EFFECT OF INDOOR RESIDUAL SPRAYING ON MALARIA INCIDENCE RATE IN SELECTED PRISON FACILITIES OF UGANDA.

BY:

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DECLARATION

I declare that this dissertation is my own work and has never been submitted to any other university or institution of higher learning for a similar award.

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DEDICATION

I dedicate this dissertation to my late sister “Caroline Kamakune” who did not get a chance to live long enough to witness God’s Greatness. Continue resting in peace dear sister!

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List of acronyms

CBA	Controlled before-and-after study
CDC	Centers for Disease Control and Prevention
DDT	Dichlorodiphenyltrichloroethane
DHIS-2	District health information system (version 2)
GMP	Global Malaria Program
HMIS	Health management information system
IDI	In-depth interviews
IRS	Indoor residue spraying
ITN	Insecticide treated nets
ITSA	Interrupted time series analysis
MoH	Ministry of Health
NMCP	National Malaria Control Program
RCT	Randomized Clinical Trial
RDT	Rapid Diagnostic test
SD	Standard deviation
TPR	Test positivity rate
UPS	Uganda Prison Service
WHO	World Health Organization

Operational definitions of terms

In door residual spraying (IRS): is the application of a residual insecticide to potential malaria vector resting surfaces, such as internal walls, eaves and ceilings of houses or structures (including domestic animal shelters), where such vectors might come into contact with the insecticide.

Malaria case. Occurrence of malaria infection in a person in whom the presence of malaria parasites in the blood has been confirmed by a diagnostic test (WHO). Alternatively, a malaria case can be defined as the occurrence of malaria infection (symptomatic or asymptomatic) in a person in whom the presence of parasites in the blood has been confirmed by parasitological testing.

Malaria incidence: Number of newly diagnosed malaria cases during a defined period in a specified population at risk.

Insecticide: Chemical product (natural or synthetic) that kills insects. Ovicides kill eggs, larvicides (larvacides) kill larvae, pupacides kill pupae and adulticides kill adult mosquitoes. Residual insecticides remain active for an extended period.

Malaria control: Reduction of disease incidence, prevalence, morbidity or mortality to a locally acceptable level as a result of deliberate efforts.

Population at risk: Population living in a geographical area where locally acquired malaria cases have occurred in the past 3 years.

IRS intervention facility: This category included prisons which were implementing IRS during the five years under consideration.

Comparison facilities: This category included prisons which were not implementing IRS for all the 5 years under consideration.

ABSTRACT

Background: Indoor residual spraying (IRS) is a powerful intervention for reducing adult mosquito vector density and reducing malaria transmission. Uganda Prison Services (UPS) had been implementing IRS in some facilities for some time but the malaria prevalence among prisoners was still as high as 20.6% in the Northern region, 10.8% in the central region and 8.5% in the East central and yet IRS program was expected to significantly reduce the malaria burden in those facilities. In addition, the effect of the IRS program on malaria incidence rates had not yet been evaluated. Therefore, the aim of the study was to determine the effect of IRS on malaria incidence rates in selected prison facilities in Uganda and describe the IRS program considering the unique context of prisons.

Methods: This was a comparative cross-sectional design with retrospective review of records and utilized mixed methods approaches for data collection. Qualitative data were generated using in-depth interviews (IDI) from 10 purposively selected participants using IDI guide. All (210) monthly malaria reports for the period of five years (2018 to 2022) for the intervention (2) and comparison (2) prison facilities located in central and northern regions of Uganda were reviewed using a data abstraction guide. Thematic content analysis was used to analyze the qualitative data. Malaria incidence rate trends were generated using Microsoft Excel software while interrupted time series analysis was conducted to determine IRS effect on malaria incidence rate.

Results: The UPS IRS program was well structured and required resources such as trained human resources, IRS equipment, incentives, IRS consumables, IRS guiding documents, and waste management resources for efficient implementation. However, the program faced a number of challenges including inadequate and unreliable access to key IRS resources, welfare challenges and limited technical skills of the IRS teams. The malaria incidence trends were at lower levels

among the intervention facilities compared with the comparison facilities across the entire study period regardless of the region. The difference in the post IRS intervention slope and level of monthly malaria incidence per 1000 population between intervention and comparison facilities (central region) was not statistically significant (slope: (P = 0.154, CI = [-76.5, 12.9]); level: P = 0.504, CI = [-118.1, 233.0]). The difference between intervention and comparison facilities (northern region) in the slope of the trend of monthly malaria incidence per 1000 population post IRS compared with the pre IRS period was statistically significant (P = 0.001, CI = [21.9, 67.7]).

Conclusion: The evaluated IRS intervention was able to reduce the monthly malaria incidence per 1000 population among the intervention facility located in northern Uganda but not significantly in the intervention facility located in central Uganda. IRS intervention facilities had consistently lower malaria incidence rates throughout the study period and across regions.

Recommendation: UPS should consider strengthening the IRS program through timely and adequate provision of IRS resources, capacity development of IRS teams, improve IRS supervision, build internal capacity to conduct entomological surveys to monitor insecticide resistance and promote rational use of insecticides. To strategically improve the malaria control efforts within the study areas, the study recommends IRS implementation before the onset of the peak seasons of malaria incidence rates particularly in the months of September and March. The study further recommends that UPS considers extending the IRS program to all the prisons especially those located in regions of high malaria transmission of Uganda where the program has proved to significantly reduce malaria incidence rates.

1.0 CHAPTER ONE: INTRODUCTION AND BACKGROUND

1.1 Introduction

Malaria is an acute febrile illness caused by *Plasmodium* parasites, which are spread to people through the bites of infected female *Anopheles* mosquitoes (WHO, 2020b, 2020a). *Plasmodium falciparum* is the deadliest malaria parasite and the most prevalent on the African continent. In 2020, nearly half of the world's population was at risk of malaria. According to the latest World malaria report, there were 241 million cases of malaria in 2020 compared to 227 million cases in 2019. Twenty-nine countries accounted for 96% of malaria cases globally, and six countries including Nigeria (27%), the Democratic Republic of the Congo (12%), Uganda (5%), Mozambique (4%), Angola (3.4%) and Burkina Faso (3.4%) accounted for about 55% of all cases globally (MoH, 2014; WHO, 2020c). Vector control remains a vital component of malaria control and elimination strategies as it is highly effective in preventing infection and reducing disease transmission (MoH, 2016; WHO, 2015, 2016a, 2019). The two important interventions are insecticide-treated nets (ITNs) and indoor residual spraying (IRS) (MoH, 2014).

Indoor residual spraying (IRS) involves the application of a residual insecticide to potential malaria vector resting surfaces, such as internal walls, eaves and ceilings of houses or structures (including domestic animal shelters), where such vectors might come into contact with the insecticide (Lo et al., 2019). When performed correctly, IRS has been shown to be a powerful intervention to reduce adult mosquito vector density and to reduce malaria transmission particularly malaria incidence. IRS is considered an appropriate intervention where the majority of the vector population feeds and rests inside houses, the vectors are susceptible to the insecticide that is being deployed and people mainly sleep indoors at night (NMCP, 2011; WHO, 2015). In addition, IRS has been recommended for areas where the malaria transmission pattern is such that the population can be protected by one or two rounds of IRS per year. IRS

is also successful in areas where the majority of structures are suitable for spraying and structures are not scattered over a wide area, resulting in high transportation and other logistical costs (MoH, 2016). However, the effectiveness of IRS has been threatened by emerging resistance to insecticides among *Anopheles* mosquitoes (Pasteur & Raymond, 1996; Roland & Timoléon Tchuinkam, 2019; Yin et al., 2021). According to the recent World malaria report, 78 countries reported mosquito resistance to at least 1 of the 4 commonly-used insecticide classes in the period of 2010–2019. In 29 countries, mosquito resistance was reported to all main insecticide classes (WHO, 2016a). The WHO has been providing support to countries in monitoring and managing insecticide resistance, and this has remained one of the core functions of its Global Malaria Programme (GMP). The use of pyrethroids for the treatment of nets and the long use of certain other classes such as organochlorines (e.g. dichlorodiphenyltrichloroethane, DDT) and organophosphate compounds for IRS could have contributed to the development of resistance against the pyrethroids in malaria vectors. Uganda Prison Services (UPS) facilities had been promoting and implementing IRS in some facilities for some time but the effect of the program on malaria incidence rates had not yet been assessed. Periodic evaluation of IRS programs coupled with assessment of IRS practices remains crucial in improving performance of IRS systems for effective control of malaria. Therefore, this study assessed the effect of IRS implementation on malaria incidence rate within the selected prison facilities. Furthermore, the study has documented for the first time the IRS program implemented in selected prison facilities of Uganda.

1.2 Background to the study

According to the world malaria report, there were 241 million cases of malaria globally in 2020 compared to 227 million cases in 2019. Twenty-nine countries accounted for 96% of malaria cases globally, and six countries including Nigeria (27%), the Democratic Republic of the

Congo (12%), Uganda (5%), Mozambique (4%), Angola (3.4%) and Burkina Faso (3.4%) accounted for about 55% of all cases globally (MoH, 2014; WHO, 2020c).

According to the malaria indicator survey (2020), the national malaria prevalence was reported to be 19% (MoH, 2018). Regarding Ugandan prisons, a recent survey reported 4.0% malaria prevalence among prison staff and 4.6% among prisoners. The same study reported that among the staff, malaria was more prevalent among men (4.5%) than women (3.1%). Similarly, malaria prevalence among prisoners was higher among men (4.7%) than women 2.6%). Among staff, the prevalence was highest in those working and living in North West (11.5%) followed by those in Mid-West (7.2%) and North Eastern regions of Uganda (6.9%). Whereas for prisoners, malaria prevalence was highest among those residing in North West (20.6%) followed by Central (10.8%) and East Central 8.5% (UPS, 2019). Compared to the general national malaria prevalence, the prevalence of malaria in prisons was generally lower than the national burden though still relatively high in some facilities like those in northern and central regions. On the other hand, Uganda prison service (UPS) was implementing indoor residue spraying (IRS) program as the major intervention for the control of mosquitoes in the prisons of Uganda. The use of insecticide treated nets (ITN) in prison settings was discouraged due to the potential risks of injury (committing suicide) they present to inmates. UPS relied majorly on IRS for controlling mosquito vectors in prisons in order to prevent malaria transmission among prisoners. The success or failure in malaria control efforts in prisons could largely be attributed to the success or failure of the IRS program implemented by UPS. Therefore, the purpose of this study was to determine the effect of implementing indoor residual spraying on malaria incidence rate in selected prison facilities of Uganda and describing the IRS program implemented by UPS facilities considering the unique context of prisons.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Indoor residue spraying program for malaria control

Indoor residual spraying (IRS) is a vector control method recommended by WHO. The use of IRS in the African region has greatly increased over the years with over 36 countries recommending IRS and an estimated over 78 million people protected by IRS (WHO, 2019). At national level, IRS was introduced in 2007 in the Mid-North region of Uganda using mostly pyrethroids and organochlorines (MoH, 2014). With rising vector resistance, the Ministry of Health switched to carbamates for IRS (MoH, 2018). Between 2010 and 2014, IRS was scaled up to cover 11 high-malaria-burden districts in the Mid-North: Oyam, Kole, Nwoya, Amuru, Agago, Gulu, Kitgum, Pader, Omoro, Apac, and Lamwo (Tugume et al., 2019). In the context of UPS, a total of 50 prison facilities were implementing IRS program in 2021 though the coverage in terms of the number of prisons which are implementing IRS remained below the target.

The implementation of IRS program requires several factors to be considered while establishing the quantities of required resources. Determining the number of structures for spraying and number of house units per prison to be sprayed remain important. Knowing the above information, the total sprayable surface area for the target areas can be estimated which can guide calculation of amount of insecticide required, number of spray operators, sprayers, protective clothing, transport needs, supervisors and spraying duration (WHO, 2016a). The success of the IRS campaign largely relies on the spray teams and their supervisors. In order to maximize the efficiency and effectiveness of the spray teams, it is recommended that they consist of no more than six persons per team (WHO, 2019). Periodic evaluation of IRS programs remains crucial in improving performance of the system. In a study conducted in Zimbabwe to evaluate the IRS program, findings showed that shortages of inputs were reported by 97% of respondents, with districts receiving 80% of requested budget. In addition,

insecticides were procured centrally at national level and spraying started late with districts failing to spray all targeted households by end of the year. Poor disposal of chemical wastes was also reported. The same study reported some challenges impeding efficient IRS implementation which included food shortages for spray men, late delivery of inputs and poor state of IRS equipment (Pugie Tawanda et al, 2015). However, IRS has proved to significantly contribute to effective control of mosquitoes and consequently malaria control especially where there is no insecticide resistance as evidenced by some studies (Katureebe et al., 2016; Kigozi et al., 2012; Tugume et al., 2019).

2.2 IRS program implementation

According to the WHO, timely and good-quality delivery of IRS operations depends on strong program leadership and a well-monitored management system (WHO, 2015). This includes collection of baseline information, thorough planning, rigorous implementation, strict supervision, careful monitoring and evaluation, and reporting. The planning and management function must take into account current epidemiological and entomological conditions. WHO recommends that epidemiological and entomological factors should be reviewed annually and IRS strategy adapted and optimized according to changing conditions. Furthermore, successful IRS campaigns require a high level of political commitment; dedicated human, logistic, transport and financial resources; adequate organizational and planning capacity (WHO, 2015). The safety of spray operators, the community and the environment must also be ensured. In order to deliver IRS effectively, temporary field staff could be recruited, trained, motivated and retained; they also require back-up and supervision (Bath et al., 2021; Gonçalves et al., 2021). While the spraying itself can be delivered by semiskilled but dedicated temporary field staff, the program requires a well-trained core of skilled environmental or public health officers, field entomologists and epidemiologists, supported by program managers. Timeliness is a key factor in obtaining maximum benefits from IRS. The spray should be applied in the shortest period

of time just prior to the onset of the transmission season (Akogbéto et al., 2020; Brown, Kramer, Ocan, & Oryema, 2016; Magaço et al., 2019; Tangena et al., 2020).

Community awareness and support are other critical factors that influence the effectiveness of IRS programs. Acceptance by the local population contributes to obtaining a high level of coverage, and this should be ensured by implementing community education and communication campaigns. Though IRS acceptance is a big concern among the communities, the prison setting allows for mandatory use of IRS and hence issues of acceptance may not carry much relevance. It is important that households intended to use IRS should be well informed about the program, and aware of both its benefits and of the necessary preparations required for a safe and successful spraying campaign. When introducing IRS in a country for the first time, it is advisable to start with one pilot area and then to expand the intervention to other districts in each region or province. IRS should be started on a small scale, with measured annual increases allowing programs to gain experience in developing the necessary operational capacities, infrastructure and systems for an efficient operation.

Recent studies observed a shortage of field-experienced IRS coordinators and supervisors and advised that when starting a new IRS program, it is recommended to seek technical assistance from well-established programs in other countries or to engage private-sector expertise (Dengela et al., 2018; Mtove et al., 2016; Zhou et al., 2022). In countries where IRS operations have been ongoing, the focus should be put on improving quality before any scale-up of coverage is considered. This should be accomplished through post-spray season reviews, which analyze timing of implementation, coverage, quality and impact on the disease. The information generated in a post-season review provides essential lessons for adapting and improving planning and management for the next season's IRS operations (Akogbéto et al., 2020; Hannatu Janada Dimas, Nasir Mohammed Sambo, Muhammed Sani Ibrahim, Ike

Oluwapo Oyeneye Ajayi, Patrick Mboya Nguku, 2019; Jumbam et al., 2020; Magaço et al., 2019; Suuron, Mwanri, Tsourtos, & Owusu-addo, 2020; Tangena et al., 2020).

2.3 Temporal trends in malaria incidence rates.

At national level, a recent study evaluated the spatial-temporal patterns of malaria incidence in Uganda using HMIS data from 2015 to 2019 and reported an estimated 38.8 million confirmed malaria cases in a period of five years (Kigozi et al., 2020). A national mean monthly malaria incidence rate of 20.4 cases per 1000 across the study period was also reported. Regarding the trend of malaria incidence in Uganda, the same study reported high seasonality of malaria incidence with the months of June and July experiencing highest peaks and February and March having the lowest peaks (Kigozi et al., 2020). At regional level, mean monthly regional incidence rates were highest in Acholi region (Northern Uganda) at 52.3 cases per 1000 per month and lowest in Kigezi region (South Western Uganda) at 7.9 cases per 1000 per month (Kigozi et al., 2020). Consistent with national trend, monthly trends in regional incidence rates showed the highest peaks in June and July and the lowest troughs in the months of February and March of each calendar year. Generally, the trends showed that Acholi, West Nile, Karamoja, East Central – Busoga, and Teso persistently recorded the highest monthly incidence rates across the entire study duration (Kigozi et al., 2020). In another study which modeled climate induced relative malaria incidence in the major sub climatic zones of Uganda projected that malaria incidence trends were likely to gradually decrease from 2020s to 2040s and then increase until 2090s across the three major sub climatic zones of Uganda. Western and Northern regions were projected to experience the highest and lowest incidence respectively considering the business as usual scenario (Mohammed, Mwanjalolo, Gilbert, Alemie, & Gathenya, 2015). The projected malaria incidence trends were likely to present similarities in terms of periodicity and the peaks (Mohammed et al., 2015). In a related study

conducted in Apac district, the authors reported high malaria incidences in the months of August, September and November (Eunice, Wanjoya, & Luboobi, 2017).

In a related study conducted in Tanzania, the authors reported that malaria cases were recorded all year round with the highest proportion of malaria cases being recorded in April and July of each year of the study period (Aikambe & Mnyone, 2020). Another study conducted in Kenya to assess malaria burden trends reported the months of April and August to have recorded the largest number of malaria cases (Maniga et al., 2022). A study conducted in Ethiopia to determine trends of malaria prevalence reported that malaria incidence had decreased from 4.08 cases per 1000 person-years in 2017 to 3.62 cases per 1000 person-years in 2018, then increased to 4.94 cases per 1000 person-years in 2021. The study concluded that malaria trend over the last five years was inconsistent with an interannual variation (Duguma, Tekalign, & Abera, 2022).

2.4 Effect of IRS on malaria incidence rates

In a retrospective study conducted in Zambia to evaluate the effectiveness of indoor residual spraying with pirimiphos-methyl (Actellic) on malaria transmission reported that IRS appeared to be associated with reduced confirmed malaria incidence (Keating, Yukich, Miller, Scates, Hamainza, Eisele, 2021). In 2010, a team of scientists reviewed the various research articles which had studied the impact of IRS in preventing malaria infection at global level (Pluess, Fc, Lengeler, & Bl, 2010). The authors reported that in one of the randomized clinical trial (RCT) conducted in Tanzania, IRS was able to reduce re-infection with malaria parasites detected by active surveillance in children following treatment with a protective efficacy (PE) of 54%. In the same RCT, malaria case incidence assessed by passive surveillance was slightly reduced in children aged one to five years with a PE of 14%. The authors further noted that among the IRS implementing group, malaria prevalence was slightly lower (PE = 6%) compared with control group but this was not significant (Pluess et al., 2010). Furthermore, in another

controlled before-and-after study (CBA) conducted in Nigeria, the authors reported that IRS showed protection against malaria prevalence during the wet season with a PE of 26% but not in the dry season where a PE of 6% was reported. In addition, one interrupted time series (ITS) study conducted in Mozambique reported that IRS had significantly reduced malaria prevalence from 60% to 8% over a period of 7 years (Pluess et al., 2010). The same review paper reported that two RCTs had showed that IRS could reduce the incidence rate of all malaria infections. The PE was 31% in India and 88% in Pakistan. These two RCTs also assessed the effect of IRS on malaria species and their findings indicated that IRS could reduce the incidence of both *Plasmodium falciparum* and *Plasmodium vivax* with a PE of 93% and 79% respectively in Pakistan (Pluess et al., 2010).

In a study conducted in Uganda to assess the impact of IRS on health outcomes in one of the high transmission districts of Uganda reported that in the first 6 months following the first round of IRS with DDT, there was evidence of a modest decrease in measures of malaria morbidity. The same study reported that after the 3rd to 5th rounds of IRS with bendiocarb, there was a more dramatic decrease in malaria morbidity (Kigozi et al., 2012). In another study conducted in Uganda to assess changes in key malaria indicators following universal ITN distribution in three sites, with the addition of IRS at one of these sites concluded that universal distribution of ITN at three sites was associated with modest declines in the burden of malaria for some indicators. However, addition of IRS at the highest transmission site was associated with a noticeable decline in the burden of malaria for all indicators (Katureebe et al., 2016). Similarly, in a separate study which assessed malaria morbidity trends before and after IRS with Actellic 300 CS in Lira District in Northern Uganda, reported that the proportion of outpatient attendance due to malaria dropped from 18.7% before spraying to 15.1% after IRS (Tugume et al., 2019). Furthermore, the proportion of outpatient attendance due to confirmed malaria also dropped from 5.1% before spraying to 4.0% after the IRS intervention.

Consequently, there was a decreasing trend in malaria test positivity rate (TPR) for every unit increase in the month after spraying (Tugume et al., 2019).

2.5 Summary of Literature review

In summary, the reviewed literature was found to be more focused on describing IRS programs implemented within community settings and limited literature was accessed concerning the IRS program implementation in prison settings in Uganda or within the region. Therefore this study explored and described the IRS program implemented in the unique prison settings of Uganda. Similar gaps in literature were found regarding the temporal trends of malaria incidence rates in prison settings. Much of the available literature was mostly reporting malaria incidence trends within communities where several malaria control interventions were being implemented concurrently excluding the prisons which rely majorly on IRS whose malaria incidence trends could not necessarily be similar to those observed from community settings. To address this information gap, we set out to determine and compare the temporal trends of malaria incidence rates among prisons implementing IRS and those that did not in two regions (northern and central) of different malaria transmission dynamics. Regarding the reviewed literature on effect of IRS on malaria incidence rates, it was observed that the majority of the available accessible literature was generated from studies conducted outside Uganda and therefore could not represent the local context well. The other observation is that the few studies conducted in Uganda focused on studying the effect of IRS on malaria related morbidities in the community settings instead of prison settings which created an information gap. Methodologically, none of the reviewed studies used interrupted time series analysis which is a strong analysis tool for determining the effect of interventions like IRS on malaria incidence rates in a given population as it controls for secular trends and any other potential confounders. Cognizant of the above gaps in the available and accessible literature, a study was necessary to

determine the effect of IRS program on malaria incidence in contexts which have not received adequate research attention such as the prisons of Uganda.

3.0 CHAPTER THREE: PROBLEM STATEMENT, JUSTIFICATION AND CONCEPTUAL FRAMEWORK

3.1 Problem statement

The Uganda prison service (UPS) has been implementing IRS program for the control of mosquitoes in many prisons of Uganda. This was expected to consequently reduce the malaria cases among prisoner population. However, the malaria prevalence among prisoners was still as high as 20.6% (higher than the national prevalence) in the North, 10.8% in the central region and 8.5% in the East central (UPS, 2019). This raised questions on the effectiveness of the IRS program in controlling malaria in prisons since it was the main intervention practiced in that context. Though IRS program had been implemented for some years in many UPS facilities, little was known about the program in terms of how it was being implemented given the unique context of prisons. Also, other than knowing the point prevalence of malaria in prisons, the temporal trends of malaria incidence rates in prisons was not well known. Overall, the effect of IRS program on malaria related morbidity such as malaria incidence rates in the prisons remained largely unknown before this study. Lack of information on the effect of IRS on malaria incidence rates in the prison facilities had brought about uncertainty regarding implementation of the IRS program as the main intervention for malaria control in the given setting. Consequently, the reported high malaria prevalence could have easily led to potentially high morbidities and mortalities among prisoners plus UPS incurring high costs of malaria treatment for prisoners. To address the identified research gaps, the study has described in detail the IRS program implemented by UPS and determined the trends of malaria incidence rates over a five year period. In addition, the study evaluated the effect of indoor residual spraying on malaria incidence rates in prison facilities of Uganda.

3.2 Justification

Individuals who live in prisons located in high malaria transmission areas remain at a higher risk of contracting malaria compared to individuals who live freely in the same communities. This is partly due to restriction of some methods of malaria prevention such as insecticide treated nets due to fear of potential injury they may cause to prisoners. In addition, the prisoners rely largely on IRS for the control of mosquito vectors to consequently prevent malaria transmission within prisons. Assessing the effect of the IRS program on malaria incidence rates in selected prison facilities has provided some information to guide decision makers within UPS regarding malaria control efforts. Without this information, it was difficult to estimate the progress UPS has made in the control of malaria among prisoners in Uganda given the fact that prisons rely on IRS for control of malaria vectors. In addition, the study has documented the IRS program implemented in the selected IRS implementing prison facilities which has to a large extent helped to identify the gaps in program implementation which require corrective actions in order to strengthen the malaria control efforts in prisons. Therefore, the study generated important information and could guide decision making for improving malaria control interventions in prison facilities in Uganda.

3.3 Conceptual framework

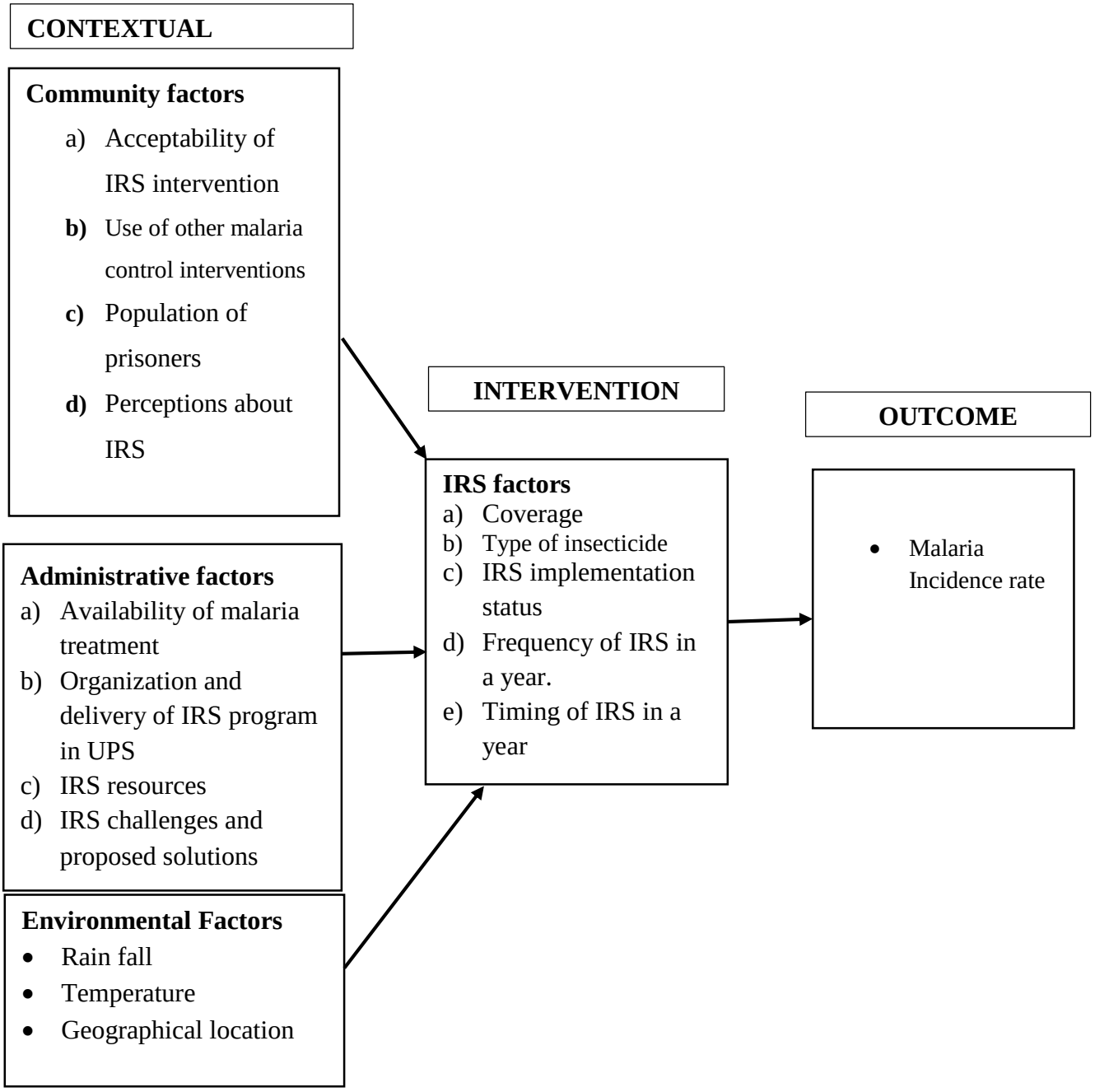

Figure 1: Conceptual framework for evaluating the effect of the IRS intervention on malaria incidence rate in selected prisons of Uganda.

Adopted from the monitoring and evaluation for malaria programs with minor modifications.

3.4 Narrative of the conceptual framework

A combination of contextual factors such as community, administrative and environmental factors could affect the effectiveness of the IRS intervention in achieving the desired outcome of reducing malaria incidence rate in selected prisons of Uganda. The community factors include; acceptability of IRS intervention, use of other malaria control interventions, prisoner population and perceptions about IRS. Administrative factors such as availability of malaria treatment, organization and delivery of IRS, IRS resources, challenges and proposed solutions could also affect the performance of the IRS program. Environmental factors include; rainfall, environmental temperature and the geographical location of the facility. On the other hand, the intervention indicators include IRS coverage, type of insecticide used, IRS implementation status, timing and frequency in a year.

4.0 CHAPTER FOUR: RESEARCH QUESTIONS AND OBJECTIVES

4.1 Research questions

1. How is indoor residual spraying (IRS) program implemented in prison facilities in Uganda?
2. What are the temporal trends (2018 to 2022) of malaria incidence rates in prison facilities that implemented IRS compared to those that did not implement IRS in central and northern regions in Uganda?
3. What is the effect of selected IRS interventions on malaria incidence rate in prison facilities located in the central and northern regions of Uganda?

4.2 General objective

To determine the effect of indoor residual spraying on malaria incidence rates among prison facilities in Uganda.

4.3 Specific Objectives

1. To describe the IRS program implemented by selected prison facilities in Uganda.
2. To determine the temporal trends (2018 to 2022) of malaria incidence rates in prison facilities that implemented IRS compared to those that did not implement IRS in central and northern regions in Uganda.
3. To determine the effect of selected IRS interventions on malaria incidence rate in prison facilities in central and northern regions of Uganda.

5.0 CHAPTER FIVE: METHODOLOGY

5.1 Study design

This was a comparative cross-sectional study with retrospective review of records and utilized mixed methods approaches for data collection. Data about IRS program in the selected IRS implementing prison facilities was generated through individual in depth interviews (IDI) and use of document reviews. The documents which were reviewed included public documents such as UPS HMIS database, IRS reports, IRS plans and correspondences. Quantitative data was collected from UPS HMIS data through document reviews following a standard data abstraction guide.

5.2 Study area

The study was conducted in a total of four prison facilities located in the northern (2) and central (2) regions of Uganda. In the northern region, Gulu main prison and Amuru prison were selected to represent the IRS implementer (intervention facility) and non IRS implementer (comparison facility) respectively. Gulu Main Prisons hosted approximately 1500 remanded and convicted inmates drawn from eight districts in Acholi Sub Region and Gulu city. The prison had a functional health facility for prisoners at the level of health center IV. Whereas Amuru prison is located in Amuru town council, Amuru district. The prison hosted approximately 250 inmates (convicts and remand inmates). Due to the small capacity of Amuru prison, it had a functional health facility at the level of health center II which served the prisoners.

In central region, Murchison bay in Luzira and Kasangati prisons in Wakiso district were selected to represent the intervention facility (IRS implementer) and comparison facility (non IRS implementer) respectively. Murchison bay prison is located in the central region, Nakawa division, Kampala city. It houses the Murchison bay hospital which serves as the national referral hospital for prisoners in the Uganda Prisons Services. Whereas Kasangati prison is

located within Kasangati town council, Wakiso district. It is relatively a small prison with capacity to host less than 500 inmates. It has a functional health facility at the level of health center II. The difference in size of the population of prisoners in the intervention and the comparison facilities was controlled for by using population rates and standardizing them to a standard population of 1000 prisoners. In this case, we adopted to use monthly malaria incidence rates

5.3 Selection criteria for prisons and prison health facilities

The specific prison facilities were selected with the guidance of the health department of UPS following a clear criteria. The study prisons were selected purposively based on their location, IRS implementation status and availability of reliable secondary data on malaria burden within the period of five years (2018 to 2022). According to IRS implementation status, in each of the regions, one prison was selected to represent prisons which implemented IRS (intervention facility) and one comparison facility to represent prisons which did not implement IRS. Within each of the selected prisons, health facilities serving the prisoner population were selected and their monthly medical reports within the UPS HMIS database were reviewed to extract the monthly malaria reports submitted within the five year period which was under consideration.

5.4 Study Population

Health workers and prison officers who were directly involved in IRS implementation in the two intervention facilities were interviewed. In addition, medical records of prisoners who were residing in any of the selected prisons during any of the five years (2018 to 2022) and had accessed medical services from the prison health facility of the respective prison facilities were also reviewed and relevant data collected.

5.5 Inclusion and exclusion criteria

This section presents the criteria which was followed to include or exclude data in this study.

5.5.1 Inclusion criteria

We conducted in depth individual interviews (IDI) with prison staff who were participating in IRS activities in the respective facilities. On the other hand, only IRS relevant documents were reviewed for collecting relevant data for purposes of this study. All the monthly malaria reports for the selected prison facilities over a five year period (2018 to 2022) were reviewed and relevant data about malaria burden extracted. The important variables about the monthly malaria reports included total number of suspected malaria cases, total number of confirmed malaria cases, total number of microscopy and RDT tests performed per facility. IRS interventions with at least 6 consecutive data points for monthly malaria incidence rates in the pre and post IRS intervention periods were considered for evaluating the effect of the program on malaria incidence rates. In addition, IRS interventions with equal number of monthly malaria incidence rate data points in the pre and post intervention period were included in the study. The specific IRS interventions evaluated in both the central and northern regions were the only ones which met the conditions for performing interrupted time series analysis for evaluating the effect of interventions on given outcomes.

5.5.2 Exclusion criteria

For the IDIs, prison staff who participated in the implementation of IRS activities in the selected facilities who did not consent to participate in the study were excluded from being interviewed. Malaria reports from health facilities within the selected prisons which served prison staff and the community were excluded from this study. Records with incomplete data were excluded from the data set. IRS interventions which violated any of the conditions for performing interrupted time series analysis were not evaluated for their effect on malaria incidence rate in both regions. For example, IRS interventions which were not implemented at regular intervals of not less than 6 months apart (the number of data points in the pre and post intervention period was not equal) or those implemented at regular intervals of less than 6 months apart were excluded from the study.

5.6 Sample size determination

The four prison facilities were selected purposively with two prisons per region. One prison facility which implemented IRS (intervention facility) and one prison which did not implement IRS (comparison facility) were selected in each region. The northern and central regions were reported to have the highest malaria morbidity in one of the UPS reports (UPS, 2019) and that was the basis of selecting prisons located in the two regions. The malaria prevalence in the northern region was reported to be as high as 20.2% which was slightly higher than the national average and was followed by central region. A total of five individual in depth interviews were conducted per IRS implementing facility making a total of 10 participants selected purposively. All the monthly malaria reports from the selected facilities for the period between January 2018 and December 2022 were extracted from the HMIS data and reviewed.

5.7 Sampling procedure

The prisons were selected purposively following a clear criteria described below. The study prisons were selected purposively based on their location, IRS implementation status and availability of reliable secondary data on malaria burden within the period of five years (2018 to 2022). According to IRS implementation status, in each of the regions, one prison was selected to represent prisons which implemented IRS (intervention facility) and one comparison facility to represent prisons which did not implement IRS. The two regions with the highest malaria prevalence among prisoners were selected. These included the northern and central region of Uganda. From each region, two facilities were selected to represent the intervention facility (IRS implementer) and a comparison facility (non IRS implementers). In the northern region, Gulu main prison and Amuru prison were selected to represent the IRS implementer (intervention facility) and non IRS implementer (comparison facility) respectively. In central region, Murchison bay in Luzira and Kasangati prisons in Wakiso

district were selected to represent the intervention facility (IRS implementer) and comparison facility (non IRS implementer) respectively.

Within each of the selected prisons, respective health facilities which exclusively served prisoners were identified and selected. With the help of the officer in charge of the respective prisons, the key prison staff who participated in IRS activities in each of the selected prisons were identified and interviewed. The key prison staff involved in IRS activities helped the researcher to identify key IRS documents at their respective prisons and shared such documents with the researcher for the sole purpose of collecting relevant data for this study. For each of the selected prisons, one data abstraction guide was filled using data collected from reviewed documents per prison. Data about the malaria burden from the selected prison health facilities was extracted from UPS HMIS database for the five years under consideration (2018 to 2022) following a clear inclusion and exclusion criteria.

5.8 Independent variables

The independent variables were broadly categorized into two; the contextual factors (administrative, community and environmental factors) and the intervention (IRS) factors. The contextual factors were measured using both quantitative and qualitative variables. Quantitative variables included; demographics, rainfall, environmental temperature, status of IRS implementation, insecticide used for IRS, frequency of IRS in a year, timing of IRS in a year and coverage of IRS. Whereas the qualitative data included exploring the following aspects of the IRS program; IRS resources, availability of malaria treatment services, selection of IRS insecticides, storage, handling and application, waste management practices plus IRS challenges and suggestions for improving the IRS program in prisons.

5.9 Dependent variables

The outcome variable was malaria incidence rate. The malaria incidence rate was determined by first obtaining the records of the monthly total number of new confirmed malaria cases by

both microscopy and RDT. The monthly number of new confirmed malaria cases was divided by the total prisoner population at risk for that particular month and the resulting proportion standardized by multiplying with 1000 for each of the prisons.

5.10 Study variables measurement

Both qualitative and quantitative variables were used to assess contextual, interventional and outcome factors in selected UPS facilities (Table 1).

Qualitative data

The qualitative data generated included exploring the following aspects of the IRS program; IRS resources, availability of malaria treatment services, selection of IRS insecticides, handling and application, waste management practices plus IRS challenges and suggestions for improving the IRS program in prisons. . The qualitative data which was collected was used to achieve objective one of this study.

Quantitative data

Quantitative variables which measured environmental factors such as rain fall and temperature were numerical (continuous) and were measured on a ratio scale. All quantitative variables which were used to measure the intervention (IRS implementation) were categorical and measured using a nominal scale. On the other hand, the variable used to measure the malaria incidence rate was numerical (continuous) and measured using a ratio scale. Quantitative data was used to achieve the objectives two and three.

Table 1: Study plan showing the data sources and analysis plan for study objectives

Objective	Data source	Plan for analysis
1. To describe the IRS program implemented by selected prison facilities in Uganda.	Primary (IDI with prison staff involved in IRS implementation) and secondary sources (IRS document reviews) data sources.	The qualitative data was transcribed verbatim. The transcripts were coded to generate a code book and the codes were transferred into Atlas ti software version 7 for analysis using thematic content analysis.
2. To determine the temporal trends (2018 to 2022) of malaria incidence rates in prison facilities that implemented IRS compared to those that did not implement IRS in central and northern regions in Uganda.	Secondary data sources mainly UPS HMIS data and IRS documents at selected prisons were used.	Total number of new malaria cases reported per month from UPS HMIS data from the selected facilities was extracted from the system in Microsoft excel spreadsheet, cleaned and later analyzed. The background characteristics of the selected prisons and summary of the quantitative data have been presented in a tabular form. Categorical variables have been presented as frequencies and percentages whereas numerical data was summarized using means, standard deviation and confidence intervals. Trends of malaria incidence rates were generated in Microsoft Excel software version 13 for the selected UPS facilities

		located in central and northern regions of Uganda. Trends were generated for individual prisons and at regional level.
3. To determine the effect of selected IRS interventions on malaria incidence rate in prison facilities in central and northern regions of Uganda.	Secondary data sources mainly UPS HMIS data and IRS documents (records) at selected prison facilities were used to achieve this objective	Interrupted time series analysis was conducted to determine the effect of the selected IRS intervention on malaria incidence rate for the selected prison facilities. The p-values of ≤ 0.05 at 95% confidence interval were considered significant. The results were presented at regional level using tables and graphs.

5.11 Data Collection procedure

Experiences on IRS program implementation in the selected IRS implementing prison facilities were generated by conducting in-depth interviews (IDI) with purposively selected prison staff (uniformed and non-unformed officers) and reviewing of relevant IRS records which were available and accessible at the selected prison facilities. A total of 5 prison staff involved in the IRS activities at each interventional facility were identified and interviewed on key aspects of IRS following a clear IDI guide (Appendix 1). The qualitative data generated from IDI was recorded using a voice recorder and written notes were also made by the researcher. The quantitative data was abstracted from prison IRS records using a data abstraction guide (appendix 2) and it was used to generate key demographic and background characteristics of the selected prison facilities.

The data for the second and third objective was abstracted from the monthly medical reports archived in the UPS HMIS database for the selected prison facilities over the five year period

(2018 to 2022). All the monthly malaria reports from the selected facilities for the period of January 2018 to December 2022 were extracted from the UPS HMIS data and reviewed. Data on average monthly rainfall and atmospheric temperature was obtained from the database of Uganda Meteorological Authority for the years 2018 to 2022 for each of the study areas (Kampala, Wakiso, Gulu and Amuru). The data was extracted from the database and transferred into excel spreadsheet (Microsoft Excel version 2013).

5.12 Data collection methods

This section presents the data collection methods which were adopted for the collection of data for this study.

5.12.1 Individual in-depth interviews

The study conducted IDIs with purposively selected members of staff of the selected prisons who had ever participated in activities related to IRS implementation. Participants were encouraged to be more open and to share their experiences, observations, views, opinions and any other facts about the IRS program implementation in their respective facilities. The qualitative data generated from IDI was recorded using a voice recorder and written notes were also made by the researcher. The interviews were conducted between the researcher and the interviewee to ensure confidentiality and anonymity of participants. The interviews were conducted in English language while seated within the premises of the respective prisons and lasted between 30 and 35 minutes.

5.12.2 Document reviews

Document review is a process used to collect data after reviewing the existing documents. It was an efficient and effective way of gathering data as documents were manageable and provided a practical resource to get qualified data from the past. Apart from strengthening and supporting the research by providing supplementary research data, document review as a data generation method has emerged as one of the beneficial methods to gather quantitative research

data. Relevant documents regarding the IRS in the selected prisons were identified with the help of the staff responsible for IRS in the respective prisons. The documents reviewed included; UPS HMIS database, IRS reports, plans, and minutes of meetings, protocols and letters. Permission to access the relevant documents was thought from the officer in charge and the relevant staff responsible for IRS in the respective prisons. The available and accessible documents were reviewed and relevant data was extracted using a standard data abstraction form.

5.13 Data collection tools

IDI guide (appendix 1) and data abstraction guide (appendix 2) were used for collecting qualitative and quantitative data respectively.

5.13.1 IDI guide

The IDI guide was developed with open ended questions, pretested and was used to guide the researcher in the process of generating the primary data at selected prison facilities. The interview proceedings were recorded using a voice recorder and written notes were also made by the researcher. The IDI guide contained relevant probes which were used to gain deeper understanding of issues or to seek clarification of the participants' submissions.

5.13.2 Data abstraction guide

The data abstraction guide was developed, pretested and was used to collect quantitative data from secondary sources at selected prison facilities. The data abstraction form collected data about the general background characteristics of the selected prisons such as location, number of prisoners, IRS insecticides used, frequency of IRS implementation, malaria cases, temperature and rainfall.

5.14 Data analysis

Objective one

The qualitative data was transcribed verbatim by two research assistants. The transcripts were coded to generate a code book and the codes together with the transcripts were transferred into Atlas ti software version 7 for analysis using thematic content analysis. Content analysis is the procedure for the categorization of verbal or behavioral data for the purpose of classification, summarization and tabulation. Themes were generated from related codes and they were interpreted by composing explanations or descriptions from the information which was further substantiated by either quotations or descriptions. The codes were generated by the two research assistants and one colleague cross-checked the codes before they were shared with my supervisors. The above measures were meant to minimize potential bias from the researcher.

Objective two

The monthly total number of new malaria cases reported for the selected facilities for the five years under consideration were extracted from UPS HMIS data in Microsoft excel spreadsheet, cleaned and later analyzed. The trends in malaria incidence rates over the study period were generated using Microsoft Excel software. The trends were compared between the intervention and comparison facilities in each region. The results of the above analysis were presented using graphs and fulfilled the second objective of this study.

Objective three

The monthly rainfall and atmospheric temperature was subjected to initial analysis using an independent samples t-test to determine whether the mean temperature and mean rainfall over the study period between two facilities located in the same region were statistically different or not. If the means were statistically different, we would control for that variable in the regression model.

Interrupted time series analysis (ITSA was also conducted to determine the effect of IRS program implementation on malaria incidence rate in selected prison facilities. A notable strength of ITSA with respect to evaluating the impact of interventional programs using observational data was that the approach enabled us to control for the effect of secular trends in a time series of outcome measures. ITSA can be conducted with respect to population rates rather than individual level. It can also help the investigator to easily conduct stratified analysis in order to evaluate the differential impact of an intervention on sub populations of individuals (for example by sex, age groups, race etc). ITSA is also credited for producing clear and easy to interpret graphical results even in the absence of statistical outputs from a corresponding segmented regression model (Penfold & Zhang, 2013). However, ITSA faces some limitations such as the need for a minimum of 6 time periods before and after an intervention to evaluate changes statistically. In addition, the challenge of getting a good comparison group and the fact that the investigator must be careful not to make individual level inferences (Penfold & Zhang, 2013).

Data analysis was done using STATA version 15 (Stata Corp, College Station, Texas, 2015). Analysis was conducted by fitting the multiple group ITSA model (Equation (1)). The IVACTEST was conducted to test for autocorrelation after estimation as proposed by Cumby-Huzinga. The model was re-run by specifying the lag order accounting for autocorrelation. The Newey-West graphs were presented to show the trends in the malaria incidence rate before and after the intervention. The results for the third objective have been presented using graphs and tables. The following regression model was used to fit the data (Bagonza et al., 2021; Linden, 2015):

$$\mathbf{Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 X_t T_t + \beta_4 Z + \beta_5 Z T_t + \beta_6 Z X_t + \beta_7 Z X_t T_t + e_t}$$

Where; $\mathbf{Y_t}$ = difference in monthly malaria incidence rate between the intervention and control prisons in each region for each time period.

$\mathbf{T_t}$ = equally spaced time points in months of indicator

$\mathbf{X_t}$ = Indicator variable representing IRS implementation period which was coded as 0, otherwise 1

Z = Indicator variable representing intervention and comparison groups (IRS implementer was coded 1 and comparison was coded 0)

$\mathbf{X_tT_t}$, $\mathbf{ZT_t}$, $\mathbf{ZX_t}$ and $\mathbf{ZX_tT_t}$ = Interaction terms

$\mathbf{ß_0}$ = intercept, represents the starting level of the outcome variable (Malaria incidence rate)

$\mathbf{ß_1}$ = the slope of the outcome variable before the implementation of IRS. The coefficient of "time" captures the overall secular trend in the outcome variable over the entire time period

$\mathbf{ß_2}$ = change in the malaria incidence rate after IRS implementation. The regression coefficient on this variable is interpreted as the immediate impact of IRS on the level of the outcome (Malaria incidence rate)

$\mathbf{ß_3}$ = Difference between pre-IRS implementation and post-IRS implementation slopes of the Outcome (Malaria incidence rate)

$\mathbf{\beta_4}$ = difference in the level between intervention and comparison prior to IRS implementation

$\mathbf{\beta_5}$ = difference in the slope between intervention and comparison prior to IRS implementation

$\mathbf{\beta_6}$ = difference in level between intervention and comparison in the period immediately following IRS implementation

$\mathbf{\beta_7}$ = difference between intervention and comparison in the slope after IRS implementation compared with the period before IRS implementation.

$\mathbf{e_t}$ = error term representing unexplained random variability in the model

The model made the following assumptions; the outcome of interest (malaria incidence rate) would remain unchanged in the absence of the IRS intervention and validity of comparisons between the intervention and comparison facilities depended on the assumption of exchangeability. The *p*-value of ≤ 0.05 at 95% confidence interval was considered significant.

To control for potential confounders such as environmental temperature and rainfall, the mean temperature and rainfall for the two facilities located in the same region was compared using the independent sample t-test to determine whether the means were statistically different or not. If the means were found to be not statistically different, the variables were excluded from the ITSA model and if the means were statistically different, we could control for them in the model. The background characteristics of the selected prisons and summary of the quantitative data has been presented in a tabular form. Categorical variables are presented as frequencies and percentages whereas numerical data was summarized using means, standard deviation, standard error of mean and confidence intervals.

5.15 Ethical Considerations

The study received approval from UPS authorities prior to implementation (appendices 3 and 6). We also received ethical approvals from the research ethics committee of School of Public Health, Makerere University (appendices 5 and 7). The study utilized secondary data sources which majorly included the UPS HMIS database with permission from UPS to access the data for the selected prison health facilities. The study involved interviewing human subjects (prison staff) and therefore informed consent (appendix 4) was sought from each participant prior to participation. The principles of voluntary participation, confidentiality, anonymity and freedom from harm were strictly adhered to during the entire research period. In the process of secondary data review, confidentiality of personal data was strictly observed and issues of double vulnerability were avoided by only reviewing medical records reported at least 3 months prior to data collection. The study also ensured that the rights of the prisoners were protected and observed at all stages of the study.

6.0 CHAPTER SIX: RESULTS

6.1.1 Description of the IRS program implemented by UPS

6.1.2 Background characteristics of IDI participants

The mean age of the study participants was 35.8 (Standard deviation, SD = 8.2years) years while the mean number of years spent working on IRS and in service was 4.5 (SD = 4.1) and 8.6 (SD = 7.5) respectively. Male study participants were the majority (80%). The large majority (60%) of the participants were health workers (vector control officers, environmental health officer, public health officers and clinical officers) while the rest were prison staff. Regarding the roles played by the research participants in IRS implementation, majority (60%) played a supervisory role while the rest were at operational level serving as fumigators (40%). The IRS coverage was less than 100% in both facilities though the facility in the northern region reported slightly higher coverage than the facility located in the central region.

6.1.3 Organization and delivery of IRS program in UPS

From the data analysis of the management structure, one theme was generated which described the IRS program as a well-structured program with clear chain of command. Participants described the IRS program in UPS as a well-structured program with a management hierarchy which spanned from the top leadership to the lowest level. The managers of the program included non-uniformed (technical) and uniformed officers (prison officers), who served at the headquarters, regional, and facility levels. At the top level, the management structure was headed by the commissioner general of prisons (CGP). The CGP is responsible for overseeing the entire IRS program in UPS. The CGP was assisted by the commissioner for health services and the assistant commissioner for health services plus the senior environmental health officer who worked from the headquarters. Both health workers and prison officers reported that the management structure at regional level was headed by a uniformed officer; the regional prisons commander (RPC) who was reported to be responsible for providing supervision to all the

prisons in his/her region. Furthermore, both categories of participants reported that RPC received reports and requisitions related to IRS from the officers in charge (OC) of the various prisons and submitted them to the headquarters. The participants established that the management structure at the facility level was headed by the OC (uniformed officer). The OC was the overall head of the facility and received IRS-related reports and requisitions from the environmental health officer. Furthermore, the participants reported that the IRS program in UPS was also supported by health workers including the medical superintendent, environmental health officers, vector control officers and public health officer at facility level and spray teams, which were composed of IRS-trained uniformed officers. The spray teams were responsible for performing the spraying during IRS.

"Yah our boss here is of course the medical superintendent, next to him is the senior environmental officer I was telling you about, under him senior vector control officer then me am the health inspector. Under us, we have the people who do the spraying (spray persons), the fumigators they are uniformed staff who are trained to do the work (Health worker_Central_IRS_04)."

"The commissioner of health who sits at the headquarters and the commissioner for health reports to the Commissioner General (Health worker_central_IRS_04)."

From the analysis, three major themes emerged from the data describing the key stakeholders in IRS program implementation in UPS. They included the multidisciplinary technical team, administrators and the general prison community comprising of prisoners and the spray teams. These stakeholders worked together to implement the various IRS activities within their respective facilities. The multidisciplinary technical team comprised of public health officers, entomologists, clinical officers and environmental health officers was responsible for planning and supervision while the administrators were responsible for providing the IRS related resources. The leaders of prisoners were responsible for mobilization of the general prison

community for IRS activities. The spray teams were involved in the actual spraying activities in the prisons.

"Actually some of the key stakeholders here the number one is the commissioner General of prisons, secondly, we come to the RPC who is the head of the region, the in charge of the hospital (MS) and from there we go to the health inspectors, then the lower people at grassroots level (Prison officer_central_IRS_05)"

6.1.4 Important IRS Resources

A total of six themes were generated from the analysis of participants' submissions describing key resources for successful implementation of IRS within UPS. These included trained human resources, IRS equipment, incentives, IRS consumables, IRS guiding documents, and waste management resources. The trained human resources included both uniformed and non-uniformed officers who worked in a multidisciplinary manner. IRS equipment included motorized pumps, measuring cylinders, and personal protective equipment. Incentives included providing means of transport for the spray teams, lunch, and allowances. IRS consumables included insecticides, water, fuel for the pump, and disposable protective equipment. IRS guiding documents included standard operating procedures and information, education and communication (IEC) materials. Waste management resources included building pits and incinerators to promote safe disposal of IRS wastes. The participants across facilities emphasized the importance of trained human resources, IRS equipment, and incentives. They said that the absence of these resources affected their motivation and the quality of work. Regarding the availability of medicines to treat malaria, the participants from the facility located in the central region reported reliable supply of sufficient quantities of drugs, while participants from the facility located in northern Uganda reported frequent stock outs. They attributed this to delayed delivery of medicines.

The participants said the following regarding the IRS resources;

"Number one is the trained personnel and the health inspector is very key there. Two, the equipment for spraying, the chemicals for spraying including the other team of human resources they work with. (Health worker_northern_IRS_09)"

"You need some SOPs to show you how the activity is done, how to mix and how to apply. The pump and the protective wear are available but the issue of the SOP, am not sure and I think the health inspector is in a better position to tell you about the SOPs. (Prison officer_northern_IRS_08)"

"Drugs for malaria treatment, we have always experienced delayed delivery of drugs from NMS, so we normally get stock outs but we manage them by borrowing malaria drugs from other units and we have never sent away a patient that we do not have malaria medicines. The stores always try to get medicines from other health facilities to cover up the delays of NMS until when it delivers medicines (Prison officer_northern_IRS_08)"

6.1.5 Handling and application of IRS insecticides

One theme was generated regarding acquisition of insecticides by the selected prison facilities. Centralized insecticide procurement system was generated from the analysis of participant submissions. All participants reported that the IRS insecticides were acquired by the specific prisons through a centralized procurement system managed from UPS headquarters. The participants further explained that lower units submitted requests for insecticides through the regional office which were procured by the headquarters and delivered to the respective prisons for use. Participants from the northern facility reported that they have been using Lambda-cyhalothrin based insecticides for IRS for a long time whereas for the central region, lambda-cyhalothrin and bendiocarb based insecticides were reported by participants. The participants from the central region facility explained further that pyrethroid based insecticides were used for a long time and recently they changed to bendiocarb based insecticides. Bendiocarb based insecticides were reported to have been introduced in the central region facility in the year 2021.

Regarding the frequency of IRS, the participants reported an average of 4 and 3 times a year for the central and northern region facilities respectively. The participants further explained that IRS was not implemented following a clear schedule but rather depended on availability of resources to support IRS activities.

"Here normally the health inspector quantifies and writes a requisition to the senior environmental health officer at the headquarters who goes ahead to review the request and sends the chemicals to us. So we don't procure chemicals here, there is a central procurement system. The people at the headquarters procure the chemicals and send them down. (Prison officer_northern_IRS_08)"

Inaccessible IRS SOPs was generated from data analysis which was explained by the inconsistencies in responses within the participants of the same and across facilities. Some participants especially health workers reported having SOPs whereas prison officers were not aware of the availability of the same. Further inquiry revealed that SOPs were not easily accessible to the IRS teams as substantiated by the quotation below;

"We wrote it sometime back when we were for that training way back but I don't know where it is located now (Prison officer_central_IRS_05)."

Unstandardized insecticide dilution process

The participants (prison officers) revealed that dilution of IRS insecticides was guided by the desire to implement integrated vector control strategies. The prison officers seemed to understand the process of insecticide dilution better than the health workers who supervised the process across facilities. The participants further explained that integrated vector control strategies involved mixing IRS insecticides and other pesticides for the control of other external parasites (bedbugs, lice and fleas) and nuisance insects such as cockroaches. From the participant reports, we observed inconsistencies in terms of volumes of IRS insecticide and water mixed within and across facilities. Irrational insecticide dilution practices were reported

by health workers which were deviating from the recommendations of the manufacturer as evidenced by the quotation below;

"Yah it is a big one, it may contain like 40ML. The target is to put like 200Ml super dichlovos in 20L. When we are mixing, we get one sucket of Icon and put in 20L (Health worker_northern_IRS_06)"

Unstandardized insecticide application process

The process was reported to begin with the spray teams checking the weather since a sunny day was preferred and putting on protective wear. The insecticides were then diluted and mixed. The prisoners were asked to remove their valuables from the wards. The spray teams could then access the wards and close the windows and doors. Participants reported that the interior was sprayed first. Some reported that spraying started with the inner rooms while other participants reported to start with the beddings. The walls and ceiling were then sprayed in no particular order. The external walls were sprayed while the doors and windows remained closed for a period of time. The inmates could remain outside the wards for at least 8 hours after spraying. Lastly, the wards were then cleaned and the wastes of dead insects were removed and disposed of.

"For us when we are going to do fumigation, like if we are fumigating this place. We first make sure all the windows are closed, all those outlets we close them. Then even the door when you enter inside, you close it, then you start spraying from inside, then when you finish spraying inside then you come out and leave it closed for like 2 hours before you can open. That's what we always do (Health worker_northern_IRS_06)"

From the analysis of data regarding factors which were considered before changing an insecticide, two themes were generated; insecticide factors and environmental factors. Insecticide factors such as the insecticide performance, safety, accessibility and affordability were reported to be influencing the decision of the technical teams at UPS to change from one

insecticide to another. However, it was found out that both study facilities had experienced prolonged use of the same class of insecticide. Environmental factors such as mosquito infestation levels and type of housing could influence the decision to change insecticides at facility level

"I would consider the side effects because there are some chemicals you use and people get allergic reactions. Such a chemical would be changed. Then I would consider changing the insecticide if we sprayed like today and a week later it looks like we did not spray, then you would have to change because it is not effective. (Prison officer_northern_IRS_08)"

One theme was generated describing how insecticide resistance was monitored among mosquito populations within UPS. Passive surveillance was the main method used to monitor mosquito response to insecticides. Participants reported that insecticide resistance among mosquitoes in the study prisons was monitored using indirect indicators such as monitoring of malaria burden trends and assessing reports from ward leaders about mosquito infestations. Direct scientific methods of detecting insecticide resistance, such as WHO and CDC recommended bioassays were reported to have been used in the past, but neither of the study facilities had the capacity to conduct such tests.

"We would know through the feedback from the data in the hospital, whether the cases are increasing or not. But for me I would like the scientific results (Health worker_central_IRS _02)."

6.1.6 IRS Waste management

Regarding IRS waste management, three themes were generated which included waste sorting, incineration and use of a contracted medical waste management company. The participants across the facilities reported that IRS wastes were managed at facility level through waste sorting, incineration and utilization of the services of a medical waste management company contracted by MOH to collect hazardous medical wastes from all health facilities in Uganda.

Generally, the IRS waste management practices of the study prisons was good as evidenced by the one of the participant's quote below;

"Green label I think is a waste company or health care waste company which is contracted by MOH to collect hazardous wastes from health care units. They are the one who come to pick plus medical wastes. So when they come, there is a particular place they put those ones, they don't mix them with normal wastes. So they pick and take because we don't have facilities here to manage such wastes. (Prison officer_central_IRS_04)"

6.1.7 Reported perceptions of prisoners regarding IRS program

Two themes were generated; positive and negative perceptions generated to describe the reported perceptions of prisoners towards the IRS program. Positive perceptions involved participants reporting that IRS was a highly accepted program within the prison partly because of the benefits which came with the program linked to the integrated vector control strategies implemented. However, some negative perceptions related to exposure of prisoners to IRS chemicals (allergies and skin allergies), inconveniences during application and conspiracy theories with a belief that government wanted to indirectly harm the prisoners were reported by prison officers in both facilities.

"At the time, people were saying that these people are trying to castrate us using the chemical, others were saying that these people want to kill us and others were saying that we want to bring cancer to us. But enough health education was given and they were told that it was not only them that were disturbed by malaria but malaria also kills people outside and therefore, the spraying was going to be done outside the prison too (Health worker_central_IRS_01)"

Regarding other malaria control interventions implemented by the selected prisons, three themes were generated which included preventing mosquitoes from breeding, prompt management of cases and malaria prevention among pregnant inmates. Strategies for preventing mosquitoes from breeding included hygiene and sanitation, larviciding and

improving drainage. Prompt management of cases was reported to involve early detection through testing and making sure antimalarial medicines were available at all times within the health facilities serving prisoners. Interventions for malaria prevention among pregnant inmates included prompt treatment of the sick, prophylactic treatment of pregnant inmates, early closing of windows and doors

"Well, they are there like having to clear the bushes around our areas of residence and also ensuring that the stagnant water where mosquitoes breed from are drained and then also closing windows and doors early so that mosquitoes don't get access to enter. (Health worker_central_IRS_01)"

"For the pregnant inmates, they give them Fancida as preventive measure. Those who are brought to prison while pregnant are given that. (Prison officer_northern_IRS_09)"

6.1.8 Reported challenges facing the IRS program in UPS

Regarding the challenges facing the IRS program, three themes were generated which included; inadequate and unreliable access to key IRS resources, welfare challenges for the spray teams and limited technical skills of the IRS teams. The above challenges were reported by participants from both facilities. Inadequate and unreliable access to key IRS resources included limited program funding, inadequate quantities of IRS insecticides, inadequate PPEs, lack of transport, lack of simple utilities like fuel, lack of IEC materials, frequent stock outs of IRS insecticides and limited number of trained personnel to operationalize the program. Welfare challenges for the spray teams was characterized by failure to provide extra incentives to the spray team such as lunch allowance, per diem and PPEs. This was reported to lower the motivation of the spray teams. Furthermore, limited technical skills of the IRS teams was partly attributed to failure to conduct refresher trainings for IRS teams in the study prisons to strengthen the skills of the members especially the non-technical members. Other participants attributed the limited technical skills among members of the IRS teams to lack of IRS IEC

materials and inaccessible IRS SOPs. Participants also reported weaknesses in the system regarding the supervision of IRS activities as much emphasis was put on reporting and following the hierarchy/ chain of command. The health workers in central region further revealed that less attention was put on supervision of the IRS activities to ensure that the program is implemented in line with known international guidelines.

"We were 11 but transfers took some. We were 11, not 11 we were 16 but right now in Kampala extra, we are only 4 and two are from Kigo to make it 6. So, we are very few. (Prison officer_central_IRS_05)"

"The other challenge is when you ask for a certain quantity and then you receive less and then you start doing some mathematics to see how to prioritize the little chemicals you have received. (Prison officer_northern_IRS_08)"

"actually even motivation because at times when you are dealing with chemicals, there are certain foods you need to eat like when we are spraying, they say take milk before you mix the chemical and start the work and after the work take milk because chemical poisoning has no proper treatment, just get the antidote so you need to avoid it early. (Prison officer_central_IRS_05)"

"Majorly here we talk about ourselves the challenges we are facing in the field. Motivation is low. (Prison officer_central_IRS_05)"

6.1.9 Proposed solutions to the reported IRS challenges

Three themes describing the proposed solutions to IRS challenges were generated. These included; capacity development of IRS teams, timely and adequate provision of IRS resources and decentralization of IRS program. Capacity development of IRS teams was a key proposal as participants advocated for regular refresher trainings to help improve the technical skills of the teams regarding IRS implementation in modern times. They also proposed to UPS management to organize IRS awareness campaigns within the prisons to address some of the

existing information gaps. Timely and adequate provision of IRS resources was another important proposal put forward by both health workers and prison officers in both facilities. The participants proposed increasing funding of the IRS program, providing sufficient PPEs, increasing the number of trained personnel, providing better insecticides, providing modern pumps, timely supply of IRS materials, and improving the welfare of the IRS teams. Lastly, the participants proposed decentralization of the IRS program to the lowest prison units to improve the efficiency of the program by reducing the delays associated with complex bureaucracy and protocol. This would require each of the prison units to have its own trained IRS team and requisitioning their own IRS materials through the regional prisons commander (RPC) to the headquarters. The participants believed that implementing these proposals would help to address the reported IRS challenges and improve the overall effectiveness of the program. The proposals were further explained by the quotations extracted from the participants' submissions as shown below.

"Number one, we need a training for all the health inspectors and people who manage the program, we need a refresher training. Number two, we need protective gears, it's a challenge because we only get a few. Last time I saw we only got like 16 which were given to people who were not involved in the actual spraying. Number three, we don't get enough chemicals. And then also, they no longer work and so need better pesticide combinations. (Health worker_central_IRS_02)"

"Of course, we need enough insecticides, we need to have spraying pumps, as the concerned people we have to recruit more people so that we spray in time. When others are in upper, another group is in the barracks and other places. We are very few on the ground. (Prison officer_central_IRS_03)"

"There is need to decentralize IRS activities to the lowest units meaning that the environmental health officer can go train the people in the lower units, provide chemicals, protective wear,

create a store for chemicals and provide pumps so that they can do the job by themselves. (Prison officer_northern_IRS_08)."

6.2.1 Temporal trends of malaria incidence rates in intervention and comparison prison facilities located in Central Uganda between 2018 and 2022.

It is noteworthy that the comparison facility in the central region began reporting malaria-related morbidities in July 2018. Throughout the entire study period, the malaria incidence trends in the intervention facility consistently remained lower compared to the comparison facility in the central region. The highest peak in the intervention facility's trend reached approximately 84 new malaria cases per month per 1000 population in March 2018. In contrast, the comparison facility had a much higher peak, reaching 650 new cases per 1000 population in November 2020. This stark visual contrast highlighted the possible long term effect of implementing IRS within the intervention facility on malaria incidence rates. Similarly, the lowest troughs in the intervention facility's malaria incidence corresponded to zero cases per month per 1000 population. This was approximately 50 times lower compared to the lowest trough (less than 50 new cases per month per 1000 population) observed in the comparison facility (as shown in Figures 2 and 3). Indeed, despite the differences in malaria incidence rate between the intervention and comparison facilities, there are notable similarities in the trends observed. One significant similarity is the seasonal and cyclical nature of the trends across both facilities. Additionally, the peak months of malaria incidence rate were September, October, November and December which remained consistent across the years in both facilities. Furthermore, the months of January, February, and March consistently exhibited the lowest monthly malaria incidence per 1000 population across all five years regardless of the facility within the central region.

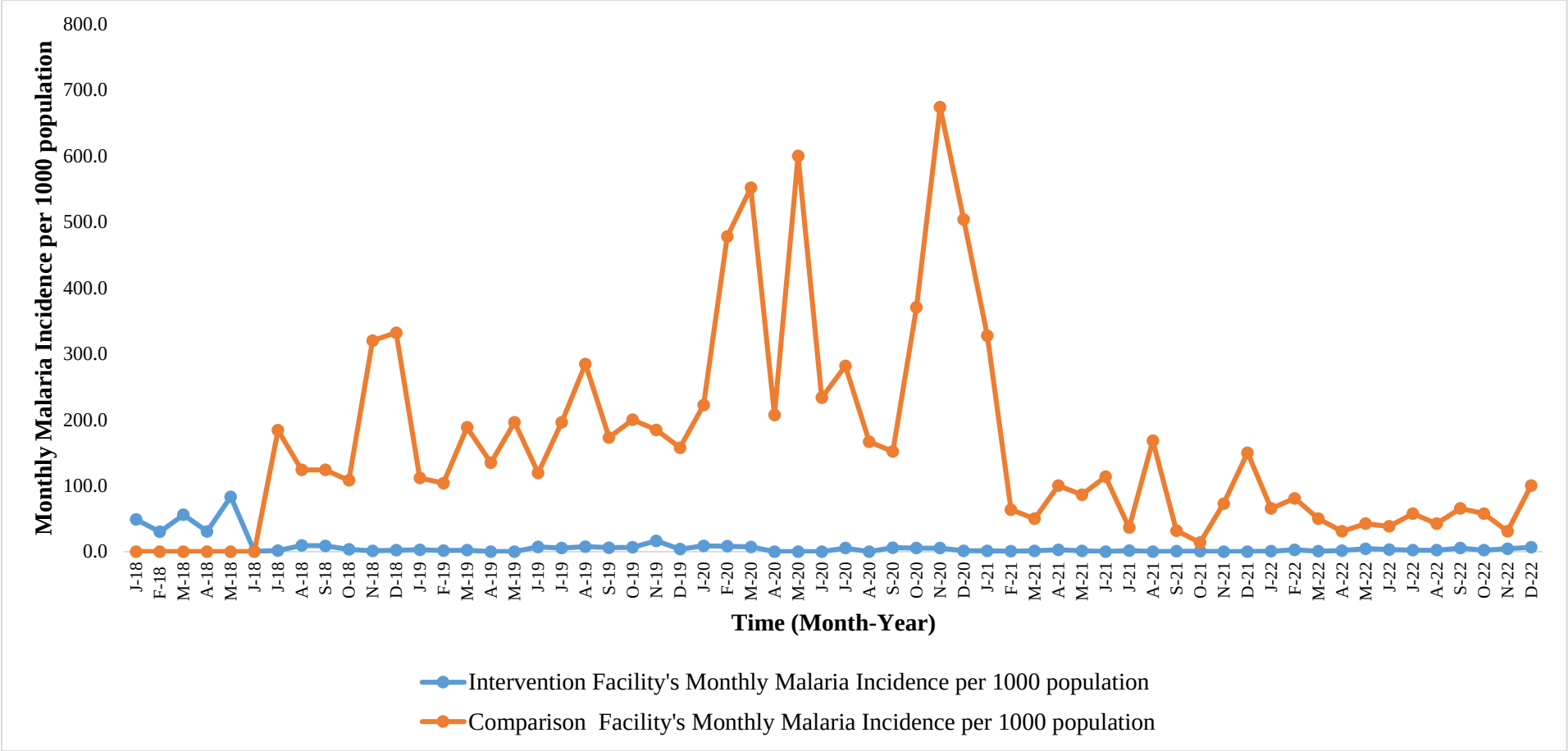

Figure 2: Trends in monthly malaria incidence per 1000 population for intervention facility (January 2018 – December 2022) and comparison facility (July 2018 – December 2022) located in Central Uganda.

Trend plots of malaria incidence rates (confirmed malaria cases per month per 1000 population) on the y-axis over the study time (monthly) on the x-axis. The study period is 5 and 4.5 years for the intervention and comparison facility respectively. The comparison facility started reporting malaria related morbidities in July 2018.

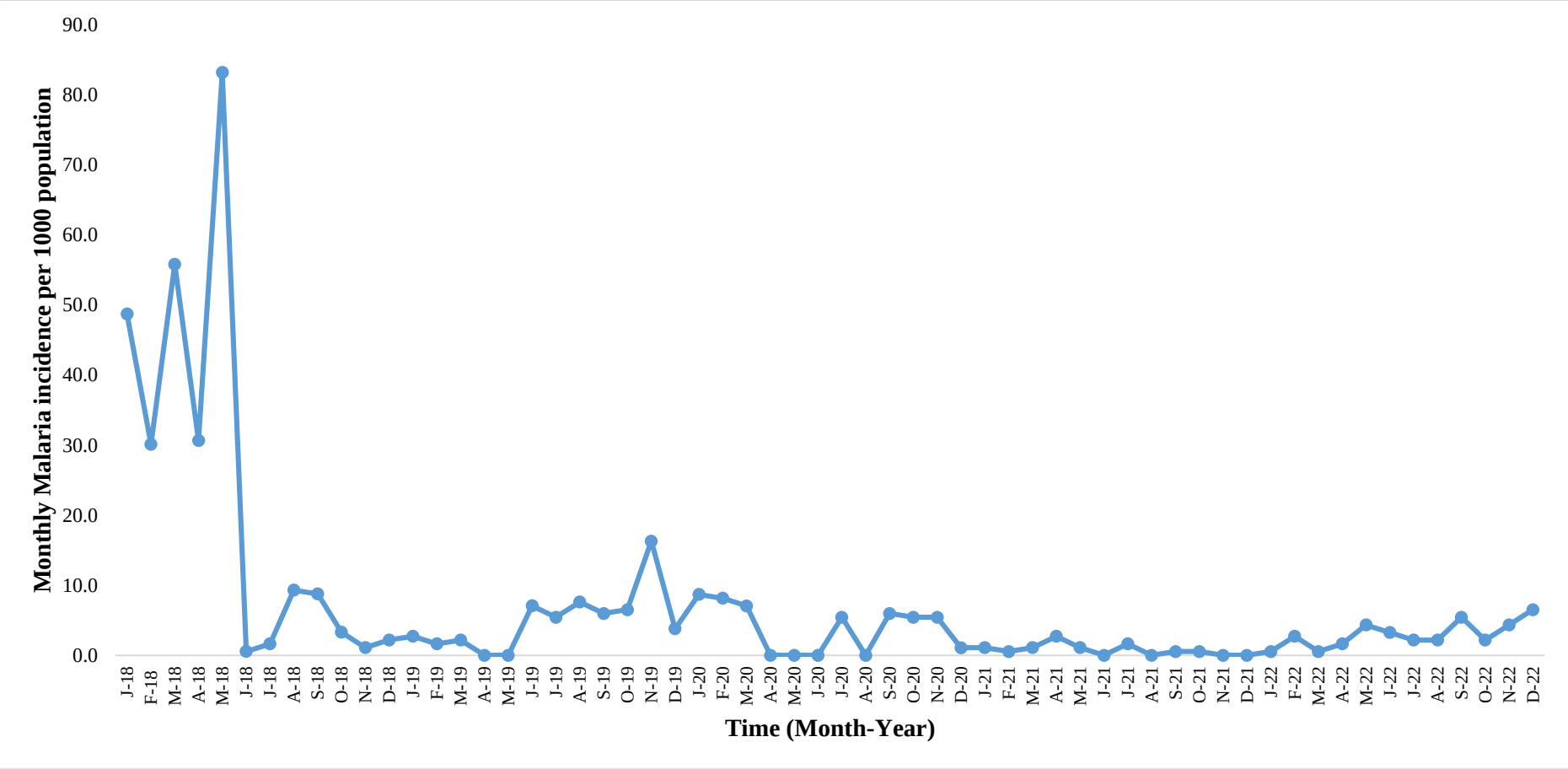

Figure 3: Trends in monthly malaria incidence per 1000 population for intervention facility (January 2018 – December 2022) located in Central Uganda.

Trend plots of malaria incidence rates (confirmed malaria cases per month per 1000 population) on the y-axis over the study time (monthly) on the x-axis.

6.2.2 Temporal trends of malaria incidence rates in intervention and comparison prison facilities located in Northern Uganda (2018 to 2022)

It is worth mentioning that the comparison facility in the northern region began reporting malaria-related morbidities in January 2020. Describing the malaria incidence rate trends in the intervention and comparison facilities located in the northern region; we observed that the malaria incidence rate trend consistently remained significantly lower among the intervention facility compared to the comparison facility. In the intervention facility, the highest peak in the trend reached approximately 41 new malaria cases per month per 1000 population in July 2019. In contrast, the highest peak in the comparison facility was much higher, reaching 368 new cases per 1000 population in November 2020. Indeed, the comparison between the two facilities in the northern region revealed significant visual differences in the malaria incidence rate trends (Figures 4 and 5). In the intervention facility, the lowest trough reached 2 new malaria cases per month per 1000 population in August 2018, which was approximately 25 times lower than the lowest trough observed in the comparison facility (approximately 50 new cases per month per 1000 population).

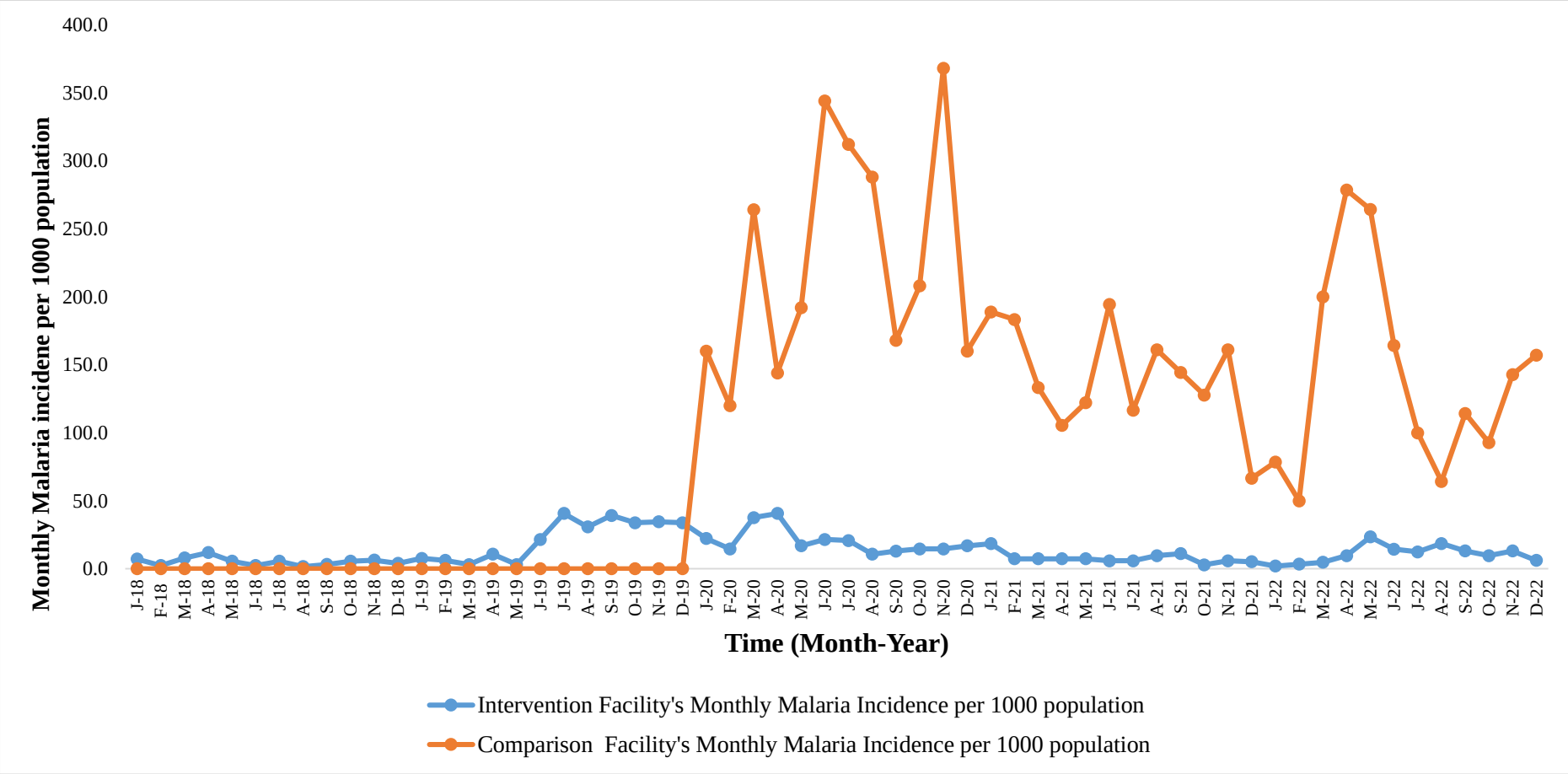

Figure 4: Trends in monthly malaria incidence per 1000 population for intervention facility (January 2018 – December 2022) and comparison facility (January 2020 – December 2022) located in Northern Uganda.

Trend plots of malaria incidence rates (confirmed malaria cases per month per 1000 population) on the y-axis over study time (monthly) on the x-axis. The study period is 5 and 3 years (starting from January 2020) for the intervention and comparison facility respectively.

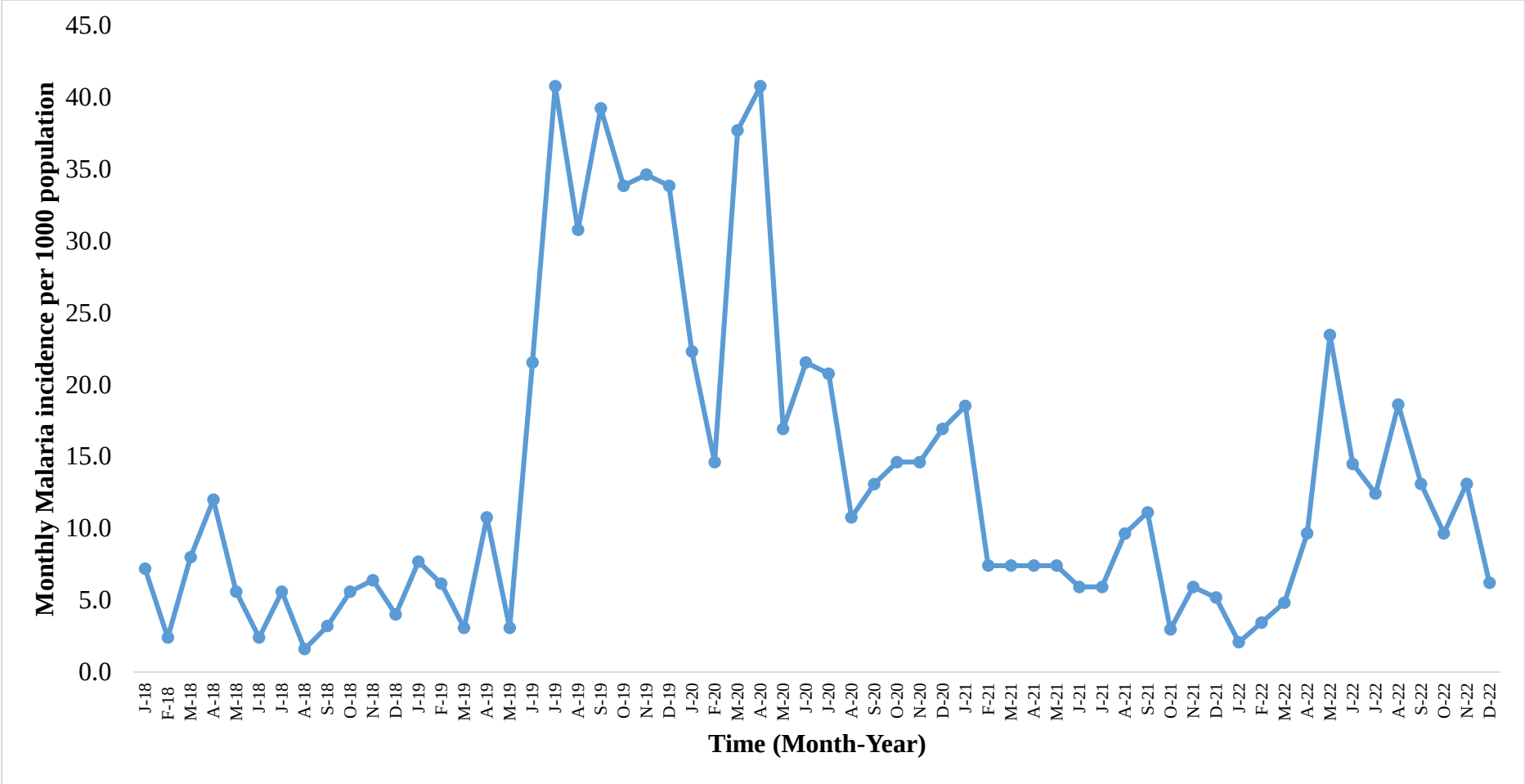

Figure 5: Trends in monthly malaria incidence per 1000 population for intervention facility (January 2018 – December 2022) located in Northern Uganda.

Trend plots of malaria incidence rates (confirmed malaria cases per month per 1000 population) on the y-axis over study time (monthly) on the x-axis.

6.3 Effect of IRS on malaria incidence rate in selected prison facilities of Uganda

In this section, we present the results for the third objective of this study which determined the effect of IRS on the malaria incidence rate in selected prison facilities of Uganda.

6.3.1 Comparing regional inter-facility environmental factors (environmental temperature and rainfall)

The results of the independent samples t-test showed that the mean rainfall and temperature experienced by the intervention and comparison facilities in both regions for the study periods were not different statistically as evidenced by the p-values greater than 0.05 (Table 3). Therefore, the factors of temperature and rainfall were excluded from the regression model since they were not statistically different across facilities in the same region and hence had less likelihood of confounding the results.

Table 2: Results of the independent samples t-test for comparing the mean temperature and mean rainfall experienced by the intervention and comparison facilities in the two regions

	Variables	Intervention facility	Comparison facility	F-statistic	P-value
Central Region	Mean (SD) temperature (^oC)	23.44 (0.877)	23.35 (0.875)	0.07	0.789
	Mean (SD) rainfall (mm)	127.19 (64.4)	114.05 (69.4)	0.29	0.596
Northern Region	Mean (SD) temperature (^oC)	25.46 (1.61)	25.91 (2.10)	0.43	0.516
	Mean (SD) rainfall (mm)	143.54 (114.3)	102.74 (70.6)	1.38	0.2496

SD: = Standard deviation

6.3.1 Effect of IRS on malaria incidence rate in selected prisons located in Central region of Uganda

The IRS intervention we evaluated was implemented in August 2019 where we considered 7 months pre and post IRS implementation periods. The seven months considered in the pre- IRS

implementation included the first 7 months of 2019 (January (1), February (2), March (3), April (4), May (5), June (6) and July (7)). IRS was implemented in August (8) 2019.The seven months of the post IRS implementation period included some months of 2019 (September (9), October (10), November (11) and December (12)) and some months of 2020 (January (13), February (14) and March (15)). A pyrethroid based insecticide (Icon®) was used in this particular IRS.

From the regression results (Table 4), the starting level of malaria incidence in the comparison facility before IRS intervention was 108.2 malaria cases per month per 1000 population (P <0.001, CI = [59.3, 157.1]) which started to increase at a rate of 10.5 cases per month per 1000 population (P= 0.086, CI = [1.59, 22.49]). Also, the initial mean level difference between intervention and the comparison facilities (z) was statistically significant (P <0.001, CI = [-156.8, -58.9]) but the difference in the mean baseline slope (z t) was not significant (P =0.105, CI = [-21.9, 2.21]) as further evidenced by visual inspection of figure 6.

The difference in level of monthly malaria incidence per 1000 population between intervention and comparison facilities in the period immediately following IRS implementation was not statistically significant (P = 0.504, CI = [-118.1, 233.0]). Similarly, the difference between intervention and comparison in the slope after IRS implementation compared with the period before IRS implementation was found to be statistically not significant (P = 0.154, CI = [-76.5, 12.9]). The current model could not detect significant effects of the IRS intervention on malaria incidence rates over time within the study facility located in the central region of Uganda.

From the post-intervention trend analysis output, the intervention facility's monthly malaria incidence trend decreased significantly (P = 0.051, CI = [-1.56, 0.029]) in the post-intervention period by 0.77 new malaria cases per month per 1000 population. Contrary, the comparison facility's malaria incidence trends increased by 40.9 new malaria cases per 1000 population per month in the post intervention period though the increase was not statistically significant

(P = 0.061, CI = [-2.12, 89.9]. However, the overall difference in the post intervention malaria incidence rate trends between the intervention and the comparison facility was not statistically significant (P = 0.057, CI = [-84.67, 1.36].

Table 3: Effect of IRS intervention implemented in August 2019 (central region) on malaria incidence rate (Intervention at t= August 2019).

Variable	Coefficients	95% CI	P-Value
Constant, starting level (**ß$_0$**)	108.2	59.3, 157.1	0.000
Time, slope (T, **ß$_1$**)	10.5	-1.59, 22.49	0.086
Pre-intervention level (X, **ß$_2$**)	-53.4	-228.9, 122.0	0.543
Interaction (slope) (X*T, **ß$_3$**)	30.4	-14.2, 75.1	0.172
Difference in pre intervention level (Z, **ß$_4$**)	-107.9	-156.8, -58.9	0.000
Difference in pre intervention slope (Z*T, **ß$_5$**)	-9.85	-21.9, 2.21	0.105
Difference in post intervention level (Z*X, **ß$_6$**)	57.5	-118.1, 233.0	0.504
Difference in post intervention slope (Z*X*T, **ß$_7$**)[a]	-31.8	-76.5, 12.9	0.154
Post intervention trend analysis			
Intervention	-0.77	-1.56, 0.029	0.051
Control	40.9	-2.12, 89.9	0.061
Diff	-41.65	-84.67, 1.36	0.057

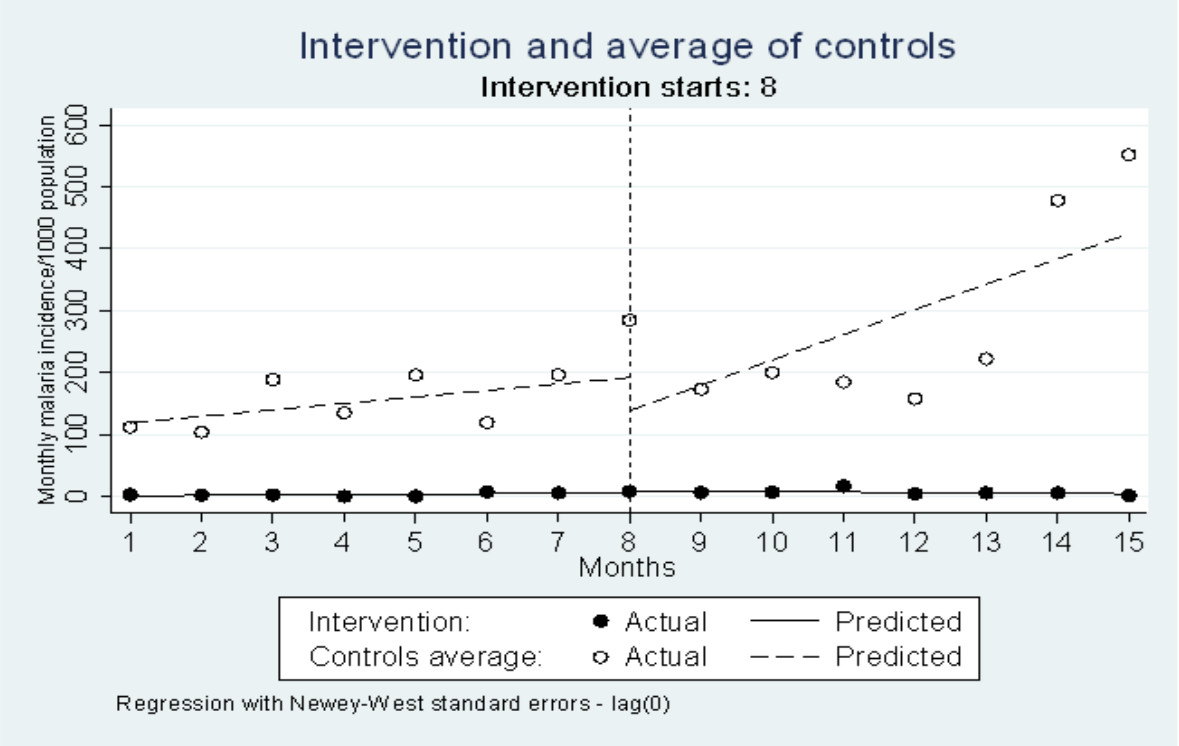

Figure 6: Multiple-group ITSA with Newey-West regression analysis for monthly malaria incidence per 1000 population, January 2019 to March 2020 (central region)

6.3.2 Effect of IRS on malaria incidence rate in selected prisons located in northern region of Uganda

The IRS intervention we evaluated in northern region was implemented in September 2020 where we considered 7 months pre and post IRS implementation periods. The seven months considered in the pre- IRS implementation included 7 months of 2020 (February (1), March (2), April (3), May (4), June (5), July (6) and August (7)). September (8) was the month of IRS implementation. The seven months of the post IRS implementation period included some months of 2020 (October (9), November (10) and December (11)) and some months of 2021 (January (12), February (13), March (14) and April (15)). A pyrethroid based insecticide (Icon®) was used in this particular IRS.

From the regression results (Table 5), the starting level of malaria incidence in the comparison facility before IRS intervention was 100.6 malaria cases per month per 1000 population (P = 0.023, CI = [15.4, 185.7]) and increased at a rate of 29.7cases per month per 1000 population

(P= 0.002, CI = [12.4, 47.1]) (Table 5 and Figure 7). The initial mean level difference between intervention and the comparison facilities (z) was not statistically significant (P = 0.091, CI = [-160.7, 12.7]) but the difference in the mean baseline slope (z t) was statistically significant (P =0.002, CI = [-47.7, -12.6]) as further evidenced by visual inspection of figure 7.

The difference in level of monthly malaria incidence per 1000 population between intervention and comparison in the period immediately following IRS implementation was not statistically significant (P = 0.311, CI = [-64.3, 192.9]). However, the difference between intervention and comparison in the slope of the trend of monthly malaria incidence per 1000 population after IRS implementation compared with the period before IRS implementation was found to be statistically significant (P = 0.001, CI = [21.9, 67.7]). The current model was able to detect significant effects of the IRS intervention on malaria incidence rates over time within the study facility located in the northern region of Uganda.

From the post-IRS intervention trend output, the monthly malaria incidence rate trend in the IRS implementing facility gradually decreased at a rate of 0.456 (P = 0.502, CI = [-1.84, 0.929]) malaria cases per month per 1000 population though not statistically significant. Contrary, the comparison facility's malaria incidence trends decreased significantly (P = 0.044, CI = [-29.8, -0.46] at a rate of 15.14 malaria cases per 1000 population per month in the post intervention period. However, the difference in the post intervention malaria incidence rate trends between the intervention and the comparison facility was not statistically significant (P = 0.051, CI = [-0.058, 29.42].

Table 4: Effect of the IRS intervention implemented in September 2020 (Northern region) on malaria incidence rate (Intervention at t= September 2020)

Variable	Coefficient	95% CI	P-Value
Constant, starting level (**ß$_0$**)	100.6	15.4, 185.7	0.023
Time, slope (T, **ß$_1$**)	29.7	12.4, 47.1	0.002
Pre-intervention level (X, **ß$_2$**)	-73.1	-201.2, 54.9	0.249
Interaction (slope) (X*T, **ß$_3$**)	-44.9	-67.6, -22.1	0.000
Difference in pre intervention level (Z, **ß$_4$**)	-73.9	-160.7, 12.7	0.091
Difference in pre intervention slope (Z*T, **ß$_5$**)	-30.1	-47.7, -12.6	0.002
Difference in post intervention level (Z*X, **ß$_6$**)	64.3	-64.3, 192.9	0.311
Difference in post intervention slope (Z*X*T, **ß$_7$**)[a]	44.8	21.9, 67.7	0.001
Post intervention trend analysis			
Intervention	-0.456	-1.84, 0.929	0.502
Control	-15.14	-29.8, -0.46	0.044
Diff	14.68	-0.058, 29.42	0.051

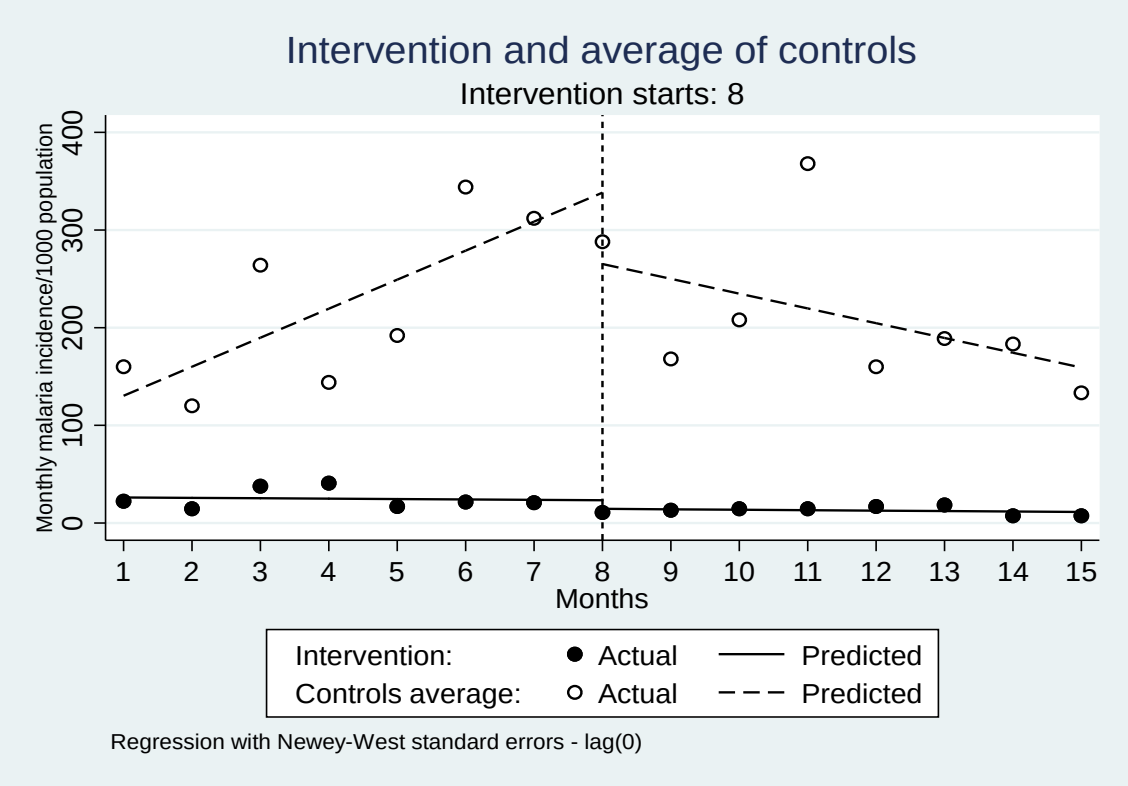

Figure 7: Multiple-group ITSA with Newey-West regression analysis for monthly malaria incidence per 1000 population, March 2020 to April 2021 (northern region)

7.0 CHAPTER SEVEN: DISCUSSION OF RESULTS

This study aimed at determining the effect of indoor residual spraying on malaria incidence rate and to describe the IRS program implemented by UPS. We also determined and described the temporal trends of malaria incidence rate for selected UPS facilities located in the central and northern regions of Uganda over a five year period (2018 to 2022). In this chapter, we discuss the major findings for the three objectives of this research.

7.1 IRS program implemented in selected UPS facilities

Regarding the organization and delivery of IRS program in prisons, the study found that the IRS program in UPS was well-structured, with a management hierarchy that spanned from the top leadership to the lowest level. A well-organized management hierarchy ensured that there was a clear line of communication between different levels of the program and that decisions were made quickly and efficiently. It also streamlined supervision and supported team building. The WHO operational manual for IRS emphasizes the role of a robust and well-structured management system in improving the performance of IRS programs in malaria endemic areas (WHO, 2015). The study further identified five key stakeholders as far as IRS implementation in UPS was concerned. They included the multidisciplinary technical team, administrators, leaders, the general community of prisoners, and the spray teams. On the other hand the study identified the key resources required for the smooth implementation of IRS program in prisons of Uganda. The 6 key resources included trained human resources, IRS equipment, incentives, IRS consumables, IRS guiding documents, and waste management resources. IRS stakeholders, resources and organization structure are some of the pillars of a robust and effective IRS program. These aspects have been emphasized by IRS protocols and guidelines developed by the World Health Organization (WHO, 2015). Other scholars have also reported similar findings regarding the key stakeholders and resources for IRS (Finda et al., 2020; Magaço et al., 2019; Suuron et al., 2020). Similarly, country level reports which have evaluated

the impact of IRS programs implemented in communities in Ghana and Zambia emphasized the importance of involving all stakeholders in the planning, implementation, monitoring and evaluation of the program in terms of program acceptability, sustainability, effectiveness and efficiency (CDC, 2014; MoH, 2010).

Regarding the handling and application of IRS insecticides within UPS facilities, the study findings showed general poor insecticide handling practicies within the study facilities and irrational use of insecticides was also identified. This was exacerbated by gross lack of relevant SOPs to guide the storage, handling and application of IRS insecticides. Furthermore, participants reported the challenge of inadequate PPEs which could be one of the drivers of the reported irrational practices. Also, the desire to implement an integrated vector control program which required mixing of IRS insecticides with other pesticides without proper training of the spray teams could have contributed to the problem at hand. The worry was that irrational use of IRS insecticides could accelerate the development of insecticide resistance among mosquito populations residing within the study areas as reported by previous scholars (Abbasi, Vahedi, Bagheri, & Gholizadeh, 2022; Chemutai, Kisakye, & Kabbale, 2022; Hakizimana et al., 2016; Okethwangu et al., 2015; Okia et al., 2018; Pinto et al., 2019). This could further complicate the malaria control and eradication efforts within UPS and surrounding areas. The other important consideration was the finding that the study facilities relied on indirect methods for monitoring insecticide resistance among mosquito populations instead of relying on scientific entomological tests recommended by WHO and CDC (WHO, 2016b). The implication of this finding on the study facilities was that they could not make evidence based decisions when it came to either the selection or changing of IRS insecticides and monitoring the performance of a given insecticide.

IRS waste management at facility level involved waste sorting, incineration and collection of the wastes by a private medical waste management company for proper disposal especially for

wastes which could not be incinerated at facility level. The IRS waste management practices reported by the study facilities largely conforms to the WHO operational manual for indoor residue spraying for Malaria transmission control and elimination (WHO, 2015).

The reported perceptions of prisoners regarding IRS were largely positive despite a few negative perceptions driven by ungrounded conspiracy theories and suspicion. However, the program was largely acceptable by prisoners because of its benefits especially by reducing the mosquito populations in the prison wards. Similar findings have been reported by researchers in previous studies in community settings (Brown et al., 2016; Madani, Soleimani-ahmadi, Davoodi, & Sanei-dehkordi, 2017; Magaço et al., 2019; Suuron et al., 2020). Regarding strategies other than IRS implemented for the control of malaria in prisons in Uganda, the study found similar strategies like those implemented in the usual communities excluding use of insecticide treated nets (ITN). Use of ITN in prisons was discouraged because of safety concerns and limited space within the prison wards. However, the prisons could be more efficient in implementing other malaria control interventions compared to the communities due to presence of free labor, better coordination and discipline.

The study identified three major challenges facing the UPS based IRS program which included inadequate and unreliable access to key IRS resources, welfare challenges for the spray teams and limited technical skills of the IRS teams. The above challenges seem to be interconnected and could be providing synergistic effect to each other. The implication of such challenges if unresolved could impede the IRS program from achieving the desired goal of effectively contributing to the control of malaria among prison populations in Uganda. Previous studies which have evaluated the implementation and performance of IRS programs in communities for the control of malaria have reported similar findings (Akogbéto et al., 2020; Bath et al., 2021; Dengela et al., 2018; MoH, 2010). In another study conducted in Botswana to evaluate the IRS program, the authors reported challenges related to limited capacity of spray teams to

maintain and repair the pumps used to spray, delayed delivery of IRS materials and poor coordination and supervision of IRS operations (NMCP, 2011). Recent studies observed a shortage of field-experienced IRS coordinators and supervisors and advised that when starting a new IRS program, it was wise to seek technical assistance from well-established programs in other countries or to engage private-sector expertise (Dengela et al., 2018; Mtove et al., 2016; Zhou et al., 2022).

To address the above challenges, the study generated three important proposals which included investing in capacity development of IRS teams, ensuring timely and adequate provision of IRS resources and decentralizing of the IRS activities to the lowest units. If the above proposals could be adopted and implemented by UPS, the IRS program would be strengthened. The importance of skilled human resources has also been emphasized by the WHO which stated in one of the reports that the success of the IRS programs largely relied on the spray teams and their supervisors and even made a recommendation that in order to maximize the efficiency and effectiveness of the spray teams, they should consist of no more than six persons per team (WHO, 2019). However, the number of persons per spray team in prisons is far less than the recommended number by WHO. A number of previous studies which assessed the performance of IRS programs among communities also made recommendations which are largely in agreement with the proposed solutions to the reported challenges (MoH, 2016; NMCP, 2011; Pluess et al., 2010).

Previous studies have already underscored the importance of ensuring the safety of spray operators by providing IRS materials such as PPEs. In order to deliver IRS effectively, temporary field staff could be recruited, trained, motivated and retained and would require back-up and supervision (Bath et al., 2021; Gonçalves et al., 2021). While the spraying itself can be delivered by semi-skilled but dedicated temporary field staff, the program requires a well-trained core of skilled multidisciplinary team of environmental or public health officers,

field entomologists and epidemiologists, supported by administrators. Studies have also emphasized the timely delivery of IRS materials as a key factor in obtaining maximum benefits from IRS programs (Akogbéto et al., 2020; Brown et al., 2016; Magaço et al., 2019; Tangena et al., 2020).

7.2 Temporal trends of malaria incidence rate in selected prison facilities located in the northern and central regions of Uganda

Consistently, the malaria incidence trends were at lower levels among the intervention facilities compared with the comparison facilities across the entire study period regardless of the region. This stark contrast could highlight the long term effect of the interventions especially IRS program implemented in the intervention facilities leading to lower burden of malaria cases compared with the comparison facilities which never implemented IRS program.

Throughout the study period, the incidence rates of malaria within the central region consistently reached their highest peaks in the months of September, October, and December corresponding to the rainy season. Conversely, the months of January, February, and March consistently exhibited the lowest monthly malaria incidence per 1000 population across all five years of the study. This pattern highlights the seasonality of malaria transmission dynamics and provides valuable insights to guide the timing for the implementation of strategic interventions. The rainy season provides a suitable environment for the breeding and survival of the malaria vectors and hence rainy seasons are associated with high vector populations and hence high malaria transmission. Similarly, a recent study which evaluated the national spatial-temporal patterns of malaria incidence in Uganda using HMIS data from 2015 to 2019 reported high seasonality of malaria incidence (Kigozi et al., 2020). Contrary to our findings, the same study reported at national level that the months of June and July had experienced the highest peaks and February and March having the lowest peaks. However the findings of the two studies are in agreement regarding the months with the lowest peaks of malaria incidence. The

observed variation could be explained by differences in the time and geographical scopes of the two studies. Our findings were also in agreement with the findings of a recent related study conducted in Apac district where the authors reported high malaria incidences in the months of August, September and November (Eunice et al., 2017). Studies conducted within the region have also reported varying months of peak malaria incidence like April and July was reported in Tanzania (Aikambe & Mnyone, 2020) whereas a study conducted in Kenya reported April and August (Maniga et al., 2022).

7.3 Effect of IRS on malaria incidence rate in selected prison facilities of Uganda

The current study was able to detect significant effects of the selected IRS intervention on malaria incidence rates over time within the study facility located in northern region of Uganda. Despite the malaria incidence trends remaining very low, no significant effect of the selected IRS intervention on malaria incidence rates was confirmed for the facility located in the central region of Uganda. This could be due to other factors such as insecticide resistance among mosquito populations, very low malaria burden in the pre-intervention period and inadequate malaria testing in the intervention facility. Regardless of the region, the level of monthly malaria incidence per 1000 population remained lower among the intervention facilities than among the comparison facilities. Since the evaluation happened after a number of IRS interventions had been implemented, the above finding could indicate the long term effect of IRS and other interventions on malaria incidence trends in the intervention facilities in both regions. Other interventions for malaria control such as removal of stagnant water, bush clearing, early closing of windows and early diagnosis and treatment of malaria cases were practiced in both the intervention and comparison facilities per region. Therefore, they were less likely to be potential confounders for the effect of IRS on malaria incidence rate in this study. Within the northern region, IRS was able to significantly reduce the monthly malaria incidence per 1000 population within the intervention facility in the period immediately after

the IRS implementation compared with the comparison facility. The results from the northern region facility are consistent with the findings of a related retrospective study conducted in Zambia to evaluate the effectiveness of indoor residual spraying on malaria transmission which reported that IRS appeared to be associated with reduced confirmed malaria incidence (Keating, Yukich, Miller, Scates, Hamainza, Eisele, 2021). In another study conducted in Uganda to assess the impact of IRS on health outcomes, the authors reported that there was evidence of a modest decrease in measures of malaria morbidity (Kigozi et al., 2012). The effectiveness of IRS in northern region could be attributed to several factors. Among them could include the fact that northern region is a higher transmission area compared to central Uganda and previous studies had shown that IRS program gave better results when implemented in a region of high transmission (Katureebe et al., 2016). The same study reported that a noticeable decline in the burden of malaria for all indicators due to IRS was observed at the highest transmission site compared with the low transmission sites (Katureebe et al., 2016). Therefore, the findings of this study provide further evidence that the effect of IRS on malaria incidence rate was likely to be higher in areas of high malaria transmission such as the northern region of Uganda compared to areas of moderate transmission like central region of Uganda. The observed effect of IRS on malaria incidence in the intervention facility located in the northern could also be attributed to better IRS practices, susceptible mosquito populations, effective insecticides and effective malaria control interventions other than IRS.

Though we did not detect significant effect of IRS on monthly malaria incidence per 1000 population within the intervention facility located in the central region of Uganda, the post intervention trend of monthly malaria incidence per 1000 population decreased significantly compared with the comparison facility in the same region whose trends were instead increasing post IRS intervention. This indicates that IRS intervention had some effect on the malaria incidence though it was not significant in statistical terms. In a related study conducted in

Uganda to assess the impact of IRS on health outcomes in one of the high transmission districts of Uganda, authors reported that in the first 6 months following the first round of IRS with a pyrethroid based insecticide, there was evidence of a modest decrease in measures of malaria morbidity despite being statistically not significant but after the 3rd to 5th rounds of IRS with organophosphate based insecticide, there was a more dramatic decrease in malaria morbidity (Kigozi et al., 2012). This showed that the central region facility could realize significant IRS effects in the subsequent interventions coupled with change of the class of insecticide used for IRS which could be facing the challenge of insecticide resistance. Possible explanations for the results obtained from the central region could be the fact that central region is located in a low transmission area and previous studies have shown that IRS program tended to give better results when implemented in a region of high transmission (Katureebe et al., 2016) and the opposite tended to be true. Lastly, the general challenges reported to be impeding the smooth and efficient implementation of IRS within the prisons such as inadequate IRS resources, capacity gaps and welfare issues could prevent the program from achieving desired effect in some facilities.

7.4 Study strengths and Limitations.

7.4.1 Study strengths.

The study utilized interrupted time series analysis (ITSA) method which is a powerful analysis tool for evaluating the effect of interventions in populations by comparing the effect of the intervention on a given outcome among the intervention and comparison groups putting into consideration the pre and post intervention periods. ITSA is credited for its ability to control for the effect of secular trends in a time series of outcome measures. ITSA was able to assess the change in both the level and slope of the outcome within the intervention facility compared with the comparison facility during the pre and post intervention periods. Furthermore, two facilities (intervention and comparison) were selected from each of the two distinctly different

regions of Uganda which increased the generalizability and representativeness of our findings. Comparing facilities from the same region helped to control for potential confounders and hence reducing bias within the study findings. The study utilized both primary and secondary data sources which made the findings of this study more accurate, reliable and holistic taking into account current and past events. The study adopted mixed methods approaches where both quantitative and qualitative data was collected which enhanced the credibility and rigor of the findings. To the best of my knowledge, this is the first study to describe and evaluate the effect of the IRS program implemented by UPS on malaria incidence rates within the prisons of Uganda.

7.4.2 Study limitations

Selection of comparison facilities without randomization was quite difficult and therefore the results could still have some level of confounding. However, we tried to cure this limitation by selecting and comparing facilities located in the same region with similar environmental conditions and similar practices. The second limitation arose from the use of secondary data sources ((HMIS database) whose completeness, consistency and accuracy could not be fully verified. In addition, challenges such as under reporting at facility level could affect the representativeness of the HMIS data. The above potential limitations could have affected the quality of the data used in this study. However, quality control measures to ensure data accuracy such as exclusion of incomplete records were implemented to mitigate the limitations associated with use of secondary data sources. Though we confirmed significant effect of IRS program on monthly malaria incidence rates, we cannot infer causality. The findings generated by ITSA could not be used to make individual level inferences but population based inferences can be made. We could not evaluate the effect of all the IRS interventions which were implemented by the study facilities within the entire study period due to violating some of the important requirements for ITSA models. Therefore, our results represent the effect of the

particular IRS intervention which was evaluated per region. However, our results are generalizable within the prisons located in the study regions of Uganda and other similar contexts in other malaria endemic countries.

8.0 CHAPTER EIGHT: CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

The study has determined the effect of indoor residual spraying program on malaria incidence rates among prison facilities in Uganda. Throughout the entire study period, the malaria incidence rate trends among the IRS intervention facilities remained consistently lower than the trends observed in comparison facilities in both central and northern regions. The current study was able to detect significant effects of the specific IRS intervention evaluated on malaria incidence rates within the study facility located in the high malaria transmission area (northern region) of Uganda. However, there was no significant effects of the specific IRS intervention evaluated on malaria incidence rates within the study facility located in the low malaria transmission area (central region) of Uganda. Participants reported that IRS program was well structured and highly acceptable within UPS. However, it faced a number of challenges including inadequate and unreliable access to key IRS resources, welfare challenges and limited technical skills of the IRS teams. The study further revealed that the IRS program implemented by the study facilities relied on integrated vector control strategies characterized by irrational use of insecticides to control both mosquitoes and other insects of public health importance.

8.2 Recommendations

The study recommends to UPS to consider addressing some of the reported challenges facing the IRS program through timely provision of key IRS resources, building internal capacity to conduct entomological surveys to monitor insecticide resistance, disseminating IRS SOPs to promote rational use of insecticides and organizing regular refresher trainings to improve the technical skills of the IRS teams. To strategically improve the malaria control efforts within the study areas, the study recommends IRS implementation before the onset of the peak seasons of malaria incidence rates particularly in the months of September and March. The study further

recommends that UPS considers extending the IRS program to all the prisons especially those located in regions of high malaria transmission of Uganda where the program has proved to significantly reduce malaria incidence rates.

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Appendix 1. In-depth Interview Guide

EFFECT OF INDOOR RESIDUAL SPRAYING ON MALARIA INCIDENCE RATE IN PRISON FACILITIES IN UGANDA

Dear Respondent

I am Joseph Byaruhanga a student of Makerere University School of Public Health pursuing a Master's degree in Public Health. As a requirement for the award of a Master's degree, a student is expected to undertake an empirical study on a topical issue. I have therefore, chosen to achieve this by **evaluating the effect of indoor residual spraying on malaria incidence rate in prison facilities in Uganda.**

. Having been purposively chosen, I request you to voluntarily participate in this 30 Minutes interview whose responses will be treated with utmost confidentiality and purely for academic purpose. Please note that for purposes of accurate reporting, the proceeding of the interview will be recorded by a voice recorder and written notes will also be made. Please feel free to elaborately explain your experiences, feelings and perceptions with me about the study subject.

Thank you

Demographics

1. Please tell me your name, sex, age, role in IRS implementation, number of years in service, number of years spent working on IRS, facility you work for and your occupation.

Organization and delivery of IRS program in UPS

2. Please tell me about the IRS management structure in your facility. Probes: Who supervises who? Who reports to who?
3. Please tell me about the key stakeholders of the IRS program at the facility level.
4. What are the IRS performance targets for your facility?
5. How would you rate your IRS coverage in this facility?

IRS Resources

6. Please list the key Resources required for IRS in your facility? (Human, financial, equipment). Probe: How many of the listed resources are available and accessible in your facility? Please comment on each of the listed resources.
7. Availability of malaria treatment
8. Access to health facility

Selection of IRS insecticides, storage, handling and application

9. How are insecticides for IRS acquired by your facility?
10. How are IRS insecticides stored at this facility?
11. Do you have standard operating procedures for handling, dilution and application of IRS insecticides at your facility? If yes, request to have a look at the SOP.
12. Please explain to me how you dilute insecticides meant for IRS at your facility?
13. After dilution of insecticides, how are they applied? Is there an SOP for this activity?
14. What are those factors you consider before changing IRS insecticide?
15. How do you monitor insecticide resistance among mosquitoes in your facility?

IRS Waste management

16. Please tell me about the way you manage wastes from IRS activities at your facility

Perceptions about IRS among the prison community

17. What are the common perceptions of the prisoners and prison staff about use of IRS?
18. Please comment on the acceptability of IRS intervention
19. Please comment on use of other malaria control interventions

IRS challenges and proposed solutions

20. What challenges has the IRS program faced in your facility?
21. Any suggestions for improving the IRS program implemented by UPS?
22. Any other comments about IRS?

Appendix 2: Data abstraction guide which guided document reviews

EFFECT OF INDOOR RESIDUAL SPRAYING ON MALARIA INCIDENCE RATE IN SELECTED PRISON FACILITIES IN UGANDA

STUDENT: BYARUHANGA JOSEPH

REG/NO: 2020/HD07/20362U

Data on IRS program implementation at selected prison facilities.

Variables	**Observations**											
Name of prison facility												
Location of facility (District)												
Actual month of IRS 2018	J	F	M	A	M	J	J	A	S	O	N	D
Actual month of IRS 2019	J	F	M	A	M	J	J	A	S	O	N	D
Actual month of IRS 2020	J	F	M	A	M	J	J	A	S	O	N	D
Actual month of IRS 2021	J	F	M	A	M	J	J	A	S	O	N	D
Actual month of IRS 2022	J	F	M	A	M	J	J	A	S	O	N	D
IRS implementation status	1. Regularly 2. Irregularly 3. Never											
Insecticides used in 2018												
Insecticides used in 2019												
Insecticides used in 2020												
Insecticides used in 2021												
Insecticides used in 2022												
IRS Coverage	**2018**		**2019**		**2020**		**2021**		**2022**			
Average population of prisoners per year	**2018**		**2019**		**2020**		**2021**		**2022**			
Date of most recent IRS	Day				Month				Year			

Appendix 3: Letter to UPS seeking approval of the study

Makerere University
College of Health Sciences
School of Public Health
P.O BOX 7062 Kampala, Uganda
Date: 28th Sept 2022

The Commissioner General of Prisons,

Dear Sir,

RE: REQUEST FOR PERMISSION TO CONDUCT MY MASTERS RESEARCH IN SELECTED UPS HEALTH FACILITIES.

Following the successful completion of my field attachment at Uganda Prisons Service under the supervision of Dr. James Kisambu, I developed interest to conduct my masters' research (masters of public health) from some selected UPS facilities. The research titled **"Effect of indoor residual spraying on malaria incidence rate in prison facilities in Uganda."** The proposed research is a continuation of one of the field studies I conducted during the attachment. The objectives of the proposed research include;

1. To describe the implementation of IRS in selected prison facilities in Uganda.
2. To determine the temporal trends (2018 to 2022) of malaria case incidence in selected prison facilities in central and northern regions of Uganda
3. To determine the effect of IRS intervention on malaria case incidence in selected prison facilities of Uganda.

I will be supervised by Dr. Yeka Adoke and Dr. Arthur Bagonza from Makerere University School of Public Health and Dr. James Kisambu from UPS.

As part of research (data collection), I would like to visit the following prison facilities; Gulu main prison, Amuru prison, Kasangati and Murchison bay prisons and conduct some interviews with the prison staff involved in implementation of IRS program.

The purpose of this email is to request for your written permission to conduct my research in the above selected facilities and to grant permission to prison staff in the selected facilities to participate in this study and to provide information related to the study objectives so that I can achieve the above research objectives. Attached is a copy of the approved research proposal.

Looking forward to receiving your positive response.

Yours faithfully,

Joseph Byaruhanga (+256774881544)

Appendix 4: Consent form

MAKERERE UNIVERSITY

COLLEGE OF HEALTH SCIENCES

SCHOOL OF PUBLIC HEALTH

STUDENT:	**JOSEPH BYARUHANGA**
REGISTRATION NUMBER:	**2020/HD07/20362U**
SUPERVISORS:	**DR. YEKA ADOKE**
	DR. ARTHUR BAGONZA

CONSENT FORM

EFFECT OF INDOOR RESIDUAL SPRAYING ON MALARIA INCIDENCE RATE IN PRISON FACILITIES IN UGANDA.

Dear Respondent

I am Joseph Byaruhanga a student of Makerere University School of Public Health pursuing a Masters of Public Health. As a requirement for the award of a Master's degree, a student is expected to undertake an empirical study on a topical issue. I have therefore chosen to achieve this by **evaluating the effectiveness of indoor residual spraying in reducing malaria incidence in prison facilities in Uganda.** Having been purposively chosen, I request you to voluntarily participate in this study as one of the respondents and your responses will be treated with utmost confidentiality and purely for academic purpose. Please note that for purposes of accurate reporting, the proceeding of the interview/focus group discussion will be recorded by a voice recorder and written notes will also be made. Please feel free to elaborately explain your experiences, feelings and perceptions with me. Thank you

Name: _____**Signature:** _____

Date: _____ **Thumbprint:**

Appendix 5: Ethical approval

MAKERERE UNIVERSITY

P.O. Box 7072
Kampala UGANDA
Email: sphrecadmin@musph.ac.ug

Tel: +256 -414-543 872/ 031-2-263158
Fax: +256-414-531807
Website: www.sph.mak.ac.ug

COLLEGE OF HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH

Research and Ethics Committee

MAKERERE UNIVERSITY
SCHOOL OF PUBLIC HEALTH
APPROVED
VALID UNTIL
★ 19 APR 2024 ★
RESEARCH & ETHICS COMMITTEE
P O. BOX 7072, KAMPALA

19th April 2023

Mr. Byaruhanga Joseph
Master student, (2020/HD07/20362U)
School of Public Health, Makerere University

Re: Approval of a research Proposal titled: "Effectiveness of indoor residual spraying in reducing malaria incidence in prison facilities in Uganda"

This is to inform you that the Makerere School of Public Health Research and Ethics Committee (MakSPH-REC) has approved your study documents for the above referenced research study.

Please note that your study protocol number with MakSPH-REC is **172.** Please be sure to reference this number in any correspondence with MakSPH-REC. Note that your study was first approved by the MakSPH-REC on **19th/04/2023**, and therefore approval expires at every annual anniversary of this approval date. The current approval is therefore valid until: **19th/04/2024.**

Continued approval is conditional upon your compliance with the following requirements:

1) No other consent form(s), questionnaire and/or advertisement documents should be used. The consent form(s) must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject must be given a copy of the signed consent form.

Appendix 6: Research approval from Uganda Prison Services

TELEGRAMS: "COMPRISONS"
TELEPHONE: 256-414-256752
FAX: 256-414-343330

A REPLY TO THIS LETTER SHOULD BE ADDRESSED TO THE COMMISSIONER GENERAL OF PRISONS AND THE FOLLOWING

UGANDA PRISONS SERVICE
PRISONS HEADQUARTERS
P. O. BOX 7182,
KAMPALA, UGANDA

REFERENCE NO. QUOTED: **ADM/MS314/01**

08 May, 2023

Regional Prisons Commander, KER
Regional Prisons Commander, CENTRAL
Regional Prisons Commander, NORTHERN
Medical Superintendent, Murchison Bay Hospital
Officer in Charge, Gulu (M)
Assistant Medical Superintendent, Gulu Prison H.C III
Officer in Charge, UG Prison Murchison Bay
Officer in Charge, Kasangati
Officer in Charge, Amuru

RE: PERMISSION TO CONDUCT MASTERS RESEARCH OF PUBLIC HEALTH OFFICERS IN SELECTED PRISONS UNITS

The subject matter refers.

This is to bring to your attention that Uganda Prisons Service has received a Masters in Public Health student by names Joseph Byaruhanga.

Please, receive him and accord all the necessary access to data pertaining the research titled **"Effectiveness of Indoor Residual Spraying in Reducing Malaria Incidence in Prisons Facilities in Uganda"** as part of his field study and also to enhance management system in our health sector. He has been briefed by Assistant Commissioner, Health Services, Dr. James Kisambu who is the internal supervisor and Dr.Yeka Adoke and Dr. Arthur Bagonza as external supervisors from Makerere School of Public Health.

NOTE: This being a security Institution, you are requested to adhere to the rules and regulations guiding the Institution and any other instructions issued by the Superintendent of the facility as well as observing the COVID-19 SOPs.

Raphael Olinga
FOR: COMMISSIONER GENERAL OF PRISONS

Copied to: Dr. Suzanne Kiwanuka, MPH Director/Chair HPPM Department.

Appendix 7: Permission to conduct research

MAKERERE UNIVERSITY

P.O. Box 7072
Kampala UGANDA
Email: sphrecadmin@musph.ac.ug

Tel: +256 -414-543 872/ 031-2-263158
Fax: +256-414-531807
Website: www.sph.mak.ac.ug

COLLEGE OF HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH
Research and Ethics Committee

19th April 2023

To whom it may concern

Dear Sir/Madam,

RE: PERMISSION TO CONDUCT RESEARCH

I hereby introduce to you **Mr. Byaruhanga Joseph**, a Master Student from Makerere University School of Public Health.

The student is required to conduct research as a requirement for the award of the Master's degree. The title of the research study is: **"Effectiveness of indoor residual spraying in reducing malaria incidence in prison facilities in Uganda".**

The student presented the research proposal to the Makerere University School of Public Health, Research and Ethics Committee and has been granted approval to go ahead with data collection.

Your support in this regard will be highly appreciated.

MAKERERE UNIVERSITY
SCHOOL OF PUBLIC HEALTH
APPROVED
VALID UNTIL
★ 19 APR 2024 ★
RESEARCH & ETHICS COMMITTEE
P O BOX 7072, KAMPALA

Yours sincerely,

Dr. Joseph Kagaayi
Chairperson: MakSPH- Research and Ethics Committee

Leveraging 100 years of Excellence In Building a Transformed Society