

# Visceral Leishmaniasis Control Strategies in Sudan: A Review with Recommendations

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## ABSTRACT

**Problem:** Visceral leishmaniasis is one of the neglected tropical diseases, and it is fatal in 95% of cases if left untreated. For more than a hundred years, the disease represents a significant Sudan problem, spreading to new regions.

**Aim of the study:** Evaluate existing control measures for VL in Sudan and develop recommendations for strengthening these control measures based on an analysis of the evidence around alternative control measures from similar contexts.

**Methodology:** This dissertation is an in-depth secondary data analysis from literature and unpublished data. Due to limited access to MoH data, personal communications with officials were done.

**Findings:** The disease is spreading to new regions due to ineffective control measures, and the latest control plan is failing to achieve the target. Lack of governance and leadership were identified as management problems preventing the National Leishmaniasis Control Program (NLCP) from working. Furthermore, Sudan's existing control strategies were examined against the WHO recommended priorities and compared with successful strategies from other endemic countries. The analysis found that the NLCP focuses mainly on case detection and treatment but has ineffective surveillance, while vector control, reservoir control, and health education are neglected.

**Conclusion and recommendations:** Sudan is far from achieving the WHO target of eliminating VL as a public health problem in 2030. The study emphasized NLCP's strong national and international partnerships to consider short- and long-term recommendations. The short-term recommendation includes the establishment of Monitoring and Evaluation to ensure the NLCP accountability, establishing clinical mentoring teams to supervise the VL treatment centres at the twelve endemic states, and starting WHO recommended web-based surveillance.

The long-term recommendations include operational research to study evidence-based vector control with apriority to Out-Door Residual insecticides Spraying impact, reservoir host control measures, and study VL diagnostics and treatment regimens. The study also recommends introducing female Community Health Workers to enhance VL's health education, which is mainly affecting children in Sudan.

**Keywords:** Visceral leishmaniasis; Kalazar; Prevention; Control; Elimination; East Africa; Sudan

**List of Abbreviations:** ASCEND- Accelerating the Sustainable Control and Elimination of Neglected Tropical Diseases; CHWs- Community Health Workers; CDC- Centre for Diseases Control; CL- Cutaneous Leishmaniasis; DAT- Direct Agglutination Test; DFID- Department for International Development; DHIS2- District Health Information System 2; DNDi- Drugs for Neglected Diseases Initiative; EU- European Union; FMOH- Federal Ministry of Health in Sudan; GAVI- Global Alliance for Vaccines and Immunization; GIS- Geographic Information System; HIV- Human Immunodeficiency Virus; HRH- Human Resources for Health; IEND- Institute of Endemic Diseases; IRS- Insecticides Residual Spraying; ITNs- Insecticide Treated Bed-Nets; IVM- Integrated Vector Management; KalaCORE- UK funded partnership to control VL; LEAP- Leishmaniasis East Africa Platform; MCL- Mucocutaneous Leishmaniasis; MOH- Ministry of Health; MSF- Medecins Sans Frontieres/ Doctors without Borders; M&E- Monitoring and Evaluation; NGOs- Non-Governmental Organizations; NLCP- National Leishmaniasis Control Program; NTDs- Neglected Tropical Diseases; OECD- The Organization for Economic Co-operation and Development; PKDL- Post Kalazar Dermal Leishmaniasis; PM- Paromomycin; PRISMA- Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RDTs- Rapid Diagnostic Test; SSG- Sodium Stibogluconate; VL- Visceral Leishmaniasis; UN- United Nations; UNICEF- United Nations Children's Fund; WHO- World Health Organization.

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## INTRODUCTION

This study is mainly desk-based review with recommendations on evaluation for Visceral leishmaniasis control strategies in Sudan in comparison with other similar endemic context.

Leishmaniasis is one of the Neglected Tropical Diseases NTDs; Leishmaniasis is neglected since it affects mainly poor communities in 149 tropical and subtropical countries and no enough attention from researches and pharmaceutical institutes [1].

## BACKGROUND

A leishmaniasis is a group of diseases caused by protozoan parasite Leishmania; it has more than 20 species, the parasite transmitted to humans by the bite of an infected female phlebotomine sand-fly which is a tiny 2 mm long insect vector [1]. The disease transmitted in two primary cycles (Figure 1), the zoonotic in which VL is transmitted from animal to sandfly to human, or anthroponotic in which directly human-sandfly-human infection occurs [2]. The disease has four forms: Visceral Leishmaniasis (VL), also known as Kala-Azar, is a potentially fatal form, Mucocutaneous Leishmaniasis (MCL), Cutaneous Leishmaniasis (CL), and Post Kala-Azar Dermal Leishmaniasis (PKDL) which usually a sequel of VL [3].

The VL is endemic in 77 countries (Figure 2). While 90% of global cases in 2000 reported from five countries Bangladesh, Brazil, India, Nepal, and Sudan in 2018 the same 90% of cases reported from seven countries: Brazil, Ethiopia, India, Kenya, Somalia, South Sudan and Sudan [1,4]. Note that South Sudan is a new state separated from Sudan in 2011.

Visceral Leishmaniasis in the old world caused by subgenus *Leishmania donovani*, *Leishmania infantum* and few cases caused

by *Leishmania Tropica* complex and may be endemic, epidemic or sporadic cases while in the new world caused by *Leishmania infantum* and may be endemic or sporadic but for both worlds all ages are susceptible and commonly affect children and young adult [2]. Primary risk factors include socioeconomic conditions where poverty increases the risk of infection. Poor housing and reduced sanitation provide breeding and resting sites attractive to sand-flies [4]; other factors include malnutrition, population mobility, and environmental change, including urbanization and climate changes. The WHO mentioned priority key strategies for prevention including early diagnosis and treatment, vector control, effective surveillance, control of animal reservoir and social mobilization and partnerships. However, it is recommended to use combinations of these strategies [4].

VL is fatal if left untreated in 95% of cases and although the patient can be asymptomatic for years, clinically patient can present with irregular fever, loss of weight, enlargement of spleen and liver, anaemia and lymph nodes enlargement may present especially in Sudan and might be the only clinical manifestation [2]. VL is the second-largest parasitic killer in the world after malaria [5]. Until the 1990s, VL diagnosis was made by combining clinical signs with parasitological, the parasitology can be performed by microscopy or culture for tissue aspiration from spleen (gold standard but can cause life-threatening bleeding), liver, bone marrow or lymph node but is invasive [1,6]. And, recently a range of blood samples antibodies detection serological tests were developed like Direct Agglutination Test (DAT) that gives result in 18 hours and Rapid Diagnostic Tests (RDTs) like dipstick rk39 and rk28 that offers results in 20 minutes with some still under development in varying degree of accuracy according to geographical region and patients factors [1,6,7].

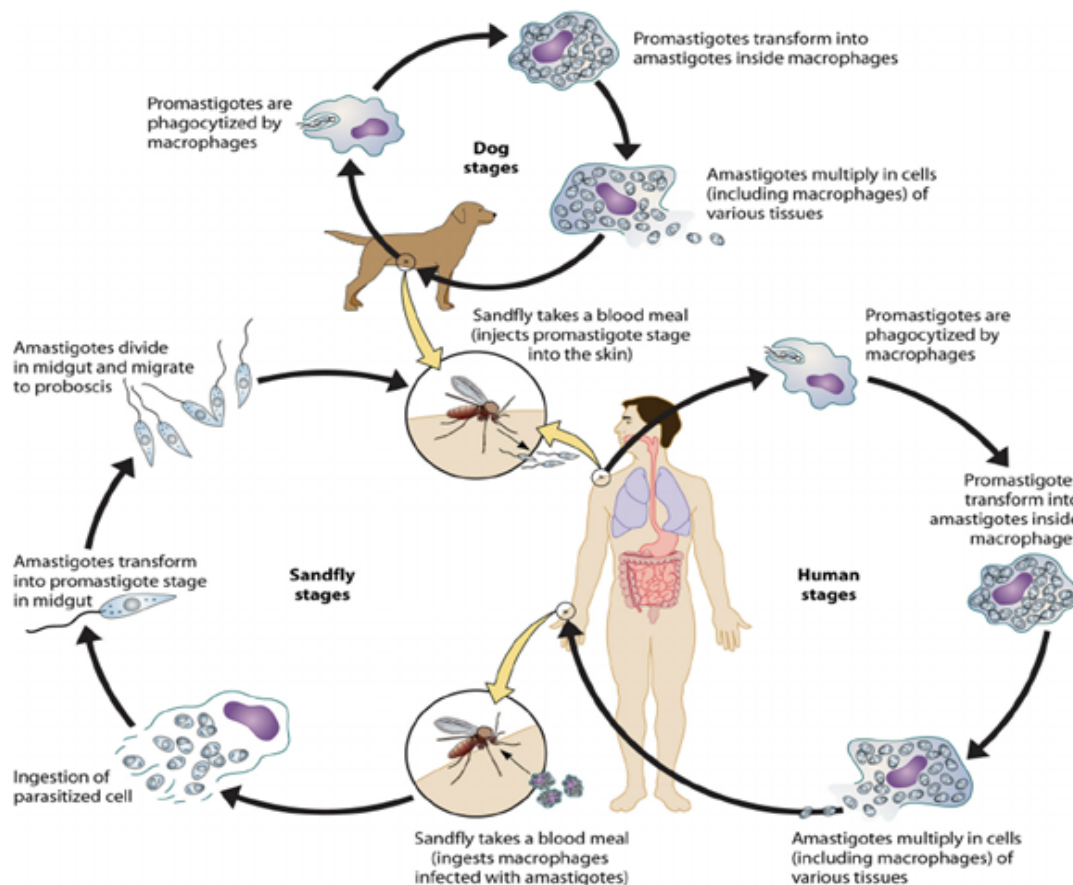


Figure 1: Life cycle of Leishmania species.

## Status of endemicity of visceral leishmaniasis worldwide, 2018

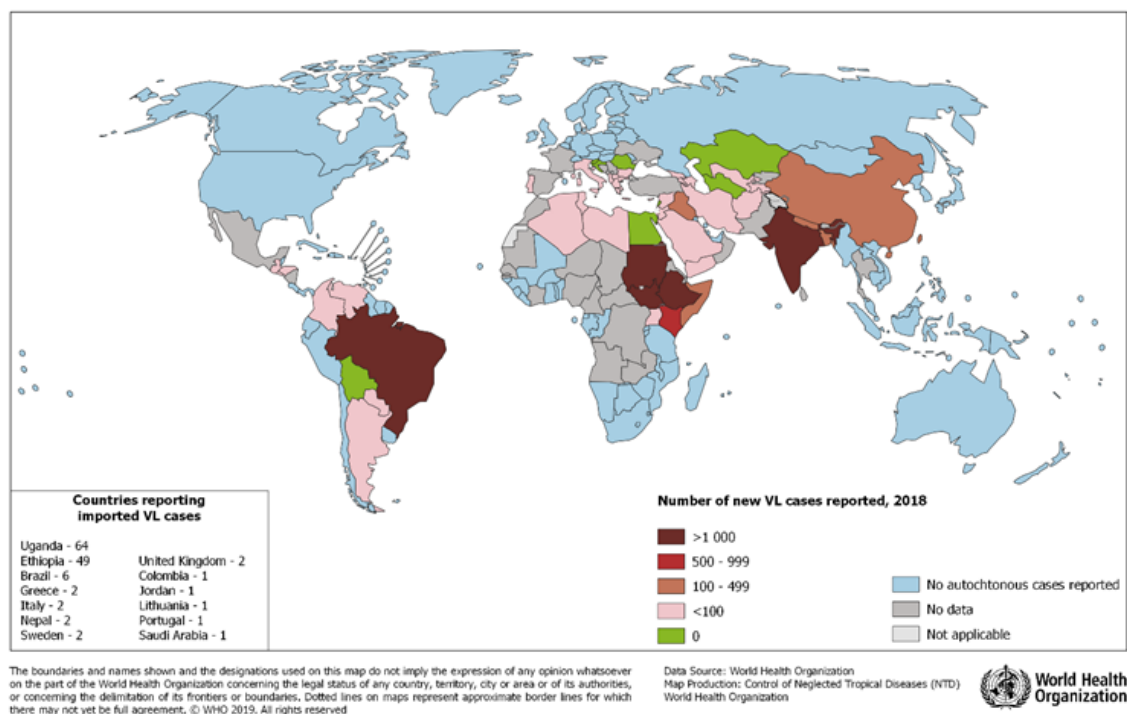


Figure 2: VL endemicity in the World 2018.

Nevertheless, serologic tests can support diagnosis, and most tests do not reliably distinguish between active and quiescent infections [6]. VL treatment strategies depend on anti-leishmanial drugs and treatment of co-morbidities, with antimonial sodium stibogluconate (SSG) and meglumine antimoniate being in use since the 1950s which are toxic drugs [7]. And, recent researches approved efficacy of some alternatives including Amphotericin B which is antifungal, Miltefosine which is Anti-cancer, Paromomycin (PM) which is Antibiotic and studies also recommend different combinations regimen of the drugs mentioned above to increase efficacy and reduce drugs resistance [7].

### Rational of the study

This study is focusing on VL in Sudan. Visceral Leishmaniasis is among significant health problems in Sudan since the early 1900s with an estimated incidence of 38.5/1,000 person-years in eastern Sudan, and case fatality rates as high as 20.5% have been observed [8]. Moreover, the country experienced over 14 primary VL outbreaks with the upper Nile 1988 outbreak alone known to have killed 1,00,000 persons [9].

Sudan, besides being among the six countries with the highest burden of VL globally, the transmission dynamics not yet understood, and the role of PKDL, which occurs in 56% of VL case in transmission not however understood as well [8]. Sudan is a fragile state ranking number eight among 178 states globally with unique poverty, conflicts and the double burden of communicable and non-communicable diseases [10]. Therefore, Studying control strategies applied in Sudan in comparison with highly endemic zones in east Africa, Indian subcontinent and south America will help in strengthening these strategies.

### Aim and objectives

**Aim:** To evaluate existing control measures for VL in Sudan and develop a strategy for strengthening these control measures based on an analysis of the evidence around alternative control measures

from similar contexts.

**Objective 1:** To demonstrate the burden of VL in Sudan 1997-2019

**Objective 2:** To analyse the current NLCP management and VL control strategies including diagnosis and treatment, surveillance, vector control, reservoir control and health education, in terms of their weaknesses, strengths, and barriers for their effective working.

**Objective 3:** To assess control strategies in other similar settings with endemic VL, and based on these identify appropriate interventions for strengthening the identified problems with the existing control measures in Sudan.

**Objective 4:** To identify requirements for successful implementation of the recommendations for strengthening the control of VL in Sudan.

### Stakeholders and intended use

The study is mainly designed to be used by the Ministry of Health (MoH) and Kala-azar partners WHO, MSF, DNDi, KalaCORE, ASCEND, Institute of Endemic Diseases, LEAP, Sudanese academia and medical associations.

### Authors' interest in the topic

I have worked in the field of Leishmaniasis 2010-2015 with Medecins Sans Frontieres (MSF) in the highly endemic states in Gedaref state and Sinnar state, I have witnessed the suffering of the people and I would like to participate in finding reasonable analysis for problem in Sudan along with suitable possible interventions to strengthen Sudanese capacity to fight the spreading Disease.

### Summary

In this chapter, I introduced and gave a background to VL in the world, including Sudan. I also indicated the Aim and objectives of the study, the rationale of the study, stakeholders involved in VL,

and my interest in the topic. In the next chapter, I will discuss the methodology for this study.

## METHODOLOGY

This chapter will discuss the methodology of this dissertation. It describes and justifies the conceptual framework and the analytical tool used in the situational analysis and the analysis of interventions in the net chapters. It also describes the data source, search strategy, and study limitations.

### Type of the study

This dissertation is an in-depth secondary data analysis from literature and unpublished data from relevant sources mentioned below. Due to scarce literature on this neglected tropical disease, I used relevant data from a similar context of VL endemic countries and personal communications.

### Conceptual framework

The conceptual framework is adapted from WHO building block and strengthening health system/program framework [11,12]. (Figure 3).

#### Description of the conceptual framework:

- **Inputs and process:** it includes the National Leishmaniasis Control Program (NLCP) leadership, Governance, and Finance as cross-cutting factors for the management of NLCP. Service Delivery: and access to treatments and diagnostics, which in the scope of this study, is represented by VL treatment centres. The focus of analysis and intervention will be on the inputs and outputs.
- **Outputs:** In this study, the outputs of NLCP are represented by the top five out of twelve WHO recommended priority strategic approaches to control leishmaniasis and the five broad priority areas for controlling leishmaniasis [13]. Furthermore, I have chosen these five because of interest, relevance to Sudan VL endemicity, and because NLCP used them in the 2016-2020 VL control plan and, Sudan NTDs master plan [14,15]. These five priority areas are:
  - » Early case detection and treatment

- » Surveillance
- » Vector control
- » Reservoir host control
- » Health education and community mobilization
- **Outcomes:** This representing the outcome indicators for the NLCP VL control plan 2016-2020 [14].
- **Impact:** This is representing the overall goal of the NLCP VL control plan 2016-2020.

Note: The outcome and impact mentioned to mirror the NLCP plan and for the consistency of the M&E framework. However, in-depth analysis and possible intervention will focus only on inputs and outputs.

**Justification and use of conceptual framework:** The original framework developed by WHO to create a common monitoring and evaluation (M&E) framework to help to strengthen developing countries' health systems and programs [12].

I found it relevant to this study's objective since it shows how inputs and processes mirrored in the outputs, which in turn reflected in outcome and impact. Overall, I see it simplify the main points of the discussions and possible interventions for strengthening the NLCP.

### Analytical tool

In chapter four, I will make use of four options appraisal criteria's defined below to assess the proposed interventions and to make recommendations based on the identified effective/feasible interventions [16]:

- **Technical effectiveness:** How well it is effective in controlling the leishmaniasis or supporting the NLCP.
- **Organizational feasibility:** How easy to implement the intervention in Sudan.
- **Gender, culture, and political study,** the outputs of NLCP are represented **feasibility:** How acceptable to community, leaders, and organization or government.
- **Financial feasibility:** This assesses the cost of resources

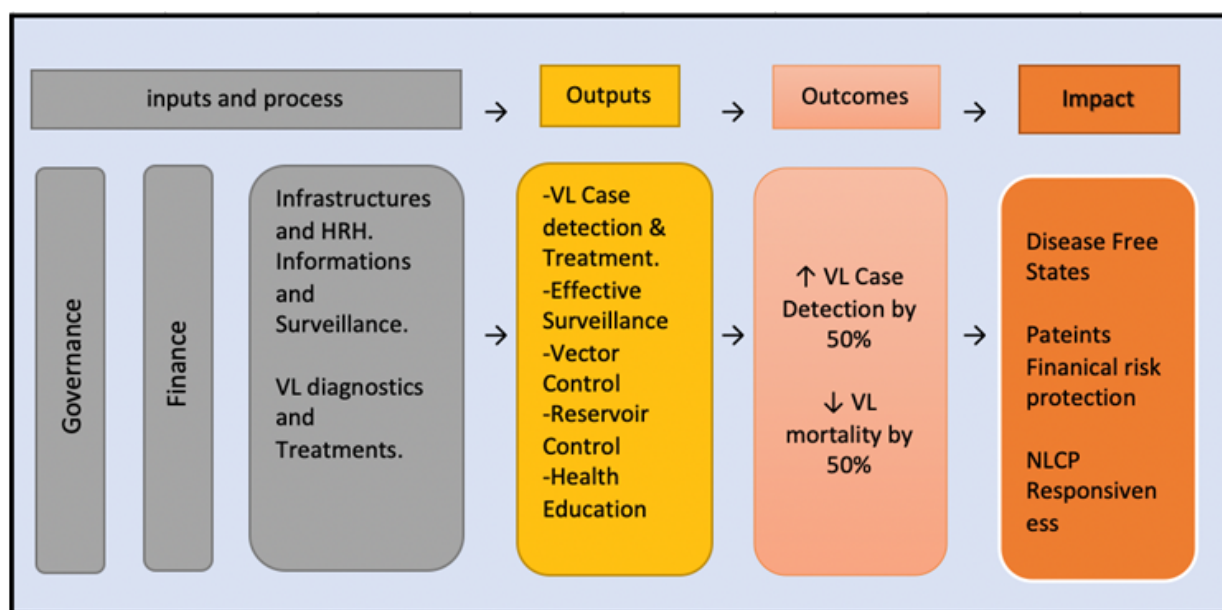


Figure 3: Conceptual framework.

(human, financial, and material) required for implementing the intervention. It also considers cost-effectiveness.

### Source of data

There are two primary sources of data used in this dissertation:

#### 1. Secondary data from literature sourced below:

**Databases-** Two sources examined the PubMed and Global health. These two used because they provide access to a wide collection of literature on tropical medicine and public.

**Search engine-** Google Scholar. This engine is used because it provides access to a wide range of literature on tropical medicine and public health. I use combinations of the keywords used for databases search, and I also used it to snow-balling specific references that I got from databases and websites.

**Websites-** WHO, KalaCORE, DNDi, and MSF. These websites used because it provides relevant literature on the dissertation topic, representing major stakeholders of Leishmaniasis in the world. I also searched the Sudanese FMOH websites.

**2. Personal communications:** Because of limited access and availability of updated MoH resources on Leishmaniasis, personal communication with Sudanese NLCP coordinator Dr Musab Alhaj and WHO/KalaCORE Leishmaniasis control manager Dr Atia Abdalla was done in order to find the latest update on VL in Sudan [17,18].

**3. Books:** The university of Leeds library and my library used.

**Search strategy-** The Databases searched using the terms above, and the combination is done using OR and AND, as seen in the Table 1.

Google Scholar also searched using combinations of keywords above (#1, #2, #3, and #4). It was also searched for the snow-balled references from articles and literature. It searched for specific evidence for options appraisal terms like “Financial feasibility” and “effectiveness,” etc. for the relevant identified interventions.

The Websites were manually searched for specific information on the VL control and VL updates in endemic countries.

I used EndNote to organize references and to remove the duplicate. The literature was also screened using the inclusion and exclusion criteria listed below. All these are illustrated in the (Figure 4) PRISMA diagram below adapted from [19].

#### Inclusion criteria:

- Articles and literature relevant to the dissertation topic
- Accessible full articles

- No time limitation
- Articles and literature are written only in the English language
- Literature from credible sources: websites and journals

#### Exclusion criteria:

- Literature or articles not written in English
- Articles not available in accessible full text
- Articles focused on clinical trials for VL treatments and diagnostics that are not relevant to the dissertation topic

#### Study limitations

The FMOH data are scarce and of minimal access. This limitation was mitigated by making personal communications and using unpublished materials from individual sources at FMOH and WHO in Sudan.

Only one option was in-depth analysed per intervention.

Other limitations include scarce publications on VL, especially in Africa, and articles not written in English that could not be reviewed.

#### Summary

This chapter discussed the type of the study, the conceptual framework, the analytical tool used in this dissertation. And, source of data, search strategy, and the study limitations. The next chapter will focus on the situation analysis of VL in Sudan.

## SITUATION ANALYSIS

In this chapter I analyse VL situation in Sudan making use of WHO strategic framework for leishmaniasis control described by with focus on National Leishmaniasis Control Program (NLCP) management and five priority Leishmaniasis control strategies [13].

### National Leishmaniasis Cotrol Program (NLCP) management

During 1909-1913 the Sudan Kalazar commission was established in response to the first VL case detected in 1908 [20] then it was not clear who was taking care of the VL despite 14 primary outbreaks documented in 6 Sudanese states during the period 1928-1994 [9]. In 1996 The NLCP was established as part of the endemic disease department, together with schistosomiasis, guinea worm, sleeping sickness, and zoonotic diseases. In 1998, the NLCP was declared as a separate program and a national program coordinator assigned. Since September 2001, the program has been integrated with the National Malaria and Schistosomiasis Control Programmes within the Ministry of Health. In 2013, the NLCP became under the Neglected Tropical disease department within the MOH, with other control programs of neglected tropical disease. Currently, the

**Table 1:** Seasonal variations effect on malaria distribution.

No.	Search terms/Keywords	Databases and Number of results	
		Global Health	PubMed
1	Visceral Leishmania OR VL OR Kalazar	3821	2209
2	Prevent OR Control OR Elimination	454672	267590
3	Sudan	3187	4594
4	East Africa OR South Sudan OR Ethiopia OR India OR Bangladesh OR Nepal OR Brazil	46201	53403
5	# 2 OR #3	66321	45898
6	#1 AND #2 AND #3	13	8
7	#1 AND #2 AND #4	47	53

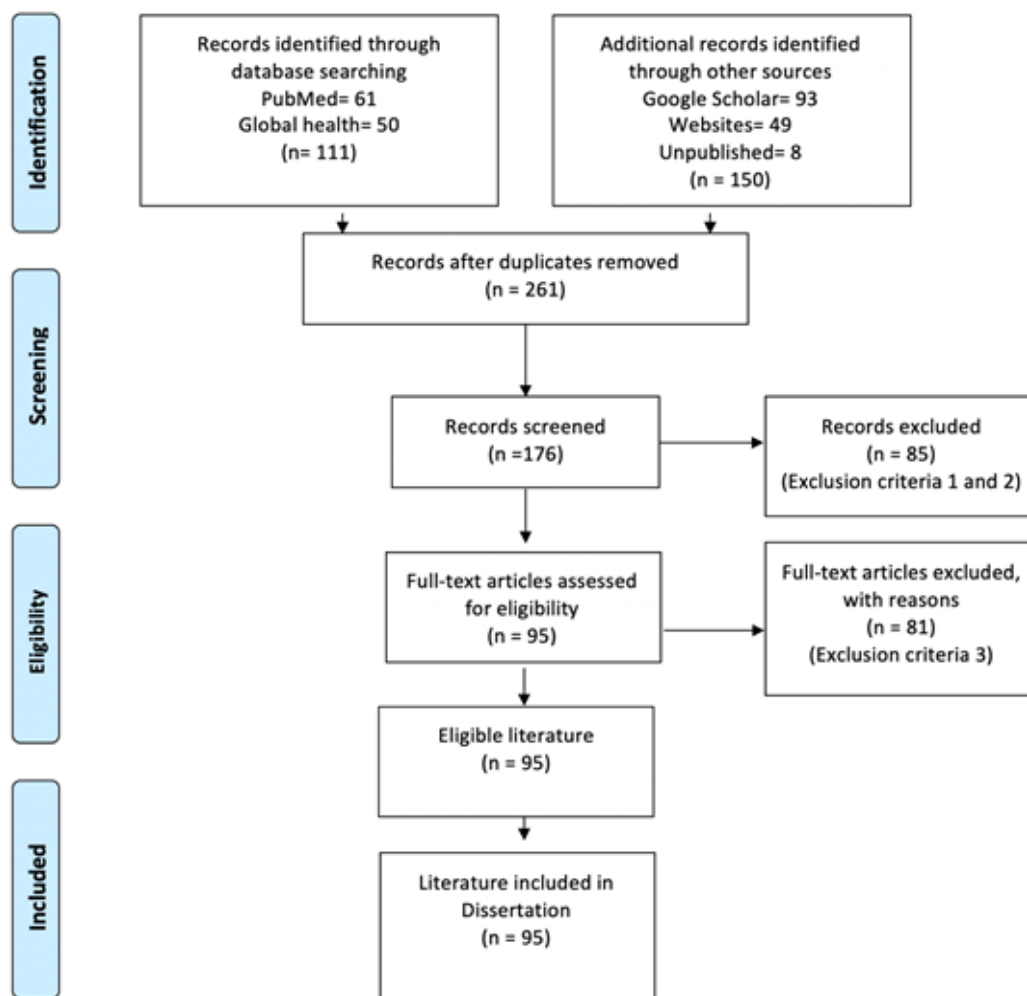


Figure 4: PRISMA flow diagram.

program has 12 coordinators in the 12 states responsible for 44 treatment centres, with annual coordination meetings taking place at FMOH. The treatment centres are mainly rural hospitals, and few referral teaching hospitals with VL diagnosis and treatment are only part of these facilities' functions except for three centres.

Historically the partnership established with WHO in building the national leishmaniasis program like in other countries. WHO role in Sudan can be summarized in Capacity building, technical support in developing evidence-based diagnostics and treatments and effective surveillance which was further enhanced by pooling funds like earliest Leishmaniasis Spanish fund and later KalaCORE fund.

Besides WHO, the program partnership includes university of Khartoum which is directly involved through the Institute of Endemic Diseases (IEND) based in Khartoum and its research centres in VL endemic region in Gedaref state that technically and financially supporting Kassab hospital, and Professor Alhassan Tropical Diseases Hospital. The national collaboration includes other academic institutes, including Ahfad university for women in which VL diagnostics researches take place, and they founded and produced the recognizable Direct Agglutination Test (DAT) for VL. And recently, The University of Gedaref and its Kala-azar research centre.

Medecins Sans Frontieres (MSF) started supporting Visceral leishmaniasis treatments, diagnostics, researches, and epidemic response from 1989 to 2020 [21,22]. The Drugs for Neglected

Diseases Initiative DNDi founded 2001 by MSF in Geneva, and later in 2003, the DNDi founded the Leishmaniasis East Africa Platform (LEAP) for strengthening leishmaniasis researches capacity in east Africa [23]. It is worth mentioning that the MSF and later the DNDi, Institute of endemic diseases, and Ministry of health formed the historic partnership for the Leishmaniasis in Sudan and represent the main pool for researches and clinical trials. Another partner, KalaCORE, 2015-2019, which is a DFID funded initiative for reducing the health and economic impact of VL in 6 hyperendemic countries, including Sudan [24]. The NLCP is currently supported by Accelerating the Sustainable Control and Elimination of Neglected Tropical Diseases (ASCEND), a DIFD fund 2019-2022 for four NTDs, including Kala-azar; it provides first-line treatments and diagnostics beside other activities [25]. The future support to Kala-azar is uncertain, with no actor identified to replace ASCEND.

One of the most important findings in the NLCP analysis in Sudan is the lack of leadership, governance and resources allocation as a cross-cutting issue that hinders the program and limits its effect to only a few outputs. Firstly, this was evident in very quick program reforms that resulted in scattering of information in different MoH directorates. Secondly, the NLCP failed to set and monitor a clear policy or strategy since inception and it seems a persistent problem with in health sector according to [26] and, I couldn't find any policy or strategy before 2016 a part from tentative annual plans. Thirdly, The NLCP is still heavily dependent on external support and the resources available before KalaCORE support were enough

to support first line drugs only two states out of twelve [17].

**Analysis of NLCP based on WHO specific priority strategies**

**Case detection and treatment:** The historical approach to control VL in Sudan mainly focuses on case detection and treatment [15,27] with no other routine activities to control VL, as we will see below. The treatment and diagnostics offered for free in treatment centres run by either FMOH or partners mentioned earlier in the endemic states; Prof A. Elhassan, the national pioneer of leishmaniasis researches, indicated that anti-leishmaniasis treatment 30 years ago was expensive with black market exist at different points before the collaboration with partners [28].

The FMOH 2016-2020 strategy has two main objectives: to increase VL case detection by 50% and decrease VL mortalities by 50% with a mortality baseline as 1.04% the average of 2011-2015 [14]. To achieve good coverage, the treatment centres witnessed tremendous efforts from FMOH and partners with the expansion of free diagnostics and treatment services from 10 centres in 4 states around 2010 to 44 centres in 12 states 2018 besides 22 decentralization site for identification and referral of VL suspects mainly in IDPs/Refugees camps and remote villages [18]. However, access is still an issue of concern in some parts with gender inequalities where women require permission from their spouses to visit the clinics [29]. Furthermore, financial issues exist since patients have to pay for other costs apart from diagnosis and treatment e.g., comorbidities diagnosis/treatment, food and hospitalization and the locals' negative perception on public facilities seeing it as lacking diagnostics and treatment beside other wrong believes that negatively affect health-seeking behaviour [30].

The strategic objective for increasing passive case detection was based on the fact that with FMOH and partners' efforts in supporting 44 treatment centres the cases reported will increase, however, taking the average of 2012-2015 VL cases of 2950 and 2016-2019 average of 4358 we see that the case detection increased by 11%. Still, the average mortality increased to 2.4% for the same period (Figure 5). This means it is very unlikely to meet the program objective in 2020.

Out of the ten priority Neglected Tropical Diseases NTDs in Sudan, the federal ministry of health targeted VL in the NTDs master plan 2017-2020 under the global goal of diseases for which disease-free

areas can be expanded [15]. Besides the 2016-2020 objectives few more indicators were added, including the percentages of vector control, surveillance, and mapping by states, percentages health education, and rates of drug procurements and distribution.

The WHO road Map for NTDs 2021-2030 [31] had put a Target for Elimination of VL as Public Health Problems by 2030 with a target indicator of less than 1% Death among Primary Kala-Azar patients; long Battle still awaiting MoH in Sudan.

**Leishmaniasis Guidelines:** The FMOH, WHO, and partner collaboration have brought new diagnostics and treatment regimens together with periodic national leishmaniasis protocol updates in 2004,2014, and 2017 and training [32]. Concerning the diagnosis, the program was depending mainly on invasive techniques for microscopic examination of the spleen, bone marrow, or lymph node aspiration, which require adequate training and serious quality control. But following 2010, it was validated to use DAT, and rk39 RDT along with standard case definition for VL suspects [32]. Analysis for leishmaniasis country profile 2015-2017 showed that in average 82% of VL diagnosis made by RDTs and 18% by microscopy with technicians tend to do more microscopy than RDTs [33-36]. The diagnostic algorithm and treatment were incorporated in the manual for diagnosis (APPENDIX ONE) and treatment (APPENDIX TWO) of Leishmaniasis that intended to be used by all partners in Sudan as simplified standards for leishmaniasis diagnostics, treatments and control protocols.

On the same line, the program was depending mainly on Sodium stibogluconate (SSG) injections as first-line VL treatment for 30 days or more before 2010. Now new short 17 day SSG/PM combination regimens have been introduced that not only increase the efficacy of treatment but also reduce the duration of costly drugs and reduce drug toxicity and reduce the chance of developing resistance [32]. Moreover, the program validated Ambisome intravenous drug as second-line treatment plus other few options for companionate therapies. However, the treatment should be administered only in the hospital to monitor patients for these toxic drugs' possible complications and treat the comorbidities, which can further complicate the treatment and delay cure [32]. The MSF hospital study showed that although SSG/PM is undeniable progress, it remains suboptimal as a first-line regimen in Sudan because many patients are excluded from taking or continuing SSG/PM due to

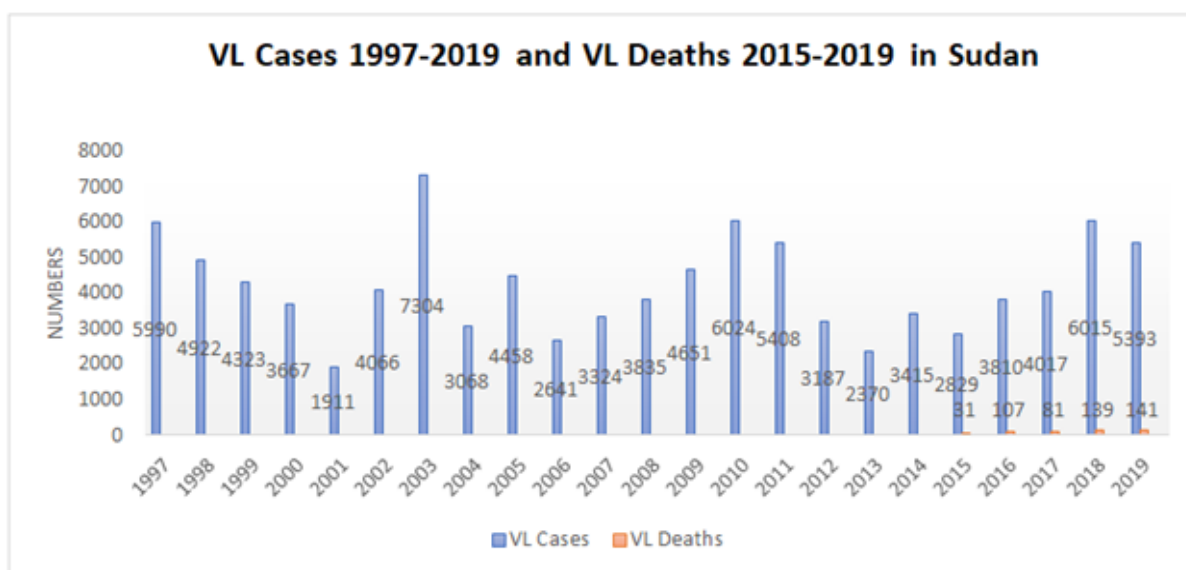


Figure 5: VL cases in Sudan 1997-2019 and VL Deaths 2016-2019.

safety concerns [37]. These facts necessitate the development of new drugs and regimen to improve VL treatment in Sudan.

The program worked efficiently with partners in updating the protocols, training for staff and communicating the updates to the medical institutes to be included in the curriculum. However, 2017 evaluation showed that 80% of staff at VL treatment centres not sticking to the protocol [36]; this assessment found that staff at 36 centres are following neither the diagnostic algorithm nor treatment protocols beside lousy management for the drugs store and inadequate infrastructure that forced the team in some centres to treat patients ambulatory. Which, in my opinion, may result in an inaccurate diagnosis, wrong unnecessary medication, the over or undertreatment and drug resistance. In my opinion these issues are mainly due to lack monitoring capacity.

**Drugs procurement and distribution:** The WHO started Amphotericin b (AmBisome) negotiated price donations 2011-2020 (WHO, 2020). For the other SSG and PM drugs and rk39 diagnostic RDT, the leishmaniasis control program currently get support from Accelerating the Sustainable Control and Elimination of Neglected Tropical Diseases (ASCEND) [25]. These mechanisms helped a lot in fighting the disease in Sudan not only because of poor health finance but also because of the USA embargo as well [17].

The NLCP coordinator supported by the state leishmaniasis coordinators are the focal persons to estimate the drugs and diagnostics supply order based on real surveillance data estimates, and they are responsible for proper storage and distribution to all treatment centres. Challenges include short shelf life for rk39 diagnostics and cold chain storage for Ambisome, and tremendous efforts are to be made to ensure the quality of the supply chain, especially for remote centres [2]. In 2017, health facility assessment conducted to 36 VL treatment centres found that 67% of these centre experienced stocks out for the first-line treatment drugs and diagnostics leaked to the black market [29].

**Surveillance:** Sudanese Leishmaniasis control program followed the WHO recommendation for global leishmaniasis surveillance using VL patient form. Currently, the 44 treatment centres are reporting monthly to the federal ministry of health, but despite the training and tools made available for District Health Information System 2 (DHIS2) the system for web-based electronic surveillance is not fully functioning yet but Sudan Leishmaniasis country profile 2016-2018 published by WHO in 2019 for the first time [17]. Hoogstraal and Heynemann first did risk mapping in 1969 and Zeese and Franke 1987 with the first detailed GIS produced in 2003 in which detailed Gedaref state mapping done [38]. Currently, Gedaref state that represents 80% of VL burden in the country is fully mapped and updated by villages. With the recently established sentinel sites, the country maps were updated as well, which provides information for control measures and epidemic preparedness. (APPENDIX THREE) shows VL incidence based on 2016 surveillance data, and it is missing two new foci in two new states, namely Kassala state and Red sea state, which included in leishmaniasis program in 2017.

**Vector control:** Sudan adopted the WHO strategic approach for prevention and control of vector-borne disease 2005 and since then has integrated vector management (IVM) department at the ministry of health. VL is the second out of ten high burdens vector-borne disease in Sudan with a known primary vector *Phlebotomus Orientalis* that is associated with *Acacia seyal* and *Balanites*

*aegyptiaca* trees and black cotton soil, however, transmission dynamic not well elucidated yet with researches suggesting existing both anthroponotic and zoonotic transmission [38,39]. In spite of that, a joint MoH and WHO assessment indicated that apart from malaria, the country had no strategic plan for vector control or routine entomological surveillance before the 2014- 2018 plan [39]. Nevertheless, campaign-based aerial spraying of insecticides and indoor residual spraying is carried out in the eastern part of the country for the control of visceral Leishmaniasis. Still, it is not supported by operational research and evaluation of the impact of vector control interventions. The latest publication by the integrated vector management departments indicates that the leishmaniasis vector control activities are confined to only two states Gedaref and Blue Nile, out of the 12 endemic states [40]. One of latest achievement for the IVM department is the establishment of routine entomological surveillance in 106 sentinel sites in the 12 endemic states for leishmaniasis vector that enabled MoH monitoring density of the sand-fly indoors and outdoors and supported the control efforts [40].

**Environmental management and personal protection:** WHO indicated that environmental management might result in reducing sand-fly and human contact if the vector is well studied, and measures could be a relocation of human settlement away from vector habitat or vector habitat modification. It should be preceded by

ecological studies and environmental impact researches [13]. Despite the researches in the last 70 years incriminating the vectors in east Africa still, outstanding problems exist with regard sand-fly breeding and resting sites and understanding its ecology, not well known; however, locals used to cut trees without evidence, and this is not recommended by the Leishmaniasis control program [30,41].

Following MSF mass distribution of Insecticide Treated Mosquito-nets in 1999 in hyperendemic villages of Gedaref state in east Sudan an MSF study found that it provides 27% protection in reducing the incidence of VL which is consistent with findings of [42-44]. Accordingly, using ITN, repellents and protective clothing are the only measure promoted by the National Leishmaniasis Control Program to provide personal protection in the absence of vaccine in the shortcoming future [32].

**Control of reservoir host:** In 1914 Scientists suggest dogs, monkeys, rodents, and rats play a role in VL transmission in Sudan [45]. Furthermore, indicated that the parasite maintained by reservoir hosts because of repeated outbreaks in Sudan [46]. However, the lack of knowledge on animal reservoir remains a gap in VL epidemiology in Sudan although [47,48] suggested dogs and Egyptian mongoose to play a role as possible reservoir host but confirmed that Dogs are more attractive to sand-fly than mongoose and Nile rats [49]. That means to date, it is not confirmed the exact role of animals in VL transmission in Sudan and, therefore, no official plans for reservoir host control while in hyperendemic areas of Gedaref state still dog culling campaigns are organized by the locals from time to time. Accordingly, the Leishmaniasis manual indicated that there is evidence that wild animals and dogs, in particular, can be infected but doesn't demonstrate whether dog a reservoir or a dead-end host, therefore, culling dogs not to be promoted [32].

**Health education community participation:** Despite the fact that Gedaref state is highly endemic by VL the found that the people know little about VL and they seek medical attention after failing



traditional remedies and basic allopathic drugs [50]. Moreover, revealed that misconception still exists in highly endemic villages of Kalazar [30].

Except for annual scant educational campaigns in Gedaref state there is no strategic plan for VL health education before the comprehensive one developed by KalaCORE, FMOH and partners that conducted with support of local NGOs in Gedaref state, Sinnar state, South Sudanese refugees camps in Kordofan and Darfur and at national level only accompanying public events in 2017-2018 [51,52]. Like many other external partners supported activities the sustainability was an issue for the health education activities with no clear funds available after 2019

**Summary**

In this chapter, I analysed the situation of VL in Sudan. The VL involved both zoonotic and anthroponotic transmission with a huge gap in knowledge. The NLCP, although managed to establish partnerships, still have management barriers represented by poor governance and leadership. The NLCP focuses mainly on case detection and treatments that is improved but still not efficient. Other control strategies surveillance, vector control, reservoir control and health education lack fundamental inputs and knowledge to ensure their efficiency.

**ANALYSIS OF FINDINGS**

In this chapter, I will systematically analyse possible interventions to strengthen the National Leishmaniasis Control Program (NLCP) in two parts: the first one is strengthening NLCP management as across-cutting factor and the second part to strengthen the specific NLCP five VL control strategies VL case detection and treatment, surveillance, vector control, reservoir host control and health education.

The conceptual framework explained in chapter two adapted from is modified (Figure 6) to indicate the possible intervention needed to strengthen the inputs and outputs which in turn reflected in the program outcomes and impact [12]. And, criteria explained

in chapter two will be used to analyse the feasibility of these interventions [16].

**Intervention to strengthen NLCP management**

This section will specifically address the findings related to the program's lack of governance and leadership, financing, and information as the essential cross-cutting factors that impacted poor functioning NLCP.

The proposed intervention is to establish and consolidate the monitoring and evaluation unit as a fundamental intervention at the NLCP; this ensures strategies, policies, and financial systems are working well in a program heavily dependent on external support. The world bank publication indicated that [53];

“Monitoring information and evaluation findings can contribute to sound governance in a number of ways: evidence-based policy making (including budget decision making), policy development, management, and accountability.”

- **Technical Effectiveness:** WHO, indicated that leishmaniasis control program should have M&E for the better management of the program [13]. The WHO has created a monitoring and evaluation guidelines for the VL elimination strategy in the Indian, Bangladesh and Nepal, and it was effectively used [54]. Through M&E, these three countries were able to assess its policy and the combined VL elimination strategies continuously, and in 2016 Bangladesh achieved the elimination target; In 2017, Nepal achieved the target, and in 2018 all Indian endemic districts achieved the target except one [55]. Other programs include the Global Fund for fighting TB, HIV/AIDS, and Malaria have also benefited from M&E units in developing countries including Sudan [56]. There is annual Kalazar coordinators meetings and introducing M&E indicators will definitely increase the productivity of ongoing monitoring and periodic or even annual evaluation. The organization for Economic Co-operation and Development (OECD) indicated that policy M&E could enhance accountability, learning, and

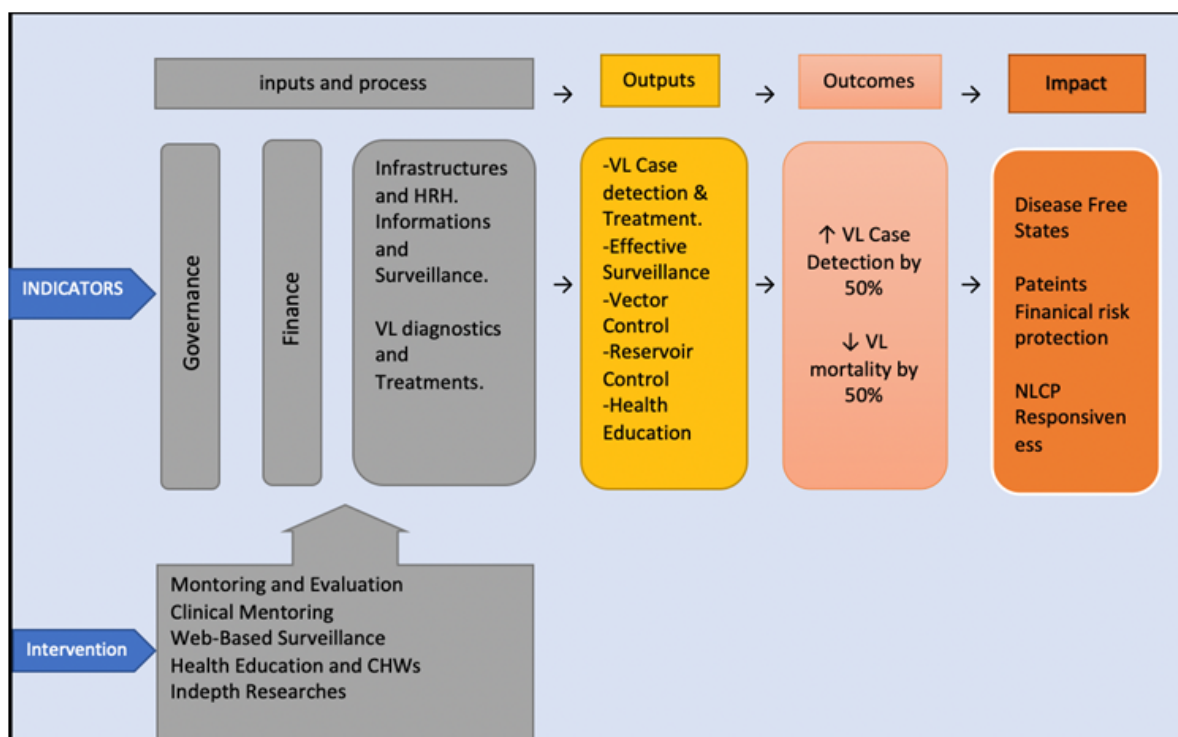


Figure 6: Conceptual framework with interventions.

policy efficiency and effectiveness [57].

- **Organizational feasibility:** The disease control directorate M&E unit and the M&E is always an essential component of TB, HIV/AIDS, and Malaria control programs in Sudan; Therefore, all MoH officials are familiar with it. Hence it can be easier to organize. The KalaCORE Implementation of VL monitoring and evaluation for VL facilities in India, Bangladesh, Nepal and Ethiopia was very successful [55].
- **Gender, culture, and political feasibility:** The study conclude that the monitoring and evaluation in South Sudan significantly contributed to the development of health sector programs with some required flexibility and adaptability to the post-conflict setting [58]. South Sudan is a similar context to Sudan; therefore, diplomacy might be necessary when implementing the system in some Sudanese states like Darfur.
- **Financial feasibility:** The M&E can't be cost-effective unless it improves the efficiency and effectiveness of the program [53]. The M&E budget generally ranges from 3% to 10% of the program budget [59], and learning from M&E experience of other countries and programs can be an excellent tool to find suitable and costless system [53]. Accordingly, allocating budget for M&E should be dealt with at the planning phase between MoH and stakeholders, and the presence of M&E unit at Federal MoH will be more feasible than diluting responsibilities among twelve states Kalazar coordinators.

#### The NLCP VL control strategies interventions

In this section, I will discuss and analyse the VLCP five specific VL control strategies. These affecting factors/findings together are indeed impacting the program's outputs, outcomes, and impact, and therefore, the attainment of intended goals.

**VL case detection and treatment:** Taking the example of India, Bangladesh and Nepal countries that have same burden of VL comparable to Sudan [60]. The VL elimination strategy in India, Bangladesh and Nepal [61] adopted five pillars for the elimination namely early case detection and treatment, integrated vector management mainly IRS, effective surveillance, health education community and researches. The VL elimination was feasible because of evidence-based effectiveness of single dose of Ambisome as first line treatment, effectiveness of oral drug Miltefosine, high efficacy of rk39 RDT and presence of only anthroponotic transmission [61]. In contrast single dose Ambisome was not effective in east Africa and diagnostic perform less in Africa, which make elimination not yet feasible [62].

And despite WHO negotiated prices still expensive for national programs in East Africa and Sudan, the program mainly depends on external partners' support [63]. Some barriers related to scarce VL commodities manufacturers can be solved by effective collaboration internationally [63]. However, some barriers to the ineffective supply chain and guidelines implementation are related to strengthening NLCP capacity and effective coordination at the national, state, and locality levels. The proposed intervention is to generalize the KalaCORE initiative 2017-2018 of VL Clinical mentoring teams with the below objectives [36]. Team composition: One doctor, one nurse, and one lab technologist:

- » Provision of on-the-job training and mentoring on VL case management, stock management and reporting at 44 VL treatment centres

- » Enhance better coordination between VL treatment centres to ensure proper management of drugs and diagnostics stock
- » Health education and community mobilization
- » Support research activities

- **Technical effectiveness:** DNDi study [64] confirmed that clinical mentoring teams achieved a significant impact on VL control in Sudan, South Sudan and Ethiopia. The enhancement of regular supervision and training conducted by the mentoring teams qualified health workers has improved the quality of diagnosis and treatment in the region and minimize the limitations of diagnostics and treatment regimens. The mentoring teams experience in reaching challenging to reach places in Sudan like Darfur, and remote areas are very encouraging [65].

- **Organizational feasibility:** The mentoring teams organized in Gedaref state with the support of the university of Gedaref can be easily generalized in other states [66], firstly because each state has a governmental school of medicine, school of nursing and school for medical laboratories. Secondly, these universities have community and health development commitments [67] and, thirdly that these schools had a successful partnership with MoH, NGOs, and UN agencies in strengthening health services [68].

- **Gender, culture, and political feasibility:** The VL mentoring teams at Gedaref state were welcomed and supported by the state governor [55] This could be interpreted as validation and facilitation to it is activities as per the culture in this context. Recruiting the teams at state levels will help reduce cultural barriers and improve retention [67]. Historically male health workers migration is predominant [69] in Sudan and generally women health workers are more stable and culturally accepted in health sector in particular.

- **Financial feasibility:** The teams organized at Gedaref university were in collaboration with WHO. There is no cost-effectiveness study conducted for similar activity; however, decentralization for mentoring activity and empowering the state and locality's supervisory role can reduce the burden on the federal resources. The fund is required from international stakeholder's support since mentoring teams stopped after ending KalaCORE support in 2019.

**Effective VL surveillance:** One of the factors favoured VL elimination in the India subcontinent was the detailed mapping of the disease by districts and subdistrict [61], which is not the case in Sudan. While, the latest published surveillance monitoring report showed 91% of the treatment centres reported with 76% completeness and District Health Information System (DHIS2) not yet implemented and questionable sustainability of funding after 2018 [18,70]. The proposed intervention web-based surveillance is not only valuable for monitoring the VL burden by districts but also for appropriate drugs and diagnostics management.

- **Technical effectiveness:** DHIS2 is a free open source, a web-based software platform for data collection, management, and analysis. It is in use by more than 72 developing countries and international organizations and some EU programs [71]. While it helped improve timely surveillance completeness in Lebanon [72], it was found appropriate for multi-country programs and by 2018 VL cases were successfully captured on real time via DHIS2 in Bangladesh [73,74].

- **Operational feasibility:** The DHIS2 was developed by the University of Oslo in collaboration with WHO [71], and supported by a global network of software developers and implementers [73]. The DHIS2 is already in use by many ministries of health, including Sudan, for routine data and the training already done to integrate leishmaniasis into the system [17].
- **Gender, culture, and political feasibility:** The Electronic government (E. Gov) for using the internet in official duties strategy was validated earlier in Sudan. And, 2014 Sudan was ranking 154 and although slowly progressing [75]; However, with existing young health generations of health workers as strength of MoH can be successful in ministry of health [26].
- **Financial feasibility:** A DHIS2 platform is a free tool with technical support from WHO and the ministry of health supporters like GAVI, Global Fund, and UNICEF [71]. The tools, including desktops and training, were provided by WHO [18]. The DHIS is a friendly user with mobile phones application that is widely used in Sudan.

**Vector control:** The Possible major interventions include reducing vector density by Insecticide Residual Spraying, Insecticides Fogging or reducing human-vector contacts using Insecticides Treated Nets (ITN) and environmental modification.

- **Technical effectiveness:** The indoor IRS was effective in India, Bangladesh and Nepal. The Indian subcontinent successfully used the WHO Monitoring and Evaluation toolkit for indoor spraying [54,76] involving evidence-based activities. While found that vector rarely found resting or biting indoors in Sudan the study indicated that majority bite indoors [77-80]. A recent study found that a new approach, a single application of deltamethrin Out-Door Residual insecticide Spraying (ODRS) to the boundary fence and exterior hut walls, resulted in an 83-99% reduction in vector numbers in Gedaref state in Sudan [81]. And, a Restricted Out-Door Residual insecticide Spraying (RODRS), whereby insecticide was applied only to the boundary fence resulted in 60%-88% reduction. The study was based on that the vector is predominantly an exophilic/exophagic, meaning rest/feeds outdoors. However, the critical threshold in sand fly abundance to achieve protection against transmission and VL is unknown. On the other hand, using ITN was found effective in providing some VL incidence reduction in Sudan and Bangladesh [42,44,82]. But, ITN require behavioural changes and sustained health education mentioned in same articles. Regarding environmental modification explained that less endemic villages in East Sudan could be due to the fact that villagers who settled earlier replaced Acacia seyal and Balanites aegyptiaca trees by Azadirachta Indica, which has anti-leishmania repellents [83]. However, mentioned that the ongoing trees cutting require further studies while pointed to study mobilization of villagers away from highly endemic villages [28,84].
  - **Organizational feasibility:** The IRS is an ongoing activity in Sudan done by IVM unit in two states out of twelve VL endemic states [40], with more than qualified 62 entomologists working in IVM in Sudan [85]. However, no evaluation made to study effectiveness or feasibility [86]. The mass distribution of ITN done in Sudan by MSF in 1998-2000 and since then, I couldn't find evidence for regular distribution or evaluation [42]. On the other hand, the environmental modification remains complicated and difficult to implement compared to IRS and ITN distribution [87]. The study indicated that outdoor insecticides spraying is more feasible than the ongoing activities of IVM [79].
  - **Gender, culture, and political feasibility:** The IRS against VL is always conducted in Sudan because of political reasons despite non availability of good evidence [86]. In addition, social barriers regarding acceptability that require behavioural change interventions according to similar Malaria Program experience in Sudan [88]. Same behavioural change intervention found to be required to enhance utilization of ITN by Sudanese [89]. Compared with ITN, Compared with ITN, the outdoor spraying is high likely to be accepted by the local communities because they used to IRS and have issues against ITN.
  - **Financial feasibility:** The found that environmental modification as costly compared to IRS and ITN in India [87]. Due to the huge knowledge gap concerning the VL vector biology and ecology in Sudan and other barriers concerning possible intervention implementation, I propose studying the impact of ODRS on VL incidence and transmission.
  - **Conclusion:** Due to the huge knowledge gap concerning the VL vector biology and ecology in Sudan and other barriers concerning possible intervention implementation, I propose studying the impact of ODRS on VL incidence and transmission.
- Control of reservoir host:** Unlike the Indian subcontinent and Brazil, where VL transmission is mainly anthroponotic and zoonotic, respectively, Sudan is predominantly anthroponotic with the zoonotic transmission that exists but not well understood [32]. The reservoir host control is concerning only zoonotic cycle referred to in chapter one (Figure 1) as dog cycle.
- **Technical effectiveness:** The known strategies including dog culling or insecticides-impregnated dog Cervical collar were both used in Brazil because it is zoonotic transmission and host reservoir is well studied and known [90]. Unlike Sudan, in which dogs, monkeys, rodents, and rats were suggested as possible host reservoir but never confirmed yet [45,47,49]. Using impregnated cervical collars in Brazil found very effective in control the disease compared to dog culling which was in use since 1950 and has limited impact [91,92]. Even if dogs confirmed as reservoir host in Sudan using any repellents for animals found to be a risk factor by because sand-fly can feed directly on human blood [84].
  - **Organizational feasibility:** The proper implementation requires intra-sectoral and intersectoral collaboration and this is not easy due to achieve due to lacking fundamental knowledge on the host reservoir.
  - **Gender, culture, and political feasibility:** Unlike Brazil where dogs' owners might refuse measures applied to dogs the Sudanese families in highly endemic states are used to randomly organized annual dogs culling campaigns. That means culturally accepted but no evidence behind it.
  - **Financial feasibility:** Due to lack of crucial knowledge on host reservoir the financial feasibility couldn't be assessed.
  - **Conclusion:** Obviously, because of the knowledge gap there are no adequate inputs to address this complex strategy yet

and therefore in-depth researches are required.

**Health education and community participation:** The proposed intervention is to educate people, correct misconceptions, and help in the referral of VL suspects by introducing subsystems of Community Health Workers (CHWs). The CHWs exist in Sudanese ministry of health other programs and NGOs systems and the VL Health Education strategy was piloted for a short duration by KalaCORE [51,93].

The [94] defined CHWs as “Community health workers should be members of the communities where they work, should be supported by the health system but not necessarily a part of the government, and have shorter training than professional health workforce”.

CHWs historically helped in health service coverage, utilization of services and were central in health education [94].

- **Technical effectiveness:** A meta-analysis study found that health education as an effective and valuable tool in community malaria prevention and control in sub-Saharan Africa [95]. In Nepal, the women CHWs had an excellent impact on VL elimination [96]. CHWs historically helped increased health service coverage and utilization of services and fundamental in health education [94]. In my opinion the main barrier will be sustainability of activities and this can be mitigated by recruitment of subsystem of volunteer CHWs and to think on suitable motivation.
- **Organizational feasibility:** KalaCORE, in collaboration with MoH, developed VL HE strategy of mixed approaches interpersonal communication, group communication, and mass media that is implemented by a local NGO 2017 and 2019 [52]. The CHWs worked well in malaria programs in Sudan, and NLCP can make use of these successful experiences.
- **Gender, culture and political feasibility:** The government showed commitment towards HRH and skill mix since 2006, and in 2012 more training was provided to community health workers [93]. The involvement of women in the CHWs subsystem will enhance their role in VL control since children are mainly affected in the Sudan context knowing that 52% of Sudanese health workers are females [97]. According to my experience in vaccination campaigns where women's health workers volunteers are predominant; women are culturally respected and comfortable to educate household members.
- **Financial feasibility:** No cost-effectiveness studies conducted in Sudan in this regard. However, the CHWs system was found cost-effective compared with no CHWs in Tuberculosis control programs in Bangladesh [98]. On top of the fifth progress report on fighting NTDs, many case studies have

shown the cost-effective involvement of community health workers in combating different NTDs and reaching unreached [99].

**Summary**

In this chapter, I discussed the six points raised in the previous chapter. Different six relevant interventions were assessed and four of them, M&E, clinical mentoring teams, web-based surveillance and Health education were identified as feasible. Two interventions, Vector control and reservoir control, found to be having a huge knowledge gap and experience from other contexts like India or Brazil can't be applied without researches due to technical differences in vector behaviour and reservoir, respectively. Accordingly, only researches were proposed to strengthen these two essential points. The below (Table 2) summarises the interventions assessed in this chapter.

**THE STUDY OUTPUTS**

In chapter four I analysed the possible interventions to strengthen the functioning of National Leishmaniasis Control program (NLCP). And, in this chapter I will write conclusion to the study and recommendations for identified interventions. The recommendations will be presented in short- and long-term recommendations along with dissemination plans.

**CONCLUSION**

As a neglected tropical disease firstly diagnosed in Sudan in 1908, the Visceral Leishmaniasis continued to be present in the highly endemic two states Sinnar and Gedaref. Due to the in-effective control measures, VL expanded to 12 states out of the 18.

As explained in different chapters of this dissertation, VL control is not an easy task, and no ready to use identical strategies prove effective everywhere since each country has its slightly different vector, reservoir, and hence the mode of transmission. However, making use of experience in other similar context experience is where strengthening can start.

The analysis showed that similar context countries achieved significant success in controlling or eliminating VL because of strong political commitment, implementing combinations of WHO-recommended VL control strategies, and importantly the evidence-based combined case detection, vector control and surveillance intervention. In contrast, the Sudanese NLCP has serious management neglected barriers. Besides, NLCP focused mainly on case detection and treatment and ineffective surveillance, while vector control, reservoir control, and health education are neglected. Accordingly, no success is expected with the current Sudanese approach unless serious steps are taken to strengthen the management of NLCP and the control strategies.

Table 2: Options appraisal summary.

Intervention	Technical Effectiveness	Organizational Feasibility	Gender, Culture, and Political Feasibility	Financial Feasibility
M&E	++++	+++	++	+++
Clinical Mentoring teams	++++	+++	++	++
Web-based Surveillance	++++	+++	+++	+++
Vector host Control	+	+	+	+
Reservoir Control	+	+	+	+
Health Education/CHWs	+++	++	+++	++

(++++) Highly effective/feasible. (+++) Moderately effective/feasible. (++) less effective/feasible. (+) not effective/feasible (source: Author)

Like many other NTDs in Sudan, the VL is competing for scarce resources; however, with some feasible interventions identified in chapter four and strong partnership support, can improve the VL control program's function and a long battle is awaiting achieving WHO 2021-2030 goal in Elimination of VL as a public health problem by 2030, in Sudan.

## RECOMMENDATIONS

The recommendations below are concluded from the analysis done in this dissertation and divided into two parts, short and long term, based on the implementation time. The successful implementation generally emphasized NLCP accountability and more robust national and international partnerships to implement better the WHO road map for VL elimination as public health problem 2021-2030.

### Part 1: Short term (2-3 years) recommendations

**Monitoring and evaluation:** The NLCP should establish M&E regularly to ensure plans and policies are well followed and to identify and correct problems. Continuous monitoring for NLCP plans inputs, processes, and outputs (Figure 6) through systematic data collection and surveillance will ensure that implementation status is well tackled. It can enable NLCP to find evidence in correcting problems. The evaluation can then be done periodically to see what works and what not works and adjust targets in impact accordingly.

This is a fundamental intervention to ensure accountability for a program heavily dependent on external partnerships and improve NLCP governance that can make better use of existing resources and future resource allocation.

**Web-based surveillance:** The accurate, reliable, and timely knowledge of the VL's magnitude in Sudan can be achieved by establishing web-based surveillance accessible to all stakeholders. The web-based surveillance led by WHO can integrate VL disease, vector, and reservoir host surveillance in one platform. Sudan has skilled human resources to establish web-based surveillance. With time, the surveillance data itself can generate the evidence necessary to support research and plan and update the VL's timely mapping in Sudan. VL diagnostics and treatments can be better controlled by effective surveillance, which can further ensure better usage of the existing resources.

**Clinical mentoring teams:** These small teams can be piloted in highly endemic states from local human resources and can work in synergy with the M&E unit. The objective is to make better use of resources and maximize care quality at VL treatment centres. MoH strong partnership with local academia and international partners is required for the sustainability of these teams.

To facilitate for better planning and supervision for the teams the Clinical Mentoring Teams can be implemented in two phases. Phase one is to focus on Sinnar and Gedaref states and in Phase two to generalize it in all endemic states. These teams would have the potential to cover all NTDs that is widely spread in Sudan.

### Part 2: Long term (3-7 years) recommendations

**Operational researches:** Compared to other endemic countries, Sudan lacks the necessary knowledge to launch effective control measures. The Ministry of Health and partners could focus on research priority areas that are including:

#### » Vector control:

- Sandfly Vector ecology and behaviour studies

are necessary to understand best possible ways to interrupt VL transmission

- Pilot interventions on vector control trials can be established. The impact of outdoor residual insecticides spraying (ODRS and RODRS) on VL incidence and transmission should be prioritised.

» **Reservoir host control:** Reservoir host control: it is unrealistic to diagnose the first case of PKDL in 1921 and remain a mystery till today; the role of PKDL, which is developed by more than 55% of VL cases in Sudan, should be studied in order to orient adequate VL control measures.

» VL Diagnostics and treatment combinations that are effective under field conditions. Importantly the first line diagnostic tests and the first line regimens for VL and PKDL.

**Health education and community participation:** The NLCP should have a clear strategy for empowering poor communities at endemic states and enabling them to own the knowledge necessary to prevent transmission and encourage early diagnosis and treat VL. Clear scientific and culturally sensitive messages on VL education should be channelled through appropriate delivery strategies to correct the existing misconceptions on VL.

CHWs recruitment at the state and locality level with a focus on women will help in Health education activities and reduce the burden of VL that is affecting mainly children in Sudan.

## DECLARATIONS

**Ethical Approval and Consent to participate:** Not applicable.

**Consent for publication:** Not applicable.

**Availability of supporting data:** Most of the data generated or analysed during this study are included in published articles and websites. Some of the Sudanese ministry of health data are not publicly available because it is not published but are available from the corresponding author on reasonable request.

**Competing interests:** The authors declare that they have no conflict of interest concerning this study.

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## AUTHORS' CONTRIBUTIONS

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