Sustainability of Malaria Elimination Strategies in Uganda and Zimbabwe: A Systematic Literature Review.

Nyatwa Douglas Gwatidzo

A Thesis Submitted in Fulfillment of the Requirements for the Degree of Master of Science in Environmental Management

Prince of Songkla University

2023

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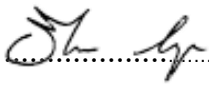
Acting Dean of Graduate School

This is to certify that the work here submitted is the result of the candidate's own investigations. Due acknowledgement has been made of any assistance received.



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I hereby certify that this work has not been accepted in substance for any degree and is not being currently submitted in candidature for any degree.

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ABSTRACT

Malaria is a parasitic infectious disease spread through the bite of an infected female Anopheles mosquito. Preventive and control measures have been put in place to eliminate this menace, but the efforts are proving futile as the number of cases continue to increase annually. Presently two, vector control strategies play a pivotal role in the control of malaria – Indoor Residual Spraying and treated bed nets. The sustainability of these control strategies entails the ability of the various program components and activities to continue achieving malaria elimination over time.

A systematic review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta Analyses. A literature search based on Patient, Intervention, Comparison and Outcomes was used on the Web of Science, EBSCO host and Science Direct databases for best relevant results. Thirty-six full text articles passed to the systematic review. Factors that were evaluated include vector resistance to insecticides; the reported extent of community involvement; sustainability prospects and the impact of IRS and LLINS in malaria elimination.

The available literature suggests that the sustainability of malaria control initiatives in Uganda and Zimbabwe may possibly be unachievable. The communities are mere recipients of the control measures, without adequate involvement, hence their sustainability is not being realized. Policy adjustments for both countries therefore becomes inevitable.

Keywords: Malaria elimination; Vector control; Sustainability.

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ABBREVIATIONS AND SYMBOLS

Covid-19	Corona Virus Disease (2019).
IRS	Indoor Residual Spraying.
IVM	Integrated Vector Management.
LLINs	Long Lasting Insecticidal Nets.
NGO	Non-Governmental Organization.
PBC	Piperonyl butoxide.
PICO	Patient, Intervention, Comparison and Outcome.
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
UN	United Nations
WHO	World Health Organization.

Chapter1: INTRODUCTION

1.1 Background

Malaria continues to pose serious public health challenges regardless of all the efforts channeled towards its control and possible elimination. The World Health Organization (WHO) calls for the protection of all malaria at risk populations using tested and reliable vector control interventions. Two forms of vector control interventions – treated bed nets and residual spraying – have been proven effective in most circumstances (WHO, 2015). The continued spread of vector-borne diseases the world over, specifically malaria, can be attributed to factors, chief among them failure of vector control interventions (Rodriguez, 2021). Another very important aspect that the current review seeks to address is the issue of community involvement in malaria control. The general community is a very crucial component in the control of malaria outbreaks (Abeku *et al.*, 2015). Malaria has not been selective in distribution (Lindsay, Thomas and Kleinschmidt, 2021), affecting both developed and developing countries, though an increased burden is in sub-Saharan Africa, as can be shown in the statistics presented in Table 1.

As presented in Table 1, malaria cases were on the increase globally from 2015 to 2017. Then in 2018, there was a slight drop in cases, only to have an increase again in 2019. For the World Health Organization's African Region alone, malaria cases were on the increase between 2015 and 2018. In 2019, the cases stagnated. This is despite the fact that IRS and the use of LLINs were adopted well in time as the most promising vector control interventions (Tangena *et al.*, 2020), though there are other interventions that can be adopted to reinforce these two. However, it is worrisome to note that malaria cases continue to be on the increase. The expectation was to see a downward trend in malaria incidence, but where there was such as in 2018, the decrease was short-lived as the following year (2019), malaria cases shot up again. Another worrisome development was the sudden increase in malaria deaths in 2019, after noting a downward trend from 2015 through 2018. The World Health Reports accessed

(2016 to 2020), supported by other published articles, indicate that the African Region has the greatest malaria burden.

Table 1: Malaria Statistics (2015 to 2019)[1].

Indicator/Variable	2015	2016	2017	2018	2019
CONFIRMED MALARIA CASES					
Global	219m	227m	231m	228m	229m
African Region*	199m	206m	212m	213m	213m
Uganda	5m	12m	14m	12m	8m
Zimbabwe	342 000	281 000	468 000	260 000	310 000
Zambia	7.2m	6.08m	5.51m	5.05m	5.14m
CONFIRMED MALARIA DEATHS					
Global	446 000	427 000	416 000	405 000	409 000
African Region**	411 000	389 000	383 000	380 000	386 000
Uganda	5153	5991	4722	2611	4545
Zimbabwe	462	235	534	192	266
Zambia	2359	1827	1423	1209	1342
VECTOR CONTROL COVERAGES					
Indoor Residual Spraying					
Africa Coverage	88%	86%	89%	91%	96%
Uganda Coverage	84%	86%	91%	95%	97%
Zimbabwe	78%	83%	88%	94%	96%
Zambia Coverage	73%	79%	82%	93%	95%
Long Lasting Insecticidal Nets					
African Region	86%	86%	85%	92%	94%
Uganda Coverage	73%	76%	74%	83%	87%
Zimbabwe Coverage	77%	80%	73%	88%	94%
Zambia Coverage	68%	71%	76%	83%	89%
MALARIA INCIDENCE RATE* **					
Global	58.9	58.7	59.2	57.2	56.3
African Region	228.3	223.6	226.2	218.4	214.1
Uganda	253.5	283.1	294.9	262.7	262.7
Zimbabwe	97.6	68.4	118.8	55.8	67.9
Zambia	219.3	206	185.2	178.8	174.4

**Sub Saharan Africa shoulders 95% of global cases as of 2020 (WHO, 2020).*
***Sub Saharan Africa contributed 96% of the global deaths in 2020 (WHO, 2020).*
****Malaria incidence per 1000 at risk population.*

The available mortality data suggests that malaria treatment medicines were probably effective, including malaria management in general. However, the fact that malaria incidence was on the increase for the period under study may indicate or suggest global or regional failure to control mosquito vectors as one of the key factors to consider or blame.

[1] Sources: (Okumu and Moore, 2011; Kenea *et al.*, 2019; Loha *et al.*, 2019; Alonso *et al.*, 2021; WHO, 2020); https://www.who.int/data/gho/data/indicators/indicator-details/GHO/malaria-incidence-(per-1-000-population-at-risk).

1.2 Rationale

Malaria remains a challenge worldwide, as presented in Table 1, despite efforts being made towards its elimination. A number of strategies have been developed towards this goal. Vector control, environmental manipulation and effective case management are some of the strategies being implemented towards malaria elimination globally. Most countries that have achieved malaria elimination like China and others have adopted the integrated vector management (IVM) approach. However, IRS and LLINs remain the most important strategies in malaria vector control. According to the World Health Organization World Malaria Report (2021), the African region remains the most affected by malaria.

According to the available statistics, Uganda had 45.74 million people in 2020 and the UN estimated (from growth models) that by 2022, its population would be around 49 million people. On the other hand, Zimbabwean statistics showed that there were 14.86 million people in 2020 and the UN estimated that by 2022, the population would have risen to 16 million.

Both countries are landlocked, and both are in Sub Saharan Africa. Their climatic conditions are almost similar and favor the survival of the vector as well as the spread of malaria. The economies of both countries are poor as both are still categorized as developing countries. Available facts show that Uganda had a GDP of about 37.37 billion USD in 2020 whilst Zimbabwe had a GDP of 16.77 billion. Both countries rely heavily on NGOs for assistance. In terms of malaria morbidity and mortality, Uganda had 15 million confirmed cases in 2020 whilst Zimbabwe had 447 000 cases according to Statista, 2022 accessed 19/09/22. According to the African rankings on malaria burden, Uganda was on number 3 while Zimbabwe was on number 28.

In Uganda, IRS was implemented in high malaria endemic districts whilst in Zimbabwe it was targeted for areas that were reporting five or more cases per 1000 population. Uganda sprays almost twice annually (January and July) and annually for Zimbabwe (October). For LLINs, mass distributions in both

countries are done after 3 years from the previous one, assuming that each net has a life span of 3 years. In Zimbabwe, LLINs are targeted for areas reporting two to four cases per 1,000 population.

The review sought to assist the National Malaria Control Programs, especially those in the WHO African region and specifically those in Zimbabwe and Uganda, in evaluating their IRS and LLINs programming. Malaria programming post 2019 was affected by the COVID-19 pandemic hence the review's five-year focus from 2015 to 2019. The review may inform policy makers on ways or approaches to sustain their IRS and LLINs programs. Sustainability in the review's context was taken to mean either the ability to keep malaria incidence going down until absolute elimination is achieved as a result of the use of IRS and LLINs over time or the capacity to continue providing IRS and LLINs to the community even after the withdrawal of international funding.

This review may provide a baseline for future malaria elimination sustainability studies. The review was overly qualitative in nature as it sought to evaluate malaria vector control interventions in the two countries. We wanted to find out if indoor residual spraying (IRS) and use of long-lasting insecticidal nets (LLINs) could be sustainable, by examining those requirements unique to different populations as well as exploring those contexts in which the programs were implemented, so as to achieve malaria elimination. The findings may therefore help influence or inform policy development or guide policy implementation

1.3 Objectives

- **Broad objective**

  To determine the sustainability of IRS and LLINs in Uganda and Zimbabwe between 2015 and 2019.

- **Specific Objectives**

1. To determine the extent to which Zimbabwe and Uganda maintained IRS and LLINs as the pillars of malaria vector control between 2015 and 2019.

2. To evaluate the impact of IRS and LLINs in Zimbabwe and Uganda's malaria elimination fight during the period 2015 to 2019.

1.4 Research Questions

To what extent did Zimbabwe and Uganda achieve sustainability of IRS and LLINs between 2015 and 2019?

- To what extent did Zimbabwe and Uganda maintain IRS and LLINs as the pillars of malaria vector control in their malaria elimination attempts between 2015 and 2019?
- What was the impact of IRS and LLINs in Zimbabwe and Uganda's malaria elimination fight during the period 2015 to 2019.

1.5 Review of literature

A lot of research has been carried out in the medical field in an effort to eliminate conditions like malaria. Such efforts have resulted in such initiatives like integrated vector management (IVM) and so on (WHO, 2016). It is common knowledge that a lot of factors are undermining the achievement in malaria elimination, despite the celebrated positive impacts of synthetic pyrethroids (Mutero *et al.*, 2012). Mutero (2012) argues that the indiscriminate use of insecticides in households for public health purposes as well as in agriculture is promoting vector resistance (Mutero *et al.*, 2012). Vector resistance is currently a challenge that scientists the world over are trying to crack or solve. Thus Mutero (2012) correctly concluded that pyrethroid resistance is threatening the success of pyrethroid treated nets since malaria vector control is under-pinned on insecticide use, particularly pyrethroids.

A thorough search of the published material shows that there was not any documented malaria outbreaks in sub-Saharan Africa during the period under study. However, the continued increase in annual cases clearly shows that outbreaks were experienced but were probably not reported, worse still with the onset of Covid 19 pandemic (World Malaria report, 2021).

1.5.1 Chemicals used in malaria vector control

Pyrethroid is the chemical that WHO has approved for use in IRS and LLINs (WHO, 2016). Another chemical used is Dichlorodiphenyltrichloroethane (DDT), which is an organochloride. Having been banned for agricultural and other general uses in most countries, DDT is still being used in Sub Saharan African countries exclusively for IRS purposes. Carbamates and organophosphates are other chemicals that can be used. Some of the chemicals are still at various stages of Hut trials for example Piperonyl butoxide (PBO) (Gari and Lindtjørn, 2018). This chemical is being used as a synergist; that is being used together with pyrethroids in treating bed nets. This is being done to counter the growing challenge of widespread pyrethroid resistance in some mosquito species.

However, trusting a single control strategy has its own sustenance issues, which include the growing resistance over time to chemicals as well as health and environmental problems (Mutero *et al.*, 2012; Guyant *et al.*, 2015). Although mosquito control using treated nets and residual spraying had been very much promising (WHO, 2016), the deliberate scale up of these strategies may have promoted resistance among the targeted vector species (Kgoroebutswe *et al.*, 2020). This adaptation by the mosquito vectors attenuates the impact of treated bed nets and residual spraying (Nalinya *et al*, 2022). This shift in vector genetics and subsequently their behaviors may have a bearing on the current limitations of these strategies (Sangoro *et al*, 2020).

1.5.2 Roll Back Malaria Program

Global efforts in malaria elimination through the Roll Back Malaria program faced some challenges (Killeen *et al.*, 2017; Monroe *et al.*, 2021). The program's Tool Kit on treated bed net programs developed by the Alliance for malaria control suggests that most member states have challenges in identifying LLIN gaps necessary for achieving set targets (Masaninga *et al*, 2018). Thus integrating a number of vector control strategies seems a noble idea in achieving sustenance of current malaria control efforts (Deressa *et al.*, 2016). However, most African countries do not have policies crafted towards integrated vector management (Mutero *et al.*, 2012).

1.5.3 Integrated Vector Control Approach

WHO recommended the use of a number of malaria control methods (WHO, 2016). It is argued that IVM offers a variety of control options suitable in different environments (Sexton, 2011; White *et al.*, 2011; Rodriguez, 2021). A combination of different methods at the same time can target the vector species at different points of their life cycle (Mharakurwa *et al.*, 2013). Program monitoring and evaluation are important aspects or prerequisites for achieving efficiency in public health programs (Mutero *et al.*, 2012).

In a study about the dynamics of malaria transmission, Buxton et al (2020) found that their management is a crucial component of integrated malaria control strategies. He argued that the spread of malaria is to some extent reliant on "vector monitoring and control, which most often involves the use of insecticides, although several other complementary approaches are also widely explored" (Buxton et al, 2020). His assertion was not divorced from the WHO's perspective on the IVM approach.

1.5.4 Indoor Residual Spraying (IRS)

This is the use of chemicals in controlling the mosquito vectors. The chemicals are sprayed onto surfaces and walls where mosquitoes rest, including the eaves. It involves the application of a residual insecticide to internal walls of housing

structures where malaria vectors may come into contact with the insecticide (Tangena *et al.*, 2020). Different pesticide classes can be used, including organophosphates, organochlorines, carbamates and pyrethroids.

1.5.5 Long Lasting Insecticidal Treated Nets (LLINs)

This is the use of bed nets impregnated with long lasting chemicals to avoid mosquito bites. Currently WHO recommends the use of synthetic pyrethroids as the chemical of choice as pyrethroids are relatively safe to humans while being highly effective against the mosquito vector species. These bed nets are treated with insecticides at the production. They are known to be effective for a minimum period of 3 years or 20 standard washes (Benelli and Beier, 2017). In most cases, LLINs are made of polyester or polyethylene and thus meet the quality, safety and efficacy standards set out by WHO. The nets must be durable enough to resist local climatic conditions as well as damage by animals like cats and rats.

1.5.6 Conclusion

In conclusion, malaria continues to pose serious health challenges in most African countries (WHO, 2016). This research seeks to identify factors impacting negatively on the sustainability of IRS and LLINs as the major malaria vector control interventions. These strategies must be sustainable enough if positive results are to be realized in malaria elimination. Some of the research conducted have shown that sustainability is a vital component in public health programs (Birkholtz *et al.*, 2012; Monroe *et al.*, 2021). Hence the successful completion of this research shall assist in identifying factors affecting the sustainability of malaria control interventions and offer recommendations to overcome them.

Chapter 2: MATERIALS AND METHODS

The broad objective of the review was to determine the sustainability of IRS and LLINs in Uganda and Zimbabwe between 2015 and 2019. Sustainability in the review's context was taken to mean the ability to keep malaria incidence going down until absolute elimination is achieved as a result of the use of IRS and LLINs over time.

2.1 MATERIALS

-Laptop

-Internet (Wi-Fi) connectivity

-Two reviewers

-Computer applications

- Covidence 2.0

  Covidence is an online screening and data extraction tool for conducting systematic reviews, allowing the screening process to be more efficient and easily tracked. The tool was used as it allows multiple authors to work simultaneously without causing conflicts. This application was used to (1) screen references (titles/abstracts and full texts); (2) create and populate data extraction forms; (3) complete risk of bias tables. All these actions were completed by two reviewers working independently.

- Zotero

  This is an open-access, easy-to-use reference, or citation management tool for collecting, organizing, citing, and sharing research sources. This application was used to (1) save references from various literature sources that were searched (2) create lists of references in the university's preferred style (3) insert citations into this thesis document while writing.

- IBM SPSS

Statistical package for the social sciences (SPSS) is a combination of programs combined together for the analysis of scientific data related to social sciences. This tool was used to (1) analyze data; (2) perform outcome predictions (3) transform data into graphs and tables for presentation.

- Microsoft Excel

Microsoft Excel is an application for formatting, organizing, analyzing, and calculating data in a spreadsheet, thus making information easier to view as data is added or changed. This application was used in coming up with the data extraction template used during the review.

- Open Science Framework

This tool promotes open, centralized workflows by enabling capture of different aspects and products of the research lifecycle, including developing a research idea, designing a study, storing, and analyzing collected data, and writing and publishing reports or papers. It was used as a repository for the storage of this review's data so that it could be publicly available accurate verification of scientific results. This allows the research to be more accessible, reproducible, and impactful.

-Databases

2.2 METHODS

A systematic literature review was utilized. This research method encompasses the extraction and interpretation of data from peer reviewed as well as published studies on a specific topic for analysis and summarizing of interpretations into a refined conclusion. This method was chosen as it is ranked by most scholars worldwide as the best to offer strong scientific evidence compared to the other research methods. A study protocol was prepared/designed though it was not registered with the likes of PROSPERO or

COCHRANE. The review followed guidelines outlined in PRISMA 2020 checklist.

a. Background to the study area

Figure 1: Map of Sub-Saharan Africa *(digitalmapsstudios.com)*.

Sub-Saharan Africa is part of the African continent characterized by tropical and temperate climatic conditions that are highly conducive for the proliferation of malaria mosquito vectors. The study focused on two countries – Uganda and Zimbabwe. Uganda has a very high prevalence of malaria (WHO, 2020) while Zimbabwe had a high prevalence pre-2015 era. Most of the countries in this region are still developing, hence their economies are not performing very well, Uganda and Zimbabwe included. This has a negative impact on health care systems. Some of the countries' economies like Zimbabwe are characterized by uncontrolled and rife small-scale artisanal mining activities. Uganda is also usually involved in tribal wars or armed

conflicts. Others like South Africa, Zambia and Malawi are involved in large-scale agricultural activities like farming. All these predispose their populations to the likelihood of contracting malaria, in the absence of adequate prevention and control initiatives. Their populations are also highly mobile as they search for greener pastures which promote cross-border movements. This also facilitates the spread of diseases like malaria.

All countries in the region have NMCPs and most of them, save for South Africa, were not greatly affected by the Covid-19 pandemic. Zimbabwe and Uganda were used as case studies for the review. The countries' literacy rates are good. For Zimbabwe, its economy is underperforming (officially) as a result of the sanctions imposed on the country as well as unverified reports of mismanagement of public funds. The health sector is not adequately financed by the government and relies mostly on donor and NGO funding and assistance. Most of the economic activities in the country promote the spread of malaria despite the government and its partners' efforts in rolling out malaria control strategies. As depicted previously, Uganda has a high burden of malaria, which is seasonal, hence the need to understand why, yet the country seems committed to the fight against the disease.

b. Methods

The review was essentially conducted by two independent reviewers, myself as the first reviewer and another one who was co-opted into the study. The second reviewer was a researcher in the field of Environmental Health based in Zimbabwe. Both reviewers followed the same review protocol, used the same computer applications, used the same search strategies but were working independently of each other. They only met in situations where there were substantial differences to discuss or resolve the conflicts.

1. Search strategy

Table 2: Database search queries, filters and records found.

Database	Search query	Filters applied	Records found
Ebsco Host	*(malaria) AND (malaria AND zimbabwe) AND (malaria AND uganda) AND ((indoor AND residual AND spraying)) AND ((treated AND bed AND nets) AND (long AND lasting AND insecticidal AND nets) OR (treated AND mosquito AND nets))*	-Online full text and peer reviewed -Date range 01/2010 to 12/2020 -Language English	2563 records 15/03/23*
Science Direct	*malaria AND zimbabwe AND uganda AND indoor residual spraying AND treated bed nets AND long-lasting insecticidal nets OR treated mosquito nets*	-Refined by period 2010 to 2022 -Review articles and research articles	1976 records 22/03/23*
Web of Science	((((ALL=(malaria)) AND ALL=(malaria and zimbabwe)) AND ALL=(malaria and uganda)) OR ALL=(indoor residual spraying)) OR ALL=(treated bed nets or long lasting insecticidal nets or treated mosquito nets)	-Publication years 2010 to 2022 -Document types – Article; Review article; Open access	3490 records 28/03/23*

*Last date search was performed.

The review followed guidelines outlined in Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA 2020) statement. A standard Boolean literature search strategy based on Patient, Intervention, Comparison and Outcome (PICO), see Table 2, was used on the Web of Science, EBSCOhost, and Science Direct databases so as to have the best relevant results since they include journals that publish articles related to public health. Their articles would have been subjected to comprehensive peer review hence they were considered to be of high quality.

Only the three stated electronic sources were consulted for articles from 2010 to 2022. Only English language publications were eligible, including conference abstracts and other official publications. The researchers believed that articles older than ten years may be outdated as science is dynamic. All un-published as well as published but not peer reviewed literature were excluded from the study as they lack the much sought after scientific relevance. However, this literature was consulted for reference and comparison purposes only. The pre-determined inclusion and exclusion criteria is shown in Table 3.

Table 3: PICOS criteria used to include/exclude studies during the study selection process.

Parameter	Inclusion criteria	Exclusion criteria
Population/ Problem	Studies undertaken only in Zimbabwe and/or Uganda on malaria vector control. There was no age restriction.	Studies not conducted in Zimbabwe or Uganda and studies not exclusively on malaria control
Intervention	Studies undertaken in Zimbabwe and/or Uganda on community centred IRS and LLINs distribution as the major malaria vector control strategies.	Other non-malaria vector control strategies such as case management; intermittent prophylaxis treatment, etc
Comparators	Studies reporting on malaria incidence before and after IRS or LLINs roll out in Zimbabwe and/or Uganda between 2015 and 2019	Studies not within the range 2015 to 2019
Outcome	Changes in malaria incidence in Zimbabwe and/or Uganda after IRS/LLINs roll out between 2015 and 2019	Studies not reporting on malaria incidence during the specified period
Study design	There were no restrictions on study designs, provided the study was a journal and peer reviewed publication.	Unpublished research studies (e.g., editorials, letters, and conference abstracts),

2. Study selection process

Two reviewers worked independently during the study selection process to eliminate issues to do with inclusion bias. Firstly, eligibility assessment of all searched articles was achieved using Zotero (Version 6.0.20). All retrieved

published articles were collected into one Zotero library and all multiple entries were deleted using the remove duplicating function, then exported into excel.

Title, abstract and full-text reviews were then done by the same reviewers using an online screening tool (Covidence 2.0). The selection of studies was generally based on the title and abstract's relevance to the sustainability of malaria elimination strategies, with a bias towards the use of IRS and LLINs.

3. Data extraction and quality assessment

Killeen et al, (2017) states that data extraction relates to a process whereby researchers obtain data concerning study characteristics from eligible studies. The Cochrane Data Extraction Template (Data collection form for intervention reviews: RCTs and non-RCTs, Version 3, April 2014) was adopted and used to develop an excel data extraction tool/checklist. Working independently, the reviewers used the tool to extract data from each of the thirty-six included studies. The data extraction tool was pilot tested first, using five randomly selected articles from those included in the review. This was to ensure the capturing of relevant information as well as ensuring consistency of the extracted data, thus reducing data extraction errors while improving validity and reliability. Data presented in graphs within the included studies was extracted using WebPlotDigitizer software (Version 4.5).

Quality assessment of each included study was necessary to determine its robustness in determining the sustenance of malaria vector control strategies in African settings. The quality assessment considered the following aspects:

- Appropriateness of study design to the research objective
- Risk of bias
- Generalizability

4. Data checking

Working independently, the two reviewers checked the extracted data so that duplicate and ineligible studies could be removed from further review. Information that was extracted from each article included: (1) vector control strategies in Sub Saharan Africa – the primary focus was on IRS and LLINs, to determine their effectiveness and applicability in African settings; (2) malaria vector resistance to pyrethroids and other chemicals – this has an impact on the chemicals that are used in IRS as well as in treating the bed nets; (3) malaria statistics in Uganda and Zimbabwe – this was for comparison purposes to determine whether or not the vector control strategies are effective in different African settings though against the same vector species and (4) malaria elimination policies in Uganda and Zimbabwe– these are most important as they are the guidelines for a country and also the policies demonstrate a country's commitment towards malaria elimination. Malaria transmission reduction – as portrayed in the morbidity and mortality data over time – was the primary measure of sustenance of the vector control strategies under study. Assumptions were made concerning missing or unclear information.

5. Risk of bias assessment

The modified Downs and Black checklist (Downs and Black, 1998) was used to determine each study's risk of bias. This tool was a fusion between elements from the original Downs and Black checklist as well as those from the Semi-Automated Quality Assessment Tool (SAQAT). The tool was designed and modified to be able to evaluate the methodological quality of both randomized and non-randomized studies. It consists of 27 items addressing methodological components such as reporting; external validity; internal validity (bias and confounding) and power. Two reviewers assessed each included study independently for risk of bias.

6. Statistical analysis

The SPSS software Version 20 was utilized to explore possible causes of heterogeneity among the different study findings. Narrative synthesis was used to synthesize data from the studies because different research designs were found in the reviewed literature. As such, meta-analysis was considered not appropriate. Descriptive statistics using Frequencies and Cross Tabs were the mostly used functions of the software. The Comparison of Means function was used to perform One Sample Tests for the extracted data.

Chapter 3: RESULTS AND DISCUSSION

3.1 Results

The review sought to determine the sustainability of IRS and LLINs in Uganda and Zimbabwe between 2015 and 2019. Sustainability in the review's context was regarded as the ability to keep malaria incidence going down until absolute elimination is achieved as a result of the use of IRS and LLINs over time.

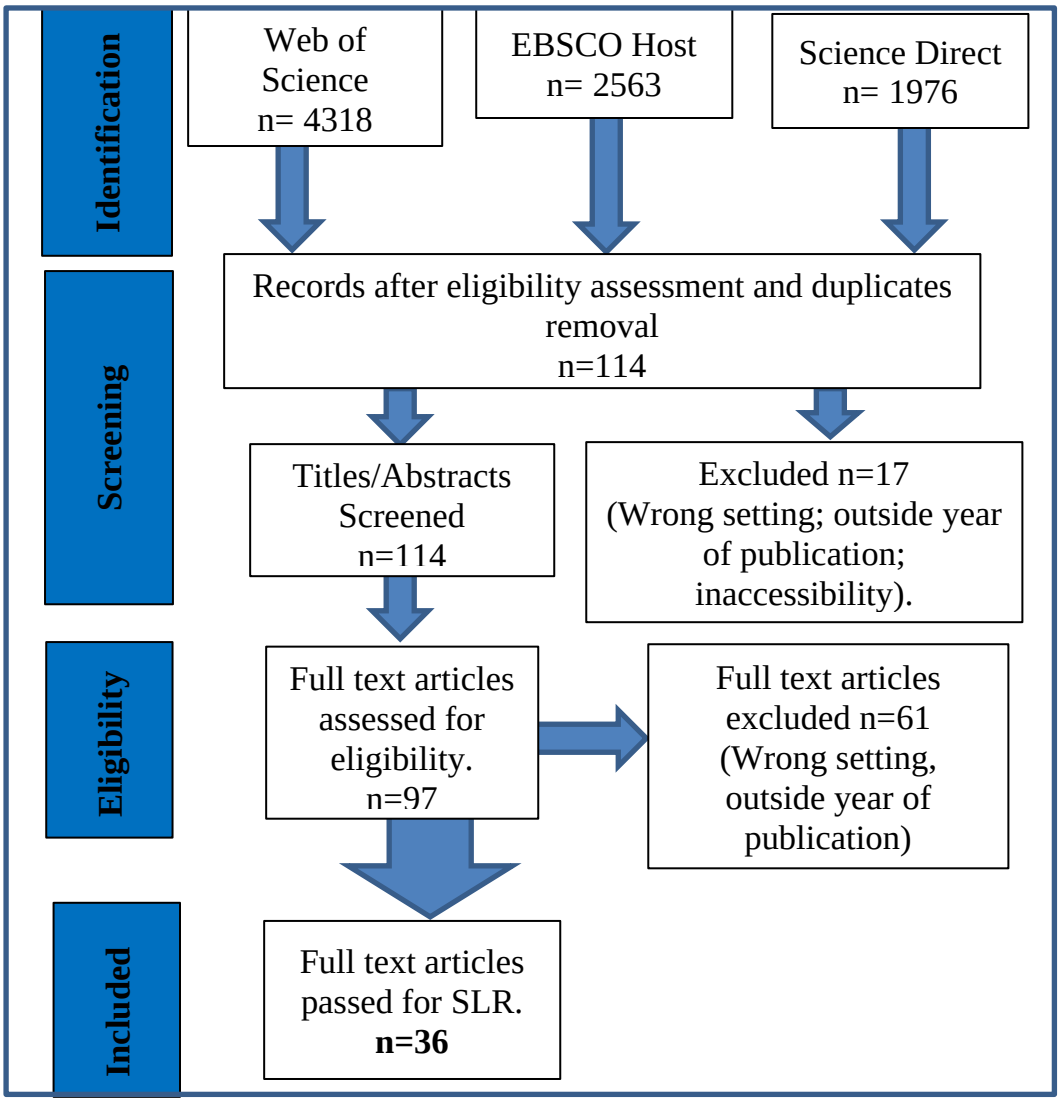

Figure 2: PRISMA Flow Diagram – Study selection

The initial search resulted in 8857 records. 2588 articles were removed as duplicates whilst 6155 records were removed after eligibility assessment, that is, they were found ineligible based on the inclusion criteria. Seventeen (17)

articles were excluded after titles and abstracts screening from the 114 articles left after duplicates removal and eligibility assessment.

Of the 97 remaining articles, 61 articles were excluded after a full text review because they did not meet fully the inclusion criteria. Sixty studies were excluded for wrong setting, that is, they were undertaken outside Zimbabwe and/or Uganda. One article was outside the year of publication restriction/bracket (2010 – 2022). Thus, the review included 36 journal articles only; 18 from Zimbabwe, 18 from Uganda.

A number of the reviewed studies (87%) were published in the malaria journal (Table 4), with some from the BMC Public health journal, Journal of Health Economics, International Journal of Infectious Diseases, Acta Tropica as well as the Parasites and Vectors journals. Different research methods were employed among the reviewed studies (Table 4), including secondary data reviews, case control studies, systematic reviews, mathematical modelling, surveys and one RCT. Malaria control strategies that were evaluated by the reviewed articles included LLINs, IRS, larviciding and IPT (Table 4). Some of the articles did not evaluate any of the control strategies but were included since they looked into other aspects essential in achieving sustenance of malaria control strategies such as effective management and leadership (Table 4).

Most of the reviewed studies suffered from incomplete outcome data, though only one study scored more than 50%. Selective outcome reporting was low among the reviewed articles, as was the random sequence generation. Using Covidence 2.0, the level of agreement between the reviewers for study selection was 94.8%; conflicts were resolved after discussion. Three articles (8.3%) had a high risk of bias (deviation from study protocol and reporting bias) (Dube, 2019; Kaddumukasa, 2020; Okia, 2018); thirteen (36.1%) had moderate risk while twenty (55.6%) had low risk of bias.

Of the reviewed articles, 6 were case studies; 2 were descriptive studies; 8 were experimental; 13 were mere data reviews; 5 were surveys; 1 was an RCT; and the last one was unspecified (Table 4).

Table 4: Characteristics of reviewed articles

Characteristic	Frequency	Zimbabwe	Uganda	Multiple	95%CI
Type of research used.					
Case study	6	3	3	0	
Descriptive study	2	1	1	0	
Experimental	8	2	3	3	
Not specified	1	0	1	0	
RCT	1	0	1	0	
Reviews	13	6	4	1	
Survey	5	1	3	1	
Number of authors per article					**3.81– 6.74**
One to four	9	5	3	1	
Five to eight	16	9	4	3	
Nine and above	11	1	9	1	
Year of publication					**1.72–3.72**
2012	3	0	3	0	
2013	1	1	0	0	
2015	6	2	3	1	
2016	3	1	1	1	
2017	2	2	0	0	
2018	4	1	3	0	
2019	5	3	2	0	
2020	5	2	1	2	
2021	4	2	1	1	
2022	3	1	2	0	
Strategies evaluated					**1.23–2.05**
Both IRS and LLINs	18	10	6	2	
No strategy evaluated	6	3	1	2	
Mixed	12	2	9	1	
Type of Journal					
Malaria Journal	24	13	8	3	
BioMed Central	4	1	2	1	
Acta Tropica	4	0	4	0	
JHE	1	0	1	0	
IJID	1	0	1	0	
PHP	1	1	0	0	
Parasites and Vectors	1	0	0	1	
Totals per characteristic	**36**	**15**	**16**	**5**	

Legend

J.H.E – Journal of Health Economics; **P.V** – Parasites & Vectors; **BMC Medicine** – BioMed Central Medicine; **BMC PH** – BioMed Central Public Health; **BMC RN** – BioMed Central Research Notes; **RCT** – Randomized Control Trial; **IJID** – International Journal of Infectious Diseases; **PHP** – Public Health in Practice

According to the observations and assessments made, Uganda had 45.74 million people in 2020 and the UN estimated (from growth models) that by 2022, its population would be around 49 million people. On the other hand,

Zimbabwean statistics showed that there were 14.86 million people in 2020 and the UN estimated that by 2022, the population would have risen to 16 million (Sexton, 2011; Kyambadde *et al.*, 2018; Ogwang *et al.*, 2018; Kigozi *et al.*, 2020; Taremwa *et al.*, 2022).

Both countries are landlocked, and both are in Sub Saharan Africa. Their climatic conditions are almost similar and favour the survival of the vector as well as the spread of malaria. The economies of both countries are poor as both are still categorised as developing countries (Yeka *et al.,* 2012; Barofsky, Anekwe and Chase, 2015; Dube *et al.,* 2019; Gavi *et al.,* 2021). Available facts show that Uganda had a GDP of about 37.37 billion USD in 2020 whilst Zimbabwe had a GDP of 16.77 billion (Talisuna *et al.*, 2015; Kaddumukasa *et al.*, 2020; Mundagowa and Chimberengwa, 2020) Both countries rely heavily on NGOs for assistance. In terms of malaria morbidity and mortality, Uganda had 15 million confirmed cases in 2020 whilst Zimbabwe had 447 000 cases according to Statista, 2022 accessed 19/09/22. According to the African rankings on malaria burden, Uganda was on number 3 while Zimbabwe was on number 28 (Abeku *et al.*, 2015; Manyangadze *et al.,* 2017; Kamau *et al.*, 2020; Wagman *et al.*, 2020).

Ten articles out of the 36 reviewed articles evaluated pyrethroid resistance. Of the 15 studies from Zimbabwe, only 6 evaluated the issue of pyrethroid resistance whilst Uganda had only 3 out of 16 studies evaluated. Only two of the 36 reviewed articles (from Uganda) offered a better assessment of the extent of community involvement in the roll out of malaria strategies. Two studies from Zimbabwe assessed the availability of international funding towards malaria elimination. None of the reviewed studies assessed the extent to which each country can fund malaria control initiatives in the absence of international funding. *Anopheles gambiae sensu lato* (s.l.) and *Anopheles funestus* s.l. are the primary malaria vector species in both countries.

Only two articles from Zimbabwe had 2 or less authors, the bulk had 4 or more authors, with one article from Uganda having the largest number of authors at 24. Others had 5,6,7,8,10,11,14 and15 authors.

On library catalogues, twenty articles were taken from the Web of Science, 12 from EBSCOhost and 4 from Science Direct. From the assessment, the rate of research work in both countries increased from 2015, with studies on malaria being published every subsequent year. However, Zimbabwe has been publishing each year since 2015 whilst Uganda started publishing yearly from 2018.

A total of 18 articles assessed both IRS and LLINs (10 from Zimbabwe, 6 from Uganda and 2 from multiple countries); 8 articles from Uganda and 2 from Zimbabwe evaluated a number of strategies while a total of 6 studies did not evaluate any of the vector control measures.

Twenty-four articles assessed morbidity and mortality (10 from Zimbabwe, 11 from Uganda and 3 from various countries) while 12 articles did not (5 from Zimbabwe, 5 from Uganda and 2 from Multiple countries).

3.2 Discussion

The initial search returned a number of records from the databases (about 6269 after duplicates removal). This shows that the literature base is well saturated on the subject (malaria). However, these records included studies from all over the world. The review only focussed on Uganda and Zimbabwe hence the inclusion criteria was revised to allow only studies published on Uganda and/or Zimbabwe. This explains why only 36 articles passed for review from the records identified during the initial search.

It was noted that there were many articles that evaluated LLINs and IRS as malaria vector control strategies. The fact that there are some articles (though limited) on pyrethroid resistance as well as studies on new insecticides under trials acknowledges the fact that there are definitely some challenges in

today's control initiatives. The fact that LLINs and IRS are the best vector control strategies cannot be argued in the current body of knowledge.

The reductions in morbidity and mortality observed by a number of researchers after the roll out of mass LLINs distribution as well as after IRS campaigns indicates that indeed, these two strategies have a positive bearing in malaria control.

A total of thirty-six articles were reviewed of which only one study was an RCT, with most of the included studies being non-randomised, in which participants were recruited into different study groups, using methods other than randomisation. This lack of concealed randomised allocation increased the risk of selection bias of the studies.

Selection bias could have been avoided by comparing the same group of participants in the before and after evaluations post control strategy roll out.

Avoiding selection bias could offer challenges in accounting for confounding factors, secular trends, regression to the mean, and differences in the care of the participants apart from the intervention of interest.

The need for achieving sustainability of preventive health services has led to a number of studies aimed at evaluating the effectiveness of one or more control strategies(Kassam *et al.*, 2015). A number of studies has observed that during controlled or hut trials, the strategies appear to offer good results in eliminating malaria from targeted communities(Cote *et al.*, 2021). When these strategies are eventually rolled out, they initially seem to achieve better results, but along the way, they lose their potency or effectiveness (Mpofu *et al.*, 2016). Whilst it can be agreed that several factors may be responsible for reducing their efficacy and effectiveness, there is need to identify the involved factors so as to promote sustainability of malaria control strategies within Sub Saharan Africa in general (Uganda and Zimbabwe in particular).

This review assessed malaria trends in Uganda and Zimbabwe to determine the possibility of sustaining malaria elimination attempts the world over,

particularly in Sub Saharan Africa. Several reviews were conducted on malaria in Africa but none of them assessed the sustainability potential of vector control strategies. The comparison between Uganda and Zimbabwe was necessitated by the fact that though incidence in Uganda is higher than in Zimbabwe, both countries seem to be feeling the brunt of malaria burden. The authors wanted to understand why Zimbabwe, with a lower burden than Uganda, is failing to sustain its gains against malaria since the inception of the Roll Back Malaria Initiative.

Most of the reviewed studies were non-randomised, with only one study being an RCT. This means that participants were recruited into different study groups, using methods other than randomisation. This lack of concealed randomised allocation increased the risk of selection bias of the reviewed studies. Selection bias could have been avoided by comparing the same group of participants in the before and after evaluations post control strategy roll out. Avoiding selection bias could offer challenges in accounting for confounding factors, secular trends, regression to the mean, and differences in the care of the participants apart from the intervention of interest.

It was noted that Zimbabwe was publishing more articles related to the sustainability of malaria vector control strategies as compared to Uganda. Grey literature consulted also supported this notion. However, the findings in most researches are not being adopted by the governments concerned. Research should inform or influence decision making by the policy makers. The number of articles reviewed per country reflects the commitment of citizens and non-citizens alike to sustain the fight against diseases - malaria to be specific.

Pyrethroid resistance is one of the new challenges downplaying the gains from malaria vector control initiatives(Brown, Dickinson and Kramer, 2013; Okia *et al.*, 2018). Pyrethroids are the chemicals that are being mainly used in IRS and LLINs since they are relatively safe to humans and the environment as compared to organochlorines, organophosphates, and carbamates. Of the 24

reviewed articles, 6 articles had assessed issues of pyrethroid resistance in Zimbabwe and Uganda. This shows that pyrethroid resistance monitoring and research is not being done effectively to influence changes in approaches to vector control. The continued use of one chemical – accompanied by widespread and indiscriminate use – can select the vector for resistance. Most African countries, Zimbabwe and Uganda included, have poor policies and poor monitoring of pyrethroid resistance (Dube *et al.*, 2019). Once the vector becomes widely resistant to pyrethroids, it then means that the malaria elimination targets and gains will not be sustained.

The authors note with great concern that most researchers are not looking at the level and extent of community ownership of malaria vector control initiatives, especially IRS and LLINs. The argument is that the more the community adopts the interventions the more they can be sustained. The community need to identify and accept the control measures for success to be realised fully over time. A number of other disease control strategies have failed before due to this pitfall (Birkholtz *et al.*, 2012). Failure to involve the community fully has led to the misuse of LLINs whereby the communities use nets for fishing and making fowl runs instead of sleeping under them.

Most African countries are relying on international funding in the fight against malaria. One of the disadvantages of this is that funders can fund for specific researches. Funds are usually availed for specific researches - that is - NGOs come with areas they need researched and fund those only, anything outside their specific scope is not considered. According to Rehman (2019), funders can play a role in the design of a study or in the collection, analysis, and interpretation of data. No wonder why researchers are expected to declare the roles and contributions of the funder where possible. Another issue associated with relying with outside funding is that once the funder pulls out or stops funding, all the gains will also be lost, unless the community is capacitated to take over to promote sustainability.

Local funding capabilities were assessed during the review because after cessation of donor funding, interventions should continue to promote sustainability. Each country within Sub Saharan Africa must be able to continue malaria control strategies even after the withdrawal of donors. Zimbabwe has a low GDP as compared to Uganda, yet Uganda has a greater malaria burden. However, both countries are classified as developing countries and as such, are most likely to fail to sustain programs on their own. Zimbabwe is experiencing an array of economic challenges which the government blames on economic sanctions. Others blame the government for mismanagement and corruption; thus, the possibility of sustaining vector control programs is minimal. The fact stands that even with the donor funding in place, malaria control seems to be failing to achieve the set goals as incidence continues to increase annually instead of declining. Efforts were made in 2011 by African leaders through the formation of the African Leaders Malaria Alliance (ALMA). The alliance aims at tracking progress and strengthening accountability for malaria control and elimination across the continent (Chung *et al.*, 2020).

A closer look at all the reviewed studies shows that Zimbabwe and Uganda share the same malaria vector species – *Anopheles gambiae sensu lato* (s.l.) and *Anopheles funestus* s.l. These species are the most widely distributed in Africa. Studies of these vectors are important in understanding issues to do with vector resistance in different African settings. Six articles reviewed had looked at vector resistance in Zimbabwe and Uganda. Only two articles (Okia *et al.*, 2018; Lindsay, Thomas and Kleinschmidt, 2021) had studied vector resistance issues, the rest were just secondary reviews of other studies.

The rate of research work in Uganda and Zimbabwe increased from 2015, with studies on malaria being published every subsequent year. This may be because considerable time had elapsed since the inception of IRS and LLINs as the major vector control strategies hence making evaluations possible. Zimbabwe

has been publishing articles on malaria each year from 2015 whereas Uganda was publishing yearly since 2018. Gaps in research result in poor policy formulations, relying on studies done in settings different from particular countries. Each country must carry out researches locally such that control measures are informed by local findings. With the advent of Information and Communications Technology Systems (ICTS), research work should be improved so that more studies are undertaken to adequately inform decision making.

Only two articles from Zimbabwe had 2 or less authors, the bulk had 4 or more authors, with one article from Uganda having the largest number of authors at 24. Number of authors per article reduce the potential for bias, thus increases reliability, precision, and the generalisation of the studies. Different ideas from different individuals need to be put together to reduce all types of bias in the research work.

The reviewed articles showed that Uganda's efforts are on evaluating all the malaria control measures at their disposal whereas Zimbabwe focuses on particular or specific aspects. The Zimbabwean approach is good to understand each strategy singly than evaluating a number of strategies at the same time. It is common knowledge in the academic world that IRS and LLINs are the most effective malaria vector control strategies. As such, these should be investigated on their own to determine their continued effectiveness in malaria control.

Chapter 4: CONCLUSION AND SUGGESTIONS

4.1 Conclusion

The review sought to determine the sustainability of malaria elimination strategies in Uganda and Zimbabwe between 2015 and 2019. Sustainability in the review's context was regarded as the ability to ensure a downward trend in malaria incidence until absolute elimination is achieved as a result of the use of IRS and LLINs over time.

African countries will continue to face challenges in the fight against vector borne diseases like malaria if they do not incorporate sustainability concepts within their public health efforts. Their continued reliance on international aid and NGOs remain a pitfall. Malaria burden remains an issue in Sub Saharan Africa despite the use of IRS and LLINs. Even with the other control measures like larviciding, IPT, etc. at their disposal, malaria remains a public health threat, resulting in morbidity and mortalities among children and adults alike. Appropriate policies also need to be put in place and followed through if any gains are to be realized. Most researchers evaluate the control strategies themselves, leaving behind an important aspect of community involvement. Most communities are not involved in the decisions that affect their lives hence in the absence of government agencies/workers/partners, they tend to forget about the strategies, thus reversing any gains that could have been made. In some cases, misuse of the control strategies such as the use of LLINs in fishing may promote insecticide resistance, considering that the mosquito vector lies eggs in water and their larvae hatch and grow in water or along water bodies. As rightfully articulated in the World Malaria Report (2021), new and better implementation approaches are required in order to realize the set 90% reduction in global malaria incidence by 2030.

4.2 Suggestions

- African governments need to consider training and mentoring public health entomologists for sustainability. Most of the ministries of health (and indeed the NMCPs) are largely medically rather than public health oriented. As such, career advancements are largely dependent on medical qualifications rather than public health qualifications. Thus, it can be challenging to integrate career opportunities for scientists or entomologists into the system.
- African governments should consider the promotion and capacitation of research institutions. Attractive career opportunities for public health researchers need to be developed. More research on LLIN effect on incidence as well as the effect of climate change on malaria is needed.
- There is also need for African governments to pursue various channels and approaches to community involvement.
- NGOs should also fund capacitation programs, besides control strategies, in much the same way as they fund monitoring and evaluation of their programs. Capacity building will undoubtedly promote sustenance of the control programs post funding withdrawal.

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APPENDICES

VITAE

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