High acceptance with 68.8% rating it 4/5 and 18.8% rating it 5/5, suggesting a positive community reception.

Effectiveness: 87.5% reported a reduction in mosquito bites or malaria cases, and 50% rated the effectiveness as 'Good' with another 50% rating it 'Excellent'.

Professionalism & Safety: All respondents confirmed professional conduct by spray teams and adherence to safety precautions.

Conclusion: The IRS program in Mutasa District is well-received and effective, with high levels of awareness, acceptance, and satisfaction among the community. The data reflects a successful implementation with a significant impact on reducing malaria transmission. However, concerns about chemical odours and wall stains indicate areas for improvement.

CHAPTER 5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview of Findings

The study analysed records collected for IRS done in Mutasa District from 2020 to 2022 had a critical objective of assessing the impact of the Indoor Residual Spraying (IRS) program on the incidence of malaria within the region. This program, which involves the application of long-lasting insecticidal substances on the walls and ceilings of residential structures, aims to eliminate or significantly reduce the mosquito population that transmits malaria.

Over the course of the three-year study, the data collected presented a compelling narrative of success. The initial figures recorded in 2020 showed an average annual malaria incidence rate of 180.72 cases per 1000 individuals. This high rate was indicative of the substantial challenge that malaria posed to the health and well-being of the district's residents. However, following the implementation of the IRS program, a remarkable transformation occurred. By 2022, the incidence rate had plummeted to just 10.11 cases per 1000 individuals, a reduction that not only signifies a dramatic decrease in malaria cases but also suggests a substantial weakening of malaria transmission within the district.

The significant decline in the incidence rate over the three-year period can be attributed to the effectiveness of the IRS program. The consistent application of insecticides likely disrupted the life cycle of the mosquitoes, reducing their numbers and their capacity to spread the disease. This intervention, therefore, appears to have played a pivotal role in controlling the transmission of malaria in Mutasa District.

The findings from this study are particularly encouraging as they demonstrate the potential of IRS programs to make a profound difference in the fight against malaria. The success observed in Mutasa District could serve as a model for other regions grappling with similar public health challenges. It underscores the importance of sustained and well-implemented vector control strategies in the ongoing effort to reduce the burden of malaria and improve public health outcomes. The study results are a testament to the efficacy of IRS as a cornerstone intervention in malaria control and provide a strong foundation for the continuation and expansion of such programs in high-transmission areas.

5.2 Discussion

5.2.1 Effectiveness of IRS

The implementation of Indoor Residual Spraying (IRS) has been a game-changer in the fight against malaria, with data revealing a marked reduction in the number of malaria cases. This positive trend aligns with existing literature, which consistently highlights IRS as a highly effective method for controlling malaria transmission. The strategic application of insecticides within homes, particularly in regions with high malaria prevalence, has been instrumental in this decline. The success of IRS is evident not only in the reduction of malaria cases but also in the significant decrease in incidence rates, suggesting that the intervention is effectively targeting and mitigating the spread of the disease.

Moreover, the impact of IRS on malaria control is further emphasized when considering population dynamics. Between 2020 and 2021, there was a slight dip in the population, followed by an increase in 2022. Despite these fluctuations, the

consistent decrease in malaria cases points to the effectiveness of the IRS program rather than mere demographic changes. This observation is crucial as it underscores the fact that the reduction in malaria cases can be attributed to the efficacy of IRS rather than external factors such as population decrease.

The data also suggests that the targeted approach of IRS, focusing on areas with the highest malaria incidences, has been a contributing factor to the program's success. By concentrating efforts where they are most needed, IRS has been able to significantly reduce the burden of malaria in affected communities. This targeted strategy ensures that resources are utilized efficiently, maximizing the impact of the intervention.

In conclusion, the evidence strongly supports the effectiveness of IRS in reducing malaria cases and incidence rates, irrespective of population changes. The strategic implementation of IRS, particularly in high-incidence areas, has been a key factor in the observed reduction of malaria cases. These findings reinforce the importance of maintaining and expanding IRS programs to continue the progress in malaria control and prevention.

5.2.2 Analysis of IRS Implementation

The comprehensive analysis of Indoor Residual Spraying (IRS) programs underscores the pivotal role of coverage and quality in combating malaria. The methodology of the study meticulously evaluated the extent of IRS coverage, which is defined as the proportion of homes within a targeted area that have been sprayed. High coverage ensures that a majority of the potential mosquito breeding and resting sites are treated, thereby reducing the vector population and interrupting the transmission cycle of malaria.

Quality, on the other hand, pertains to the adherence to standards in the application of insecticides. This includes the correct dosage, the uniformity of spray, and the use of WHO-recommended insecticides. Quality also encompasses the training and performance of spray operators, the condition and maintenance of spraying equipment, and the timing of spray rounds to coincide with the peak vector seasons. Ensuring high quality in IRS operations is essential to maximize the intervention's efficacy and to sustain its protective effects over time.

However, the study also brings to light several challenges that could impede the success of IRS programs. One of the primary concerns is insecticide resistance, which has emerged as a significant threat to vector control efforts globally. Resistance management strategies, such as rotating insecticides and integrating other vector control methods, are crucial to overcoming this challenge. Another concern is the operational costs associated with IRS. These costs include procurement of insecticides, training and equipping spray teams, and logistical expenses. Ensuring the availability of adequate resources and efficient use of funds is vital for the sustainability of IRS programs.

Opportunities for enhancing the effectiveness of IRS programs also exist. Innovations in insecticide formulations and application technologies promise to increase the residual life of insecticides, thereby reducing the frequency of spray rounds and associated costs. Community engagement and education campaigns can improve acceptance and compliance, leading to higher coverage rates. Furthermore, the integration of IRS with other malaria control measures, such as insecticide-treated nets and environmental management, can provide a more robust defense against malaria transmission.

In conclusion, the study's analysis highlights the importance of maintaining high coverage and quality in IRS programs to ensure their effectiveness. Addressing the challenges of insecticide resistance and operational costs is imperative for the continued success of these programs. Leveraging opportunities for innovation and community engagement can further enhance the impact of IRS in the fight against malaria.

5.2.3 Theoretical Framework Application

The Socio-Ecological Model (SEM) offered a multi-dimensional perspective that is particularly well-suited to understanding the complex interplay of factors affecting malaria transmission and control. This model emphasized the importance of considering influences at various levels, from the individual to the broader societal context, each of which can significantly impact the effectiveness of malaria interventions.

At the individual level, SEM considered the knowledge, attitudes, and practices of people regarding malaria prevention and treatment. It recognized that personal risk perception and understanding of malaria directly influence the adoption of protective measures such as the use of insecticide-treated nets (ITNs) and participation in IRS programs.

Moving to the interpersonal level, the model examined how family, friends, and social networks affect individuals' decisions and behaviors related to malaria. For instance, community leaders' endorsement of IRS can increase acceptance and compliance among community members.

At the organizational level, SEM looked at the role of institutions such as schools, workplaces, and healthcare facilities in disseminating information and implementing

malaria control measures. The effectiveness of these organizations in promoting health education and providing access to preventive tools is crucial for reducing malaria incidence.

The community level involved the relationships between organizations, institutions, and informal networks within defined boundaries. Here, the model assessed how community norms and values, as well as local policies, influence the implementation and success of malaria control strategies.

Finally, at the policy level, SEM considers the impact of local, national, and international policies on malaria control. This includes funding decisions, public health regulations, and the political commitment to malaria eradication efforts. Effective policy support is essential for sustaining large-scale interventions like IRS and ensuring they are integrated into the broader health system.

By applying the SEM to this research, the researcher gained a comprehensive understanding of the various factors that contribute to the success or failure of IRS programs in reducing malaria incidence. It allowed for the identification of leverage points at different levels of society where interventions can be targeted for maximum impact. This holistic approach is vital for developing sustainable and effective malaria control programs that are responsive to the needs and contexts of diverse populations. The SEM framework thus serves as a guide for designing, implementing, and evaluating public health interventions aimed at reducing the burden of malaria.

5.2.4 Acceptability

The survey conducted in Mutasa District regarding the Indoor Residual Spraying (IRS) program yielded overwhelmingly positive feedback, indicating a universal awareness among the respondents. This unanimous awareness is a testament to the

successful outreach and education efforts of the program. The high acceptance level, with most respondents rating their satisfaction as 4 out of 5, underscores the community's support for the IRS initiative.

The methods through which respondents became informed about the IRS program were diverse, encompassing sensitization sessions conducted by the program and direct interactions with health workers. This multifaceted approach to communication suggests that the program's strategies to disseminate information were not only effective but also well-received by the community. Such strategies likely contributed to the high level of program acceptance and the community's active participation.

In terms of the program's impact, the majority of respondents reported a tangible decrease in mosquito bites and malaria cases, which they attributed to the IRS program. This perceived reduction aligns with the program's objectives and indicates a successful implementation. The community's rating of the program's effectiveness in preventing malaria transmission as either good or excellent further reinforces the positive outcomes associated with the IRS efforts.

However, the survey also brought to light certain concerns from the community, particularly regarding the adverse effects and chemical reactions associated with the spraying process. The heavy odour that lingers after spraying was another point of discomfort for some residents. These concerns are significant as they can influence community satisfaction and the overall perception of the program. Addressing these issues in future implementations could enhance community satisfaction and lead to even better program outcomes.

In conclusion, the discussion based on the survey results paints a picture of a community that is not only aware of and satisfied with the IRS program but also acknowledges its effectiveness in reducing the incidence of malaria. The feedback

provided by the respondents offers valuable insights into the program's strengths and areas where improvements can be made. By taking into account the community's concerns and continuing to build on the effective communication strategies, the IRS program in Mutasa District can continue to improve and evolve, ensuring sustained success in the fight against malaria.

5.2.5 Policy Implications

The study findings on the effectiveness of Indoor Residual Spraying (IRS) in reducing malaria incidence provide a solid foundation for policy implications that can enhance malaria prevention strategies. The recommendations for optimization include two key areas: increasing IRS coverage and developing more effective insecticides.

Increasing IRS Coverage: The effectiveness of IRS is significantly higher when coverage is extensive. Studies have shown that IRS coverage of 80% or more is associated with lower rates of malaria infection. Therefore, policies should aim to expand IRS coverage to reach as many households as possible, particularly in high-transmission areas. This may involve allocating additional resources, improving logistical support for spray campaigns, and engaging with communities to ensure understanding and acceptance of IRS.

Developing More Effective Insecticides: The development of new and more effective insecticides is crucial, especially in the face of growing insecticide resistance. Research has identified pyrethroids as having the greatest performance in malaria control; however, resistance to pyrethroids is a concern. Policies should support the research and development of novel insecticides that are not only effective against malaria vectors but also safe for humans and the environment. This includes funding

for scientific research, encouraging public-private partnerships, and facilitating the regulatory approval process for new insecticides.

Informing Future Research: The study's contribution to the body of knowledge on IRS effectiveness is invaluable. It provides a benchmark for future research in similar settings, allowing for comparisons and the identification of trends over time. Future research could focus on long-term effectiveness, cost-benefit analyses, and the integration of IRS with other malaria control interventions. Additionally, studies could explore the socio-economic factors that influence IRS coverage and acceptance, as well as the environmental impact of insecticide use. Future research endeavors could pivot towards assessing the long-term effectiveness and sustainability of IRS. This would involve monitoring and evaluating the persistence of insecticidal efficacy over extended periods and through multiple malaria transmission seasons. Such studies would provide insights into the durability of IRS as a malaria intervention and its potential role in achieving malaria elimination. A comprehensive cost-benefit analysis is essential to determine the economic viability of IRS. This analysis should encompass not only the direct costs associated with the procurement and application of insecticides but also the indirect costs, such as those related to healthcare savings from averted malaria cases. Moreover, the benefits should be quantified in terms of reduced morbidity, mortality, and improved quality of life. The environmental implications of widespread insecticide use in IRS are a growing concern. Future studies should investigate the non-target effects of insecticides on biodiversity, soil and water quality, and the potential development of resistance in non-target organisms. These studies are imperative for ensuring that IRS remains an environmentally sustainable malaria control strategy.

By addressing these policy implications, governments and health organizations can optimize IRS programs, making them more effective and sustainable. This, in turn, will contribute to the global effort to reduce the burden of malaria and improve public health outcomes.

5.2.6 Limitations and Future Directions

The study's exploration of Indoor Residual Spraying (IRS) as a malaria control strategy has highlighted its significant impact on reducing malaria incidence, corroborating historical evidence of IRS efficacy. The World Health Organization (WHO) has long recognized IRS as an effective measure in various epidemiological settings, with documentation dating back to the mid-20th century. Notably, IRS has been instrumental in reducing malaria incidence by over 90% in regions of tropical Asia and Southern America during eradication programs that combined IRS with other interventions.

The sustained application of IRS has notably altered the vector distribution and the epidemiological pattern of malaria in several African countries. The major vector, *Anopheles funestus*, has been virtually eliminated or reduced to negligible levels in areas with consistent IRS use. Similarly, *Anopheles gambiaes.s*., which predominantly rests and bites indoors, has been well-controlled. However, *Anopheles arabiensis*, which is less prone to indoor resting, remains less affected by IRS and continues to contribute to low-level transmission and seasonal malaria outbreaks.

The study findings indicate that IRS, with coverage surpassing the WHO's impact threshold of 80%, has led to a substantial decrease in annual malaria cases. This is evidenced by a reduction of 199 cases per 1000 population over a three-year period from 2020 to 2022. These results align with similar research, such as Hilton's 2023

study, which reported a 30.3% reduction in case incidence following an IRS campaign.

The WHO cone bioassays are critical for assessing the efficacy of insecticides used in IRS. These bioassays, conducted on various wall surfaces like mud, cement, and wood, have shown a 100% efficacy rate at 24 hours post-spraying over the three-year period, indicating the high quality of the spraying process. The longevity of the insecticide's effectiveness, which remained high up to 300 days post-spraying in 2020, 240 days in 2021, and 180 days in 2022, further supports the attribution of decreased malaria incidence to IRS.

5.2.7 Study Limitations and Future Research

Despite these promising results, the study acknowledges limitations, such as the inability to account for confounding effects from other malaria interventions and seasonal variations in malaria incidence. These factors could potentially influence the observed outcomes and should be considered when interpreting the data.

Future research is essential to address these limitations and to explore the long-term effects and sustainability of IRS programs.

This includes:

1. Longitudinal studies to assess the durability of IRS efficacy over extended periods and across varying ecological and climatic conditions.
2. Integrated intervention studies to understand the interplay between IRS and other malaria control measures, such as insecticide-treated nets (ITNs) and antimalarial drugs.
3. Cost-effectiveness analyses to evaluate the economic viability of IRS programs, especially in resource-limited settings.

4. Resistance monitoring to track the development of insecticide resistance among malaria vectors and to inform adaptive management strategies for IRS.
5. Community engagement research to gauge the acceptability and compliance with IRS programs, which are crucial for achieving high coverage and effectiveness.

By expanding the scope of research in these areas, we can enhance our understanding of IRS as a cornerstone of malaria control and work towards more robust, sustainable, and effective strategies to combat this persistent public health challenge.

Conclusion

The Indoor Residual Spraying (IRS) program implemented in Mutasa District has demonstrated a notable decrease in malaria incidence, underscoring the efficacy of IRS as a public health intervention. The positive outcomes from this study advocate for the ongoing and expanded application of IRS strategies, emphasizing the necessity of sustained high coverage and adherence to quality standards to combat malaria effectively. Despite the progress, the study acknowledges the emergence of challenges such as insecticide resistance, which necessitates persistent monitoring and the evolution of IRS methodologies. These findings have significant policy implications, reinforcing the need for evidence-based decision-making to integrate IRS into broader malaria control and elimination policies. Looking ahead, the research underscores the importance of continued investigation into the long-term effectiveness and sustainability of IRS, encouraging the pursuit of integrated control strategies that can adapt to changing environmental and epidemiological landscapes, ultimately contributing to the global goal of malaria eradication.

RECOMMENDATIONS

The recommendations from the research on Indoor Residual Spraying (IRS) in Mutasa District provide a strategic framework for enhancing malaria control efforts.

Enhance IRS Coverage

- Targeted Expansion: Focus on reaching remote and high-risk areas to ensure equitable IRS coverage.
- Data-Driven Strategies: Utilize geospatial data and malaria transmission models to identify gaps in coverage and prioritize interventions.
- Community-Based Distribution: Empower local health workers and volunteers to support the distribution and application of IRS, ensuring deeper penetration into the community.

Monitor Insecticide Resistance

- Resistance Surveillance: Establish sentinel sites for continuous monitoring of vector susceptibility to insecticides used in IRS.
- Molecular Monitoring: Incorporate genetic testing to detect early signs of resistance development.
- Adaptive Management: Develop a responsive strategy that allows for the rapid switch to alternative insecticides when resistance is detected.

Integrate Interventions

- Complementary Tools: Enhance IRS with complementary tools like spatial repellents and larvicides for broader vector control.
- Health System Strengthening: Strengthen health systems to ensure prompt diagnosis and treatment of malaria cases, reducing the parasite reservoir.
- Education Campaigns: Conduct education campaigns to increase the correct and consistent use of LLINs alongside IRS.

Community Engagement

- Participatory Planning: Involve community members in decision-making processes related to IRS planning and implementation.
- Feedback Mechanisms: Establish channels for community feedback to continuously improve IRS programs.
- Cultural Sensitivity: Tailor communication and engagement strategies to be culturally sensitive and relevant to the local context.

Leveraging the Socio-Ecological Model (SEM) Framework

- Individual Level: Increase personal knowledge and skills regarding malaria prevention and IRS through targeted education.
- Interpersonal Level: Foster social support networks to encourage community-wide participation in IRS activities.
- Organizational Level: Collaborate with local organizations to integrate IRS into existing health and community services.
- Community Level: Engage with community leaders to endorse IRS and mobilize resources for its implementation.
- Policy Level: Advocate for policies that support sustainable funding and the integration of IRS into national malaria control programs.

Additional Recommendations

- Innovation in IRS Application: Explore new technologies for IRS application, such as drones for hard-to-reach areas.
- Environmental Considerations: Implement environmentally friendly IRS practices to minimize ecological impact.
- Economic Analysis: Conduct cost-effectiveness studies to optimize resource allocation for IRS interventions.

By expanding upon these recommendations and integrating new strategies, the IRS program can be more effective, sustainable, and responsive to the evolving landscape of malaria control. The application of the SEM framework ensures a holistic approach that considers the multifaceted influences on health behaviors and outcomes, ultimately contributing to the reduction of malaria incidence in the community.

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APPENDICES

Appendix 1 Consent form

- **Consent Statement**: “I, [Household Head’s Name], consent to participate in this survey assessing the acceptability and quality of the IRS program in Mutasa District. I understand that my responses will remain confidential and will be used for research purposes only.”
- **Bvumirano**; “ Ini (ZITA), ndinobvumiranakuvandichingendrimutsvakurudzoyekugashirikakwechirongwachekufiritamudzimbakudzivirira malaria. Ndinonzwisisakutimhindurodzangudzichachengetedzwauyedzichangoshandiswapatsvakurudzochete.

Appendix 2 Questionnaire for IRS Program Acceptability and Quality

Section 1: Demographic Information

1. **Household Identification**: Please provide an address for your household.
2. **Head of Household Information**:
    - Name:
    - Age:
    - Gender:
    - Contact Number:

Section 2: Acceptability of IRS Program

1. **Awareness and Knowledge**:
    - Were you aware of the IRS program in Mutasa District? (Yes/No)
    - How did you learn about the program?
    - What do you know about the purpose and benefits of IRS?
2. **Perceptions and Attitudes**:
    - On a scale of 1 to 5 (1 = Not at all, 5 = Very much), how acceptable do you find the IRS program?
    - What concerns or hesitations do you have regarding IRS?
3. **Experience with IRS**:
    - Have you personally experienced IRS in your household? (Yes/No)
    - If yes, how would you rate the quality of the IRS application? (Poor/Fair/Good/Excellent)
    - Were you satisfied with the communication and information provided during IRS?

Section 3: Quality Assessment of IRS

1. **Application Process**:
    - Was the IRS conducted at a convenient time for your household?
    - Were the spray teams professional and respectful during the application?
2. **Effectiveness**:
    - Have you noticed a reduction in mosquito bites or malaria cases since the IRS program started?
    - How would you rate the effectiveness of IRS in preventing malaria transmission? (Poor/Fair/Good/Excellent)
3. **Safety and Health**:
    - Were safety precautions followed during IRS (e.g., covering food, keeping children away)?
    - Did anyone in your household experience adverse effects due to IRS?

Appendix 3Approval for research

Telephone 026209-2503/2509

Fax 0228-2502

Reference:

Ministry of Health and Child Care
Hauna District Hospital
P.O. Box 1022
Hauna

Subject: Approval of Research

Dear Dr Arthur Kapfunde,

This is with reference to your letter dated October 30, 2023, regarding approval for research on the effectiveness of Indoor residual spraying program in reducing malaria incidence in Mutasa district 2022-2022. I am pleased to inform you that you have been granted permission to conduct your research in the district of Mutasa in Manicaland.

As the district health executive , we appreciate your interest and efforts in pursuing this research, which will contribute to the advancement of medical knowledge and practice. We understand that your research will involve registry reviews and inter

You are requested to follow the ethical guidelines and protocols for conducting medical research, and to ensure the safety and confidentiality of the participants. You are also required to submit a progress report to the district health office.

Please contact us on (0262092503) if you have any questions or concerns regarding the research. I wish you all the best and success in your research.

Sincerely,

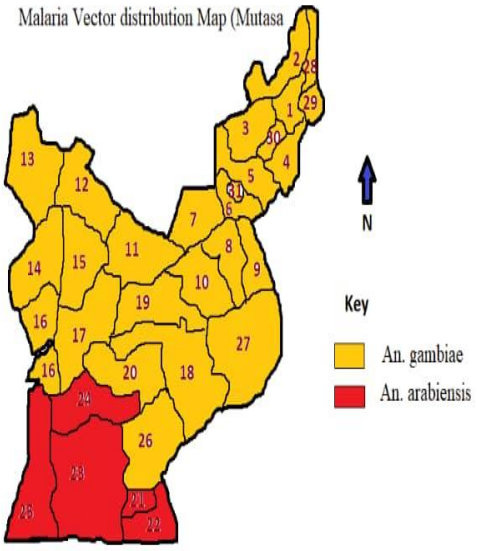
MUTASA DISTRICT
DISTRICT MEDICAL OFFICER
19 JAN 2024

Hazel Tandadzawa Dunga

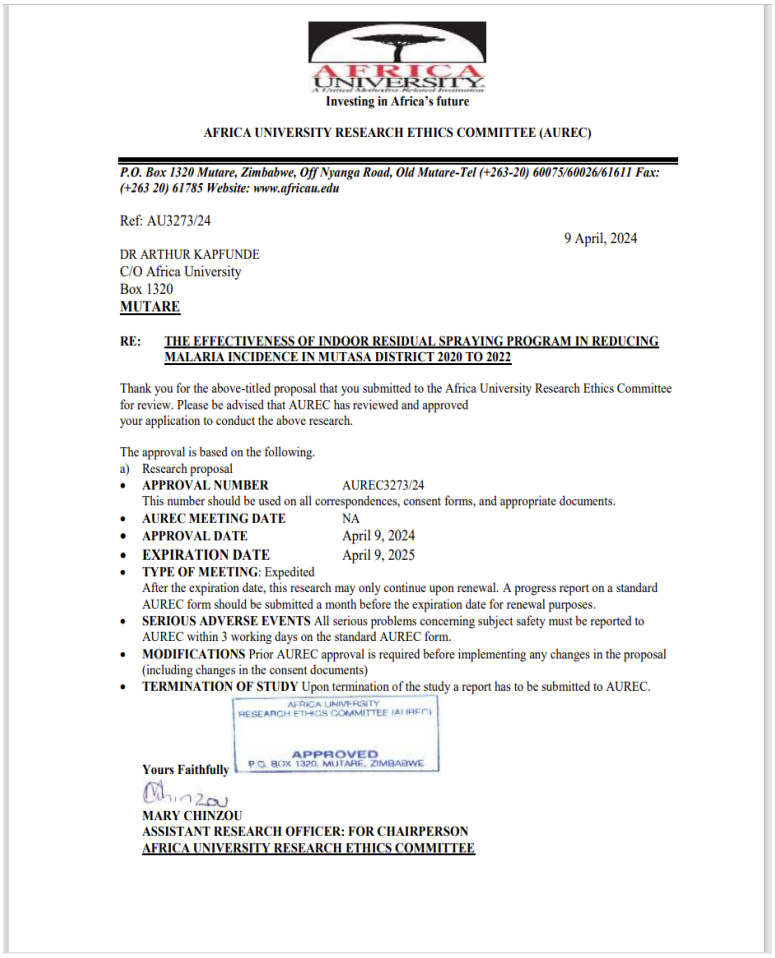
Mutasa District Adminstrator

P. BAG 1022, HAUNA
ZIMBABWE

Appendix 4Mosquito vector spatial Map



Appendix 5: AUREC approval



Investing in Africa's future

AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE (AUREC)

P.O. Box 1320 Mutare, Zimbabwe, Off Nyanga Road, Old Mutare-Tel (+263-20) 60075/60026/61611 Fax: (+263 20) 61785 Website: www.africau.edu

Ref: AU3273/24

9 April, 2024

DR ARTHUR KAPFUNDE
C/O Africa University
Box 1320
MUTARE

RE: **THE EFFECTIVENESS OF INDOOR RESIDUAL SPRAYING PROGRAM IN REDUCING MALARIA INCIDENCE IN MUTASA DISTRICT 2020 TO 2022**

Thank you for the above-titled proposal that you submitted to the Africa University Research Ethics Committee for review. Please be advised that AUREC has reviewed and approved your application to conduct the above research.

The approval is based on the following.

a) Research proposal

- **APPROVAL NUMBER** AUREC3273/24
  This number should be used on all correspondences, consent forms, and appropriate documents.
- **AUREC MEETING DATE** NA
- **APPROVAL DATE** April 9, 2024
- **EXPIRATION DATE** April 9, 2025
- **TYPE OF MEETING**: Expedited
  After the expiration date, this research may only continue upon renewal. A progress report on a standard AUREC form should be submitted a month before the expiration date for renewal purposes.
- **SERIOUS ADVERSE EVENTS** All serious problems concerning subject safety must be reported to AUREC within 3 working days on the standard AUREC form.
- **MODIFICATIONS** Prior AUREC approval is required before implementing any changes in the proposal (including changes in the consent documents)
- **TERMINATION OF STUDY** Upon termination of the study a report has to be submitted to AUREC.

AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE (AUREC) APPROVED P.O. BOX 1320, MUTARE, ZIMBABWE

Yours Faithfully

MARY CHINZOU
ASSISTANT RESEARCH OFFICER: FOR CHAIRPERSON
AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE