Incidence of Malaria in relation to residual efficacy of 2017 Indoor Residual Spraying during 2018 malaria season in Engela district, Ohangwena, Namibia

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Abstract

Introduction: Malaria remains a public health problem in Africa and other countries of sub-tropical. In 2017, an estimated 219 million cases of malaria occurred worldwide (95% confidence interval [CI]: 203–262 million), compared with 215 million malaria cases in 2016. Most malaria cases in 2017 were in the WHO African Region (200 million or 92%), followed by the WHO South-East Asia Region with 5% of the cases and the WHO Eastern Mediterranean Region with 2%. In 2017, there were an estimated 435 000 deaths from malaria globally, compared with 451 000 estimated deaths in 2016. In 2017, Namibia recorded high number; (66141 (27.3%) of malaria cases as compared to 2016 (24869 (10.3%) and 2018 (36451(14.8%). Primary malaria prevention on a large scale depends on two vector control interventions which are indoor residual spraying (IRS) and insecticide treated mosquito nets (ITNs). In 2017, Engela district, Ohangwena region used only Deltamethrin in both structures because of unavailability of DDT at the moment of spraying season. The duration of Deltamethrin effectiveness (residual efficacy) is 6 months as per WHO guideline. Therefore, the researchers determined the residual efficacy of insecticide (Deltamethrin) used in 2017 Indoor residual Spraying program in relation to incidence of malaria in Engela district, Ohangwena region.

Methods: The researchers conducted an analytic quantitative cross sectional study to determine the residual efficacy of insecticide used in 2017 Indoor residual Spraying program in relation to incidence of malaria in Engela district, Ohangwena region. Malaria line list for 2018 was used to identify the villages affected by Malaria. The researchers collected mosquito larva for wild mosquitoes at mosquito breeding sites around Engela district and grew them into adult mosquitoes at the Oshakati Insectary laboratory. Wild common malaria vectors, which were unfed adult female anopheles' mosquitoes were transported in the cage to the field at the time of testing. The WHO bioassays cone was used during testing of

Deltamethrin residual efficacy which was used for both traditional (rough) and modern (smooth) sprayed walls. Four cones (high, middle and low surface level) per surface with twenty mosquitoes per cone were used. Three cones were experimental cones and one was control cone per structure. The study was done during 2018 malaria season after five and six months (April to May 2018) from 2017 IRS to find out the residual efficacy of 2017 IRS insecticide used. Bi-variate analysis was calculated to determine the statistical significant between mortality rate and types of the walls as well as time interval. Statistical significant was calculated at P-value < 0.05 and odds ratios at Confident Interval (CI) 95% confidence level to determine significant associations.

Results: The district recorded 460 malaria cases from January –July 2018, of which 65 (14%) were local transmission and did not travel outside the district for about one incubation period (2-14 days) before the onset of symptoms. The peak months were March (23%), April (26%) and May (25%). The district had the total of 376 villages of which 156 (41%) were managed to be sprayed in 2017 and 220(59%) were not sprayed. Malaria local transmission cases were reported in 44 (10%) villages; of which 30/44 (68%) villages received IRS while 14/44 (32%); Odd ratio=3.8 CI 1.9-7.5; P value=0.0006). Only villages reported cases in the last 3 years were part of spraying campaign. In 2017, Engela district, Ohangwena region used only Deltamethrin in both structures because of unavailability of DDT during spraying season. Residual efficacy was tested in 23 malaria affected villages and on 50 sprayed structures. The time interval was one month, five to six-month time interval between IRS and testing of residual efficacy. The overall mortality rate (residual efficacy) was 46%. There is statistically significant between mortality rate and traditional structures with OR 1.66 CI 1.42-1.95 (P0.001), painted modern structures OR 0.77 CI 0.65 – 0.91 (P 0.002), time interval with OR 0.35 (0.29 – 0.41) P 0.001 and high position of the cone on the wall OR 0.76 CI 0.65 -0.88 (P 0.001).

Conclusion: In conclusion, it is worth noting that villages that were sprayed during 2017 IRS program recorded many cases as compared to non-sprayed villages and it were found to be significant. This can be influenced by areas with source of infection, travelling, evening activities, and age. The effectiveness (residual efficacy) of 2017 IRS during malaria peak months was 46% and it was found that it was direct proportional with time interval. Therefore, the researchers recommended active case detection team to consider other control intervention such as use of Long Lasting Insecticide Treated Nets, increase community malaria awareness and early seeking of treatment, early contact tracing of malaria cases to cut-of the infection and behavioral community change.

Table of Contents

List of Table

List of Figures

Abbreviations

CDC: Center Diseases Control and Prevention

CI: Confidence Interval

CTPS: Carbamate –treated Plastics Sheeting

DDT: Dichlorodiphenyltrichloroethane

IRS: Indoor Residual Spraying

ITN: Insecticide-Treated Mosquito Nets

LLINS: Long-Lasting Insecticide Mosquito Net

MOHSS: Ministry of Health and Social Services

MSAT: Mass Screening and Treatment

OR: Odds Ratio

PHC: Primary Health Care

PPT: Place Person Time

RH: Relative Humidity

WG: Weighted granule

WHO: World Health Organization

WHOPES: World Health Organization Pesticides Evaluation Scheme

WP: Weighted Powder

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This study is dedicated to my retired supervisor Ms Lucia Nghishongwa and my supervisor Ms Anneli-Lina Ekandjo under the division of Public and Environmental Health, who made it possible for me to go for further my study. I would also want to dedicate this project to Public and Environmental Health department at regional levels for their contribution toward Malaria Elimination. Let this study be the source of information to your entire action plan toward Malaria control interventions.

DECLARATION

I, Padelia N. Ngenokesho, declare that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

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Padelia Ndeutala Ngenokesho

CHAPTER ONE

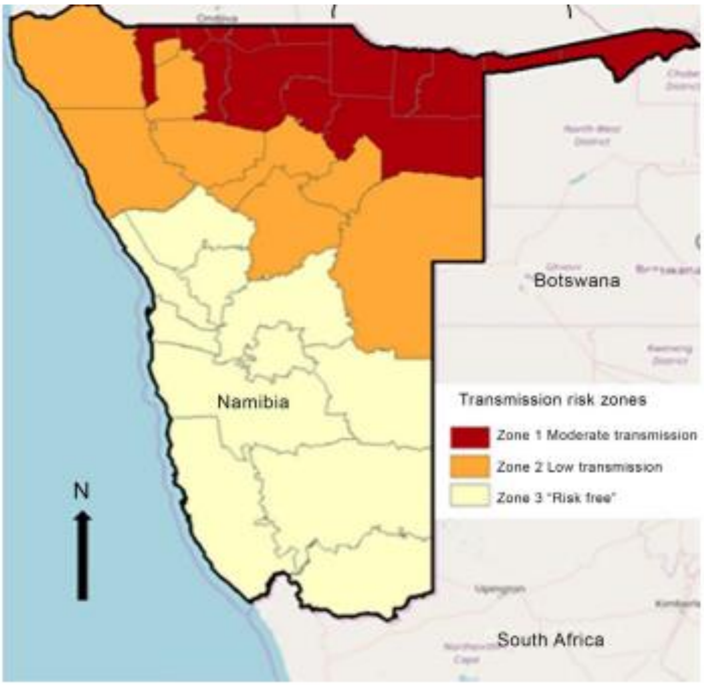
INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND INFORMATION

Malaria remains a public health problem in Africa and other countries of sub-tropical. In 2017, an estimated 219 million cases of malaria occurred worldwide (95% confidence interval [CI]: 203–262 million), compared with 215 million malaria cases in 2016. Most malaria cases in 2017 were in the WHO African Region (200 million or 92%), followed by the WHO South-East Asia Region with 5% of the cases and the WHO Eastern Mediterranean Region with 2%. Globally, in 2017, there were an estimated 435 000 deaths from malaria, compared with 451 000 estimated deaths in 2016. (1,2,3). Namibia recorded high number; (66141 (27.3%) of malaria cases in 2017 as compared to 2016 (24869 (10.3%) and 2018 (36451(14.8%).

Primary malaria prevention on a large scale depends on control interventions such as indoor residual spraying (IRS), larvaciding, prophylaxis, use of insecticide treated mosquito nets (ITNs) (1) and community awareness.

Namibia have a total population of 2,484,780 of which 85% have access to public health care system driven by Primary Health Care (PHC) strategy (including Malaria screening campaign during malaria season in malaria endemic area) and 15% have access to private health facilities to ensure health coverage at all levels (4). A total of 1458600 (77.3%) are at risk of being infected with malaria (2,4). Namibia is stratified into three malaria zones such as high transmission zone (>1 case per 1000 population), low transmission zone (0-1 case per 1000 population) and Malaria free zone (0 cases). The district under study (Engela, ohangwena region) is in high transmission zone.



Map of stratification by malaria transmission zone in Namibia 2016-2017(4)

Namibia is one of 8 countries in Southern Africa (E8) ready to move from the control phase to the elimination phase by 2022(2). However, interventions that were successful in bringing down malaria cases during the control phase may no longer be appropriate now that malaria transmission patterns have changed.

Malaria transmission in Namibia is higher in the north-eastern regions with a peak transmission in April - May; this is influenced by rainfall, temperature and humidity (4). The principal vectors are *Anopheles arabiensis*, *Anopheles funestus*, and Anopheles *gambiae* which are all susceptible to insecticides being used as per Namibia Vector control guideline and WHO Pesticide Evaluation Scheme (WHOPES) (5). The study done by the Ministry of Health and Social Services, in 2014, found that *Plasmodium falciparum* is the main parasites with high prevalence 97% and 3% was other parasites (*Plasmodium vivax, Plasmodium ovale, and Plasmodium malariae)* (1,2.3).

Vector control is the cornerstone of malaria control and/or elimination programs. African countries developed wide-scale distribution of vector control interventions to affected community such as Long Lasting Insecticide Treated Nets (LLINs) and Indoor Residual Spraying (IRS). This has over the years contributed to the significant decrease in malaria incidence and mortality (2,4). The efficacy and effectiveness of LLINs and IRS is determined by WHO resistance monitoring assays and CDC bottle bio-assays whereas effectiveness is measured by reduction of malaria incidence in relation to the scope of the intervention coverage.

The common malaria vectors in Namibia are *An. arabiensis, An. gambiae, An. Funestus* that feed and rest indoors (3, 4, 5). IRS is an infrequent spraying inside houses with a residual/ persistent insecticide. IRS relies on the fact that mosquitoes enter houses during night to feed on humans and rest on walls and roofs before or after feeding. Mosquitoes are mobile and travel to rest after feeding, and had been retiming before feeding. IRS is used to target mosquitoes that bite and rest indoor, thus why is the appropriate intervention to use. The IRS always target mosquitoes during resting, if they rest on the sprayed structure they get a lethal concentration of the insecticide used during spraying and die. These give them no chance, to feed again and transmit the malaria parasite (3, 5).

Namibia has sustained IRS as a key intervention for malaria vector control since 1965. Indoor residual spraying is one of the key vector control interventions for malaria control in Namibia. The insecticides used during the IRS program were selected due susceptible to common malaria vectors. Malaria transmission in Namibia is seasonal; hence a single round of spraying can usually provide effective protection against malaria, provided the insecticide remains effective over the entire malaria transmission season (4).

The insecticides being used are Dichlorodiphenyltrichloroethane (DDT) 75% Weight Powder (WP) for traditional structures and its duration of effectiveness is >6 months and Deltamethrin (Pyrethroid) 250 Weight Granule (WG) for modern structures with duration of effectiveness is 6 months (5, 6). However, during 2017, Engela district used only Deltamethrin in all types of structures (traditional, painted and unpainted modern structures) due to unavailable DDT insecticide during the spraying season.

Currently, IRS implementation runs from September to November, which targeting only villages that reported malaria cases within three consecutive years (3, 4). Timely, good-quality spraying, insecticides can be effective for 6 months or longer (5, 6).

1.2 Problem statement

Even though Namibia has implemented multiple vector control interventions such as IRS, distribution of LLINs and larvaciding, the country still experiences high cases of malaria 2016 (60%) in the northern regions (2,4). Despite a sustained IRS above 80% from 2015 to 2017, the country failed to reach elimination stage of zero local transmission. In Namibia, malaria is seasonal with peak months in April to May, while the IRS intervention is conducted from September to November each year with the purpose to protect the people during malaria season. The aim of the IRS as part of the vector control intervention is to protect the community from common malaria vectors which are present in the community. The duration of insecticide effectiveness (residual efficacy) which is used in Namibia are as follow DDT >6 months and Deltamethrin 6 months as per WHO (7). In 2017, Engela district, started Malaria spraying program in September to November 2017 using Deltamethrin insecticide to protect the people from Malaria during Malaria season (December 2017 – May 2018) (1, 4). Importantly, the country needs to know the effectiveness of the insecticides used on wild type malaria vectors (mosquitoes) because these are the vectors that are aimed by the intervention being implemented.

Therefore, the study addressed to find out the effectiveness of IRS of Deltamethrin during 2018 malaria season as it was intended toward the female anopheles' mosquitoes (malaria vectors) that are in the community. Despite the high (80%-85%) (2,4) IRS coverage in the above mentioned regions during 2016 and 2017; the number of malaria cases were still existing. Some of the contributing factors to the increasing number of malaria cases might be; resistance of vectors to chemicals used for IRS and impregnation of LLINs, poor IRS quality as a result of weak capacity of IRS during malaria season, poor spraying techniques and refusal of IRS by community members.

There is an urgent need to better assess insecticide efficacy to help decision makers to strengthen IRS training of spray operators on spraying techniques in order to ensure the efficacy of the insecticide is effective during malaria season.

1.3 Definition of concept below:

The main concepts related to this study were defined:

Malaria: is a vector-borne disease caused by protozoan parasites from the *plasmodium genus* and it is transmitted to people through the bites of infected female Anopheles mosquitoes (2).

Residual efficacy: a residue that remains effective for some time after application residual insecticides (5).

Indoor residual spraying: the application of long-acting chemical insecticides on the walls and roofs of all houses and domestic animals' shelters, in order to kill adults' vector mosquitoes that land and rest on these surfaces for reducing and interrupting Malaria transmission (5).

Anthropophagic: Description of mosquitoes that show a preference for feeding on humans, even when non-human hosts are available (5).

Endophagic: Tendency of mosquitoes to blood-feed indoors (5).

Endophilic: Tendency of mosquitoes to rest indoors (5).

Malaria season: Period of the year during which most mosquito-borne transmission of malaria infection occurs (4).

Local transmission case: A case acquired locally by mosquito-borne transmission (1, 2).

Low transmission: refer to 0-1 malaria case per 1000 population (2).

1.4 Conceptual framework

The framework of this study was divided into three components: a) Incidence of Malaria in 2018, b) the residual efficacy for October and November 2017 Indoor Residual Spraying during April and May 2018 malaria season and c) the comparison of malaria cases in sprayed village and non-sprayed villages. The first objective was to determine the monthly incidence of Malaria in area where IRS was conducted in 2017. The second objective was to test for residual efficacy for 2017 IRS during Malaria season and compared Malaria cases between sprayed and non-sprayed villages as reported at health facilities and investigated (active case surveillance). The case investigation forms from the health facilities are sent to surveillance focal person and Environmental Health office for further investigation.

1.5 PURPOSE AND OBJECTIVES OF THE STUDY

1.5 .1 Purpose of the study

The purpose of this study was to determine the residual efficacy (effectiveness) of 2017 Indoor Residual Spraying (Deltamethrin insecticide) during 2018 malaria season in Engela district, Ohangwena region.

1.5.2 Research objectives

- To determine the monthly incidence of Malaria local transmission cases in area covered with IRS as from January 2018 - July 2018
- To compare Malaria local transmission cases among people living in sprayed and non- sprayed villages

- To test residual efficacy for the insecticide(Deltamethrin) used during 2017 IRS program at the time of 2018 malaria peak months in sprayed villages which reported malaria case

1.6 Significance of the study

There is a lack of base line data for spray quality or information on how long the sprayed insecticide remains effective. This information can help NVDCP plan better for IRS campaign as well as monitor spray quality. Addition to that, Namibia is in low transmission settings (0-1 case per 1000 population) (1,2) and there is little data available for how effective the interventions.

Additional, the study was meant to guide policies maker in the Ministry of Health and Social Services (MOHSS) in line with the goal of malaria elimination. The findings of this study were meant to inform partners and stakeholders on relevant areas of partnerships with MOHSS in malaria vector control programme implementation.

It also meant to guide the MOHSS, National Vector Diseases Control Programme in fighting the burden of malaria in order to choose the right insecticides and improve spray techniques in the country to achieve elimination by 2022.

1.7 Limitation of the study

Low sample size of structures affected the outcome of the study. The results of this study were not a representation of all health districts or regions in Namibia because it was only conducted in Engela health district, Ohangwena region. The study was limited as it only tested the residual efficacy for the IRS not considering amount of insecticide deposited on the walls during the spraying. In addition, the study was only able to determine the effectiveness of the IRS but was did not test the resistance of mosquitoes to the insecticide and the amount of insecticides on the wall. The study used the common present malaria vectors (female anopheles' mosquitoes) wild types and this can be problematic as one cannot conclude whether the results were due to poor residual efficacy or resistance. Importantly, the country needs to know the effectiveness of the insecticides used on wild type malaria vectors (mosquitoes) because these are the vectors that are aimed by the intervention being implemented.

1.8 Delimitation of the study

Even though the study was conducted in one district, expanding the study to other districts was logistically feasible because the sprayed structures are the same in the whole region, procedures and spraying techniques used during IRS are also the same and spray operators and supervisors were trained at the same place respectively.

The study population in testing of residual efficacy was limited to sprayed villages only, as testing of residual efficacy is only done in sprayed structures. Therefore, by limiting the testing of residual efficacy for IRS to previously sprayed villages will pave a way for targeted public health interventions.

1.9 Summary

This chapter provided background information concerning prevalence of Malaria and Indoor Residual spraying. The researcher highlighted the research problem, purpose, objectives, significance and limitation of the study. The next chapter will concentrate on the literature review with regards to the malaria and Residual efficacy of IRS in worldwide.

CHAPTER TWO

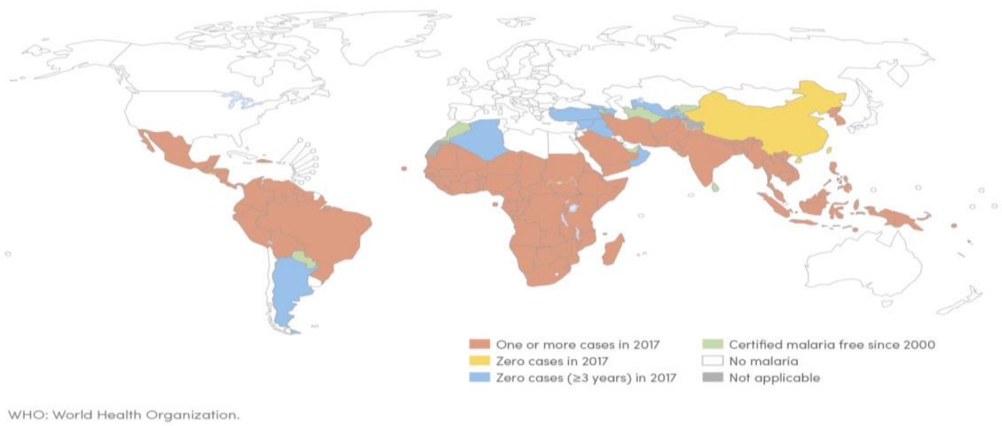
LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of a literature review was to establish what other researchers have done in an area of interest, and to identify methods that can be applied to the study under consideration. It was to convey to the reader what was currently known regarding the topic of interest and what their strengths and weaknesses are. The literature review for this study focused on the prevalence of Malaria in relation to residual efficacy for IRS in Africa and beyond.

2.2 The Burden of Malaria in Africa

Malaria continues to be a serious health problem despite it being a preventable and curable disease. It is reported to cause more than 250-660 million infections and more than 1 million deaths yearly in Africa. The most severe form of the disease prevails in Sub-Saharan Africa where ninety percent of global malaria deaths have occurred (1). The most severe form of malaria is caused by P. falciparum with variable clinical features which include fever, chill, headache, muscular aching and weakness, vomiting, diarrhea and abdominal pain (2).



Estimated number of Malaria cases in 2017 (2).

Malaria control efforts and elimination in Africa are being challenged by the development of resistance of vectors to insecticides (Pyrethroid-resistance) and parasite to anti-malarial drugs.

2.3 Effectiveness of Indoor Residual Spraying (IRS) in relation to Malaria

The distribution of malaria in Namibia is mainly confined to the northern parts of Namibia. The main malaria vectors were presumed to be Anopheles arabiensis, Anopheles gambiae. The main vector control intervention has been indoor residual house spraying (IRS) with 75% DDT wet table powder since the 1960's and Deltamethrin 25 g granules (8, 30). The primary vectors of malaria in Southern Africa are *Anopheles funestus* and *Anopheles arabiensis*. The species are highly anthropophagic and endophilic, making it especially susceptible to be controlled by IRS (9, 30).

A case study of malaria strategies and costs along the northern border done in Namibia found that indoor residual spraying is the main intervention, but coverage varies, related to acceptability, mobility, accessibility, insecticide stock outs and staff shortages (28). In Ohangwena region, the key informants in the study believed that most cases originated in Angola: 87% of the region's malaria cases were reported from Engela District, where the official border post is located (28).

A study done in Equatorial Guinea found an association between IRS and malaria. IRS offered protection to those in sprayed and unsprayed houses alike when neighborhoods spray coverage was high (80%) compared to those living in areas of low IRS coverage (,20%), regardless of whether the house they lived in was sprayed or not (adjusted OR = 0.54, 95% CI 0.33–0.89). The study stated that similar effects were seen in Malawi, but the evidence was much weaker than in Equatorial Guinea (10). Additional study found that, indoor residual spraying (IRS) was commonly used by countries. There were several examples of severe reductions or halting of IRS coverage and subsequent resurgence of malaria (11).

A systematic review done on the associations between malaria, interventions, and the environment, found out that bed net ownership was statistically associated with decreasing risk of malaria, OR of 0.75 (95% CI 0.60, 0.95) (12).A different study that look at both ITN and IRS found that living in households with both ITNs and IRS was associated with a significant risk reduction against parasitaemia in medium and high transmission areas, 53% (95% CI 37% to 67%) and 31% (95% CI 11% to 47%) respectively. In rural and urban areas, exposure to both interventions provided significant protection against parasitaemia, 57% (95% CI 48% to 65%) and 39% (95% CI 10% to 61%) respectively; however, this effect was not significantly greater than having a singular intervention. Statistically, risk for all-cause child mortality was not significantly reduced by having both ITNs and IRS, and no additional protectiveness was detected for having dual intervention coverage over a singular intervention (10).

Evidence over several decades has confirmed the effectiveness of IRS in reducing levels of infection and incidence of malaria. The malaria incidence was reduced by 90% or more in major areas of tropical Asia and Southern America during the eradication programme through a combination of IRS and other measures (3).

The similar study that also used wild Anopheles gambiae s.l to conduct the residual efficacy of a routine spray program found that, the residual efficacy was differ between the types of wall surface. It differs with the current study in terms of time interval between sprayed time and testing time. First bioassay was carried out after 1 day of spraying, then after 1 week and then every 4 weeks for 4 months from August to November 2016. The study found residual efficacy differ as per wall surface as follow, 89.3% on painted, 61.3% on smooth and 65% on rough surface. The painted wall surface showed the highest effectiveness (mortality rate) for the routine spray; which was more than 80% on both spray types. The insecticides used were Propoxur used on both wall types (11).

However, a study on correlation between malaria incidence and IRS coverage in western Zambezi region, Namibia which found IRS coverage in western Zambezi region was low, ranging from 42.3% to 52.2% for administrative coverage vs. 45.9–66.7% for reported coverage. This study found that there was no significant correlation between IRS coverage and malaria incidence for this region ($r = -0.45$, $P = 0.22$) (12).

A study in Malawi, indicated a sign of insecticide resistance which determined by increased of malaria cases even in the areas where the intervention is in place, which shows poor effective of the chemical (3). The same study shows that across a highly endemic country, one of the main malaria vectors, *Anopheles funestus,* is resistant to several insecticide classes, including the insecticides used for bed nets. Effective management of resistance requires an understanding of the dynamics and mechanisms driving resistance this includes testing of the chemical efficacy and this help improve resistance management and vector control strategies throughout Southern Africa (3).

A cluster randomized controlled trial done in Benin, investigated whether the combination of long-lasting insecticidal mosquito nets (LLINs) with indoor residual spraying (IRS) or carbamate-treated plastic sheeting (CTPS) give enhanced protection against malaria and better management of Pyrethroid-resistance in vectors than LLINs alone (13). The study showed that using combined LLIN+IRS have no extra benefit in reducing malaria morbidity, infection, and transmission compared to LLIN or IRS alone (13).

In a study done Nigeria and Mozambique with the objective to quantify the impact of IRS alone, and to compare the relative impacts of IRS and ITNs, on key malariological parameters showed IRS with protection against malaria prevalence during the wet season (PE 26%; 95% CI 20 to 32%) but not in the dry season (PE 6%; 95% CI -4 to 15%) (14). In Mozambique, the prevalence was reduced substantially over a period of 7 years (from 60 to 65% prevalence to 4 to 8% prevalence; the weighted PE before-after was 74% (95% CI 72 to 76%) (14).

The same study but different approaches were surveys conducted in Kenya, which evaluated the impact of an IRS program on malaria related outcomes in western Kenya, an area of intense perennial malaria transmission and moderate ITN coverage (55–65% use of any net the previous night) (15). Surveys were conducted in the IRS district and a neighboring district before IRS, after one round of IRS in July-Sept 2008 and after a second round of IRS in April-May 2009. The study showed that at baseline and after one round of IRS, there were no differences between the two districts in the prevalence of malaria. It further revealed that after two rounds of IRS, the prevalence of malaria was 6.4% in the IRS district compared to 16.7% in the comparison district (OR = 0.36, 95% CI = 0.22–0.59, $p<0.001$). The prevalence of malaria was also lower in the IRS district (1.8% vs. 4.9%, OR = 0.37, 95% CI = 0.20–0.68, $p = 0.001$) (15).

The study in Western Kenya about the effective of Malaria control interventions highlighted the risk of acquiring new parasite infections in children (16). It was substantially and independently reduced by ITN use (odds ratio, OR: 0.69; 95% confidence interval, CI: 0.48-0.99) (16) and larvicide application (OR: 0.44; 95% CI: 0.23-0.82) (16), after adjusting for confounders (16).

In a low-transmission setting, 80% coverage with Long Lasting Insecticide Treated Net (LLINs) reduced the malaria prevalence to below 1% in all age groups (17). In two moderate-transmission settings, LLINs scale-up alone failed to reach this target but the addition of Indoor Residual Spraying (IRS) and Mass Screening and Treatment (MSAT) drove the parasite prevalence below 1%. However, this combination of interventions did not control malaria in a moderate-transmission setting in which a mosquito species that bites and rests outside houses contributes to malaria transmission. Finally, in two high-transmission settings, malaria prevalence could be driven below 1% only by setting unrealistic coverage targets for existing interventions (17).

A different scenario on historical review of malarial control in Southern African which emphasizes on the use of indoor residual house-spraying conducted in Namibia, South Africa, Botswana, Swaziland, Zimbabwe, and Mozambique to determine the effective of the Indoor Residual Spraying (IRS). The team investigated the malaria situation before and after the introduction of IRS using historical malarial data and related information collected from National Malaria Control Programme, national archives and libraries as well as academic institutions in respective countries (18). The results show dramatic reductions in Malaria and its vectors after the implementation of the IRS. This happened because countries that developed National Malaria Control Programme during this phase had built up human and organizational resources made significant advances towards malarial control. The study concluded IRS as the best malarial control tool in six southern African Countries due to its effectiveness (18).

A Comparative test done in Tanzania, Ifakara town was to find the effectiveness of IRS and LLINs using experimental huts fitted with LLINs, IRS, and combinations of LLINs and IRS, in an area where *Anopheles arabiensis* is the predominant malaria vector species (19). The finding of the study found increased mortality of malaria vectors in huts with Nets and sprayed (IRS) as compare to the huts with IRS alone. They exposed the number of the mosquitoes on the impregnated papers and on treated and untreated net for an hour and calculate the number of mosquitoes killed per time. The tests were done for four months in dry season and another six months in wet season, each time using new intact nets (19).

A study in Cameroon, tested bio efficacy of Bayer Life Net (Deltamethrin) and DDT to determine the effectiveness of Deltamethrin used in manufacture of the net and DDT chemical toward *Anopheles gambiae* (20). Larval collections using standards for WHO tube assay was done to test for susceptibility (Bio-efficacy) of *Anopheles gambiae* to the chemicals. Bio-efficacy of the mosquito net was done using WHO cone test by exposing the mosquitoes on the net. These mosquitoes were found to be resistant to DDT and Deltamethrin because of 50% knockdown within 18-40 minutes and 59-77% mortality, the bio efficacy of the chemical supposed to be 100% mortality of the vector. The study showed that chemical dose application plays a big role in managing the resistance of the chemical (20).

A similar study done in Tanzania compared the bio-efficacy of durable wall lining (DL) (treated with Deltamethrin 265 mg/m^2) and IRS (with Deltamethrin 5% WP at 20 mg/m^2) in comparison with houses without either DL or IRS as a control. Total of unfed females of *Anopheles gambiae* raised from larvae were collected from natural habitats in the same village for bioassays. When the comparisons were done between DL and IRS houses, the densities were significantly lower in DL houses compared to IRS houses (P-value = 0.021) (12). In the DL installed houses, indoor mosquito density declined notably and sustained throughout the 6 months of the study. However, in those houses sprayed with Deltamethrin5% WP, the density noted to increase four months after spraying. This showed that DL with Deltamethrin 265 mg/m^2 has longer efficacy than IRS with Deltamethrin 5% WP 20 mg/m^2(21).

A descriptive study which was conducted in Namibia with the aim to determine IRS coverage (administrative and reported), its effect on malaria incidence, and reasons for non-uptake of IRS in western Zambezi region, Namibia, for the 2014–2015. It found that IRS coverage in western Zambezi region was low, ranging from 42.3% to 52.2% for administrative coverage vs. 45.9–66.7% for reported coverage. There was no significant correlation between IRS coverage and malaria incidence for this region ($r = -0.45$, $P = 0.22$). The main reasons for households not being sprayed were that residents were not at home during spraying times or that spray operators did not visit the households (22).

A series of retrospective time series analyses were performed on 1,382,202 rapid diagnostic test-confirmed cases of malaria reported by district routine health systems in Ségou Region from January 2012 to January 2016. Districts were stratified by IRS implementation status and all-age monthly incidence rates were calculated and compared across strata from 2012 to 2014. During 2012–2014, rapid reductions in malaria incidence were observed during the 6 months following each IRS campaign, though most of the reduction in cases (70% of the total) was concentrated in the first 2 months after each campaign was completed. Compared to non-IRS districts, in which normal seasonal patterns of malaria incidence were observed, an estimated 286,745 total fewer cases of all-age malaria were observed in IRS districts (23).

A cluster randomized trial study conducted in Sudan with Pyrethroid-resistant and carbamate-susceptible malaria vectors stated that the insecticide-based interventions have contributed to ~78% of the reduction in the malaria burden in sub-Saharan Africa since 2000. Insecticide resistance in malaria vectors could presage a catastrophic rebound in disease incidence and mortality. Clusters were randomly allocated to receive either long-lasting insecticidal nets (LLINs) alone or LLINs in combination with indoor residual spraying (IRS) with a Pyrethroid (Deltamethrin) insecticide in the first year and a carbamate (bendiocarb) insecticide in the two subsequent years. Malaria incidence was monitored for 3 years through active case detection in cohorts of children aged 1 to <10 years. However, when Deltamethrin was used for IRS, incidence rates in the LLIN + IRS arm and the LLIN-only arm were similar, with the IRS providing no additional protection [incidence rate ratio (IRR) = 1.0 (95% confidence interval [CI]: 0.36–3.0; *P* = 0.96)]. When bendiocarb was used for IRS, there was some evidence of additional protection [interaction IRR = 0.55 (95% CI: 0.40–0.76; *P* < 0.001)] (24, 25).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter is outlining the processes, procedures and guidelines involved in the production of this research. It covers the research design, sampling, data collection instrument, data management as well as analysis. The ethical consideration and the rights of the participants have also been explained in this chapter.

3.2 Study design

An analytical quantitative cross sectional study was conducted to test residual efficacy in the villages that were covered with 2017 IRS and reported malaria cases in 2018. Malaria linelist for 2018 was analysed per person, place, and time; to identify the villages affected by malaria and to conduct residual efficacy testing. The Researchers used wild female anopheles mosquitoes (Malaria vectors) identified and collected in the breeding site around the Engela community. Wild malaria vectors were used as they were targeted during 2017 IRS program to check if insecticides used was effective during malaria 2018 peak season. The researcher used Oshakati insectary with the assistance of the Oshakati insectary manager to grow the larvae into adult mosquitoes. Female anopheles, larvae were collected from stagnant water ponds in Engela district and kept in containers with water in the insectary (Oshakati insectary) until they develop into adult mosquitoes. Then unfed adult female anopheles mosquitoes, malaria vector present in the community were then used to test residual efficacy in sprayed structures which were sprayed during 2017 IRS campaign which took place in September to November 2017. The insecticide used is to protect the community against malaria by common malaria vector in the community which is supposed to be susceptible to the insecticide.

3.3 Study population

To determine the incidence of Malaria, the study included people in Engela district. Houses that were sprayed in the district during 2017 malaria spraying campaign were involved in the study. All local malaria transmission cases (cases with the source of infection considered to be within the district) formed part of the study. The information about travelling history to obtain the source of infection was obtained from Malaria Investigation form which was used during Malaria contact tracing. Malaria case investigation forms of all malaria cases were completed at health facility level and sent to the surveillance focal person and Environmental Health Office for active case investigation to identify the source of infection and implement other interventions. There was a system in place between regions that if one case reported at the health facility in different region or district, the case investigation forms were sent to the region or district for further investigation where the case came from and included in malaria data for that particular region. The study provided good scope of tools and selected a region, where malaria is taken very serious whereby communities seek treatment at health facilities. Engela district (Ministry of Health and Social Services) conducts Malaria screening campaign, community mobilization on Malaria during malaria season and during contact tracing, with the aim to ensure that every citizen suspected of having malaria was advised to seek hospital services, and ensure malaria cases were all treated to reduces transmission of malaria under this health facility catchment area (26, 27).

On the residual efficacy of IRS, the researcher used unfed female anopheles mosquitoes, grown from collected larva in the field to the insectary.

3.3.1 Inclusive

All houses that were part of 2017 IRS program with unpainted, traditional and painted walls were eligible for the study. Villages reported with malaria and covered with 2017 IRS were part of the study. Only mosquitoes that were exposed on the sprayed wall surfaces were included in the study. The study considered the structures that were sprayed with time interval of 5 and 6 months between sprayed time and testing time as the duration of Deltamethrin effectiveness is 6 months (3). The researcher only considered structures with hut card that were left by spray operators during the spraying season (SEE APPENDIX).

All local transmission malaria cases seen at health facility and during malaria screening campaign formed part of the study. The cases were determined as local or non-local transmission during active case investigation and indicated in malaria line list. Malaria case investigation forms of all malaria cases were completed at health facility level and information were also verified during contact tracing.

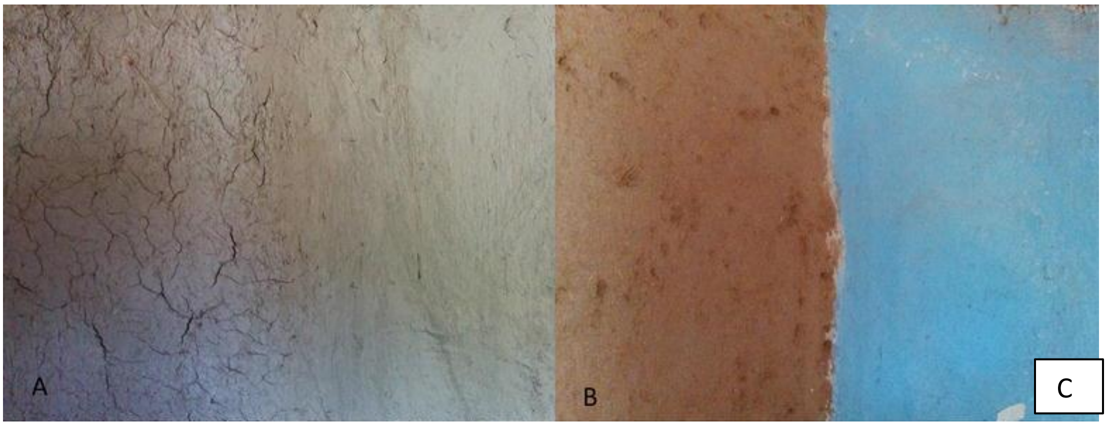
The forms were sent to the surveillance focal person and Environmental Health Office whereby they did active case investigation to the patient's house to determine if the case was local or non-local transmission depend of where the source of infection occurred. The researcher was part of the investigation team.

The information about travelling history was obtained from Malaria Investigation forms which were used during Malaria contact tracing. Travelling history referred to the person travel outside the district for about one incubation period (7-14 days) before the onset of symptoms.

3.3.2 Exclusive

All non-local Malaria cases with the source of infection outside the district either from outside the country or from different regions were not included in the study. Travelling history referred to the person travel outside the district for about one incubation period (7-14 days) before the onset of symptoms. Householders who declined informed consent and newly constructed houses were not part of the study. Female anopheles mosquitoes that died before being exposed to the surfaces was not included in the study.

Types of wall (structures) used during the testing of residual efficacy in Engela 2018.



A: Traditional wall insecticide used Deltamethrin

B Unpainted wall insecticides used Deltamethrin

C Painted walls insecticides used Deltamethrin

3.4 Study Materials

To find malaria incidence in terms of person, place and time the following documents were used:

- Malaria line list for 2018; this document was used to find out the villages with local transmission cases. This is the list of all malaria cases seen in the district, it contains the information such as name of the patients, village name, house sprayed or not, nationality, health facility treated and gender (see the appendix G)

- Malaria Investigation forms: This form was used in the health facilities or community to record malaria case and it was used during the case investigation (contact tracing). The forms contain case information which was obtained within the health facility and also during active (field) investigation at the patient house (see the appendix H).

Testing of the residual efficacy for IRS

Once female anopheles mosquitoes were collected from Oshakati Insectary Laboratory to the field for testing the residual efficacy:

- Tray, scoop, and pipette were used to collect larvae at the breeding site.
- Four cones were placed on the sprayed surface per room, three were used as an experimental and one was as a control. Mosquitoes in control cones were not exposed to the sprayed wall in order to check some other contributing factors that may kill anopheles mosquitoes.
- Two mouth aspirators were used to take mosquitoes from the cage to the cone; one was used for control cones and one for experimental cones. Twenty mosquitoes were used per cone.

3.5 Sample size

The study was conducted in 23 sprayed (IRS) villages that reported with malaria in 2018. The total of 50 sprayed structures (see table 1) were used. Sample size was obtained using EPI Info 7.2, STAT calc. Over 4000 unfed female anopheles mosquitos were used. Three types of common structure walls in the villages were conducted; the structures were rough mud, unpainted and painted wall and chemical used in all structures was Deltamethrin due to un available of DDT at the time of spraying season. Unfortunately, the region (district) did not have DDT in stock, therefore they used Deltamethrin for both structures because it was the only insecticide which was available. Rough and unpainted walls were supposed to be sprayed with DDT.

Twenty (20) female *Anopheles* mosquitoes (Malaria vectors) were place in each both experimental and control cones to test for residual efficacy using WHOPES guideline (25,29). Addition to the tested sprayed structure for 2017 IRS program, four structures were sprayed during malaria contact tracing in May 2018 were tested for residual efficacy after a month in June 2018 to see the effectiveness in one-month interval.

- Total number of mosquitoes used = 4000: 20 mosquitoes per cone, four cone per structure (1 control cone and 3 experimental cones)
- Number of structure tested = 50

Over the course of the study, about 4000 unfed female Anopheles mosquitoes were used to test for residual efficacy in 46 structures that were part of IRS program for 2017 in October and November. Addition to the tested sprayed structure for 2017 IRS program, four (4) structures were sprayed during malaria contact tracing (May 2018) and tested for residual efficacy after a month interval (June 2018) to check the effectiveness of Deltamethrin in one-month interval as compare to 5 and 6 months (2017 IRS) interval. Overall of 50 sprayed structures that were both part of 2017 IRS in October and November, and structures that were sprayed during 2018 malaria contact tracing were part of the structure tested for residual efficacy (effectiveness). The residual efficacy was conducted during malaria peak season (April and May 2018). Time interval between IRS and testing of residual efficacy was as followed: October 2017 to April and May 2018, November 2017 to April and May 2018.

Table 1: Time interval between IRS and testing of residual efficacy

Time IRS occurred	Time interval	Time the residual efficacy done
May 2018	1 month	June 2018
October 2017	6 months	April 2018
November 2017	6 months	April 2018
November 2017	5 months	May 2018

Table 2: Villages sprayed during 2017 IRS program and Malaria incidence in 2018, Engela district.

Village name	Homestead/structures	Village name	Homestead/structures
1. Okanghudi	5	13. Ongha	2
2. Engela	4	14. Onamunhama	1
3. Odibo	3	15. Epoli	1
4. Oshikango	3	16. Onawa	2
5. Odiboya Haiti	2	17. Oshali	2
6. Ouhongo	4	18.Onhaminda	2
7. Oilangati	3	19 Eehongo	1
8. Omungwelume	3	20. Ohadiwa	1
9. Okatale	2	21. Omafo	1
10. Omatunda	2	22. Oilyateko	1
11. Epoli	2	23. Onhuno	1
12. Omahenge	2		

3.6 Data collection methods and procedures

3.6.1 Prevalence of Malaria

The researcher analyzed Malaria Surveillance data (line list) in terms of person, place and time (PPT) to identify the villages that reported malaria in comparison with IRS.

3.6.2 Testing of residual efficacy

Larva and pupa of *Anopheles* mosquitoes were collected from the breeding site (water ponds) in Engela district and transported to Oshakati Insectary. Larvae were collected using tray, scoop, pipette to pick the selected larvae from the tray, and specimen containers to put the selected larvae then transported to Oshakati insectary for growth into adult Anopheles mosquitoes. Larvae sampled were first classified at the breeding site as malaria vectors (female Anopheles mosquitoes) based on crude morphological criteria until developed into adult female. Larvae collections were made from a 10 number of different breeding sites; to avoid sampling individuals from single egg batches (25, 29).

Once the pupas develop into adult Anopheles mosquitoes; they were transferred into a cage made of a net enable the air to enter into the cage for breathing. Then, 3–5 days old sugar-fed female *Anopheles anopheles* as malaria vectors were used for wall bioassay tests (25, 29).

At the time of testing, unfed adult female anopheles mosquitoes (common malaria vectors in the community) were transported from the Oshakati insectary in Oshana region to the field in Engela district for residual efficacy testing.

Three cones and one paper cup were used per structure; three cones were experimental (exposure) cones affixed on the sprayed wall surface per structure using a sole tap and one paper cups was a control, covered with non-treated net (chemical free) and place in the same structure but not exposure to the sprayed wall. The exposure cones were affixed inside the structures at different heights of the structure: high (40 cm below the roof), middle and low (40 cm high from the floor) to evaluate the persistence of insecticides (25, 29).

Twenty female anopheles mosquitoes were selected from the cage based on crude morphological criteria before place in the cones. Twenty mosquitoes were then transferred into the cone that is placed on the sprayed wall using aspirator and exposure them for 30 minutes on the sprayed surface (23, 30). After the exposure time they were removed from the cones with the aspirator and placed in the paper cups covered by chemical free net (untreated net), and then transported to the insectary in a cooler box with a wet towel. The mosquitoes in the paper cups were kept in the insectary for 24 hours at temperature of 27 °C ± 2 °C and at 80% ± 10% relative humidity (RH). After 24 hours' mortality rate was recorded in both control paper cups and exposure (experimental) paper cups. A mosquito was considered as alive if it was able to fly (25, 29).

After 24hours mosquitoes mortality in both exposure and control cones were recorded and the mortality rate were calculated using the following formula:

- Mortality rate= No. of mosquitoes dead/number of mosquitoes applied to control or exposure cones x 100(29).

We did not use Abbott's formula because control mortality rate was 0% but not between 5%-20%, Abbott's formula:

- Exposure mortality= {E-C/100-C} x 100 (29).

In every sprayed structure, the spray operators leave a hut card (see appendix), in the structure as a proof that the structure was sprayed, therefore, the researcher only considered structures with hut card as sprayed.

3.6.3 Disposal of Mosquitoes

After the completion of the study the mosquitoes were killed with insecticide and all wastes generated from the insectary were then incinerated at Oshakati Intermediate Hospital incinerator.

3.7 Validity of the study

Instrument validity ascertains that the instruments were accurately measure. Content and face validity methods were used to verify the validity of the data collection instrument for this study. Content validity evaluates/measures whether all the components of the variables to be measured are fully represented by the instrument. While, face validity of instrument was verified by an expert on the research subject who evaluate its' intent and concludes that it measures the characteristic of interest. The researcher used equipment from the Oshakati insectary laboratory, Ministry of Health and Social Services. The forms were modified according to WHO guideline on testing of residual efficacy. Research supervisors reviewed drafted forms for content and face validity and made conclusion. The forms were also reviewed by the Insectary Manager and Environmental Health Practitioners at the Oshana and Ohangwena Regional Health directorate. Then the forms were edited and refined based on Insectary Manager, Environmental Health Practitioners and the supervisors' comments before submitted to UNAM Review Ethical Committee (UREC). A pilot study was conducted in Oshana region among sprayed villages to assess for the form's acceptability, relevance and sensitivities.

Oshakati insectary manager conducted a refresh training before the study on how to test for residual efficacy.

3.8 Reliability of the study

Reliability is regarded as the regularity of measurement applied to identical entities, and still producing equivalent results every time. The researcher conducted a pilot study before the main study in the different village as the study area in order to test the reliability of the data collection (study) techniques. The researcher is familiar with malaria as she is part of malaria active case detective team employed by Ministry of Health and Social Services under the department of Public and Environmental health, in Oshana region and worked as Malaria surveillance office under Global Fund.

3.9 Sampling methods

Malaria cases for January – July 2018 were analyzed for comparison between sprayed and non-sprayed villages. Villages covered with IRS and affected by malaria were selected using simple random sampling. Three types of sprayed walls which were rough mud, smooth unpainted wall and painted wall were selected per village using simple random sampling. Every sprayed third house in the affected village was selected.

3.10 Data Analysis

Data were analyzed using Epi Info 7.2, to generate proportion and frequencies. Odds ratio with 95% confidence Interval was used to test for association at P-value ≤ 0.05 between IRS residual efficacy and malaria cases. Mosquitos' mortality rate among exposed mosquitoes and non-exposed was calculated. Bivariate analysis between mortality rate (residual efficacy) and variable such as time since spraying, type of the wall surface, and type of the chemicals was determined. A malaria secondary data analysis was conducted to identify villages that are affected in 2018. Mortality rates were calculated and analyzed according to WHO protocol to determine the residual efficacy of IRS. The mortality rate was calculated after 24 hours holding period. Percentage of knockdown was not calculated as there was no knockdown observed after 30 min exposure. Control mortality was 0% in all cones during the study period and hence was not corrected by Abbott's formula

WHO bioassays cones were used to monitor residual efficacy on each selected sprayed walls. Mosquito mortality rate for exposed mosquitoes was expected to be more than 97% -100% for the chemical to be called effective and below that the chemical considered non effective (25, 29). The following formula was used to calculate the mortality rate which determined if the insecticide was effective.

- Mortality rate = No. of mosquitoes dead/number of mosquitoes applied to control cones x 100 (25, 29)

3.11 Ethical Consideration

Permission Ethical clearance was sought from the University of Namibia and a second approval was sought from the Ministry of Health and Social Services. The ethical clearance letter from MOHSS was presented to Ohangwena Regional Director prior to data collection. Participants' wellbeing in this study was a priority. The principal researcher ensured that participants were treated with respect, and given enough information for them to make an informed voluntary consent. No harmful activity regarding their participation in the study occurred. Permission to test residual efficacy in the houses was obtained from community leaders, and house owners.

3.12 Autonomy

Informed signed consent forms from all participants were required to enter in their houses. The consent forms were translated from English to Oshiwambo (local language). The aim of the study was explained to the study subjects. The right and dignity of the study subjects was respected through the research period. Participation was voluntary and they were allowed to withdraw from the study at any stage without being coerced or intimidated.

3.13 Confidentiality

Forms used were anonymous and were assigned with unique identification numbers. The electronic data base was locked on the restricted computer which was allocated with a password and paper based data was stored in a restricted lockable cabinet.

3. 14 Non – Maleficence

The study subjects did not undergo procedures or processes which may cause physical or emotional discomfort.

3.15 Benefit of the study

It is envisaged that, this study will serve as a benchmark for implementation malaria control strategies in Ohangwena region, Engela and country at large in order to reach Elimination by 2020.

3.16 SUMMARY

This chapter addressed design and methodologies used to enroll study participants and to collect data. It contains the root of the research which includes: the data collection instrument, data management and analysis and steps taken to ensure that the results are valid and reliable. The ethical principles taken were also included.

Chapter 4

Results of the study

4.1 Introduction

This chapter was dedicated to the findings and data analysis of the study. The main findings of the study were incidence of malaria in relation to residual efficacy of 2017 IRS program. The results were presented as descriptive and analytical statistics in tables, pie charts and graphs according to objectives of the study.

Descriptive analysis

4.2 Monthly Incidence of local transmission of Malaria cases

The district recorded 460 malaria cases as from January to July 2018, of which 65/460 (14%) malaria cases had no travelling history (local transmission) and 395/460 (86%) had travelling history from Angola (non-local transmission). The district experienced a peak of malaria cases during March, April and May.

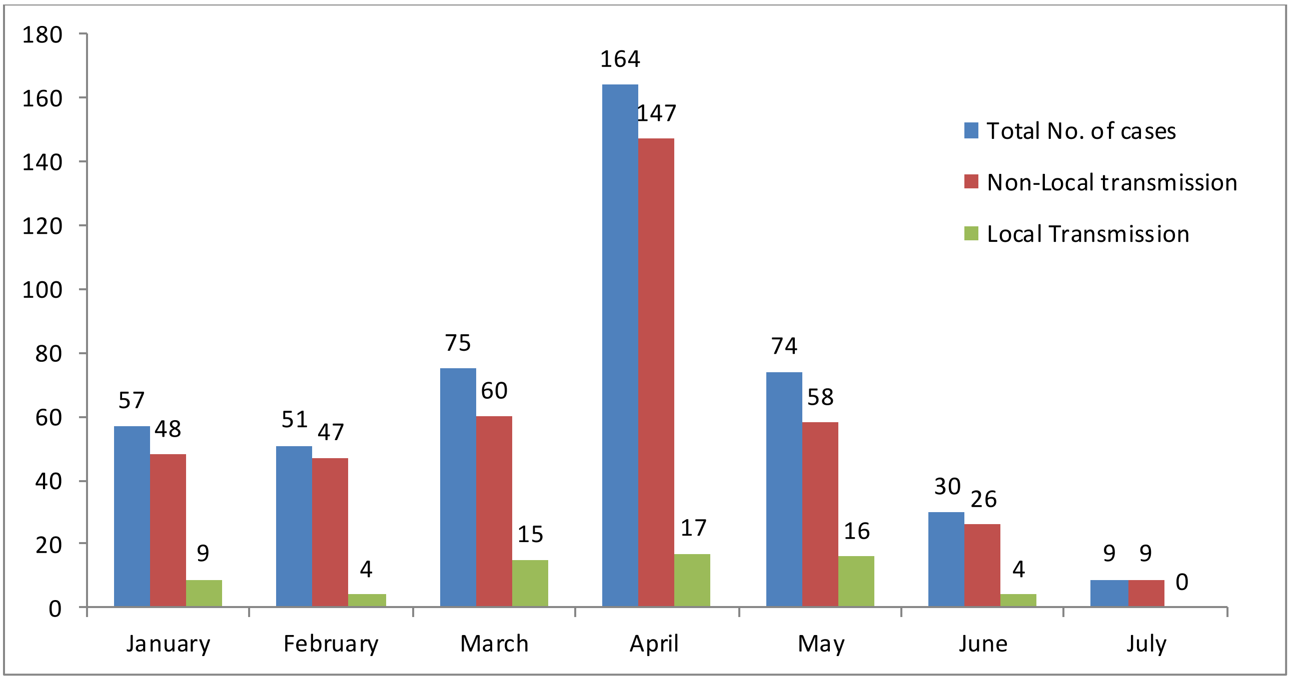


Figure 1: Local and non-local transmission of Malaria cases reported in Engela district, Jan – July 2018 n= 460.

The study recorded 460 Malaria cases of which 395/460 (86%) were non local transmission and 65/460 (14%) were local transmission. The study recorded a high number of Malaria cases in April with 164/460 (36%) cases, whilst a low number of malaria cases were recorded in July with 9/460 (2%). Both local and non-local transmitted cases were recorded from January to June, while in July there was no local transmission. The highest numbers of local transmission were recorded in April with 17/460 cases followed by May with 16/460 local transmissions.

The demographic information of malaria cases in Engela health districts are presented in table 3.

Table 3: Demographic information of Malaria local transmission cases in Engela district, Ohangwena 2018.

Variables	Number of cases	Percentages (%)
Gender : Male	40	62
Female	25	38
Age group:		
0 – 10 years	21	32
11 years – 20 years	12	18
21 years – 30 years	10	15
31 years – 40 years	10	15
41 years – 50 years	5	8
51 years – 60 years	4	6
+60 years	3	5
Total	**65**	**100**

Majority of case were male 40/65 (62%) compared to female 25/65 (38%) P value =0.23 (not significant). However, among age group the young generation with the age range from 0 – 10 years recorded high number of cases 21/65 (32%), followed by the age ranges from 11 – 20 years 12/65 (18%) and the least number of cases were recorded in the ages above 60 years (P value=0.4) with no association.

4.3 Malaria local transmission cases between sprayed villages versus non- sprayed villages

The district had the total of 376 villages of which 156 were managed to be sprayed in 2017 and 220 were not sprayed. Malaria local transmission cases were reported in 44 villages; among that 30 villages received IRS while 13 villages did not receive IRS in 2017 (Odd ratio=3.8 CI 1.9-7.5; P value=0.0006). Only villages reported cases in the last 3 years were part of spraying. The district recorded 65/460 (14%) malaria local transmission cases.

The cases were scattered (sporadic) all over the district in both sprayed and non-sprayed villages. Okanghudi was sprayed and was recorded with the highest number of cases 4 (6%) followed by Engela, Odiboya Haiti and Oshikango with 5%. The local transmission of malaria affected more in rural areas, then semi-urban and urban areas.

Table 4: Incidence of malaria local transmission against sprayed villages in 2018, Engela district, Ohangwena 2018, n=46.

No	Villages	Set-up	Number of cases
1.	Okanghudi	Rural	4
2.	Engela	Semi urban	3
3.	Odiboya Haiti	Rural	3
4.	Oshikango	Urban	3
5.	Eenghango	Rural	2
6.	Epoli	Rural	2
7.	Odibo	Rural	2
8.	Oilagati	Rural	2
9.	Okatale	Rural	2
10.	Omungwelume	Rural	2
11.	Onamunama	Rural	2
12.	Others (19 village)	Rural (17 rular, Semi rular 2)	1x19
	Total		46

Thirty villages that were sprayed in 2017; recorded 46 (71%) malaria local transmission cases. Okanghudi in rural area was recorded with highest malaria cases 4/46 (6%), followed by Engela (semi urban), Odibo ya Haiti (rural) and Oshikango (urban) with both 3/46 (5%) cases.

Table 5: Incidence of malaria local transmission against non-sprayed villages in 2018, Engela district, Ohangwena 2018, n=19.

	Village name	Set-up	IRS conducted	Number of cases	Percentages
1.	Omahenge Shaduka	Rural	No	2	3%
2.	Omatunda	Rural	No	2	3%
3.	Ongha	Rural	No	2	3%
4.	Oshimbibi	Rural	No	2	3%
5.	Ouhongo	Rural	No	2	3%
6.	Okadiva	Rural	No	1	2%
7.	Okatope	Rural	No	1	2%
8.	Omakango	Rural	No	1	2%
9.	Omanyoshe	Rural	No	1	2%
10.	Onangwe	Rural	No	1	2%
11.	Oshatotwa	Rural	No	1	2%
12.	Oshimumu	Rural	No	1	2%
13.	Enghandja	Rural	No	1	2%
Total				19	

Total numbers of 19 malaria local transmission cases were recorded in 13 non sprayed villages. The five villages were recorded highest malaria cases with 2 (3%) cases, the rest were only recorded with 1 (2%) case.

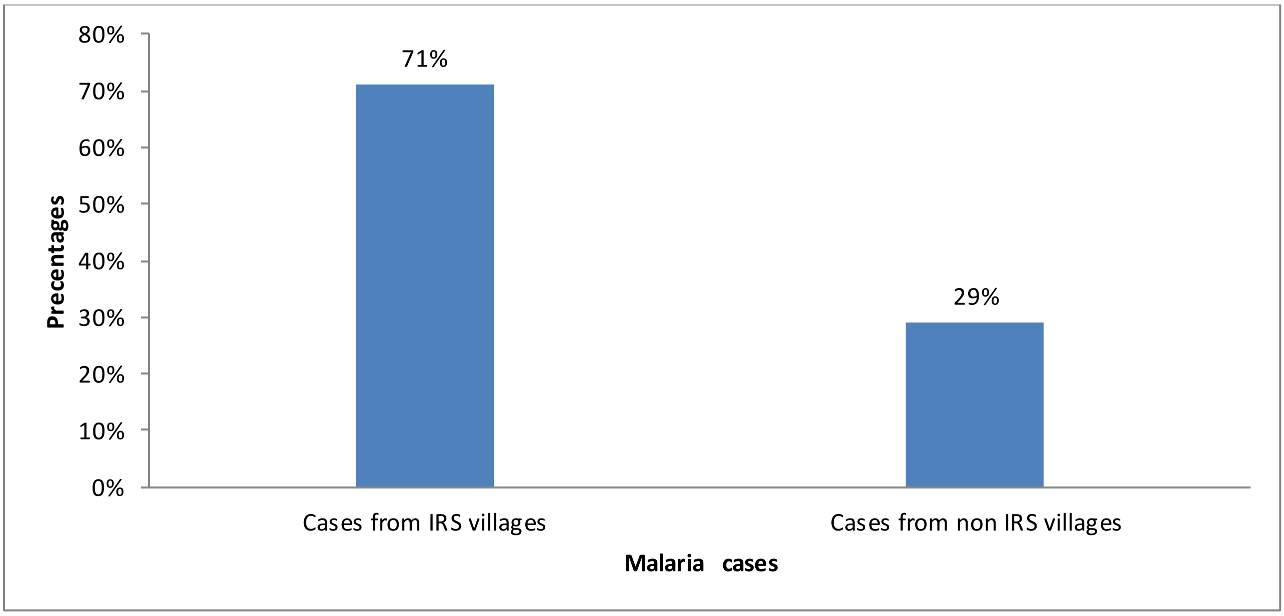


Figure 2: Incidence of locally transmitted malaria cases in villages covered with IRS in 2017 and non IRS villages in Engela district, 2018.

Most cases 71% (46) of local transmission cases came from the villages that were covered by IRS 2017 while 29% (19) cases came from the villages that were not covered with IRS 2017.

4.4 Residual efficacy of Deltamethrin

The testing of residual efficacy was conducted in 50 structures among 23 villages that reported with malaria local transmission in 2018 (January to July) and were also sprayed during 2017 IRS used Deltamethrin. Percentage of knockdown was not calculated as there was no knockdown observed after 30 minutes of exposure to the wall. Deltamethrin was the only insecticide used during 2017 IRS due to the shortage of DDT at the time of spraying season, therefore, it was the only insecticide that was tested for residual efficacy in April to May 2018 (peak Malaria season). In 2017, Engela district started malaria spraying program in September to November 2017 using only Deltamethrin insecticide.

The residual efficacy of Deltamethrin on sprayed structures was tested for the period of 2 months (April and May) in 2018 for the 2017 Indoor Residual Spraying. The structures that were tested were the ones with the time interval in the range of 6 months as the duration of effectiveness is 6 months. It was conducted in different structures which were traditional structures 18/50 (36%), Painted modern structure 12/50 (24%) and unpainted modern structures 20/50 (40%). Fourteen (28%) structures were sprayed in October 2017 and 32 (64%) were sprayed in November 2017 and 4 (8%) were sprayed in May 2018 (table 5).

However, the mortality rate (residual efficacy) in exposure cones was obtained using below mentioned formula was 46% and control mortality rate (residual efficacy) was 0%, so the Abbott's correction formula was not used.

The variables such as types of the structure (wall), time interval since spraying, and position of the cone on the wall (high, middle or low), were used to test for statically significant (see table 4). They were all found to be significantly associated with the mortality of mosquitoes. The bivariate analysis for the mentioned variable is shown in table 8.

Mortality rate Formula to find residual efficacy:

Total number of mosquitoes used = 4000: 20 mosquitoes per cone, Four cone per structure (1 control cone and 3 experimental cone)

Number of structure tested= 50

Number of dead mosquitoes=1850

The overall Mortality Rate (Residual efficacy)

Residual efficacy (Mortality rate) = No. of mosquitoes dead/number of mosquitoes applied to exposure cones x 100

$$\frac{1850}{4000} \times 100$$

$$\text{Mortality Rate} = 46\%$$

Table 6: Residual efficacy (mortality rate) for 2017 IRS (October and November) program against time interval Engela district, 2018.

Time for IRS	**Time interval (Month)**	**Types of structure**	**Number of structures conducted**	**Mortality rate**	**P value**
May 2018	1	Unpainted	2	95%	**0.0001**
		Painted	1	97%	
		Traditional	1	100%	
October 2017	5	Unpainted	7	39%	**0.0001***
		Painted	4	43%	
		Traditional	3	53%	
November 2017	4	Unpainted	0	0	0.06
		Painted	2	68%	
		Traditional	9	69%	
November 2017	5	Unpainted	11	63%	**0.0004***
		Painted	4	69%	
		Traditional	5	74%	

The effectiveness (mortality rate) of 2017 IRS (October &November 2017) was 1850/4000 (46%). The sprayed structures that was done in May 2018 and tested after one-month interval was found to be effective with 232/240 (97%). The least effectiveness was the structure that was sprayed October 2017 and tested in April 2018 (5month interval) with 365/840 (43%). It was found to be statically significant between the effectiveness of the insecticide and the interval between the times since spraying (P value 0.0001).

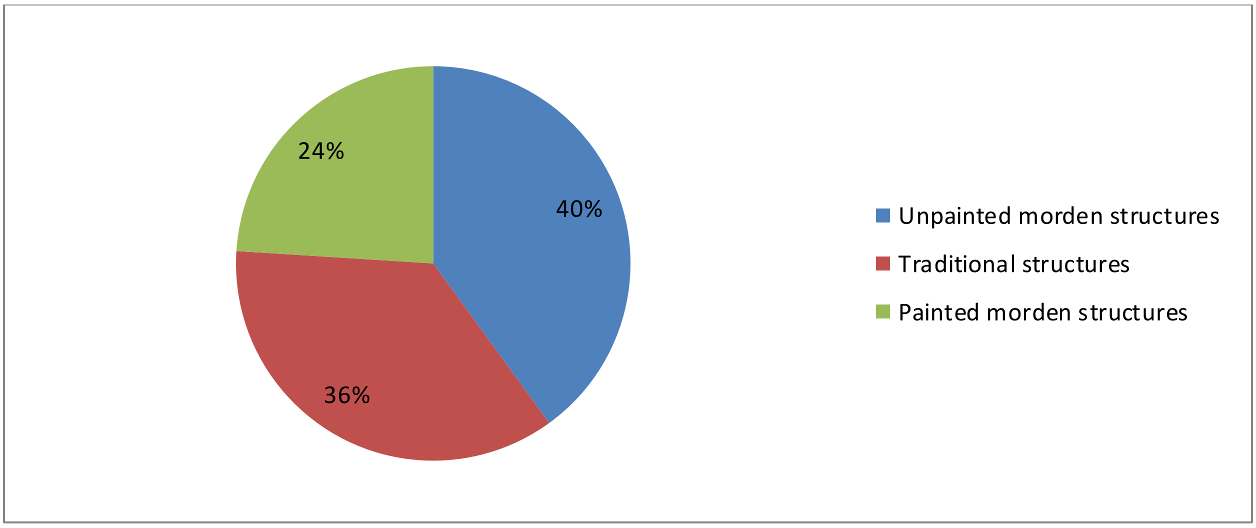


Figure 3: Types of sprayed structures used during testing of 2017 IRS residual efficacy, Engela health district, Ohangwena 2018

Testing of Residual efficacy was conducted in 50 sprayed structures, of which unpainted modern structures were the most with 40% (20) tested, and then traditional structures with 36% (18) and the least were painted modern structures.

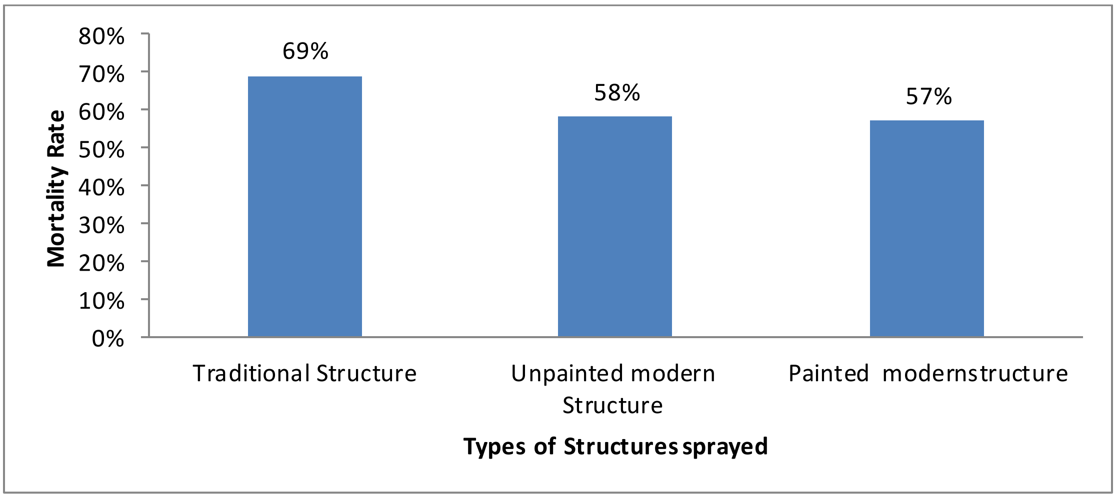


Figure 4: Residual efficacy for 2017 IRS program per type of the structure during April and May 2018, Engela.

The figure shows the residual efficacy of Deltamethrin per type of structure used in IRS program in October and November 2017 during peak malaria season in 2018. Traditional structure was found with high residual efficacy with 69% followed by unpainted modern structures with 58% and the least was painted modern structures with 57%.

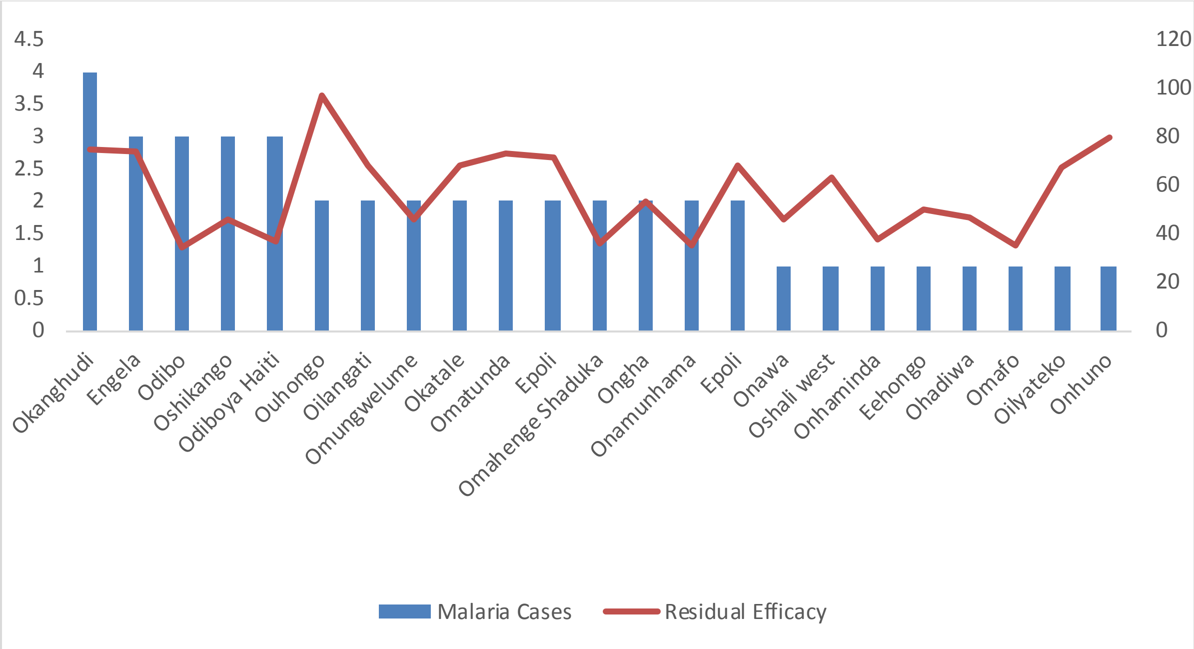


Figure 4: Villages with Malaria cases in relation to residual efficacy in Engela district, 2018.

The figure illustrates that the most villages with malaria cases were recorded with low residual efficacy which is below 80%. Among the villages only two villages were found to have high effective insecticides namely Ouhongo and onhuno (97% and 80%) respectively the rest were all below 80%.

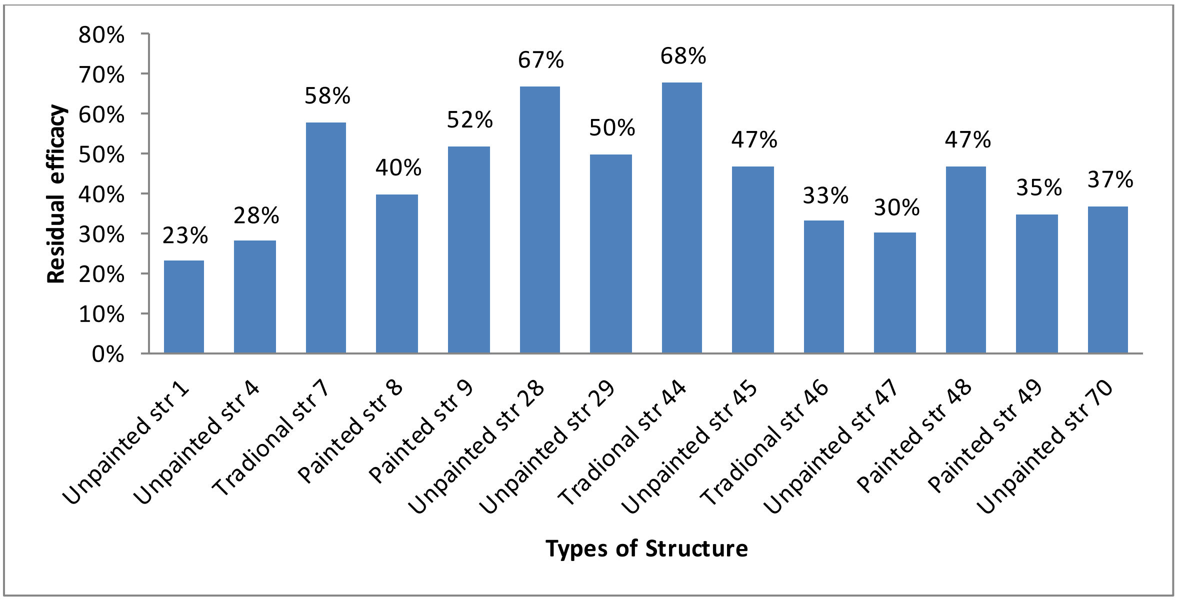


Figure 5: Residual efficacy for October 2017 IRS during April 2018 in Engela n=14.

A total of 14 structures that were sprayed (IRS) in October 2017 were tested for residual efficacy in April 2018 and the residual efficacy was recorded per structure. The structures with the highest effectiveness was traditional structure number 44 recorded with 41 (68%)and unpainted structure number 28 with 40 (67%) while the lowest residual efficacy was the unpainted structure number 1 that recorded with 14 (23%).

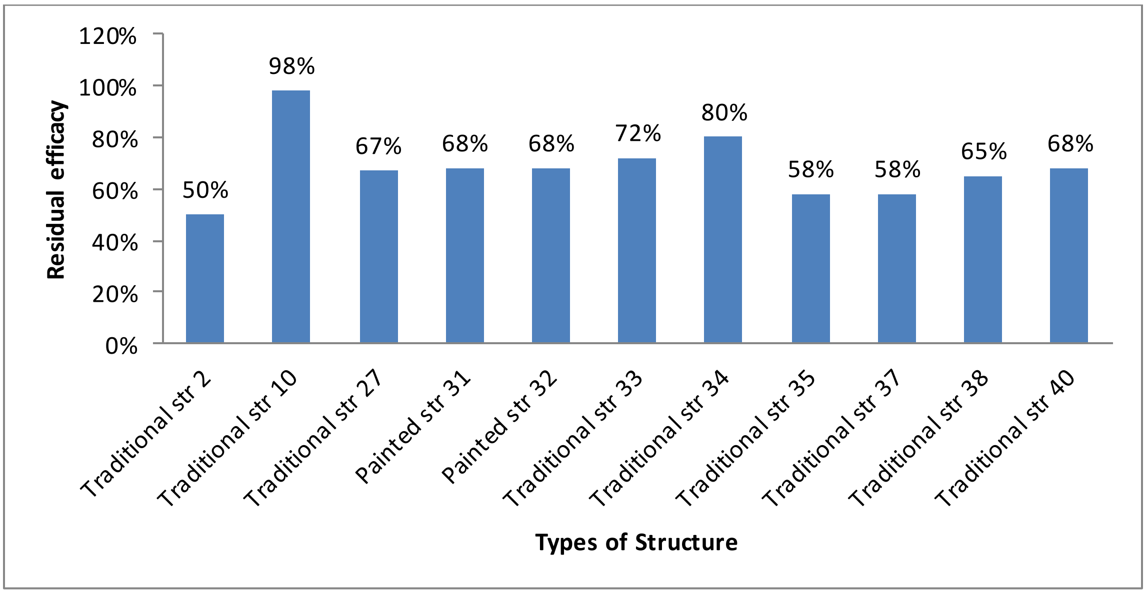


Figure 6: Residual efficacy for November 2017 IRS during April 2018, Engela district n=11.

The total of 11 structures that were sprayed (IRS) in November 2017 were tested for residual efficacy in May 2018. Only 2 structures (98% and 80%) were found with higher residual efficacy (effective insecticide) and the rest structures had below 80% residual efficacy. The structure with the highest residual efficacy recorded 98% (59) and the least was 50% (30).

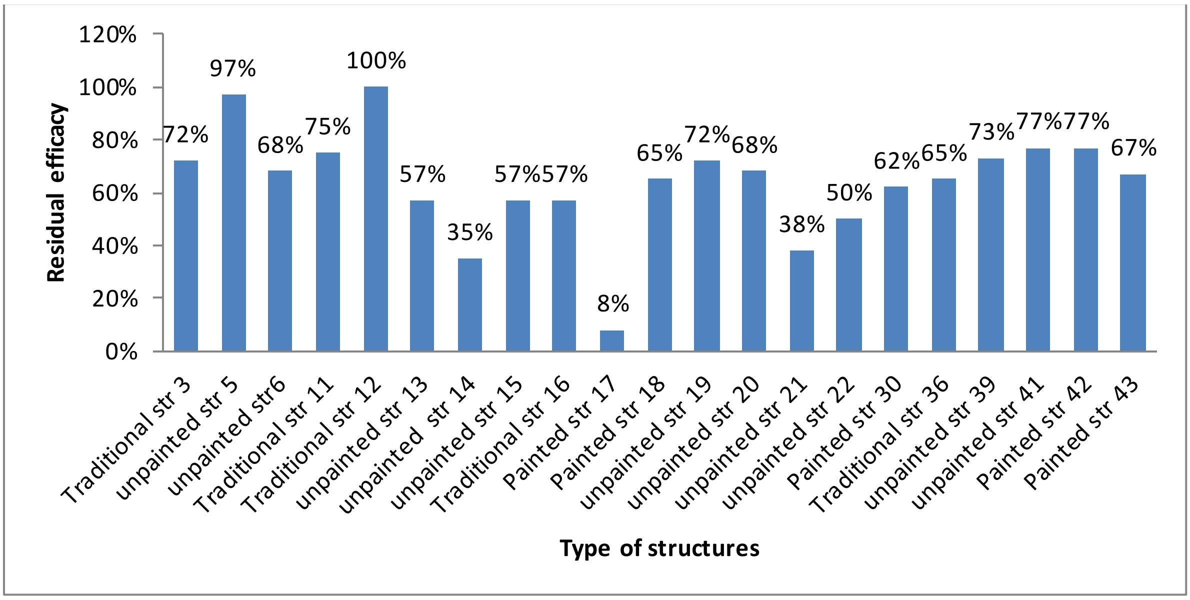


Figure 7: Residual efficacy for November 2017 IRS during May 2018, Engela district n=21.

The total number of 21 structures that were sprayed (IRS) in November 2017 were tested for residual efficacy in May 2018. The structures with the highest residual efficacy were the structures that recorded with 100% (60) then 97% (58). The structure with the least residual efficacy was the one with 8%.

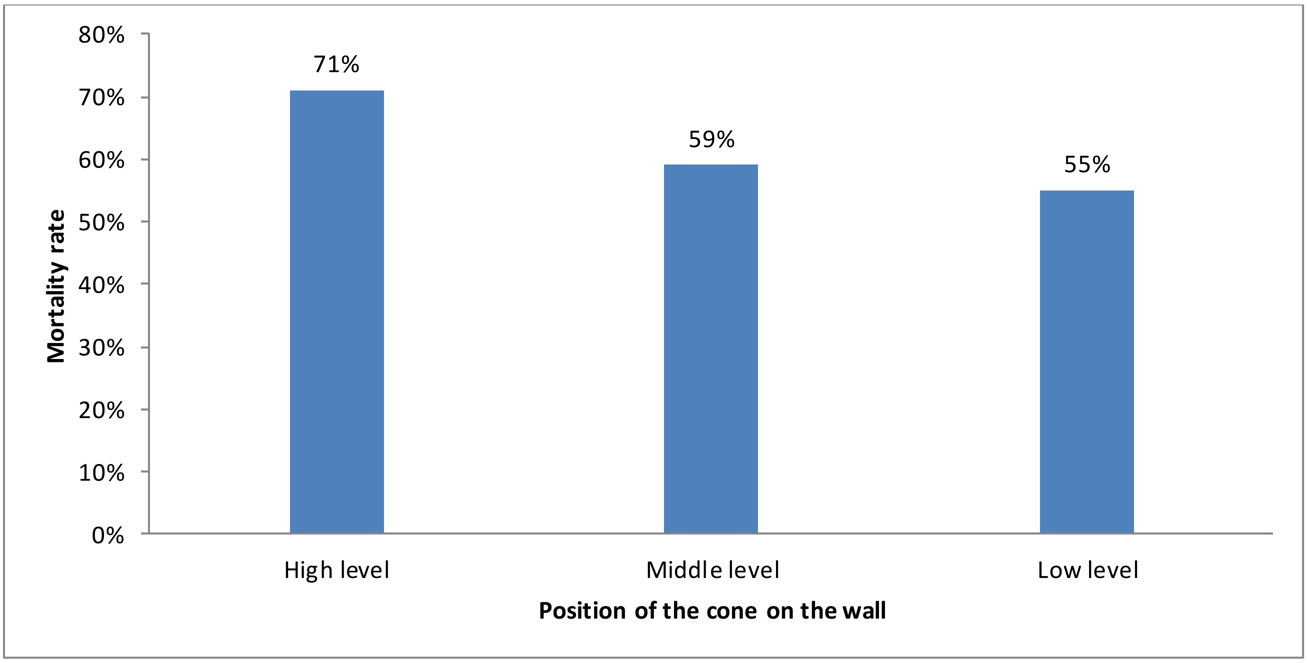


Figure 8: Residual efficacy for 2017 IRS against position of the cone on the wall during April/May 2018, Engela

As reflected in figure 8, there is high residual efficacy at the high level of the wall with 71% compare to middle and low level (59% and 55% residual efficacy respectively), P –value 0.0001

4.4.1 Bivariate Analysis

Variables that may influence the mortality of mosquitoes such as types of structure (wall), time since sprayed (time interval), and position of the cone on the wall were used during bivariate analysis against morality of mosquitoes.

Table 7: Bivariate analysis of contributing factors that can influence the efficacy of the insecticides, Engela district 2018.

Variables		Dead	Alive	P-value	Bivariate Odd Ratio (Cl)
Types of Structures	**Traditional structure**	747	333	**0.0001***	1.66 (1.42-1.95)
	Painted modern structure	409	311	**0.0002***	0.77 (0.65-0.91)
	Unpainted modern structure	694	506	**0.0004***	0.76 (0.66-0.89)
Time interval since spraying	**May 2018 – June 2018 (1month Interval**	232	8	**0.0001***	20.5 (10.07-41.59)
	October 2017-April 2018 (6 month interval)	356	475	**0.0001***	0.35 (0.29-0.41)
	November 2017 – April 2018 (5 month interval)	452	208	**0.0004***	1.4 (1.22-1.76)
	November 2017 – May 2018 (6 month interval)	801	1049	0.06	1.15 (0.99-1.33)
Position of the cone on the wall	**High level**	735	265	**0.0001***	2.202 (1.87-2.59)
	Middle level	572	428	**0.0003***	0.76 (0.65-0.88)
	Low level	543	457	**0.0001***	0.63 (0.54-0.74)

This table illustrates bivariate analysis for the variable that may influence the mortality of mosquitoes. There was significant association between all variable. The variable were types of structures: traditional structure P value 0.001, painted modern structure p value 0.002 and unpainted modern structure 0.004), time since sprayed (time interval): 1-month interval p value 0.001, 5 months' interval P value 0.004, position of the cone on the wall. Only one variable that was found to be not significant associated with the mortality of mosquitoes which was 6-month interval under time since sprayed. Position of the cone on the wall was found to be significant associated with mortality rate (0.001; cl 1.87-2.59) high level position.

CHAPTER 5

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS AND LIMITATIONS

5.1 INTRODUCTION

This chapter looked into the interpretation of the main findings of the study. In this section, the findings of the current study were compared with studies previously done in other countries. In this chapter, research findings were summarized and concluded in line with the study objectives. Based on the concluding points, recommendations were generated and limitations of the study were highlighted in this section.

5. 2 Discussion of findings

5.2.1 Monthly prevalence of Malaria

This study shows that malaria cases were high during March, April and May 2018. However, most cases were imported cases from Angola, which made the source of infection to be classified as non-local transmission cases. Similar findings from the study conducted in Namibia found that Malaria risk was observed to cluster along the border with Angola, and travel patterns among cases were comparatively restricted to northern Namibia and Angola. In addition, travel to Angola was associated with excessive risk of malaria in males (OR 43.58 95% CI 2.12-896) (9,24, 30). However, importing of Malaria cases is not only in Namibia but across the world. A study in People's Republic of China in 2014 stated that as from 2001 to 2011, they recorded 918 malaria cases and six malaria deaths and they were due to malaria imported from other countries, which accounts for 12.4% of all malaria cases and 100% of all malaria deaths (33). In Europe and Mediterranean countries increased number of imported cases was supported by the increased number of international traveler from malaria endemic countries (35).

In this study, high prevalence of Malaria was recorded during March to May while malaria peak months in Namibia is known to be in April to May which influenced by climate (30, 32). Similar setting but different time season in South Africa, Limpopo province experienced high incidence of malaria during the pre-peak season which is from September to November which was also associated with the climate phenomenon La Niña and cool air temperatures over Southern Africa (31). This province is in a high-risk malaria transmission zone because it borders Mozambique, Zimbabwe and Botswana, countries that still have high malaria incidence throughout the year (31).

5.2.2 Malaria local transmission in terms of person and place

In terms of persons, this study found that all the age groups were affected but the most affected one was the age group ranges from 0 – 10 years which can be due to their low immunity. In comparative between children and adults' groups, adults group as from 11 to 60+ years old were more affected. This can be contributed that most malaria vectors are exophilic and adults spend time outside due to outdoor activities as compared to children (29). Findings in the study of Gabon found the rate of infection significantly higher in children aged between 0 to 4 years than in children of 5 years and above, and in adults (35). Analysis of the retrospective malaria statistics in Namibia showed that, children under the age of five years were more affected by malaria as compared to those above five years. This pattern is similar in all malaria endemic areas because of lack of immunity among the children under the age of five years. Immunity due to malaria is known to build up with age. In non-malaria endemic areas on the other hand, there is usually no significant difference between the different age groups (4).

The study found that the local malaria cases were sporadic within the district. Most area with local transmission of Malaria cases in this study were from rural areas. However, they recorded with few (one) cases per villages as compared to urban and semi urban with more than one case per area (location). This might be that in urban areas there is high migration of people for jobs seeking and other development as compare to rural areas. Addition, this might also have contributed to high number of breeding site and malaria vector in the area. Addition to most affected, the district is mainly a rural area set-up thus why many rural villages are affected. In contrary, Malaria in Gabon was more in urban and semi-urban areas; and remained mostly unchanged or even increased in Makokou in the Ogooué-Ivindo province for 8 years (38). On the other hand, the differences might simply result dissimilarities in countries.

5.2.3 Malaria local transmission against sprayed and non-sprayed villages

The study found that more cases were reported at the area where IRS was carried, as compared to area were no IRS was not conducted and it was found to be significant (Odd ratio=3.8 CI 1.9-7.5; P value=0.0006). This can be contributed by many factors which this study did not look into, such as poor spraying techiques, vector changing behavior from endophilic or endophagic to exophilic or exophagic, and human behavior (prefer being outside then inside) (30). It can also be that people in unsprayed village implement some control measures while those in sprayed village do not protect themselves relaying only on IRS. Similar findings by the study done in Equatorial Guinea found the association between IRS and malaria. IRS offered protection to those in sprayed and unsprayed houses when neighborhoods have high spray coverage compared to those living in areas of low IRS coverage (,20%), regardless of whether the house they lived in was sprayed or not (adjusted OR = 0.54, 95% CI 0.33–0.89) (36). The study done in Mali during 2012–2014, found rapid reductions in malaria incidence during the 6 months followed each IRS campaign, as compared to non-IRS districts. Further analysis suggests that the timing of the 2012–2014 IRS campaigns (spraying in July and August) was well positioned (27). Unlike a study done in Namibia, Zambezi region 2018 about correlation between malaria incidence and IRS coverage, found that there was no significant correlation between IRS coverage and malaria incidence for this region ($r = -0.45, P = 0.22$) (24). However, in Uganda, there was a consistent decrease in the proportion of patients diagnosed with clinical malaria after IRS and it was found to be statically significant with P value = 0. 001(39).

Residual efficacy (mortality rate) of Deltamethrin for IRS 2017, October and November was found at 46% and as per WHO standard is recorded as poor effective because is below 80%. However, the efficacy differs per structure, time since sprayed and the position of the cone on the wall and this difference was found to be statistically significant (p=0.001). The structure that have been sprayed during malaria season (May 2018) with one-month interval between sprayed and testing of the efficacy; the insecticide was found to be effective over 80%. In contrast, the structures that were tested after 5 and 6 months were found with low residual efficacy (effectiveness). In addition, the study found statistically significant between time interval between time IRS conducted and time the residual efficacy was conducted, the effectiveness (residual efficacy) decrease as the time increased. The challenges can be in application of the targeted dose of insecticide to a wall during indoor residual spraying programmes, mixing of the insecticide or the resistance of mosquitoes to the insecticide. A regular part of the spray operators training is done using water in the tanks so that sprayers can apply the correct amount to a wall, moving the spray wand at the appropriate speed and distance from the wall to ensure that the spray is applied correctly. It is known that spray operators in the field may not follow such exact protocols, and as a result the quality of the spraying can be affected.

In Addition, the quality of the IRS can be influence by types of the walls as Deltamethrin that was used was made for painted and smooth walls but it was used for rough wall during 2017

IRS program. It can also be influenced by types of chemical used as some chemical have shorter residual efficacy for only 6 months (25, 29, 34). In Benin, they tested the residual efficacy for ITN and IRS in Malan Ville town and Ladji town. However, for ITN they found high mortality rate in Malan Ville which is 98% and low in Ladji with 30% mortality rate while the efficacy for the IRS was equally compromised which was 72% mortality rate (residual efficacy) (15).

5.2.4 Residual Efficacy per type of structures

The residual efficacy for Deltamethrin found to be different from structure to structure. The only four structures found to have high effectiveness of the insecticide which was above 80% have short time interval of one month between spraying in May 2018 and testing of residual efficacy in June 2018. These structures were not part of 2017 IRS campaign but sprayed during 2018 contact tracing of the cases to just to compare the insecticide effectiveness within short time interval. There might be contributing factors to the low efficacy such as time interval, poor spraying techniques, resistance, and amount of insecticide on the wall. Answers to these questions, were not part of the initial objectives of the present study. Structures used during the study which were traditional structure (mud rough structure), modern unpainted structures (smooth) and modern painted structures (smooth). More worryingly, Deltamethrin is known or designed to be used for modern painted smooth structures, however it was found to be more effective in traditional structure as it was found to be with high mortality rate (residual efficacy) as compared to other structures. Study in Ethiopia, found high mortality (residual efficacy) in painted smooth walls for the following insecticides which were Pirimiphos-methyl, bendiocarb, Propoxur 1g, and Propoxur 2g (11). A similar study with different findings, used wild Anopheles gambiae s.l to conduct the residual efficacy of Propoxur used during routine spray program found that, the residual efficacy was differ between the types of wall surface as follow 89.3% on painted, 61.3% on smooth and 65% on rough surface. The painted wall surface showed the highest effectiveness (mortality rate) for the routine spray (11).

The way the insecticides deposited on the wall, may differ per position (level) of the cone on the wall. The study found that the efficacy on the high position (level) of the wall had high mortality rate (residual efficacy) and it was statistically significant (P vale= 0.0001) with the mortality rate of mosquitoes. Other variable such as types of structure (wall), time since sprayed (time interval) were all found to be significant associated with the mortality of mosquitoes. Unlike, the study in Ethiopia which found the position of the cone on the wall not significantly associated with the mortality of mosquitoes in the cone bioassays, but all other variables (time interval, types of the wall) were significantly associated ($p < 0.05$) (26).

5.3 Conclusions

In conclusion, it is worth noting that villages that were sprayed during 2017 IRS program recorded many cases as compared to non-sprayed villages. The outcome of low residual efficacy may not necessarily because of resistance of mosquitoes to Deltamethrin but this can be attributed by poor initial spraying and decreases of effectiveness over time as also found by this study. The Deltamethrin effectiveness (residual efficacy) for 2017 IRS during malaria peak months (April and May 2018) was 46% and it was found that it direct proportional with time interval. Traditional structure was recorded with high effective of insecticide (Deltamethrin) as compared to other structures. Time interval, types of structures and position of the cone on the wall were found to be significant associated with the mortality rate of female anopheles mosquitoes (malaria vector) in the community. The use of wild type common malaria vectors can be problematic as one cannot conclude whether the results are due to poor residual efficacy or resistance. The Ministry is advised to ensure the resistance of wild common malaria vectors against the insecticides to be used before implementing the IRS programme in order to ensure the effective of its intervention.

As the country moves from the control to elimination phase, community awareness on the possible preventive measures and interventions at the community level is highly important in bringing down the transmission

5.4 Study Limitations

During the execution of this study, some limitations were discovered that may have affected the data collected and therefore affected the quality of the results.

The use of wild type common malaria vectors can be problematic as one cannot conclude whether the results are due to poor residual efficacy or resistance and this can be a different study to be conducted. Importantly, the country needs to know the effectiveness of the insecticides used on wild type malaria vectors (mosquitoes) because these are the vectors that are aimed by the intervention being implemented.

In-completeness of case investigation forms greatly determined the ability to trace cases for classification if it’s local or non-local transmission. Missing information with regards to patient contact details and accurate detailing of the village the patient came from often times rendered some cases untraceable as they either couldn’t be called or the particular village was missing or too big to determine a starting point considering the fact that time was not always available.

The study was done only in the affected villages, therefore, the village with no malaria in 2018 their efficacy was not tested and cases with missing village and contact details information.

The number of the structures that were conducted for testing the residual efficacy was few as compared of the number of structures sprayed in IRS program 2017. This unfortunately, was not possible because of time and transportation (financial) because the study was not sponsored.

The study was limited that it’s was only testing the residual efficacy for the IRS not considering amount of insecticide deposited on the walls during the spraying. In addition, the study was only able to determine the effectiveness of the IRS but was unable to test if the mosquitoes were resistance or was the amount of insecticides on the wall.

5.5 Recommendations

In terms of low residual efficacy, Malaria investigation team which is called Active case Detection should consider other alternative interventions such as larvaciding when doing contact tracing for malaria case in order to stop the infection by killing the possible malaria vector because the residual efficacy was found to be low.

Additional, the team also should or continue to include larvaciding of breeding site during the contact tracing.

This study recommended, that a future study is needed to determine the resistance or acceptability of mosquitoes species (Anopheles gambiae, Anopheles funestus complex, Anopheles Arabienses) to the insecticide.

It is therefore important for neighboring countries to strengthen border coordination for malaria control and prevention as malaria knows no borders.

5.6 Pictures taken during data collection

Picture 1: Anopheles female mosquitoes in the paper cup after being exposed on the sprayed wall Engela district 2018.

Picture 2: Bioassay cones in modern and traditional with mosquitoes exposure on the sprayed wall for 30 minutes, Engela district, 2018.

Picture 3: Researcher busy with the testing of residual efficacy the modern painted structure, Engela district 2018.

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APPENDIXES

Appendix A: Table of WHO Approved Insecticides

WHO approved insecticides for malaria mosquito control. (David *et al.*, 2013; WHOPES, 2014)

Date	Insecticide	Class group	Compound & formulation	Application IRS &	ITN	Dosage g a.i/m^2	Mode of Action	Duration (months)	P450 Resistance (3)
1940 - 1945	DDT	OC	WP	X		1-2	contact	>6	R
1951 - 1955	Malathion	OP	WP	X		2	Contact	2-3	R
1961 - 1965	Fenitrothion	OP	WP	X		2	Contact & airborne	3-6	R
	Propoxur	Ca	WP	X		1-2	Contact & airborne	3-6	R
1971 -	Primiphos-methyl	OP	WP & EC	X		1-2	Contact &airbor	2-3	R

1975							ne		
	Bendiocarb	Ca	WP	X		0.1-0.4	Contact & airborne	2-6	R
	Permethrin	Pyr		X	X	0.02-0.03	Contact	4-6	R
1981 - 1985	Alpha-cypermethrin	Pyr	WG-SB		X			Up to 4	
	Cyfluthrin	Pyr	WP	X	X	0.02-0.05	Contact	3-6	R
	Lambda-cyhalothrin	Pyr	WP, CS	X	X	0.02-0.03	Contact	3-6	R
	Deltamethrin	Pyr	WP, WG	X	X	0.02-0.025	Contact	3-6	R
	Bifenthrin	Pyr	WP	X	X	0.025-0.05	Contact	3-6	R
1986 - 1990	Etofenprox	Pyr	WP	X	X	0.1-0.3	Contact	3-6	R

Appendix B: Insecticide Efficacy (wall) for IRS testing monitoring form

Date: ___________________

Mosquito species: ____________________________________

Insecticide tested: ___________________________________

Village name_______________________

End time: ________________________

Row	Time (min)		Cup 1 (HIGH LEVEL)	CUP 2(MIDDLE LEVEL)	CUP 3 (LOW LEVEL)	CONTROL Control	Dead	ALIVE	Temp/HUMIDITY	
			NUMBER OF KNOCK DOWN MOSQUITOES AFTER EXPOSURE							
		No. of exposure								
	Start									
	5									
	10									
	15									
	20									

	25									
	30									
	NUMBER OF DEAD AND ALIVE MOSQUITOES AT THE END OF HOLDING PERIOD (24Hrs)									
		No. of dead								
		No of alive								
		Observed mortality %								
Name of supervisor										
comment										

Appendix C: Locality form

House no:	Village	Region	Last spraying date	Insecticide used	Time	Date	24hrs Mortality rate	Name of the operator

THE UNIVERSITY OF NAMIBIA

Appendix D: ETHICAL CHECKLIST

Name of Student: Padelia N. Ngenokesho **Student Number:** 201038170

Research Title: Prevalence of Malaria in relation to residual efficacy of Indoor Residual Spraying in Engela district, Ohangwena, Namibia, 2017- 2018

Date:

Main supervisor: Dr J. Sheehama **Co-Supervisor: Mr. S. Nghoshi**

Ethical Principles and Guidelines for the protection of human subjects of research

Representatives and committees can assess the following principles and its compliance within research proposals of Post graduate students in the recommendation of ethical approval by UNAM RPO.

1. PREVENTION OF HARM AND ENSURING GOOD TO RESEARCH PARTICIPANTS

1.1 Can this study be done without using human subjects?

Yes	**X**
No	

1.2 Are vulnerable persons participating in the study? (Infants, children, prisoners, Mentally impaired, non- autonomous persons, over exposed research subjects**)**

Yes	**X**
No	

1.3 Did student motivate the appropriateness of including vulnerable subjects in study?

Yes	**X**
No	

1.4 Did the student ascertain and explicitly described the possible harm that may ensue from the research?

(Physical, emotional, psychological. social, economic, legal harm, should be considered) It is not acceptable to just state that no harm will follow because being embarrassed or uncomfortable is also harmful)

Yes	X
No	

1.5 Did the student consider and describe the benefits of the research to the participants?

(Not the significance of the study, but advantages to participants).

Yes	**X**
No	

1.6 Is the description of risks/benefits included into the informed consentInformation to participants?

Yes	**X**
No	

1.7 Does the committee think that the students' assessment of 1.1 - 1.6 is reasonable?

(Depending on the risks involved in the study, the benefits to participants should be Satisfactory = risk/benefit ratio must be considered)

Yes	X
No	

2. RESPECT FOR RESEARCH PARTICIPANTS

Did the student indicate the following in the research proposal?

2.1 **The information that will be provided to research participants** (purpose; risks; benefits;

procedures; expectations from participants; opportunity to ask questions and seek Clarification; why participants were selected and research responsible for research and his/her contact number)

Yes	X
No	

2.2 **How researcher will ensure that participants and third parties (**children and challenged comprehension situations) understand the information that is provided. *Explaining them before conducting the study*

Yes	X
No	

2.3 **How informed consent will be obtained from participants/third parties**

(Preferably by written consent form that provides all information and contact details

of the researcher. Researcher and participant get copies of document): both *writing and verbal*

Yes	**X**
No	

2.4 **Considerations of voluntariness of research participation** (by ensuring no undue reward, coercion and opportunity to withdraw from study)

Yes	X
No	

3. FAIRNESS TO RESEARCH PARTICIPANTS.

3.1 Did the student motivate the appropriateness of including specific

Participants to the study?(Adults before children; non-institutionalized persons before institutionalized persons; overburdened participants; researched fatigue classes of persons)

Yes	X
No	

3.2 Is any researcher biases present with the selection of research participants?

(These include any social, racial, sexual, cultural biases. Students should have Considered fairness regarding any unjust social patterns e.g. selecting racial Minorities, the economically disadvantaged, sick and dependent persons; readily Available) persons; administrative convenient reasons for selection or easily manipulated persons)

Yes	X
No	

Supervisors should assist students in considering all these ethical issues before research proposals are submitted for ethical assessment and clearance of proposals.

Appendix E: Consent Form

Topic: Prevalence of Malaria in relation to residual efficacy of Indoor Residual Spraying in Engela district, Ohangwena, Namibia, 2017- 2018

Dear participant

Your house has been chosen to form part of a research study to be conducted by Padelia N Ngenokesho from University of Namibia. The purpose of this study is to determine the efficacy of insecticide used in Indoor residual Spraying in relation to trends of malaria in Engela Ohangwena region. This study will contribute to my research completion of master's thesis.

Research Procedures

You will be asked to allow the researcher to use your sprayed structure for testing the efficacy.

Time Required

The testing will require 30 minutes. **Risks**

The researcher does not perceive any risks from your involvement in this study (that is, no risks beyond the risks associated with everyday life).

Benefits

There is a potential benefits from participation in this study at a country. The study will help the Ministry of Health and Social services on deciding the Indoor residual spraying chemicals.

Confidentiality The researcher will make sure that no information provided by the participants during the course of the study will either be divulged or be made available to any person other than the supervisors. The data will be protected with a usage of a password.

Consent

I have read this cover letter and I understand what is being requested of me as a participant in this study. I freely consent to participate.

____ _______________

Signature Date

Appendix F

Hut Card: guided the researcher to find out if the structure was sprayed or not.

Appendix G

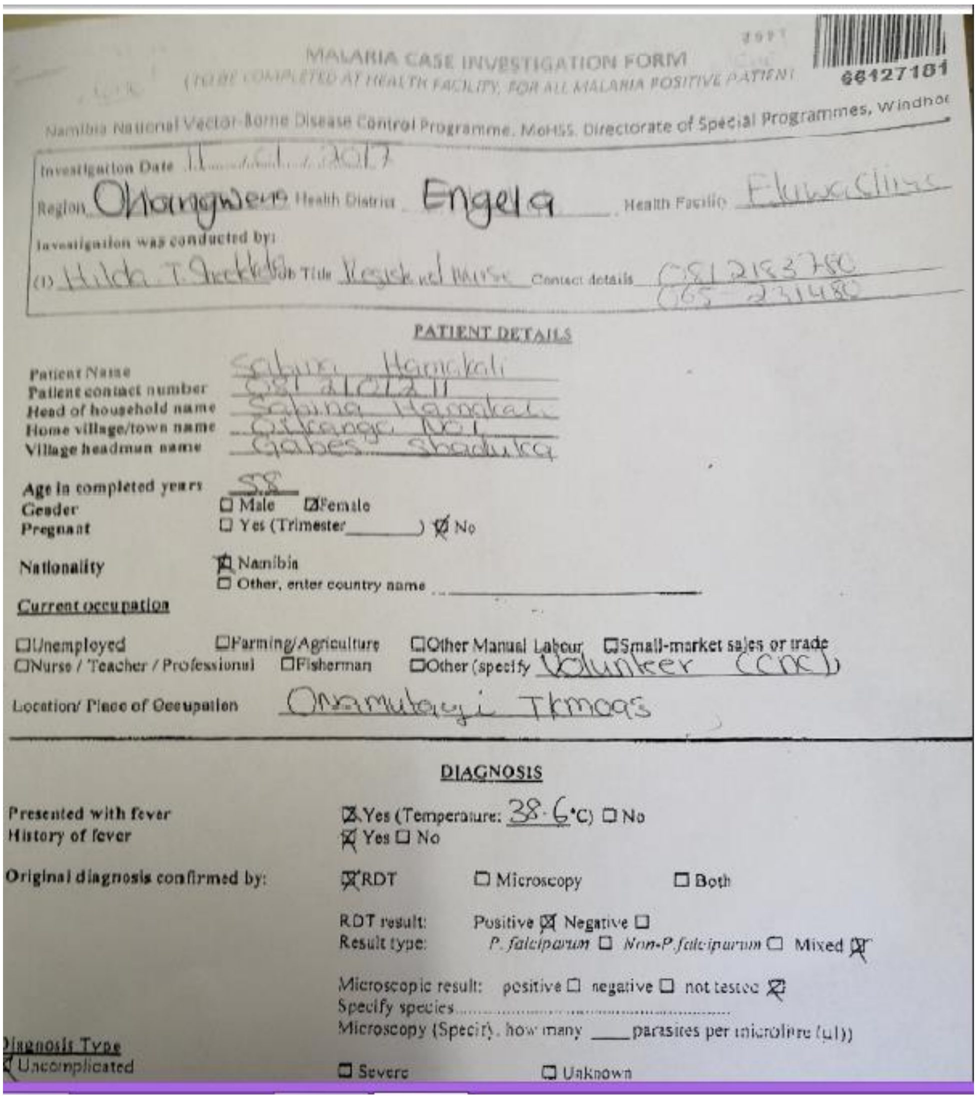
	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	type	Age	Sex	Physical address	Constituency	District	Region	Nationality	Reporting Facility	Year	Date seen	Travelled	Travelled Place	Local	WK	Month	Diagnosis type	me
2	Years	68	M	Windhoek	Khomas	Khomas	Khomas	Namibian	Engela clinic	2018	08.02.2018	Yes	Angola	Non local	6	February	Severe	Alive
3	Years	52	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	04.01.2018	Yes	Santa Clara-Angola	Non Local	1	January	Uncomplicated	Alive
4	Years	7	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela Hospital casualty	2018	07.01.2018	Yes	Santa Clara-Angola	Non local	1	January	Uncomplicated	Alive
5	Years	8	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	17.01.2018	Yes	Angola	Non local	3	January	Uncomplicated	Alive
6	Years	36	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	31.01.218	Yes	Santa Clara-Angola	Non Local	5	January	Uncomplicated	Alive
7	Years	54	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	02.02.2018	Yes	Santa Clara-Angola	Non Local	5	February	Uncomplicated	Alive
8	Years	2	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Odibo HC	2018	03.02.2018	Yes	Santa Clara-Angola	Non local	5	February	Uncomplicated	Alive
9	years	22	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	05/02/2018	Yes	Angola	Non local	6	February	Uncomplicated	Alive
10	Years	2	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	05.02.2018	Yes	Angola	Non local	6	February	Uncomplicated	Alive
11	Years	22	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	05.02.2018	Yes	Santa Clara-Angola	Non Local	6	February	Uncomplicated	Alive
12	Years	3	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	06/02/2018	Yes	Angola	Non local	6	February	Uncomplicated	Alive
13	Years	14	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	13.02.2018	Yes	Santa Clara-Angola	Non local	7	February	Uncomplicated	Alive
14	Years	12	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	15.02.2018	Yes	Santa Clara-Angola	Non local	7	February	Uncomplicated	Alive
15	Years	11	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	19.02.2018	Yes	Angola	Non local	8	February	Uncomplicated	Alive
16	Years	10	F	Santa clara	Namacunde	Ondjiva	kunene	Angolan	Engela clinic	2018	20.02.2018	Yes	Santa Clara-Angola	Non Local	8	February	Uncomplicated	Alive
17	Years	9	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	21.02.2018	Yes	Santa Clara-Angola	Non Local	8	February	Uncomplicated	Alive
18	Years	18	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela Hospital casualty	2018	23.02.2018	Yes	Santa Clara-Angola	Non Local	8	February	Uncomplicated	Alive
19	Years	7	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	27.02.2018	Yes	Santa Clara-Angola	Non local	9	February	Uncomplicated	Alive
20	Years	5	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	28.02.2018	Yes	Santa Clara-Angola	Non local	9	February	Uncomplicated	Alive
21	Years	47	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	02.03.2018	Yes	Santa Clara-Angola	Non local	9	March	Uncomplicated	Alive
22	Years	29	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	02.03.2018	Yes	Santa Clara-Angola	Non local	9	March	Uncomplicated	Alive
23	Years	24	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	02.03.2018	Yes	Santa Clara-Angola	Non local	9	March	Uncomplicated	Alive
24	Years	29	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	02.03.2018	Yes	Santa Clara-Angola	Non local	9	March	Uncomplicated	Alive
25	Years	1	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	06.03.2018	Yes	Santa Clara-Angola	Non local	10	March	Uncomplicated	Alive
26	Years	37	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	06.03.2018	Yes	Santa Clara-Angola	Non local	10	March	Uncomplicated	Alive
27	years	34	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela Hospital casualty	2018	09.03.2018	Yes	Santa Clara-Angola	Non local	10	March	Uncomplicated	Alive
28	Years	35	F	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	09.03.2018	Yes	Santa Clara-Angola	Non Local	10	March	Uncomplicated	Alive
29	Years	1	M	Santa clara	Namacunde	Ondjiva	Kunene	Angolan	Engela clinic	2018	09.03.2018	Yes	Santa Clara-Angola	Non local	10	March	Uncomplicated	Alive
30	Years	35	F	Santa clara	Santa clara	Ondjiva	Kunene	Angolan	Engela clinic	2018	09.03.2018	Yes	Santa Clara-Angola	Non local	10	March	Uncomplicated	Alive

Malaria Linelist2017 / Malaria linelist2018 / Malaria Linelist2017 After Case / Analysis / Sheet1

Ready 90%

Malaria Line list 2018 for Engela district

Appendix H



MALARIA CASE INVESTIGATION FORM

(TO BE COMPLETED AT HEALTH FACILITY, FOR ALL MALARIA POSITIVE PATIENT)

66127181

Namibia National Vector-Borne Disease Control Programme, MoHSS, Directorate of Special Programmes, Windhoe

Investigation Date 11 / 6 / 2017

Region Ohangwena Health District Engela Health Facility Eluwa Clinic

Investigation was conducted by:

(1) Hilda T. [illegible] Job Title Registered nurse Contact details 0812183780 065 231480

PATIENT DETAILS

Patient Name Sabina Hamakali

Patient contact number 081 2101211

Head of household name Sabina Hamakali

Home village/town name Otkango No 1

Village headman name Gabes Shaduka

Age in completed years 58

Gender ☐ Male ☒ Female

Pregnant ☐ Yes (Trimester_______) ☒ No

Nationality ☒ Namibia

☐ Other, enter country name __________

Current occupation

☐ Unemployed ☐ Farming/Agriculture ☐ Other Manual Labour ☐ Small-market sales or trade

☐ Nurse / Teacher / Professional ☐ Fisherman ☐ Other (specify Volunteer (CMC))

Location/ Place of Occupation Onamutayi Tkmaas

DIAGNOSIS

Presented with fever ☒ Yes (Temperature: 38.6 °C) ☐ No

History of fever ☒ Yes ☐ No

Original diagnosis confirmed by: ☒ RDT ☐ Microscopy ☐ Both

RDT result: Positive ☒ Negative ☐

Result type: *P. falciparum* ☐ *Non-P. falciparum* ☐ Mixed ☒

Microscopic result: positive ☐ negative ☐ not tested ☒

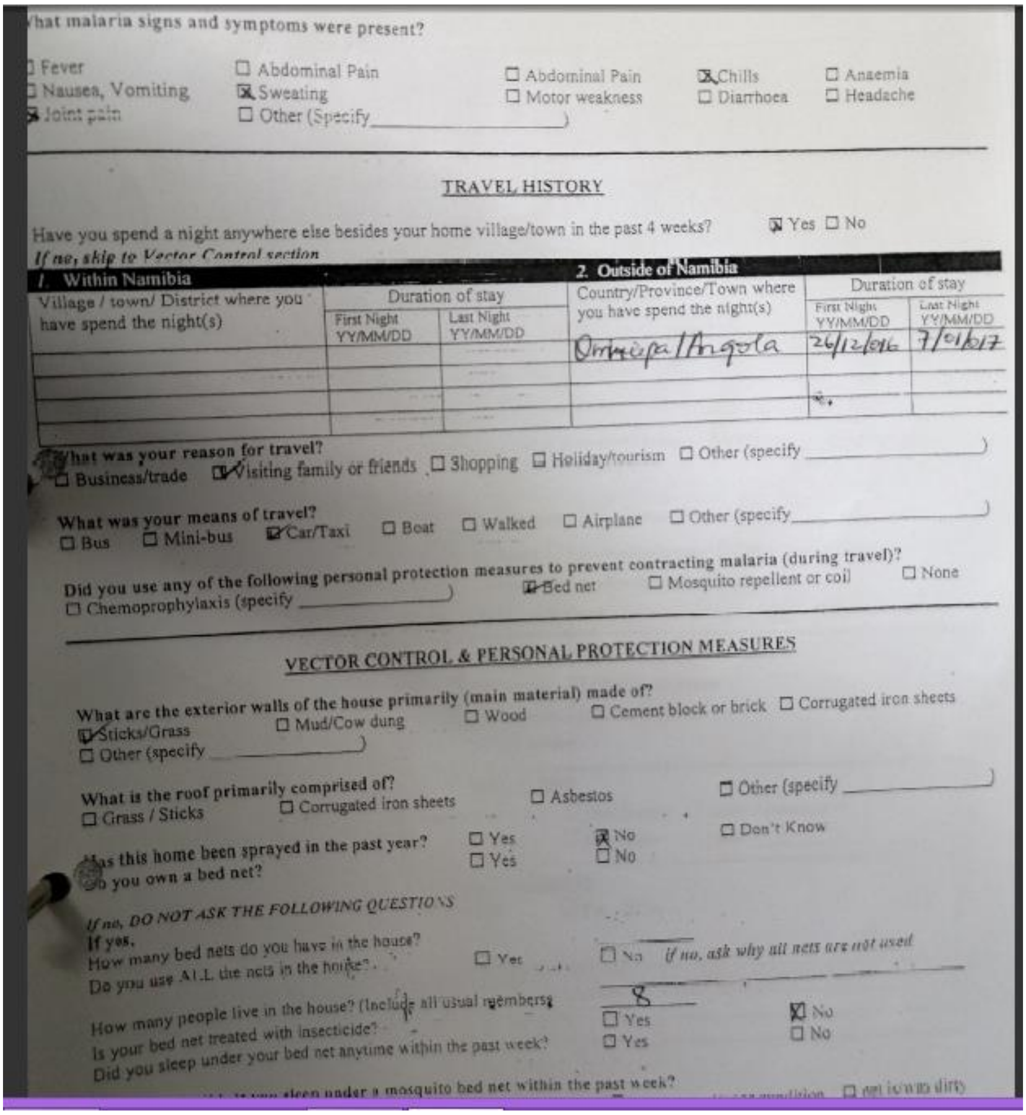
Specify species..

Microscopy (Specify how many ____ parasites per microlitre (ul))

Diagnosis Type

☒ Uncomplicated ☐ Severe ☐ Unknown

Malaria case Investigation form Page 1


What malaria signs and symptoms were present?

☐ Fever ☐ Abdominal Pain ☐ Abdominal Pain ☒ Chills ☐ Anaemia
☐ Nausea, Vomiting ☒ Sweating ☐ Motor weakness ☐ Diarrhoea ☐ Headache
☒ Joint pain ☐ Other (Specify ______)

TRAVEL HISTORY

Have you spend a night anywhere else besides your home village/town in the past 4 weeks? ☒ Yes ☐ No
If no, skip to Vector Control section

1. Within Namibia			2. Outside of Namibia		
Village / town/ District where you have spend the night(s)	Duration of stay		Country/Province/Town where you have spend the night(s)	Duration of stay	
	First Night YY/MM/DD	Last Night YY/MM/DD		First Night YY/MM/DD	Last Night YY/MM/DD
			Omhupa/Angola	26/12/016	7/01/017

What was your reason for travel?
☐ Business/trade ☒ Visiting family or friends ☐ Shopping ☐ Holiday/tourism ☐ Other (specify ______)

What was your means of travel?
☐ Bus ☐ Mini-bus ☒ Car/Taxi ☐ Boat ☐ Walked ☐ Airplane ☐ Other (specify ______)

Did you use any of the following personal protection measures to prevent contracting malaria (during travel)?
☐ Chemoprophylaxis (specify ______) ☒ Bed net ☐ Mosquito repellent or coil ☐ None

VECTOR CONTROL & PERSONAL PROTECTION MEASURES

What are the exterior walls of the house primarily (main material) made of?
☒ Sticks/Grass ☐ Mud/Cow dung ☐ Wood ☐ Cement block or brick ☐ Corrugated iron sheets
☐ Other (specify ______)

What is the roof primarily comprised of?
☐ Grass / Sticks ☐ Corrugated iron sheets ☐ Asbestos ☐ Other (specify ______)

Has this home been sprayed in the past year? ☐ Yes ☒ No ☐ Don't Know
Do you own a bed net? ☐ Yes ☐ No

If no, DO NOT ASK THE FOLLOWING QUESTIONS
If yes,
How many bed nets do you have in the house? ______
Do you use ALL the nets in the house? ☐ Yes ☐ No *If no, ask why all nets are not used* ______

How many people live in the house? (Include all usual members) 8
Is your bed net treated with insecticide? ☐ Yes ☒ No
Did you sleep under your bed net anytime within the past week? ☐ Yes ☐ No

... sleep under a mosquito bed net within the past week? ... condition ☐ net is too dirty

Malaria Case Investigation form Page 2