National Vector Control Strategy (2023-2027) April 2023

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National Vector Control Strategy

(2023-2027) April 2023

1. Foreword

Dr J Phaahla, MP

Minister of Health

The National Department of Health (NDOH) presents this National Vector Control Strategy 2023-2027 for the Republic of South Africa.

Emerging and re-emerging vector-borne diseases is a cause of concern globally and in South Africa. The proposed National Vector-Borne Disease Strategy is a bold decision by the South Africa government to adapt to the World Health Organization's Global Vector Control Response (GVCR) (2017-2030). The vision of the GVCR is a world free of vector-borne diseases. Priority vector-borne diseases targeted for elimination in South Africa include malaria, schistosomiasis and plague. South Africa is at risk of mosquito-borne arboviral diseases, particularly outbreaks of endemic viruses (West Nile, Sindbis and Rift Valley fever viruses) as well as the importation of chikungunya, dengue and yellow fever viruses.

This National Vector Control Strategy was developed in consultation with a broad range of stakeholders and partners, from provincial malaria programme managers to international partners including the World Health Organization, and technical experts from the South Africa Malaria Elimination Committee. National consultations were held in September 2018, March 2019 and October 2019, to reach consensus on the National Vector Control Strategy framework.

The National Department of Health would like to acknowledge leadership provided by the Directorate of Malaria and Other Vector-Borne Diseases, and participation of all government sectors and stakeholders, the World Health Organization and a WHO consultant who guided the development of the Vector Control Strategy. The process of development of the Strategy has been inclusive and participatory, involving stakeholders from different sectors of government, academia/research, development partners and the non-governmental organizations. This is a living document that will stimulate planning processes towards control and ultimately elimination of vector-borne diseases affecting South Africa.

The department of Health calls upon all stakeholders to take part in the implementation of the National Vector Control Strategy to ensure the Country moves towards preventing, responding to and ultimately eliminating vector-borne diseases.

Dr MJ Phaahla, MP
Minister of Health
Date:16/08/2023

2. Acknowledgement

Dr SSS Buthelezi

Director General of Health

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The National Department of Health would like to especially thank the following persons for finalising the Strategy:

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Dr SSS Buthelezi
Director-General of Health
Date:16/05/2023

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ABBREVIATIONS & ACRONYMS

E8	Elimination 8
DDT	Dichloro – diphenyl –trichloroethane
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEFF	Department of Environment, Forestry and Fisheries
DHIS2	District Health Information Software 2
DWA	Department of Water Affairs
DEET	Diethyltoluamide
EIA	Environmental Impact Assessment
FAO	Food and Agricultural Organization
GPIRM	Global Plan for Insecticide Resistance Management
GR	Geographical Reconnaissance
GVCR	Global Vector Control Response ()
IHR	International Health Regulations
ISHP	Integrated School Health Program
ITNs	Insecticide - Treated Nets
IEC	Information, Education and Communication
IR	Insecticide Resistance
IRM	Insecticide Resistance Management
IRS	Indoor Residual Spraying
IVM	Integrated Vector Management
HAT	Human African Trypanosomiasis (Sleeping sickness)
LLINs	Long-lasting Insecticides-treated Nets
MSDS	Materials Safety Data Sheet
NDOH	National Department of Health
NICD	National Institute for Communicable Diseases
NIDC	National Infectious Diseases Control
NGO	Non-Governmental Organization
NMC	Notifiable Medical Condition
NMEP	National Malaria Elimination Program
NTDs	Neglected Tropical Diseases
PMEP	Provincial Malaria Elimination Program
PPE	Personal Protection Equipment
RBM	Roll Back Malaria
SADC	Southern Africa Development Community
SAMEC	South African Malaria Elimination Committee
SAMRC	South African Medical Research Council
SBCC	Social Behavioural Change Communication
SVC	Sub-committee for vector control
UNEP	United Nations Environmental Programme
UP	University of Pretoria
WCO	World Health Organization Country Office
WHO	World Health Organization
WHO-AFRO	World Health Organization African Regional Office
WHO-PQ	World Health Organization Prequalification programme
WITS	University of Witwatersrand
WRIM	Wits Research Institute for Malaria

1. Situation analysis of vector control in South Africa

The World Health Organization (WHO) recommended Integrated Vector Management (IVM), defined as a rational decision-making process for the optimal use of resource for vector control. As a result of recent threats from emerging and re-emerging vector-borne diseases (VBDs), the WHO developed a Global Vector Control Response (GVCR) 2017-2030, a new advocacy strategy to elevate vector control as a key public health service worldwide, and countries are called upon to update and harmonize their national vector control strategic plans accordingly [1]. The GVCR goes beyond IVM with the goal to reduce the burden and threat of VBDs that affect humans, through the implementation of effective locally adapted and sustainable vector control. The proposed Vector Control Strategy are aligned to GVCR 2017-2030 with a view to accelerate effort towards elimination of vector-borne diseases in South Africa.

Malaria remains one of the priority diseases for the South Africa National Department of Health (NDOH). Schistosomiasis is an important vector-borne neglected tropical disease in South Africa, as are various arboviruses that affect humans and animals. In recent years the country has experienced outbreaks of Rift Valley fever in Free State Province (animal cases in 2018), and sporadic imported cases of chikungunya, dengue and Zika virus. Endemic and epizootic cases of West Nile virus and Sindbis virus are detected annually with occasional large outbreaks following climatic events that increase the local mosquito vectors (Table 2). Many other arboviruses have been reported from South Africa, but surveillance is lacking to inform current distribution and public health burden associated with these infections. South Africa hosts several arthropod species of medical significance including mosquitoes, ticks, bedbugs, and fleas, as well as flies and lice that serve as known potential carriers of pathogens. Except for malaria, there is no national strategic plan for vector control in South Africa. No routine entomological surveillance is carried out for vector-borne diseases other than malaria.

The proposed strategy outlines all aspects of vector-borne disease control strategies in South Africa, using malaria as an entry point, to serve as a guide for the planning and implementation of country-specific integrated vector management (IVM) for the elimination of priority vector-borne diseases.

1.1 Incidence and control of vector-borne diseases in South Africa

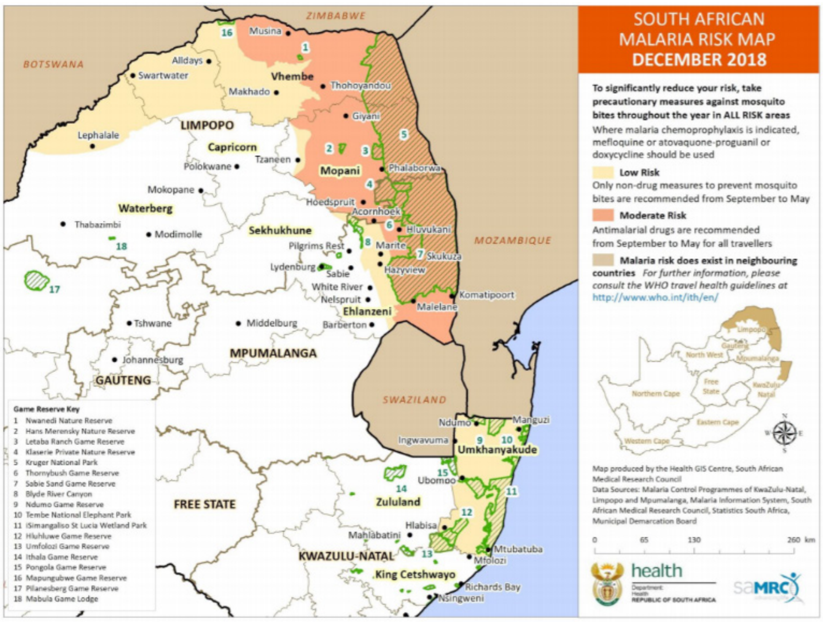


Figure 1: South Africa malaria risk map, 2018

1.1.1 Malaria

Plasmodium falciparum is the predominant species in South Africa accounting for over 98% of malaria cases, with the remaining infections due to P. vivax and P. malariae. Local malaria transmission occurs mainly in the low-altitude areas (below 1,000 meters above sea level) of the Limpopo, Mpumalanga, and KwaZulu-Natal (KZN) provinces, especially in areas bordering Zimbabwe and Mozambique (Fig. 1). Currently, Limpopo and Mpumalanga provinces are most affected, especially the Vhembe, Mopani (Limpopo) and Ehlanzeni (Mpumalanga) districts[1], with the incidence rate ranging from 0.12 to 3.8 per 1000 population at risk. KZN had three districts reporting malaria, with the lowest incidence rate ranging from 0.002 to 0.21 per population at risk (Table 1).

1 South Africa National Department of Health malaria statistics. Unpublished data

Table 1: Malaria incidence rates by districts in South Africa, 2017-2018

Province	Medium > 1 per 1000 population at risk		Low 0.1 – 1.0 per 1000 population at risk		Very Low < 0.1 per 1000 population at risk	
	District	Rate	District	Rate	District	Rate
Limpopo	Mopani	2.51	Capricorn	0.12	Sekhukhune	0.06
	Vhembe	3.79	Waterberg	0.18		
Mpumalanga			Ehlanzeni	0.69		
KwaZulu-Natal					Umkhanyakude	0.21
					Uthungulu	0.002
					Zululand	0.01

Since the mid-1940s, South Africa has maintained an extensive indoor residual spraying (IRS) program with insecticides (dichloro-diphenyl-trichloroethane (DDT) and later pyrethroids). Indoor residual spraying based on a mosaic of pyrethroid and DDT as the main intervention which is supplemented by larval source management (larvicide) in limited settings during winter when there are few mosquito breeding sites.

The primary vectors of malaria in South Africa are Anopheles arabiensis and, historically/during outbreaks, An. funestus. Secondary vectors include An. vaneedeni, An. parensis and An. merus. Populations of some of these species include indoor and outdoor-biting components, which partially explains persistent locally-acquired malaria (due to residual transmission) despite control. The highly endophilic An. funestus has been near eliminated from South Africa owing to the use of DDT. In addition to pyrethroid resistance in An. funestus, resistance to other insecticide classes has been detected in An. arabiensis in northern KwaZulu-Natal. These phenotypes are currently of low frequency and intensity and are not considered to be operationally significant. The surveillance information by province and municipality shows that IRS needs to be maintained at a high rate of coverage, that insecticide resistance management should inform insecticide choice, and that quality spraying should ideally be completed before the onset of each malaria season.

1.1.2 Schistosomiasis

Schistosomiasis is endemic in the northern and eastern (quarter of the country) region of South Africa. Schistosoma haematobium is more prevalent than S. mansoni. All surveys conducted in South Africa except for a few done in uMkhanyakude District have measured prevalence and intensity in the school going aged children [2]. That said, the countrywide burden of the disease among pre-school aged children (PSAC) is not known in South Africa although studies elsewhere have shown that this group carries the burden as well (Fig. 2) [3].

Chemotherapy administered through Mass Drug Administration (MDA) is the main prevention measure recommended by WHO. Apart from sporadic treatment programs South Africa has not had a country-wide MDA program for the treatment of Schistosomiasis.

Snail control, mainly by mollusciciding but also by environmental modifications, provision of water and sanitation, and hygiene education, is recommended for schistosomiasis control [4] and has contributed to

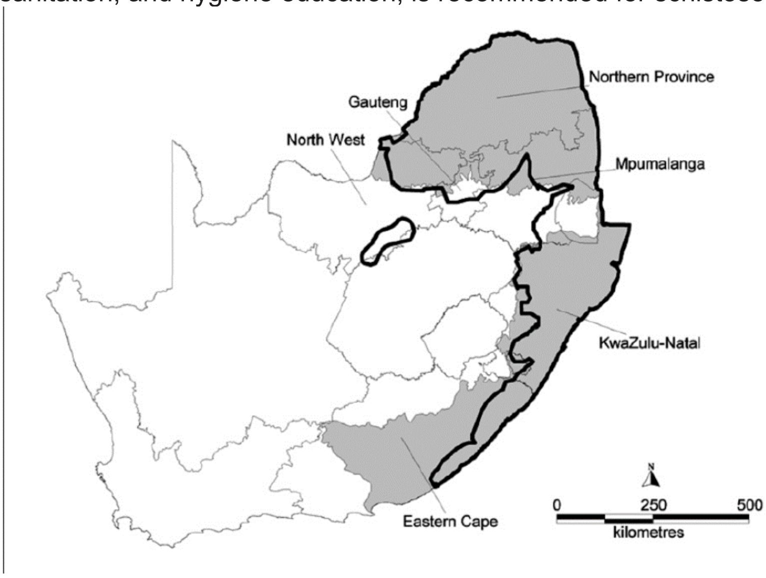


Figure 2: Urogenital Schistosomiasis in South Africa: shaded area mapped in 1938, solid black line in 1980.

successful control outcomes [5, 6]. Successful snail control requires sector collaboration between the Departments of health, agriculture and environment, and private sectors such as mining and the community at large. However, to do that requires knowledge of the spatial and temporal distribution of intermediate host snails for schistosomiasis. Such data is currently unavailable on a national scale in South Africa. However, there is some data covering several years for the Ingwavuma and uMkhanyakude Districts, and ongoing mapping in KZN will provide information on the distribution of intermediate host snails in relation to the burden of schistosomiasis in PSAC. South Africa should take advantage of the proposed VBD strategy and intensify schistosomiasis elimination campaigns, with introduction of snail control [7], to supplement chemoprevention through MDA.

1.1.3 Plague

Plague is an infectious disease caused by the bacterium Yersinia pestis. Fleas, especially those that parasitize rodents, are the main vectors of plague. The last outbreak of plague in South Africa occurred in Johannesburg in 1904, during which 113 cases were reported. Plague can be controlled by rapidly applying insecticidal dust in rodent burrows and runways. Dusting against fleas should be followed by measures to control rodents. Overall rodent control is necessary to reduce the risk of plague outbreaks. Effective control of plague vectors and their rodent hosts requires a multi-sectoral approach involving Health (vector control, health promotion, environmental health, and port health), Environmental Affairs, Agriculture, and municipalities as implementers, as well as research institutes to provide technical expertise on flea identification. Regular monitoring of rodent and flea population dynamics is necessary.

1.1.4 Tick-borne diseases

Crimean-Congo haemorrhagic fever (CCHF): A zoonotic disease caused by the CCHF orthonairovirus, an orthonairovirus which is a member of Nairoviridae family of viruses. The CCHF virus is transmitted to humans mainly through bites of Hyalomma ticks or contact with infected animal tissues and blood. People at risk of CCHF include farmers, veterinarians, abattoir workers and hunters. The virus infects the tick vector permanently across developmental stages and also transovarially to the eggs to infect the next generation of ticks. There are three recognized species of Hyalomma in South Africa, and although they are widely distributed, they tend to be most numerous in the drier north-western parts of the country – the Karoo, western Free State, Northern Cape and North West Province.

Crimean-Congo haemorrhagic fever disease has been known in South Africa since 1981 when it was first recognised in the country. Up to 20 cases of CCHF are diagnosed each year (Fig. 3). Although cases have been reported from all the nine provinces in the past 35 years, more than half of them originate from the semi-arid areas of Northern Cape Province (31.5% of cases) and Free State Province (23% of cases) [2]

CCHF is a category 1 notifiable medical condition in South Africa.

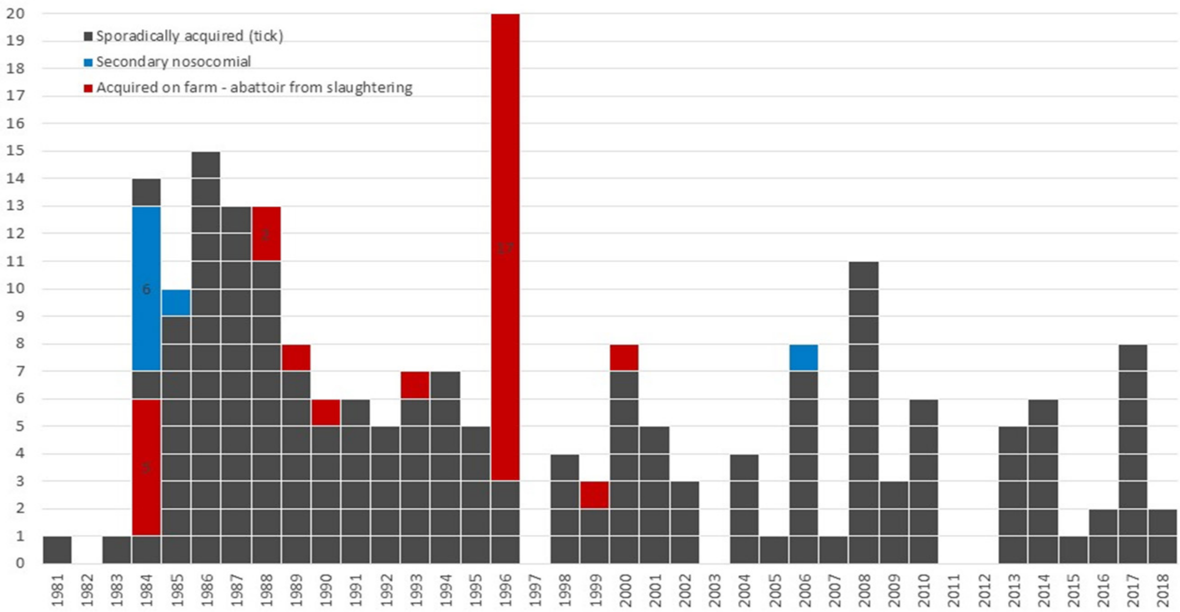


Figure 3: Confirmed cases of CCHF in South Africa – 1983-2018: Source: NICD, 2018

2 Source South Africa NICD diagnosis surveillance program 2019

Tick bite fever: This is a rickettsial infection transmitted by ticks. Two types of tick bite fever that occur throughout sub-Saharan Africa and South Africa. Rickettsia conorii-like infection is transmitted by dog ticks, often in urban or peri-urban areas, and is sometimes responsible for severe illness. African tick bite fever or ATBF, caused by Rickettsia africae, is transmitted by cattle and game ticks (especially Amblyomma or 'bont' ticks) in rural farming and game reserve areas and is usually a milder infection [8]. Persons who walk, camp or work in the bush are at high risk of infection. Personal protection using repellents (DEET) and suitable clothing are the main preventive measures against tick bites. Tick bite fever is a commonly diagnosed disease in South Africa and frequently reported in travellers to South Africa.

1.1.5 Aedes vector species and arboviral diseases

The common mosquito-borne arboviral diseases include dengue, yellow fever, chikungunya and Zika. Globally, Aedes aegypti and Ae. albopictus are the main vectors of viruses that cause these diseases. Dengue in the urban setting is primarily transmitted by Ae. aegypti and, to a lesser extent, Ae. albopictus. An assessment of vector competence in South African mosquitoes in 1993 revealed that there are several species of mosquito other than Ae. aegypti that are potentially or feral vectors of dengue viruses [9]. The NICD also assessed the vector competence of South African populations of Ae. aegypti for dengue-1 and -2 viruses and yellow fever virus [9, 10], demonstrating that local Ae. aegypti could potentially support dengue and yellow fever virus transmission. Endemic and imported arboviral infections are category 3 notifiable medical conditions in South Africa.

Although neither dengue nor yellow fever viruses are currently in circulation in South Africa, 176 confirmed imported dengue cases were recorded during the period 2000 - 2016, with the incidence increasing over this period and at least 30 confirmed cases reported in 2018 – 2019.[3] Outbreaks of arboviral diseases have been reported in other countries in the Southern Africa region. For example, a recent outbreak of yellow fever in Angola in December 2015.

Interventions against Aedes mosquitoes often involve the application of insecticides within domiciles, though this is difficult to do properly and is often insufficient. Vector control can be enhanced by educating and empowering communities to identify, empty, remove or treat containers that act as Aedes larval habitats in and around their homes. Urban settings can also be made more resilient by supplying reliable piped water to circumvent the storage of domestic water at the household level. Screened windows and entrances will reduce exposure to mosquitoes that are capable of biting humans. Control of Aedes-transmitted viruses by targeting vectors requires an integrated approach that involves multiple partners within and outside the health sector, and particularly the involvement of the community. Recent data on cases infected with different mosquito-borne arboviruses are summarized below (Fig. 4).

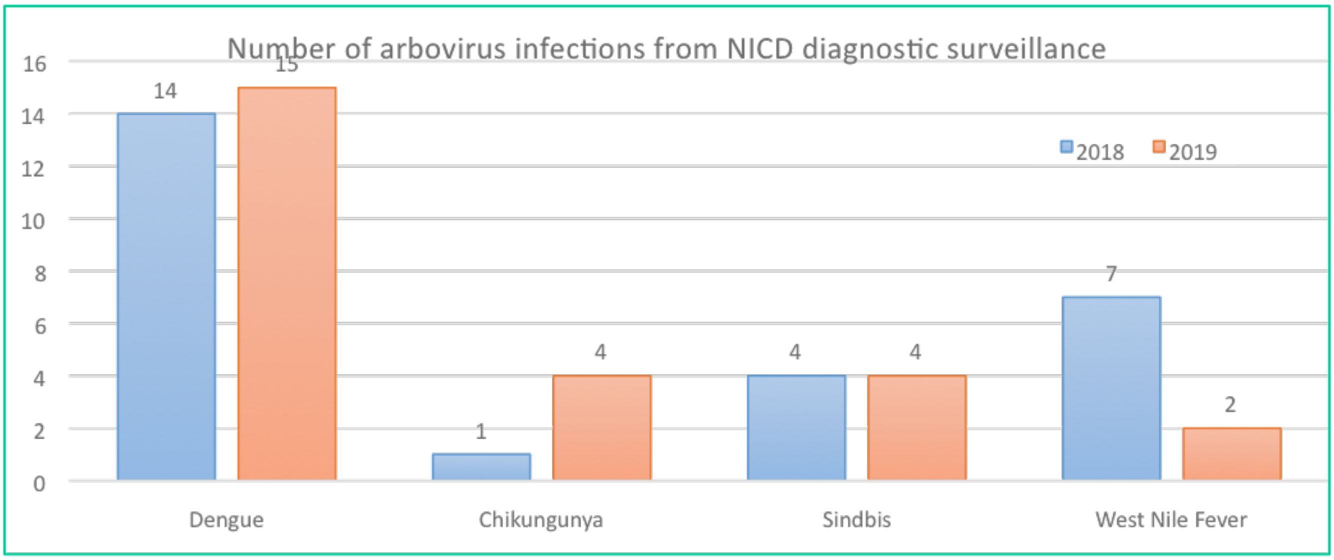


Figure 4: Arbovirus infections in South Africa, Jan-Dec 2018, Jan – Aug 2019

Rift Valley fever (RVF): Caused by the Rift Valley fever virus (RVFV), an arbovirus belonging to the genus Phlebovirus, family Phenuiviridae, order Bunyavirales and circulates in central, West, East and Southern Africa and the Arabian Peninsula [11, 12]. The infection causes severe and often fatal illness in domesticated animals, with occasional spill over to humans, in whom the infection shows no symptoms other than a mild illness associated with fever and liver abnormalities. In a subset of human cases, more severe disease may occur with symptoms including encephalitis, ocular disease, and haemorrhagic manifestations and case fatality rates may be as high as 10% [13]. The virus is transmitted to vertebrates by mosquitoes, mainly of the genera Culex and Aedes. RVF outbreaks have occurred in South Africa and neighbouring countries, particularly Botswana in the Okavango Delta, Namibia, and Zambia [14].

3 NICD Bulletin Vol. 16, Issue 1, 2018. Increased importation of dengue cases into South Africa: a risk for establishment of local endemicity? <link>

West Nile Virus (WNV) and Sindbis virus: The most common endemic mosquito-borne arboviruses in South Africa are West Nile virus and Sindbis virus [15, 16]. These viruses circulate between Culex mosquito vectors and birds as vertebrate hosts and affect humans and sensitive animals that act as dead-end hosts. These viruses are widespread across the country but most cases in humans and animals are detected in the Gauteng (Highveld) and Northern Cape provinces where the vectors are most prevalent, although cases also occur in all the other provinces. Large outbreaks of WNV co-circulating with Sindbis occurred in 1974 and 1981 in the Karoo and Highveld. Approximately 7-25 cases are reported annually in South Africa although the incidence is likely under-reported (Fig. 4).[4] Most human cases are mild and associated with fever, morbiliform rash, muscle, and joint pains. Approximately 1% of West Nile cases may develop more severe disease including meningo encephalitis, Guillain-Barre syndrome and death. Recent studies suggest up to 3% of undiagnosed neurological infections in hospitals in Gauteng may be due to WNV. Horses are also sensitive to WNV and, to a lesser extent Sindbis virus, and display severe neurological signs in up to 90% of clinical cases, with a fatality rate of up to 35%. Horses are therefore sensitive sentinels for outbreaks of WNV [15].

1.1.6 Trypanosomiasis:

The Tsetse fly of genus Glossina is the carrier of trypanosomiasis known as sleeping sickness in humans (Human African trypanosomiasis - HAT) and Nagana in domesticated animals. Although there is no report of HAT in South Africa, the parasite is circulating among wild and domesticated animals, that a major concern in livestock and tourism industry. A 2016 survey report showed that trypanosome infection was widespread among cattle in norther-eastern KZN with transmission sustained by different species of Glossina, including Gl. brevipalpis and Gl. austeni. Trypanosome prevalence ranged from 20% in the Ubombo district to 3% in the Enseleni district.[5] A long-term solution to the Nagana problem in South Africa requires multiple approaches, including dipping, curative treatment of infected cattle and vector control.

1.2 Prioritisation of vector-borne diseases in South Africa:

Data on control of mosquito-borne viral diseases and associated vector biology are sparse in Africa, [16] including South Africa. There is, therefore, a need to improve knowledge of priority VBDs other than malaria, and to develop specific plans and capacity for arboviral disease surveillance, prevention and outbreak responses. Furthermore, South Africa is potentially at risk of imported mosquito-borne arboviral diseases because of the presence of suitable vectors and proximity of countries that have reported outbreaks of arboviral diseases such as yellow fever and Zika. Neglect of vector surveillance activities could lead to a resurgence or introduction of priority VBDs.

A vector control guideline in the event of outbreaks is necessary for the majority of VBDs found in South Africa (Table 2). This guideline provides a framework for long-term disease and vector surveillance and the strengthening of the country's capacity for rapid recognition of, and response to outbreaks and emerging arboviral diseases. This will involve screening suspected cases among local populations, migrants and returning travellers, a key function of South Africa's Integrated Disease Surveillance strategy.

4 Source NICD Disease Surveillance Program from Jan to Dec 2018, and Jan to Aug 2019

5 De Beer, CJ et al., (2016) An update of the tsetse fly (Diptera: Glossinidae) distribution and African animal trypanosomiasis prevalence in north-eastern KwaZulu-Natal, South Africa. Onderstepoort Journal of Veterinary Research 83(1), a1172. http://dx.doi.org/10.4102/ojvr.v83i1.1172

Table 2: Vector-borne diseases situation in South Africa

Disease	Response	Status	Vector	Comments
Malaria	Control	Endemic	An. arabiensis, An. funestus, An. merus, An. vaneedeni, An. parensis	Controlled by IRS and larval source management
Schistosomiasis	Control	Endemic	Bulinus Snail, Biomphalaria pfeifferi	Preventative chemotherapy needed, and snail control
Rift valley fever	Control	Endemic	Ae. (Neomelaniconion) spp.; Cx. theileri; Cx. zombaensis	Significantly controlled by vaccination of livestock and mosquito control
West Nile	EPR	Endemic	Cx. univittatus	Insect repellents containing DEET, interventions targeting larval habitats around homes
Sindbis	EPR	Endemic	Cx. univittatus	Difficult to control due to ubiquity of vector's breeding habitats
Chikungunya	EPR	Endemic	Ae. furcifer, Ae. cordellieri	Limited distribution in SA
Plague	EPR	At risk	Fleas	Surveillance for fleas and rodents
African tick bite fever	EPR	Endemic	Amblyomma hebraeum	Notifiable
Crimean-Congo haemorrhagic fever	EPR	Endemic	Hyalomma rufipes, Hyalomma truncatum	Notifiable; Controlled by reducing vector-human contact, e.g. DEET based repellents, Acaricide in domesticated animal
Mediterranean spotted fever	EPR	Endemic	Haemaphysalis leachi ticks	Controlled by reducing vector-human contact, e.g. DEET based repellents, Acaricide in domesticated animals
Yellow fever	EPR	Non-endemic, but at risk	Aedes aegypti	Vaccine controlled
Dengue	POI	Non-endemic	Aedes aegypti, Ae. strelitziae, Ae. furcifer group	Continual introduction through travellers from endemic areas
Japanese Encephalitis	POI	Non-endemic	Cx. tritaeniorynchus	Vaccine available in endemic regions in Asia
Ross River	POI	Non-endemic	Australian mosquitoes (Ae. camptorhynchus, Ae. vigilax, Cx. annulirostris)	Endemic in Australia; rarely introduced by travellers
Zika	POI	Non-endemic	Aedes aegypti	
Lymphatic filariasis	EPR	Non-endemic, but at risk	Anopheline and Mansonia species	Endemic in countries neighbouring South Africa
Trypanosomiasis	POI / Control	Non-endemic for HAT, Endemic for Nagana	Tsetse fly, Glossina species	No record of HAT; Management of Nagana by dipping and treatment, without vector control.

Key: EPR – Epidemic Preparedness and Response plan; POI – Prevention of Importation; HAT – Human African Trypanosomiasis

1.3 Vector-Borne Diseases Programs in South Africa

1.3.1 South Africa Malaria Elimination Strategic plan 2019 – 2023

The current National Department of Health (NDOH) Malaria Elimination Strategic Plan 2019-2023 (MESP 2019-2023) for the Republic of South Africa aims for zero local malaria cases and deaths by 2023. NDOH provides policy and technical oversight of the Malaria Elimination Plan, whereas the Provincial Malaria Elimination Programs in the three endemic provinces are centres for planning and implementing malaria elimination activities. To achieve the goal of zero malaria by 2023, five objectives have been identified, including objective 4 "Protect all populations at risk to achieve at least 95% coverage with key vector suppression strategies and interventions for the period 2019-2023"that specifically deals with vector control.

A long-standing IRS program is the major malaria vector control intervention. The malaria program review of 2018 identified challenges specific to vector control implementation, as follows: 1) Lengthy processes to recruit spray operators and procure vector control commodities, especially insecticides, causes delays in the timely implementation of IRS and affects the quality, rendering the intervention less effective; 2) Limited data on insecticide resistance to inform the selection of insecticides to deploy for IRS; and 3) human resource capacity for the implementation of vector control is declining due to the attrition of staff, especially for technical and supervisory positions.

While vector surveillance is conducted in endemic districts, there is inadequate program capacity for vector behavioural studies and insecticide resistance monitoring. The following challenges should be addressed with the funding allocations from National Treasury from 2019 to 2021:

1. Renewed commitment to malaria elimination with the strengthening of human resource capacity and adequate financial resources to implement appropriate interventions to reverse the negative trend and accelerate progress towards malaria elimination;
2. Revitalized vector control program implementing timely interventions, conducting vector surveillance, and using data to inform decision making; and
3. Implement the appropriate malaria surveillance activities in all endemic and non-endemic districts, and ensure all information required for the documentation of malaria elimination is collected, analysed, used for planning and implementation, and appropriately archived.

1.3.2 Neglected Tropical Diseases Elimination program in Strategic plan 2023-2027

The South Africa Neglected Tropical Diseases (NTDs) Master Plan 2023-27 provides a framework to guide all efforts towards the goal of eliminating NTDs. The priority NTDs targeted for elimination include those that are vector-borne namely: schistosomiasis and plague. Schistosomiasis is endemic throughout the country. South Africa aims for the elimination of schistosomiasis and other priority NTDs by 2027. However, there is a need to determine the current epidemiology of vector-borne NTDs and vector distribution in South Africa because available data is either out of date or inadequate. The South Africa NTD Master Plan endorsed the IVM strategy as an approach to accelerate toward the elimination of NTDs.

Overall, the majority of epidemic-prone zoonotic diseases other than malaria and schistosomiasis (see Table 2) have no cure and therefore the main intervention in case of an outbreak is through vector control. All these are notifiable diseases and the strategic approach for prevention is mainly through epidemic preparedness and response to outbreaks. Going forward, a better understanding of vector biology and distribution is critical for epidemic preparedness and response.

1.4 SWOT analysis of vector-borne disease control in South Africa

South Africa aims to eliminate malaria and priority vector-borne diseases which collectively included in One Health approach for zoonotic diseases risk and events in the country. The main threats to VBD control, particularly malaria, relates to parasite resistance to drugs and mosquito resistance to insecticides used for vector control. Inefficient management and poor coordination at all levels of operation will adversely affect the success of the program and impact on the disease. The majority of weaknesses relate to systems and structure of the provincial programs and coordination within, and beyond, the health sector which need to be addressed during the implementation of this guideline. Overall climate change, affecting vector population and disease trends, is a threat to epidemic-prone VBDs and needs to be considered going forward. Strengthening epidemic early detection and response is critical to mitigating the risk of epidemic diseases.

Analysis of strengths, weakness, and opportunities available for VBDs in South Africa was done to determine how vector control should be planned and implemented within the broad context of IVM in South Africa. Major constraints and opportunities for improvement summarized in Annexe 1.

1.5 Priority actions and activities (aligned with GVCR priority activities)

Based on the SWOT analysis above the following priorities, aligned with the Global Vector Response (GVR), were identified:

1. The focus of vector control and, where possible, elimination will be on non-endemic and epidemic-prone diseases including malaria, schistosomiasis, dengue, yellow fever, Zika and chikungunya. Surveillance for the other endemic VBDs will be conducted at institutional or on an ad hoc basis;
2. Implement the following recommendations from the 2013 Malaria Vector Control Needs Assessment (VCNA)[6]:
    - To increase capacity through annual training of existing staff in IRS management and operations; annual joint program reviews and planning; national quarterly supervisory visits to provinces; and increasing human resource capacity at the national level.
    - Strengthen the capacity for vector surveillance by recruiting two to three entomologists per province and establishing vector surveillance systems that work hand in hand with case-based surveillance.
    - Improve data management and utilization for decision at all levels to provide timely and regular reports.
    - Ensure proper and safe insecticide management by conducting pre- and post-delivery quality control, providing sufficient storage space and waste disposal facilities.
    - Make available all required Strategy, standard operation procedures for supervision, vector surveillance and proper insecticide management.
3. Conduct a broad VCNA to identify gaps and areas that need to be improved in the context of malaria/VBDs elimination;
4. Establish a national vector-borne pathogen database system for all VBDs. The existing NMC will capture notifiable pathogen data and the DHIS2 can be expanded to capture the vector data;
5. Strengthen human and infrastructural resources to support vector surveillance, including insecticide resistance monitoring: update distribution maps of priority endemic VBDs and their vectors; develop protocols and SOPs for vector surveillance, epidemic preparedness and response of emerging vector-borne diseases; and support implementation;
6. Update the national Strategy for life-cycle pesticide management to cover transportation, storage, handling of chemicals and disposal of waste and containers used by VBD control programs. Develop a national scheme for collection and disposal of pesticide-based vector control products; Upgrade the malaria camps to include facilities to support safe handling of pesticide, washing of PPEs and spray equipment;
7. Identify VBD stakeholders, establish a national VBD steering committee to oversee the coordinated implementation of the VBD strategy, advocate for political and funding support; strengthen coordination and partnerships by enhancing the SAMEC with a mandate specified with terms of reference and membership from the different government sectors, research institutes and private sector;
8. Strengthen vector surveillance, monitoring and evaluation, and operations research to support control of VBDs and build data management for evidence-based decisions;
9. Scale-up coverage and quality of vector interventions against malaria and schistosomiasis;
10. Strengthen health education and promotion concerning VBDs, community engagement and mobilization for VBD control;
11. Implement the priority actions recommended by IHR review[7] to strengthen South Africa One-Health approach to zoonotic diseases;
    - Finalization of a national policy for One Health including the governance structure;
    - Training of health stakeholders with a focus on early detection of Zoonoses and joint preparedness and response to emergency zoonotic events, particularly at the local level;
    - Joint simulation exercise on a major zoonosis emergency involving all the major stakeholders; and regular evaluation and refining the effectiveness of One-Health systems coordination.

6 NDOH (2013) Report on Vector Control Needs Assessment. Malaria Directorate, Pretoria South Africa
7 WHO (2018) Joint external evaluation of IHR core capacities of the South Africa. Geneva, WHO.

2. Vector-Borne Disease Control in South Africa

Given the threat of emerging and ongoing vector-borne diseases (VBDs), there has been a renewed global emphasis on integrating vector management to eliminate vector-borne diseases, including malaria. Integrated vector management (IVM) is a rational decision-making process to optimize the use of resources for vector control. IVM incorporates decision-making based on technical, programmatic and management information, engages communities to promote sustainability, encourages multi-disease approaches, promotes the application of different interventions in combination and in synergy, and its implementation extends beyond the health sector to other sectors and stakeholders.

In response to recent threats from emerging and re-emerging VBDs, WHO developed a Global Vector Control Response (GVCR) 2017-2030, a new advocacy strategy to strengthen vector control worldwide, and countries are called upon to update and harmonize their national vector control strategic plans. The vision of GVCR is a world free of vector-borne diseases. This can be achieved through four pillars of action: Inter-and intra-sectoral action and collaboration (pillar 1), Engagement of communities (pillar 2), Vector surveillance, monitoring and evaluation (pillar 3) and Scaling up and integration of tools (pillar 4). Combined, these should lead to more effective, locally adapted and sustainable vector control. Key to achieving the bold vision of a world free of VBDs, and the goal to reduce their burden requires country leadership commitment; advocacy, resource mobilization, partner coordination and regulatory, policy and normative support. The GVCR advocates for the elevation of vector control as a key public health service.

The proposed National Vector Control Guideline is an attempt by South Africa to implement vector control in the context of IVM principles and as outlined in the GVCR 2017-2030.

2.1 Purpose

The proposed Vector control Strategy provide a basis for national and provincial departments of health, in coordination with other government sectors and stakeholders, to plan and implement control of vector-borne diseases, using malaria as an entry point of operation. It describes the principles of key vector control components and the general implementation approach to VBDs prevention and control. The target audience is the NDOH at national, province and district levels, and other relevant sectors involved, directly or indirectly, in the control of VBDs, as well as the community. Although the focus of the guideline is malaria, there is also overlap with other diseases transmitted by mosquitoes or other vectors. The Vector Control guideline is a working document and will require periodic updating and adapting to changes in local eco-epidemiological or socioeconomic conditions for malaria and other VBDs.

The South Africa Department of Health recognizes the need to improve efficiencies in disease management and harmonization of a national strategy with current international standards. As part of preparations for the development of the Vector Control Strategy, national consultations were held in September 2018, March 2019 and October 2019, to reach consensus on the framework of the National Vector Control Strategy.

This VBD strategic plan has been formulated to align with national and global policy guidance as follows:

- At the global level: Sustainable Development Goals (SDGs); the WHO's Global Malaria Technical Strategy 2016-2030; WHO Framework for Malaria Elimination 2017, and the Roll Back Malaria's Global Action and Investment to defeat malaria 2016-2030 and Global Vector Control Response 2017-2030, the principles of WHO Integrated Vector Management (Annexe 2) and First WHO Report on NTDs (2010) which recommended 5 combinable key strategies including vector control [7]. The International Health Regulations (2005) which requires countries to prevent and respond to public health risks including vector-borne diseases;
- At the regional level: The African Union's goal of malaria elimination in Africa by 2030; The SADC Malaria Elimination Framework E8 Initiative that promotes malaria elimination efforts through strong cross-border coordination. South Africa is a signatory to the Abuja Declaration on Roll Back Malaria (RBM) partnership;
- At the national level: Government of South Africa demonstrates a strong political commitment to fight malaria and other communicable diseases. The Malaria Elimination Strategic plan 2019-2023 aims to accelerate towards zero local transmission of malaria by 2020; South Africa NTDs master plan 2019-2025;

2.1.1 Goal and objectives of Vector Control Strategy for South Africa

The overarching aim of the Vector Control Strategy is to establish a robust framework for the coordination of national efforts and mobilizing appropriate resources to accelerate the achievement of national goals for elimination of malaria and other priority VBDs. The goal and objectives of the Strategy will be as follows:

Goal: Protect the South African population from endemic and emerging VBDs and detect and respond to outbreaks

Strategic Objectives

Objective 1. Protect all populations at risk of VBDs with effective vector control strategies and interventions;

Objective 2. Monitor the spatial and temporal occurrence of vectors of priority diseases in targeted areas in South Africa;

Objective 3. Develop capacity for surveillance, detection, and response to VBD outbreaks;

Objective 4. Increase knowledge and practices to 100% nationally and improve utilization of key VBDs interventions to 95% by 2027;

Objective 5. To provide effective management, leadership, and coordination for the optimal implementation of the Vector Control Strategy at all levels by 2027.

The fourth strategic objective of the current Malaria Elimination Strategic Plan (2019-2023) aims to protect all population at risk to achieve at least 95% coverage with key vector suppression interventions. The priority interventions include IRS, winter-larviciding and community awareness campaigns to promote compliance and utilization of interventions. South Africa's NTD strategy (2023-2027) provides a framework for the control and prevention of priority NTDs including schistosomiasis. Chemoprevention is the main intervention used to prevent schistosomiasis. South Africa is at risk of mosquito-borne arboviral diseases, particularly outbreaks of endemic viruses (WNV, Sindbis and RVF) as well as the importation of Chikungunya, dengue and yellow fever. Thus, information on the biology of relevant Aedes, Anopheles and Culex mosquitoes needs to be established, as this will be useful to inform response action in case of outbreaks. The above-mentioned VBDs and priority interventions have been expanded under the VBD strategic approach.

2.2 Strategic Objectives

Below is a description of each objective and related activities to be implemented for the duration of this plan.

Objective 1: Protect all populations at risk of VBDs with effective vector control strategies and interventions.

In South Africa, malaria is the only VBD against which vector suppression measures are currently used. Indoor residual spraying (IRS) of specially formulated insecticides is used to interrupt malaria transmission. The coverage and quality of IRS operations are sometimes affected by several factors including procurement bottlenecks sometimes leading to delay of the delivery of insecticides or training of spray operators, and a decline in human resource capacity for the implementation of vector control due to attrition of staff, as well as out-of-date maps to help in quantification and measurement of coverage; and spray campaign taking too long extending into malaria transmission season.

Schistosomiasis is a priority vector-borne disease in South Africa. Chemoprevention through MDA supplemented by snail suppression measures will contribute to the elimination of Schistosomiasis in South Africa. Data on the distribution of snails, the intermediate host of schistosomiasis, is limited and/or the information is outdated. A survey on the distribution of snails will generate critical data needed to inform the deployment of intervention measures. Community engagement and participation is key to this process and as such the Strategy aim to forge partnerships with affected communities and stakeholders to support VBD control.

A robust pesticide life cycle management system is required to minimise or completely avoid contamination of people and the environment. There is a need for greater collaboration amongst relevant sectors to address challenges facing the implementation of the pesticide management legislation (section 3.1). Good pesticide management will be promoted. Workers handling public health pesticide will receive training on proper handling and application of public health pesticide. Likewise, the community benefiting from pesticide applied for vector control will be informed on what to do to maximise the effect on vectors and minimise exposure to human and environment.

Overall, the activities under strategic objective 2 will contribute to a scaling-up of vector suppression measures for the control and eventual elimination of malaria and schistosomiasis (Table 3).

Table 3: Key activities for Strategic objectives 1

Objective 1: Protect all populations at risk of VBDs with effective vector control strategies and interventions		
Key activities	**Sub-activities**	**Resources**
1. Implement quality IRS to achieve 95% coverage of the targeted population at risk of malaria, supplement with larviciding appropriately	1. Conduct timely IRS macro/micro plans at endemic district/province; 2. Conduct timely procurement of quality insecticide and related commodities; 3. Conduct timely IRS operation and completion; 4. Apply larvicide in breeding sites mapped in an area with the population at risk; 5. Supervision of field IRS and larviciding operation, including entomological activities;	Human resources, material, insecticides for IRS / larvicides, logistics,
2. Routine malaria entomological surveillance	1. Routine larval and adult sample collection and species identification; 2. Annual insecticide susceptibility testing; 3. Annual training of province/district vector/entomology teams;	Human resource, material, lab, insectary
3. Basic/applied operational research conducted with partner institutions	1. Identify research areas to address operational bottleneck related VBD control; 2. Implement operation research studies and report findings;	Human resource, experts, material
4. Protect all population at risk of schistosomiasis	1. Conduct snail control activities targeting areas where the population is at risk;	HR, material, logistics, molluscicides, budget
5. Quality assurance of IRS and winter larviciding	1. Procure supplies of wall bioassay kits; 2. Maintain susceptible colony for quality control testing; 3. Conducting IRS quality assurance by insecticide class and house wall types;	Human resource, material, logistics, budget
6. Introduce new tools and approaches for VBD control	1. Micro plans and procurement of supplies for snail control operations; 2. Conduct a pilot on community-based molluscicide for snail control to inform scale-up strategy;	Human resource, protocol, experts, budget
7. Promote good practice and capacity for public health pesticide management	1. Implement and monitor occupational exposure profile for different exposure groups of workers, as part of a comprehensive occupational health and safety risk assessment and management; 2. Develop Strategy for handling, use and disposal of public health pesticides; 3. Establish and implement a scheme for monitoring of pesticide exposure by spray workers, through the development of a consolidated inventory of pesticides used within the department and ensuring appropriate management of overexposures; 4. Develop a nationally coordinated occupational health and safety management system including establishment of health and safety committee and legal appointments in line with South African legislation;	Human resources, budget

Objective 2: Monitor the spatial and temporal occurrence of vectors of priority diseases in targeted areas in South Africa

Effective vector control is reliant on knowledge of local vector species, there distribution and susceptibilities to insecticides, as well as on vector and human behaviours that may allow vectors such as mosquitoes to avoid contact with interventions and thereby maintain residual transmission. Periodic collection of such data is essential to inform vector control strategies and track their impact on the transmission of pathogens. This will generate a better understanding of the spatial and temporal occurrence of vectors which is useful to inform programmatic decision-making such as targeting interventions and response to outbreaks.

Intervention monitoring and evaluation: There is also a critical need for ongoing monitoring of the coverage, usage, quality and durability of vector-control interventions following their deployment. For instance, quality control of IRS operation, through cone bioassay using a susceptible colony of mosquitoes, should be done and results used to improve the quality of spray operations.

Entomological surveillance activities are conducted within malaria-endemic areas of Limpopo, Mpumalanga, and KwaZulu-Natal provinces. Information collected includes vector species composition, vector population densities, resting behaviour, larval habitats, and insecticide susceptibilities in adult mosquitoes. Each malaria-endemic province has entomology teams and limited infrastructure which can be used to support routine entomological activities and quality assurance of interventions, especially IRS. All malaria-endemic provinces have an insectary with the capacity to sustain a mosquito colony and a laboratory that can be used for molecular analysis of Anopheles vector for species identification and infectivity detection, but these facilities are not fully utilized to support entomological activities. As of October 2019, only one insectary in the three provinces had mosquito colony of sufficient size for quality control of IRS operations. Insecticide resistance monitoring is not done regularly which hampers decisions on the selection of insecticides for vector control.

The NDOH and province MEP will strengthen entomological surveillance, monitoring and evaluation of vector control interventions. Vector surveillance at pre-determined sentinel sites in provinces where malaria is a problem should be strengthened to monitor changes in vector bionomics, including insecticide resistance status. This will include quality assurance of vector interventions. Vector monitoring at ports of entry will also be implemented as a measure to mitigate importation of exotic vector species and emerging VBDs. It will be necessary to establish a consortium of experts from relevant sectors that will advise and support measures to deal with emerging VBDs. Investment in surveillance will also include other priority VBDs, such as schistosomiasis and emerging mosquito-borne arboviral diseases. For example, a national cross-sectional survey will be necessary to understand the distribution of snail, the intermediate host of Schistosoma. A better understanding of snail distribution will inform a targeted approach to suppress snail populations and contribute towards the elimination of schistosomiasis. Existing human and infrastructural resources available in provincial malaria elimination programs and the NICD should be extended to support other priority VBDs such as schistosomiasis (Table 4).

Table 4: Key activities for strategic objective two

Objective 2: Monitor the spatial and temporal occurrence of vectors of priority diseases in targeted areas in South Africa		
Key activities	**Sub-activities**	**Resources**
1. Surveillance, monitoring and evaluation of priority VBD vectors to support decision-making	1. Establish sentinel sites for VBDs Surveillance Monitoring and Evaluation; 2. Collection, identification and incrimination of priority VBD vectors; 3. Generate vector distribution maps and reports on priority VBDs; 4. Budget for refresher training of EHPs and other vector staff on basic identification of vectors; 5. Conduct testing and screening of vectors for pathogens	Human resources, protocol/SOP, material, budget
2. Strengthen national vector surveillance & integrate with HIS to guide vector control	1. Establish a national vector database for all VBDs; 2. Finalize entomological/vector component of malaria DHIS2 trackers for integrated vector surveillance, monitoring and evaluation of VBDs	Human resources, expert
3. Establish a consortium of experts on VBDs	1. Conduct annual scientific meetings for data review, policy/guideline/protocol/SOP development;	Human resources, VBD focal person, budget
4. Monitor ports of entry for potential vectors of pathogens of emerging VBDs	1. Conduct refresher training on vector surveillance for EHPs; 2. Conduct vector surveillance and monitoring vector control at ports of entry; 3. Supervision and inspection of the ports of entry surveillance; 4. Conduct desk review to assess the risk of VBD importation at the various port of entries	Human resources, VBD focal person, expert, budget
5. Surveys of priority VBDs and stratification mapping	4. Update malaria stratification maps for endemic provinces to inform targeting of interventions; 5. Conduct mollusc surveys and produce distribution maps of pertinent species; 6. Determine susceptibility status of snails to larvicides/molluscicides;	Human resource, material, logistics, expert, budget
6. Pilot study on new tools and approaches for vector surveillance	1. Conduct a study to identify efficient methods for sampling priority vectors: Anopheline, Culicine mosquitoes and Tsetse fly;	Human resources, research institutes, material, budget

Objective 3: Develop capacity for surveillance, detection and response to VBD outbreaks

Enhanced capacity for public health entomology is necessary to support the elimination of malaria and other VBDs. WHO urges malaria-endemic countries to invest in public health entomology capacity to support the control and elimination of malaria and other VBDs. This implies an appropriate technical capacity to facilitate the systematic collection of data to inform decision-making on vector control, including trained and experienced staff, reference insectaries and associated equipment. Technical expertise and national decision-making mechanisms are required to ensure effective and timely use of such data to inform vector suppression strategies and their implementation.

Surveillance is a core intervention for countries targeting malaria elimination. As South Africa aims to achieve zero malaria transmission by 2023, significant investment to strengthen the surveillance system is critical to ensure collection of data necessary for understanding disease trends, heterogeneity in transmission levels and vector bionomics, and overall program performance. The objectives of entomological surveillance are as follows: 1) characterize receptivity to guide stratification and selection of interventions; 2) track relative density of vectors (and bionomics) to determine seasonality of transmission and the optimal timing of intervention; 3) track insecticide resistance as a basis for choosing insecticide for vector control; 4) identify other threats to the effectiveness of vector control and 5) monitor vector control intervention coverage and quality and identify gaps and opportunities to optimize vector control. In South Africa, trained provincial entomologists are either not present, have limited experience in practical field and laboratory skills or are engaged in responsibilities other than entomological work.

At a bare minimum, provinces endemic to priority VBDs would have a public health entomologist,[8] field technicians, laboratory technicians (including insectary staff), data clerks/database and administrative staff (Annexe 3). Public health entomologists will head provincial entomology teams responsible for vector surveillance and quality assurance of vector interventions and use of data generated to inform decisions. Access to staff with other skill sets, such as social scientists and health promoters, is also imperative. Skill and experience requirements for each role must be outlined, with a focus on leveraging expertise beyond entomology to ensure broad experience across the team(s) tasked with implementing vector surveillance and control. Training of community volunteers is also important.

As there is no national entomologist to guide and assist provincial entomologists, this gap needs to be strengthened urgently, at least for all three malaria-endemic provinces need. Furthermore, continuous short-term training and long-term courses in field entomology, insectary management and entomology laboratory techniques are recommended for all provincial vector control team members. Also, laboratory technicians are required to process samples of vectors for species identification and other entomological indicators to support the entomological surveillance, including IRM (Annexe 6). Refresher training of current staff and training of new staff will be conducted in collaboration with research institutions. There are four research institutions, two situated in Johannesburg (NICD and University of the Witwatersrand - WITS), one in Pretoria (University of Pretoria - UP) and one in Durban (SAMRC), that have advanced entomological capacity. NICD and WITS have adequate capacities for advanced malaria entomology work for identifying vector species and resistance mechanisms. UP currently has an arbovirus research program with PhD students trained in arbovirus vector identification and molecular testing.

8 A public health entomologist is a professional with at least basic vector and ecological knowledge and skills, who is also a public health practitioner skilled in epidemiology and program management.

Table 5: Key activities for strategic objective three

Key activities	Sub-activities	Resources
1. Strengthen surveillance of VBDs	1. Conduct a seroprevalence survey of priority VBDs in endemic regions; 2. Conduct risk assessment of VBDs in SA; 3. Strengthen reporting of VBDs through the NMCSS/IDSR; 4. Conduct knowledge gap analysis for VBDs surveillance; 5. Conduct Arbovirus syndromic sentinel surveillance in humans and sentinel animals in targeted VBD endemic regions;	Human resource, expert institutes, budget
2. Strengthen system for early detection of VBDs and response to outbreaks	1. Evaluate outbreak response capacity; 2. Develop VBD EPR plans and protocols; 3. Train response team – vector control staff & EHPs - on priority VBDs control and prevention; 4. Develop and validate diagnostic tools; 5. Establish VBD samples management and logistic system;	Human resource, expert institutes, budget
3. Conduct training in public health entomology of relevant staff at DHOP and provinces	1. Assess training needs of provincial senior staff supervising vector control; 2. Conduct training on VBD control and outbreak response; 3. Conduct field supervision /data review visits to provinces by research institutes & NDOH;	Human resource, experts, budget

South Africa is potentially at risk of arboviral diseases because of the occurrence of vectors, circulation of endemic viruses such as West Nile, Sindbis and occasionally Rift Valley fever in animal/bird hosts and local mosquitoes, and proximity to countries that have reported outbreaks of arboviral diseases. However, data on the biology and insecticide susceptibility status of potential arboviral vectors is sparse in South Africa. Risk assessments of arboviral diseases will be conducted in collaboration with research institutes and relevant government departments. Other measures will include screening suspects among local populations, migrants and returning travellers, a key function of South Africa's integrated Disease Surveillance (IDSR). Vector surveillance at points of entry is necessary to minimize the risk of introduction of exotic vector species (Table 5).

Objective 4: Increase knowledge and practices to 100% nationally and improve utilization of key VBDs interventions to 95% by 2027

For any vector control to be effective, coverage and utilization of interventions by the population at risk must be high to have the desired impact. A better understanding of community knowledge, attitude, and practice (KAP) on malaria and other VBDs are necessary to inform necessary changes to a health communication strategy. Well-informed and knowledgeable health workers and communities at large, on the cause of diseases and prevention methods, is critical for the success of a disease control program. Currently, the community surveillance officers, and IRS spray operators are providing communities with health education on malaria prevention and treatment, but this activity is currently limited to provinces where malaria is still a problem.

There is a gap in terms of community knowledge, attitudes and practices towards malaria, schistosomiasis and other VBDs. Part of the solution is to conduct a KAP on priority VBDs to get insight on levels of understanding and misconceptions on VBD prevention and control. Findings from the KAP will be useful to revise the communication strategy to include all priority VBDs in South Africa and inform the development of IEC/SBCC materials that will be used for health education and promotion. Refresher training of health promoters in provinces and districts with key health messages on priority VBDs is necessary to empower them with the knowledge to educate their communities. More importantly, NDOH will designate a dedicated fund for health education and social mobilization activities in all provinces. A multi-channel approach to social behavioural communication will be used to promote awareness of VBDs control to scale up intervention coverage and utilization.

Advocacy and promotion of VBD control are critical as part of the implementation. New avenues for advocacy and the spreading of messages on prevention of all priority VBDs will be required. Annual events to promote vector control is another avenue for advocacy. The existing health promotion avenues such as World Malaria Day and SADC Malaria Week should be expanded to include all priority VBDs.

Operational research and innovation on priority VBD is needed to guarantee that integrated programs provide optimal benefit to affected populations. Research activities at present are actively supported by some academic and research institutions. To properly guide operational research, a stakeholder consultation will be held to update a national research agenda and identify priority areas that need to be addressed to inform VBD control in South Africa. A national research agenda will prioritize specific research questions that address operational bottlenecks in the implementation of VBD control (Annexe 4). For example, new tools and approaches for vector surveillance and VBD control will be needed to address biological threats such as insecticide resistance in vectors and residual transmission of pathogens despite the use of standard interventions. Also, the introduction of molluscs/snail control may require a pilot study to identify efficacious products and the best delivery method suitable to the country's situation. Various study designs will be required to address these operational research questions and its implementation will require specialized research skills. NDOH will organize annual stakeholder meetings to discuss progress in the implementation of operational research, information dissemination for completed studies and revision of research priorities. Findings should support evidence-based decision-making and inform programmatic adjustment for optimization of vector control.

Community engagement and mobilization: Communities play a major role in vector control for prevention and elimination of malaria and other vector-borne diseases. Critical to success and sustainability of VBD prevention is the effective engagement and mobilization of the communities who are end-users of public health interventions. Vector control can be enhanced by educating and empowering communities to identify, empty, remove or treat vector (mosquito or snails) aquatic habitats in and around their homes. NDOH and provincial DOH will strengthen engagement and mobilization of local communities to support vector control activities. Health education through school system will contribute to broader community awareness and desirable behavioural changes on good practices for VBDs prevention and control. The Departments of Basic Education and Health are jointly implementing the Integrated School Health Program (ISHP) offering a comprehensive and integrated package of services. The ISHP Health Services Package includes a large component of health education for each of the four school phases (such as how to lead a healthy lifestyle and drug and substance abuse awareness), health screening (such as screening for vision, hearing, oral health and tuberculosis) and onsite services (such as deworming and immunization). The NDOH health promotion should work with the Department of Education to ensure VBDs prevention and control is included in the ISHP.

Implementation of the activities proposed below will increase knowledge and practice to improve the utilization of key interventions (Table 6).

Table 6: Key activities related to strategic objective four.

Objective 4: Increase knowledge and practices to 100% nationally and improve utilization of key VBDs interventions to 95% by 2027		
Key activities	**Sub-activities**	**Resources**
1. Strengthen health education to promote compliance and utilization of vector control interventions, enhance social and community mobilization on VBDs	1. Conduct IEC/BCC messaging and radio campaigns to promote IRS and larviciding;	Radio slots, IEC/SBCC Materials, transport
	2. Conduct KAP studies on VBDs 3. Training on social mobilization of health promoters in high-risk areas;	Transport, IEC materials, accommodation, conferencing, training materials
	4. Develop a VBDs webpage for information dissemination;	Electronic IEC materials
	5. Develop and disseminate key health education messages on VBD control for advocacy and awareness creation;	Translation, IEC materials (pamphlets, posters, Billboards), transport,
2. Strengthen advocacy to decision-makers and opinion leaders on VBDs	1. Develop a concept note and motivation for VBD control for the Minister/DG; 2. Conduct advocacy for VBD control;	Human resources, budget, advocacy materials
3. Social and community mobilization on VBDs	1. Conduct community engagement meetings, community dialogues, Roadshows and radio slots 2. Conduct health education and promotion in schools;	Transport, IEC materials, budget for mass campaigns, promotional materials
4. Develop a national agenda for basic and applied research on VBD entomology and vector control	1. Research stakeholder meeting to develop a national research agenda on VBDs; 2. Conduct an annual national VBD research symposium	Human resources, budget

Objective 5: To provide effective management, leadership, and coordination for the optimal implementation of the Vector Control Strategy at all levels by 2027

Successful prevention and elimination of VBDs will require a supportive policy environment, advocacy for sustained political and financial support, community engagement and empowerment to ensure acceptance and utilization of interventions. Critical to the success of prevention and elimination of VBD is effective collaboration within the health and beyond the health sector for coordination and action. Details of activities are provided below (Table 7). Current status of program management and areas that requires strengthening:

Policy and regulatory environment: In South Africa, existing policies, and legislation conducive to support the implementation of the Vector Control Strategy include

- Pesticide regulation – provided by two legislations:
  - The South Africa Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act No. 36 of 1947).
  - Health Act (Act 36 of 1919) provide legislation on public health pesticide and requirement to report incidents of pesticide “poisoning” as a “notifiable disease”.
- Environmental Management – The National Environment Management Act, 1998 (NEMA Act No. 107 of 1998) provides for the Environmental Impact Assessment (EIA) process. The EIA is a key regulatory instrument to mitigate and/or manage the negative impacts of new developments on the environment.
- VBDs specific policies; National Malaria Elimination Strategy 2019-2025; National Master plan for the elimination of NTDs 2019-2025; the Integrated Vector Management for malaria control in South Africa, 2015 (outdated); and Insecticide Resistance Management plan which now is the part of the Vector Control Strategy.
- Policy and mechanism that support sector coordination and arrangements may include existing inter-sectoral committee on health; parliamentary committee; multi-sectoral committee on chemical management; malaria technical committees such as SAMEC and SVC, and One Health Forum.

Institutional framework: Adequate formal frameworks are required in South Africa to ensure coordination between sectors to support the VBD program, to streamline multi-sectoral collaboration and communication. A Multisectoral collaborative arrangement is a requirement in alignment with the GVCR 2017-2030 and IHR 2005. South Africa IHR review of 2017 noted the need to strengthen collaborative approach by establishing a clear chain of command and decision-making structures to prevent, detect and respond to emerging health emergency such as zoonotic diseases. To that end, a national inter-sectoral steering committee (ISC) with broad participation from government departments, stakeholders, private sector and community organizations should oversee the national implementation of Vector Control Strategy. Roles and responsibilities of ISC will be clearly defined and formalized with an MOU and TOR (details, section 3.3).

Focal person for Vector Control: There should be a single focal person at NDOH to coordinate the implementation of a VBD strategy in collaboration with different government departments at national and province-level and other stakeholders. The focal person should have access to each member of the inter-sectoral steering committee, technical working groups and partners. The main tasks of the focal person would be to manage networking among national partners and to coordinate the implementation of the recommendations of the committees.

Cross-border collaboration: One of the greatest threats to infectious disease elimination is the proximity and connectedness with higher transmission neighbours and the risk of cross-border transmission. Avenues for strengthening cross border collaboration include policy harmonization, joint implementation of VBD interventions along shared borders, synchronized vector control along bordering districts, and determination of the source of transmission between countries to inform targeted interventions that address transmission at the source. Effective cross-border collaboration requires a multisectoral approach with involvement of different government agencies such as health services, environment and immigration.

Table 7: Key activities related to strategic objective five.

Objective 5: To provide effective management, leadership and coordination for the optimal implementation of the Vector-Control Strategy at all levels by 2024		
Key activities	**Sub-activities**	**Resources**
1. Adapt and implement Vector Control Strategy	1. Develop the VBD Strategy;	HR, IEC materials, budget
2. Strengthen inter-sectoral action and sector coordination for VBD control	1. Map out VBD stakeholders and identification of roles to support VBD control; 2. Conduct consultation with all stakeholders to agree on role and operational mechanisms;	HR, budget
3. Strengthen partnerships and coordination to support the planning, execution and monitoring of control efforts	1. Annual VBD control review and planning meetings; 2. Collaboration with government departments; 3. Partnership forum/network with VBD research institutes	HR, budget for meeting,
4. Establish National inter-sectoral committee and institutional network for multi-sectoral engagement in vector control	1. Constitute the ISC on VBDs with TOR and relevant members; 2. Conduct ISC meeting (once a year); 3. Establish ISC technical committees (Surveillance, Case Management & Vector control/Entomology), with clear TOR and membership to align with Vector Control Strategy; 4. Conduct VBD TWG meetings (once a year);	HR, materials, experts, budget
5. Strengthen stakeholder collaboration at provinces and districts on VBD control	1. Conduct engagement activities and meetings with government sectors, community representatives, municipality and private sector; every quarter	HR, materials
6. National vector control needs assessment (VCNA) and resource mobilization plan	1. Conduct VCNA and produce a report that identifies priorities and gaps to be addressed to strengthen VBDs control; 2. Develop an implementation plan to address gaps revealed through VCNA;	HR, experts
7. National entomology and cross-sectoral workforce appraisal to meet identified requirements for VBD control	1. Appraisal of organizational structures, the job description of posts and evaluation of career structure at all level – national, province and district	HR, VBD focal, experts,
8. Strengthen cross-border collaboration and joint action on VBD control	1. Annual national meeting with neighbouring countries to share information and plan prevention VBD control activities, through existing forums;	HR, VBD focal,
9. VBD control program reviews	1. Biannual Review Meetings with Provinces; 2. Mid-term program review to inform adjustment of IVM/VBD strategy 3. End-term program review to inform new IVM/VBDs strategy	HR, experts, budget

2.3 Vector Control Interventions

Vector control is a vital component of VBDs prevention and elimination strategies because it can be highly effective in providing personal protection and/or reducing disease transmission. Proven and cost-effective vector control interventions for malaria include IRS and LLINs. Interventions such as space sprays, larvicides and environmental management may be important for other vector-borne diseases, depending on the target vectors (Annexe 5). There is a rich pipeline of vector control products under different stages of evaluation to determine efficacy and public health value. These new tools and approaches for vector control are needed to address key challenges such as vector insecticide resistance.

2.3.1 Indoor Residual Spraying (IRS)

IRS is the main malaria intervention fully funded by the government of South Africa. Coverage of IRS does not always reach the target of 95% due to multiple reasons including delays in procurement of insecticide and recruitment of spray operators, refusal by the community, over-long spray campaigns and suboptimal quality of IRS. Strengthening program management, advocacy and community engagement will solve some of these challenges. Critically, each provincial program needs to improve its capacity to plan, procure insecticides on time and enhance supportive supervision for quality control. Strengthening entomological surveillance will ensure adequate quality assurance monitoring of spraying activities, monitoring of insecticide resistance to inform the selection of insecticide effective against local vectors and as a strategy to manage insecticide resistance. Insecticide formulations available for IRS, which have been prequalified by WHO, fall into five major insecticide classes with three modes of action, based on their primary target site in the vector (Table 8). Periodic geographical reconnaissance of areas targeted for IRS is critical to generate accurate demographic data useful to inform planning and monitoring of IRS coverage. Quality assured and properly maintained equipment should be used for IRS.[9] Although IRS is now used for malaria control, the same intervention could be applicable to control endemic mosquito-borne arboviral diseases, and response to contain outbreaks of epidemic-prone diseases such as dengue.

Table 8: The list of WHO insecticide prequalified and mode of action available for IRS

Mode of action*	Class of Insecticide	Types of insecticides
Sodium channel modulators	Pyrethroid	Alphacypermethrin, Deltamethrin, Lambda-Cyhalothrin, Etofenprox, Bifenthrin, Cyfluthrin
	Organochlorine	DDT
Acetylcholinesterase inhibitors	Organophosphates	Malathion, Fenitrothion, Pirimiphos-methyl
	Carbamates:	Bendiocarb
Nicotinic acetylcholine receptor competitive modulators	Neonicotinoids	Clothianidin

*As per the Insecticide Resistance Action Committee Mode of Action Classification Scheme, available on the IRAC website: www.irac-online.org (Pyrrole Chlorfenapy product under WHO evaluation not included in Table 8). The availability on the market of the WHO prequalifies "new generation IRS products" the IRS program should consider insecticide rotation to manage insecticide resistance.

2.3.2 Long-lasting Insecticidal Nets (LLINS)

LLINs are recommended for use in protecting populations at risk of malaria but are currently not the main intervention in South Africa. As the transmission of malaria in South Africa has reduced significantly, LLIN distribution may be used to target foci of malaria transmission, especially at border districts where the movement of people is expected to be high or areas with mining activities or special populations (displaced population during a natural disaster) with temporary shelters where IRS is not applicable. NDOH and the vector control technical committee will assess the need for LLINs in the future and as new innovative nets become available.

2.3.3 Larval Source Management (LSM)

LSM measures such as larviciding and environmental management are used to diminish vector habitat sites and kill vectors at their aquatic stages to reduce the emergence of adult vectors leading to a reduction in transmission of disease pathogens. In malaria control, larviciding only reduces malaria vector density, it does not have the same potential for health impact as IRS or LLIN – both of which reduce vector longevity and provide protection from biting vectors. As a result, larviciding should never be seen as a substitute for LLINs or IRS in areas with significant malaria risk.

Winter-larviciding is implemented in some targeted districts in South Africa to supplement IRS. Larviciding is operationally feasible during winter because the number of water bodies requiring treatment is reduced and therefore likely to be cost-effective. There is an opportunity to scale up larviciding in South Africa through community engagement. LSM is recommended for the control of Aedes, nuisance mosquitoes and molluscs. LSM may include the use of Bacillus thuringiensis israelensis (Bti), as well as chemical actives (Table 9). Overall successful larviciding requires sector collaboration between health, agriculture and environment, and private sector such as mining and community at large.

Table 9: The list of WHO prequalified larvicides and mode of action

Mode of action*	Class of Insecticide / AI	Active agent (AI)
Acetylcholinesterase (AChE) inhibitors	Organophosphates	Fenthion, Pirimiphos-methyl, Temephos
Nicotinic acetylcholine receptor allosteric activators	Spinosys	Spinosad
Juvenile hormone mimics	Pyriproxyfen	Pyriproxyfen
Microbial disruptors of insect midgut membranes	Bacillus thuringiensis	*Bacillus thuringiensis subsp. Israelensis* strain AM65-52; *Bacillus sphaericus*, strain ABTS-1743
Inhibitors of chitin biosynthesis type 0	Benzoylureas	Diflubenzuron, Novaluron

*As per the Insecticide Resistance Action Committee Mode of Action Classification Scheme, available on the IRAC website: www.irac-online.org

9 WHO 2016 IRS Operational manual, second edition

South Africa will intensify schistosomiasis elimination campaigns to include targeted snail control via the use of molluscicides [7], provision of water and sanitation, and hygiene education. A strategy for schistosomiasis control and prevention in South Africa will require the following:

1. Understanding the countrywide distribution of intermediate host snails;
2. Identify local transmission sites and related human risk behaviour;
3. Implementation of an effective snail control measure. Possible options include plant-based and chemical-based molluscicide, and environmental management/ modification;
4. Partnerships and collaboration with other sectors, e.g. Farming and mining & affected communities, different government departments (Department of Agriculture, Land Reform and Rural Development (DALRRD), Department of Environment, Forestry and Fisheries (DEFF), Education, Water and Sanitation etc.) and the community at large; and
5. Aligning snail control with the Mass Drug Administration program.

2.3.4 Personal protection and other vector suppression measures

Personal protection measures have the primary function of protecting individual users, although they may have some as yet unproven public health value. Personal protection measures include topical repellents and insecticide-treated clothing. Although the available evidence base is insufficient to support their use for malaria prevention, these measures may apply to other VBDs. Space spray is effective in responding to dengue /chikungunya outbreak. Use of topical repellents may be useful to prevent nuisance vectors such as ticks and fleas.

2.3.5 New Tools and Technological approaches for vector control

There is a pipeline of innovative new tools, technologies and approaches for vector control under different stages of evaluation to establish public health value.[10] A list of new vector control product classes and prototypes under assessment is available on the WHO web site.[11] Once the protective efficacy of new tools has been proven to reduce or prevent infection or disease in humans, South Africa should firstly; determine in consultation with WHO, whether a given new tool is suitable to local disease situations and secondly; quickly register and deploy the new tool in targeted areas. NDOH will work with regulators to ensure quality-assured vector control products, including new tools, are registered and deployed rapidly at the required scale to maximize their impact on VBDs.

2.4 Vectors Insecticide Susceptibility Status in South Africa.

Majority of these vector suppression measures commonly used against malaria and arboviral diseases (Annexe 5) are pesticide-based. That said, the scale-up of vector control interventions will necessarily be accompanied by an increase in the use of insecticides. Given the malaria vector control in South Africa relies heavily on the use of insecticides, and already high levels of pesticides used in agriculture mean possible increased selection pressure that may lead to the development of resistance in the local vector populations. Monitoring insecticide resistance in malaria vectors and characterization of the underlying mechanism is essential to inform operational decisions such as choice of alternative insecticide for public use. The proposed Vector Control Strategy include an Insecticide Resistance Management Plan (IRMP) required for the prevention and mitigation of insecticide resistance in South Africa (Annexe 6, 7).

Vector Insecticide Susceptibility Status in South Africa

Insecticide resistance status of malaria vectors is well established than vectors of other priority VBDs in South Africa. Although insecticide resistance (IR) in malaria vector populations is widespread in many countries, it is a relatively recent occurrence in South Africa. Below is a summary of insecticide susceptibility status in vector mosquitoes.

- High frequency and intensity of pyrethroid (Permethrin) resistance in An funestus, which is mediated by metabolic mechanisms, but local An funestus is fully susceptible to DDT [17];
- Anopheles arabiensis in certain parts of Mamfene northern KZN is resistant to organochlorine (DDT), pyrethroid and carbamate (bendiocarb) but fully susceptible to organophosphates (pirimiphos methyl) [18]. The primary mechanism of Pyrethroid is metabolic involving monooxygenase enzymes;
- An. arabiensis from Thomo and Malahlapanga in Limpopo Province and Mamfene in KZN susceptible to DDT, Pyrethroid and organophosphate fenitrothion but the population is resistant to propoxur [19];
- Susceptibility status of local An funestus unknown for carbamate and organophosphate, and requires investigation;
- Susceptibility status of non-malaria vectors such as Aedes is unknown and require investigation.

10 Public health value is defined as: proven protective efficacy to reduce or prevent infection and/or disease in humans
11 World Health Organization (2018): Overview of product classes and prototype/products under Vector Control Advisory Group (VCAG); review for assessment of public health value. World Health Organization <link>

2.5 Vector-borne diseases data management for decision

There is a robust malaria data management system in South Africa which can be expanded to include other VBDs. Vector and entomological data captured during routine or reactive survey and processed by either province or research institutions should be entered into DHIS2 malaria tracker. Information collected in the national database will be used to produce national reports, inform targeting of interventions and evaluating the impact of the intervention on disease outcome. Vector information and relevant data will also be discussed by the relevant technical working groups and make recommendations to inform decisions.

The malaria DHIS2 tracker has different modules that enable the integration of different source of data such as parasitology, entomology, and vector intervention coverage. The DHIS2 mapping capability is useful for planning and supervision of field operations and assessing the impact of interventions on targeted diseases. The existing malaria DHIS2 system will be extended to include data of other priority VBDs. Schematic of vector surveillance data flow and decision matrix is summarized below (Fig. 5).

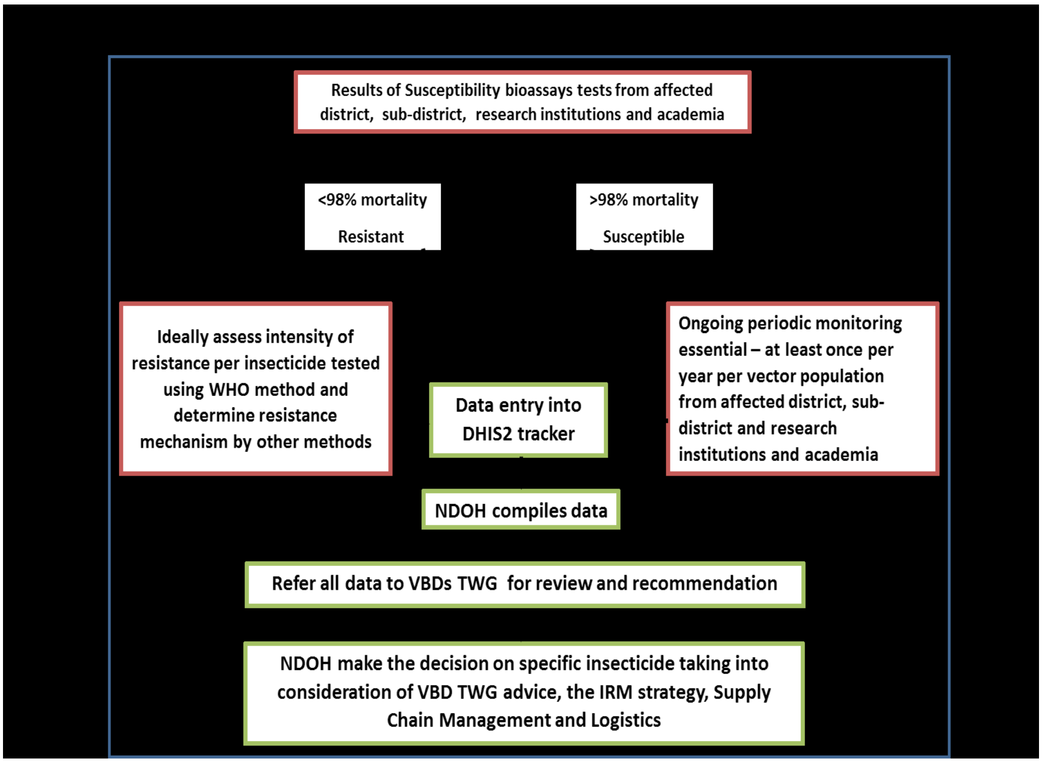


Figure 5: Insecticide resistance management data flow and decision matrix for South Africa

3. Cross-cutting issues related to Vector-Borne Diseases

6.4 Life cycle management of pesticides and regulation

Legislation and regulation of pesticides:

- The Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act No. 36 of 1947), under DALRRD, provides for pesticide regulation in South Africa. The Act is supported by the regulations and Strategy in respect of the requirements for registration, manufacturing, labelling and packaging requirements, fees and advertising. Pesticide regulation unit under DALRRD has a statutory mandate to regulate pesticides in South Africa. The unit has 6 functions;
    - Review applications for registration of pesticides;
    - Conduct science-based health, environmentally and efficacy assessments;
    - Develop and implements policies and Strategy related to pesticide management;
    - Promote sustainable development;
    - Enforce compliance with the legislation, and Disseminate information on pesticide management issues.

- Public Health Act (Act 36 of 1919) provide legislation on public health pesticide and requirement to report incidents of pesticide "poisoning" as a "notifiable disease". Overall, challenges to implementation and inadequate financial and human resources of the existing legislation are the limiting factors for enforcement, monitoring, and evaluation;

- Existing regulation makes provision for verification of efficacy, safety, and quality specification of a product as a requirement for registration. The legislation, however, makes no provision for quality assurance of product after registration and the safe disposal of pesticide wastes. These are key components of the life cycle management of pesticides that need to be addressed going forward. Challenges to implementation of the existing legislation are the limited mechanisms for enforcement, monitoring, and evaluation and inadequate financial and human resources to implement.

- The National Environment Management Act, 1998 (NEMA Act No. 107 of 1998) provides for the Environmental Impact Assessment (EIA) process. The EIA is South Africa's key regulatory instrument to mitigate and/or manage the impacts of new developments and activities that are considered to potentially impact on the right to an environment that is not harmful to health and well-being. DALRRD and NDOH will collaborate with DEFF to ensure environmental health impact assessment (EHIA) is integrated into the EIA process to include mitigation measures against the sprayed of vector-borne diseases that may result from new development projects.

- Quality assurance of pesticides product and equipment for vector control is critical. The quality assurance of vector control pesticides is normally verified before importation into the country. With IRS and LLIN products, WHO advocate for pre-and post-testing of insecticides for quality control. In South Africa requirements for quality assurance of vector control products and handling of waste product such as empty pesticide containers are stipulated in the tender procurement process. It will also be beneficial, as a country, to develop laboratory capacity for quality assurance and control of vector control products. Spray equipment for public health use should be based on WHO standards. [12]

- Effective public health pesticide regulation calls for collaborative effort amongst relevant government sectors (e.g. NDOH, DALRRD, DEFF, DWA) to strengthen life cycle management of pesticides in South Africa. Ideally, all these departments should be involved in any coordination efforts if an integrated and comprehensive approach to the implementation of pesticide management is to be assured. The key role players involved in chemical management (through the MCCM) at a national level and their role is summarized below (Table 10).

Table 10: South Africa departments and their role in chemical/pesticide management

Department	Role
Agriculture, Land Reform and Rural Development	Lead department for the regulatory control of agricultural chemicals
Environment Forestry and Fisheries	Lead department for chemicals co-ordination; Environmental aspects of chemicals, including waste management and air quality
Health	Regulatory control of industrial and public health chemicals
Labour	Lead department for the implementation of GHS; Regulatory control regarding the use of chemicals in the workplace (excluding mines)
Mineral Resources	Regulatory control regarding chemicals used in mining operations
Trade and Industry; Economic Development	Management of the import and export of chemicals; promotion of the chemicals sector
Transport	Regulatory control over the national and cross-boundary transportation of chemicals
Water Affairs	Indirect control where chemicals impact on water quality
South Africa Revenue Services	Customs and excise
Other with secondary involvement	Department of International Relations; Department of Science and Technology; South African Bureau of Standards

12 WHO 2016 IRS operational manual, Geneva.

Public health pesticides use and safeguard for human and environmental protection:

A detailed assessment of the potential risks to human health and the environment is essential before the widespread use of an insecticide for vector control. This assessment will look into peculiarities of the intended operational area, and the verifiable implementation of safeguards. The decision on selection of specific public health insecticides for use in any vector control intervention (e.g., IRS, larviciding) will provide a clear rationale for selection including adequate consideration of the impact on pre-existing tolerance/resistance in targeted vector populations and potential handling risks. There will be appropriate educational, advisory, extension and health-care services linked to the use of insecticides for vector control. The following will be specifically addressed:

1. Adequate protection of human health and the environment in vector control operations is critical and will be based on relevant pesticide management laws, regulations, and institutional arrangements. Consequences for breaking laws regulating the use of insecticides will be clarified and published, and access to public health insecticides will, always, be restricted to authorized persons/programs.
2. Public health insecticides for vector control will be procured with the full involvement and consent of NDOH, from internationally recognized/ certified manufacturers and/or their certified and authorized local agents. There will be a verifiable chain of custody within the country, and country capacity for assuring the quality of procured insecticides will be enhanced in collaboration with relevant government departments such as DALRRD and advanced laboratories. Centralized procurement of public health pesticides and application equipment through national NDOH is favourable for efficient use of resources and ensuring favourable conditions such as disposal of waste, training of health workers and servicing of equipment;
3. All categories of insecticide handlers, particularly spray operators and drivers, will be appropriately trained and certified on Best Practices covering the whole insecticide life cycle – including storage, transportation, end-use and disposal. All spray operators must be certified based on the completion of stipulated training or periodic refresher training. Insecticide handlers (transporters, storekeepers, spray operators, etc.) will use approved personal protective equipment (PPE) at all times during the handling of insecticides;
4. Harmonized pesticide storage, inventory practices and procedure for disposal of chemical waste will be established and informed by national regulations and relevant recommendations of WHO and FAO. There will be a certification and maintenance scheme for all insecticide application equipment. Malaria/VBD camps used as stations to implement malaria control activities should have essential facilities to ensure safe handling and disposal of materials related to IRS operations;
5. The use of insecticides in vector control (e.g., IRS, larviciding) will involve trained environmental compliance inspections as an integral part of programming to monitor field operations and promptly correct anomalies. Malaria camps will be equipped with adequate facilities to provide adequate storage condition, safe handling chemical and disposal of waste. Continued special attention will be given to DDT to satisfy the Stockholm Convention requirements;
6. Health facilities where pesticide-based interventions are deployed will be facilitated and equipped to handle insecticide poisoning.

6.5 When and how to scale-back malaria vector control

Given the general decline in malaria transmission in many settings, it may be appropriate to scale back vector control interventions to targeted deployment in specified geographic areas. However, a historical review of eradication programs and modelling different scenarios indicated that the scale-back of malaria vector control was associated with a high probability of malaria resurgence, including most areas in which malaria transmission was extremely low or had been interrupted [20]. Even in areas where there are significant reductions in malaria transmission, with an annual incidence of <1 local case per 1000 population, curtailing vector control posed a high risk of malaria resurgence in most situations. This risk increased in situations of relatively high rates of vulnerability (defined as the frequency of influx of infective malaria mosquitoes and or infected individuals or groups), high receptivity (defined as the ability of an ecosystem to support the proliferation of malaria mosquitoes to allow transmission of malaria), and low coverage of disease surveillance and case management. In this regard, South Africa shall implement the following WHO recommendations:

- In areas with ongoing local malaria transmission (regardless of the pre-intervention and the current level of transmission), the scale-back of vector control will not be recommended. Universal coverage with IRS in such areas will be pursued and maintained.
- In areas where transmission has been interrupted, the scale-back of vector control will be based on a detailed active disease surveillance system and capacity for case management and vector control response.
- These Strategy aim to strengthen capacity in health systems, particularly in disease and entomological surveillance, because identification of areas for geographical scale-back and timely detection and appropriate response to resurgence depends on this capacity.

6.6 Collaborative and coordination arrangements for VBDs

The factors determining the local transmission of VBDs usually go beyond the purview of the health sector – cutting across several sectors. This means inter-sectoral collaboration and action is necessary to fully and adequately address and eliminate all VBDs.

6.6.1 National Inter-sectoral Steering Committee (ISC) on VBDs

A National Inter-Sectoral Steering Committee (ISC) will be established, under the leadership of the NDOH to promote a multi-sectoral approach to vector control, ensuring that non-health sectors such as agriculture and environment play proactive roles to fully address disease transmission. The ISC will compose of senior officers representing relevant government sectors (Health – NDOH Malaria Other Vector-Borne and Zoonotic Diseases, Occupational Health, Health Promotion, Port Health); Department of Agriculture, Land Reform and Rural Development (DALRRDD); Department of Environment Forestry and Fisheries (DEFF); Education; Water Affairs; Tourism and Immigration), partnering institutions (research/academia, NICD, WHO, UNEP), non-governmental organisation (NGOs working on VBDs control e.g. EcoHealth). Levels of coordination necessary for successful implementation will include:

1. Intra-collaboration within the health sector, in this case between relevant directorates and programs of NDOH such as Directorate of Malaria and other VBDs, NTD program, and Environmental and Occupational Health, and Port Health. Through effective coordination between programs, it will be possible to share resources in planning, implementing, surveillance and monitoring and evaluation and reduce overlap and duplication.
2. Inter-sectoral /stakeholder collaboration between the health and other sectors is important because often the non-health sector is unaware of how their actions or inactions contribute to VBD and many determinants of VBD such as agriculture, environment, housing, urban development, and sanitation, as well as mining, are outside the scope and jurisdiction of conventional VBD control programs. List of sectors and stakeholders and anticipated role provided in Tables 10 and 11.
3. The need for a One Health approach to address VBDs is clear. The ISC will therefor provide feedback and align with the One Health Forum organised through the Multi-sectoral outbreak response team (MNORT) and the countries' compliance with the International Health Regulations requirements to be able to respond to Zoonotic diseases through One Health platform.

The NDOH will provide overall strategic and technical guidance to province/district level planning, implementation, monitoring and evaluation of the VBD, ensuring multidisciplinary, multi-disease approaches and proactive inter-sectoral action. The ISC chaired by the Director-General of the Department of Health (or his designee) will provide appropriate oversight and guidance to the VBD control. The ISC will pool relevant stakeholders into ad-hoc subcommittees around focal thematic areas to support VBD implementation. Thematic areas include 1) Surveillance 2) Case Management / EPR and 3) Vector control/Entomology. Each sub-committee will have a TOR defining role and responsibilities for all sectors and their linkage to the function of the One Health Forum and IHR. The ISC sub-committees will have designated chair and co-chair and will include members with a relevant mix of expertise such as entomology, acarology, limnology, virology, epidemiology, environmental management, and program management. Specialists in these sub-committees will advise on the implementation VBD program; make recommendations to enhance national policy for VBDs; technical support to the organization, monitoring and evaluation of national programs; and support training of staff and conducting priority operational research on VBDs using a One Health approach. Specific advice and recommendation from technical working groups, with policy and operational implication, will be submitted to ISC for decision and/or endorsement.

6.6.2 Functions of ISC and governance structure

The mandate will include the following:

1. Review national policies relevant to vector-borne diseases control and develop a unified overarching national policy and strategies for their control;
2. Coordinate and provide oversight to the implementation of Vector Control Strategy and work plans, ensuring cost-effectiveness, efficiencies and sharing of lessons/experiences;
3. Coordinate the mobilization of resources for inter-sectoral action consistent with national aspirations for VBDs control and elimination ensuring transparency and accountability;
4. Facilitate rationalized roles and responsibilities among stakeholders and evolve mechanisms to promote/ ensure accountability;
5. Undertake a regular review of the implications of policies, strategies and work plans on VBDs and make recommendations to government and appropriate authorities to enhance the achievements of national objectives on vector control;
6. Establish technical working groups on thematic areas: Surveillance, Case Management/EPR and Vector control/ Entomology - drawing upon national and international expertise; and
7. Create opportunities for generating broad-based national consensus on issues and ensure that the genuine concerns of at-risk populations and communities are adequately considered.

The ISC will strive to balance sectoral /partner expectations with the broader national VBDs goals and ensure that all VBDs risks are given appropriate consideration. It will also have the responsibility of ensuring the VBD program and individual partner agendas fit and are integrated into the overall national strategic objective. The ISC governance structure is summarised below (Fig. 6).

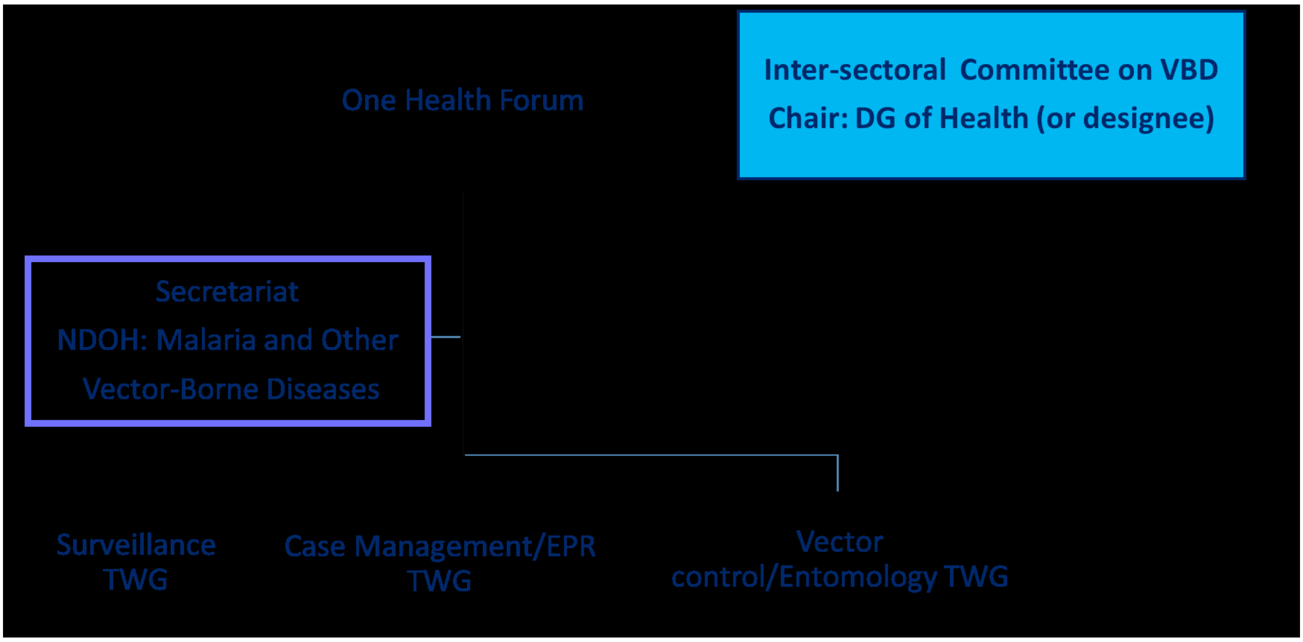


Figure 6: Structure of Inter-sectoral coordination on Vector-Borne Diseases in South Africa

Roles and responsibilities of stakeholders will be established to facilitate collaboration, as listed in Table 11. Inter-sectoral arrangements at the national level will be reflected within the provinces to enable effective joint action on VBDs control at all levels.

Table 11: Potential Stakeholders and anticipated roles in vector control

Sector/Ministry/Department	Roles in vector control
Health - National (Malaria & other VBDs, Environmental Health) and province (PMEP, Environmental Health)	Provide leadership on VBD strategy, disease information, and procurement of anti-vector consumables, intervention implementation, and impact assessment of interventions; and promote vector control mitigation in development projects; Environmental compliance and vector control and monitoring in communities; water and sanitation; regulation of public health insecticides in coordination with DALRRD and DEFF;
DALRRD	Advise farmers on best practices in pesticide use in agriculture and management; promote IPM to reduce environmental contamination with insecticide and prevent the development of resistance; Regulation and control of agricultural pesticides; Participate in training of spray operators and supportive supervision of spray operations; Develop and disseminate operational Strategy on the management of pesticides;
Land Human Settlements; Water Affairs	Ensure compliance on environmental and health regulation on development projects (housing, roads, dams and other infrastructure); Ensure good sanitation; enforce vector control mitigation in development projects (EHIA) Develop Health–smart (Malaria/VBD) environmental impact assessments on all settlements and water projects at all levels; Quick repair of leaking clean- and wastewater pipes; clearance of blocked drains; and LSM on oxidation ponds;
Education	Create awareness on vector-borne diseases control; health education on vector-borne preventive measures; Include VBD prevention and control into the Integrated School Health Program (ISHP) curriculum (e.g. malaria-safe habits and information on the malaria community project in teaching; Extend the peer education program to include health promoters visiting schools to lectures on VBD prevention and control; Promote formation and functionalization of school health clubs with malaria activities in school & surrounding communities;
National Treasury	Ensure financial sustainability towards vector control; Tax exemption and tariffs on public health products
Tourism	Promote vector control in the tourism industry health education of tourists

Sector/Ministry/Department	Roles in vector control
DEFF	Ensure health impact assessment as part of environmental impact assessment of development projects to include safeguard on vector proliferation; On-site control of compliance with norms and standards, enforcement of mitigation measures; Gather climate data for forecasting and prediction. Strengthen pesticide management to minimize environmental pollution (participate in the training of spray operators; field supportive supervision and inspection of public health pesticide use for environmental compliance)
Human Settlements; DALRRD	Pest control services and waste management, community engagement through local authorities; Ensure compliance on building regulation/code of standards– promote build environment that is protective against vectors (mosquito-proof screens, sanitation); enacting and enforcing urban by-laws to prevent mosquito breeding in domestic and peri-domestic areas, and construction sites.
Defence; Police; Trade and Industry; Home Affairs;	Joint border operations as part of cross border collaboration to prevent importation of VBDs; Vector control in police/military barracks; logistic support of public vector control operations (Regular IRS in prisons, military camps and police barracks);
UN: WHO, FAO, UNEP/GEF, Donors: GFTAM, USAID,	Technical and financial support; Commodity management support;
Private sector: Mining Industry; Plantations and Agricultural concessions; (SANPARKS) Lodges and camps, Farmers Associations	Collaboration and support for vector control; Supply of vector control product and support implementation; Support health promotion, advocacy of good practices in vector control;
Research and Training (NICD, UP, WITS, UKZN, SAMRC)	Implementation of basic and operational research on VBDs Training in vector control; independent evaluation of interventions; specialized services – lab diagnosis; supportive supervision and mentorship of vector control;
Local NGOs: farmer-Cooperatives, Civil societies	Promote end-user compliance of insecticide and environmental management best practices among targeted communities; Community advocacy and mobilization to support vector control activities
Communication; Media and Mobile phone service provider	Broadcast health education messages, advocacy and community sensitization on vector control and IVM
One Health stakeholders/Forum	One Health stakeholders from the above that are part of a formal or informal forum to address Vector-borne diseases through human, animal and environmental health. South Africa is a signatory to the IHR and also have a formal policy on using a One Health approach to detect and respond to Zoonotic diseases.

Frequency of meetings

The ISC will meet once annually. The subcommittees on three thematic areas will meet before the ISC.

Major action points for inter-sectoral collaboration

1. The NDOH / NMEP to lead the development of a formal mandate, terms of reference and commissioning of an ISC to oversee the national implementation of Vector control Strategy;
2. The NDOH shall appoint a VBD focal (a senior-level staff) to coordinate ISC activities and identify major stakeholders to invite as members. Each member-sector and organization of the ISC shall appoint a relevant senior staff representative. An influential person identified to act as VBD ambassador to advocate for and solicit political support for vector control;
3. Province NDOH/PMEP will oversee VBD control activities at the implementation level with the support of local VBD focal, municipality and relevant partners;
4. The ISC will oversee collaboration between stakeholders on control of malaria and other vector-borne diseases and evolve criteria for recognizing stakeholders who excel in collaborative efforts;
5. Revamp SAMEC and establish working groups on 1) Surveillance, 2) Case management and 3) vector control/entomology;
6. Convene the technical working groups and ISC meetings, once annually;
7. The NDOH will promote adequate consultations on the national Vector Control Strategy with all stakeholders;
8. The NDOH will recruit one senior entomologist at the national level to incorporate capacity into the ISC to address other vectors apart from malaria vectors. As needed, entomologists in other sectors will also be mobilized to support specific vector control efforts; and
9. The NDOH and province DOH will facilitate the development of province/district work plans for VBD.

4. Program budget

Cost of core interventions, human resource and infrastructure related to malaria elimination will be covered under the provincial department of health budget. While effective systems are in place for logistics and insecticide procurement, storage and distribution for the deployment of malaria vector control interventions, there is limited human resource for effective and quality assured control of malaria and other priority VBDs. Additional resources are needed to implement priority activities for each of the Vector Control guideline objectives, coordination of sectors and stakeholders and capacity building of health workers and entomology teams, as well as supportive supervision required for successful implementation. Also, additional resources are needed to establish a system to support the prevention and elimination of VBDs building on the existing malaria infrastructure.

4.1 Budget estimates

The cost of core activities of VBD strategy such as procurement of pesticides for spraying, spray equipment, salary for human resources, and maintenance of infrastructures such as insectary and laboratory will come from the budget allocated for malaria at the provincial department of health. There are additional costs to support the implementation of the Vector Control Strategy. This will involve an additional cost for human resources at NDOH for coordination of sectors/stakeholders, support for national public VBD advocacy events, and community engagement activities. Other major cost items include the national surveys on KAP of community to VBD prevention and control, and survey of the snail – intermediate host of Schistosoma - to inform targeted snail control, and implementation of priority operation research to address bottlenecks and improve VBD control program. Multi-sectoral coordination and collaboration will require resources, including the convening of ISC and technical committees on VBD prevention and control, as well as supportive supervision of programmatic and control activities.

5. Monitoring and Evaluation

Currently, the NDOH via the national malaria elimination program is strengthening its information system to make it robust for tracking progress towards elimination and inform evidence-based decision-making. Surveillance, Monitoring and Evaluation indicators used are aligned with the WHO framework for malaria elimination [21] and the WHO Surveillance operational manual [22]. The DHIS2 malaria information system being developed includes data on vectors (entomology), cases (epidemiology) and interventions coverage (vector control). The systems will enable linkages and triangulation of different types of malaria data. The improved data management system will enable malaria transmission risk mapping, planning preventive control measures, guiding routine vector and epidemiological surveillance, and facilitating assessments of the impact of interventions. As part of the implementation of the VBD Strategy, the DHIS2 by the NDOH will be expanded to include other priority VBDs.

The vector-borne disease program will be evaluated at regular intervals for compliance with the appropriate targets and objectives. Surveillance, monitoring and evaluation parameters will focus on four key issues:

- Monitoring the operational aspects of the program and measuring impact or process indicators to ensure that the activities are yielding the desired results and moving the program towards achieving its operational targets and objectives;
- Monitoring changes in epidemiological indicators resulting from the activities implemented;
- Appropriately interpreting results and informing policy and guideline revisions, when needed, to help ensure progress;
- Documenting progress towards malaria/ VBDs elimination—information on coverage and quality of interventions, mapping out transmission foci, and maintaining relevant eco-epidemiological data - is important to update stratification maps. This type of information is usually collected through a national information system for disease surveillance and health management.

Monitoring and evaluation will identify progress made in program implementation, the advocacy and communication, policy and institutional framework, partner coordination for action and capacity-building. The Vector Control Strategy M&E indicators are summarised in Annexe 8.

6. Conclusion

To effectively implement vector control as a critical component of disease control strategies in South Africa, the following components of IVM are essential: strengthening inter- and intersectoral coordination and action; enhancing entomological and epidemiological surveillance to characterise transmission risk and use evidence to inform targeting of interventions; supportive supervision, integrating tools and new innovative approaches for vector control; engaging and mobilizing communities; strengthening human resource and infrastructures to support vector control; expanding operational research to resolve operational constraints for optimal uptake of interventions; strengthening country leadership, advocacy and resource mobilization and partner coordination; and supporting the policy and regulatory space for vector control. The ultimate goal of South Africa's VBD strategy is to eliminate priority VBDs, particularly malaria and Schistosoma. Importantly, the national health system-based response among stakeholders and political commitment is needed for successful VBD control and elimination.

References

1. WHO (2017). Global Vector Control Response, 2017-2030. World Health Organization, Geneva
2. Mngomezulu N., Govere JM, Durrheim DN, et al., (2002). Burden of schistosomiasis and soil transmitted helminth infections in primary schoolchildren in Mpumalanga Province, South Africa. S. Afr. J. Sc. 98, 607-610.
3. Magaisa K, et al., (2015). A review of the control of schistosomiasis in South Africa. S Afr J Sci.;111(11/12),
4. WHO (1992). The role of mollusciciding in schistosomiasis control. Fergus McCullough. Geneva: World Health Organization (WHO/SCHIST/92.107; http://apps.who.int/iris/bistream/10665/62295/1/ WHO_SCHISTO_92.107.pdf).
5. King CH, Sutherland LJ, Bertsch D. (2015). Systematic review and meta-analysis of the impact of chemical-based mollusciciding for control of Schistosoma mansoni and S. haematobium transmission. PLoS Negl Trop Dis. 9(12):e0004290. doi:10.1371 ;
6. Sokolow SH, Wood CL, Jones IJ, et al., (2016). Global assessment of schistosomiasis control over the past century shows targeting the snail intermediate host works best. PLoS Negl Trop Dis. 10(7):e0004794.
7. WHO (2017). Field use of molluscicides in schistosomiasis control programs: an operational manual for programme managers. WHO, Geneva
8. Frean J, Blumberg L, and Ogunbanjo GA. (2008). Tick bite fever in South Africa. SA Fam Pract 2008;50(2):33-35
9. Kemp A, Jupp PG. (1991). Potential for dengue in South Africa: mosquito ecology with particular reference to Aedes aegypti. J Am Mosq Control Assoc 1991; 574-563. 643.
10. Jupp PG, Kemp A. (1992). Laboratory vector competence experiments with yellow fever virus and five South African mosquito species including Aedes aegypti. Trans Roy Soc Trop Med Hyg 96, 493-498
11. Gould E, Pettersson J, Higgs S, et al., (2017). Emerging arboviruses: Why today? One Health;4:1-13
12. Bird BH, Ksiazek TG, Nichol ST, Maclachlan NJ. (2009). Rift Valley fever virus. Journal of the American Veterinary Medical Association. 2009;234(7):883-893
13. Archer BN, et al., et al., (2013). Epidemiologic Investigations into Outbreaks of Rift Valley Fever in Humans, South Africa, 2008-2011. Emerging Infectious Diseases, 19:12,
14. Weetman D., et al., (2018). Aedes Mosquitoes and Aedes-Borne Arboviruses in Africa: Current and Future Threats. Int. J. Environ. Res. Public Health 2018, 15, 220; doi:10.3390/ijerph15020220
15. Zaayman D, Venter M. (2012). West nile virus neurologic disease in Humans, South Africa, September 2008-May 2009. Emerging Infectious Diseases 18:2051-2054.
16. Storm N, Weyer J, Markotter W, et al., (2014). Human cases of Sindbis fever in South Africa, 2006-2010. Epidemiol Infect 142:234-238
17. Brooke BD, Kloke G, Hunt RH, et al. (2001). Bioassay and biochemical analyses of insecticide resistance in southern African An. funestus (Diptera: Culicidae). Bull Entomol Res 2001;91(4):265-272.
18. Hargreaves K, Hunt RH, Brooke BD, et al., (2003). Anopheles arabiensis and An. quadriannulatus resistance to DDT in South Africa. Med Vet Entomol;17 (4):417-422.
19. Brooke BD, Robertson L, Kaiser ML et al., (2015). Insecticide resistance in the malaria vector Anopheles arabiensis in Mamfene, KwaZulu-Natal. S. Afr. J. Sci. vol.111 n.11-12
20. WHO (2019). Guideline for Malaria Vector Control. World Health Organization, Geneva
21. WHO (2017). A framework for malaria elimination, World Health Organization, Geneva
22. WHO (2019). Malaria Surveillance, Monitoring and Evaluation: An operational manual. World Health Organization, Geneva

Annexes

Annexe 1: Major constraints and opportunity for improvement of vector control in South Africa

Policy and institutional environment (management, financial and human resources)		
Strengths	**Weaknesses**	**Opportunities**
• The political and financial will to support VBDs control: ○ The malaria program in South Africa is almost entirely funded by government resources. Some cross-border activities implemented through the E8 and MOSASWA initiatives are financed by the Global Fund and other partners. ○ The NTD program is funded by the government • There are institutions and expertise in place to support VBD surveillance, drug and insecticide resistance monitoring e.g. NHLS, NICD, SAMRC, UP and others • IVM and IRM strategy in place inclusive other Strategy on VBDs • Local authority and municipalities supporting vector control activities in certain areas • A good collaborative arrangement between province malaria elimination program and research institutions • A malaria communication strategy 2017-2022 provides a framework for SBCC, country commemorate World Malaria Day and SADC Malaria Week, as avenues for advocacy; • Legislation, regulation and control of pesticide. Centralized procurement of public health pesticides and application equipment favourable for efficient use of resources;	• The environment is not enabling for implementation for set policies and Strategy e.g. procurement procedures; Administration and policy not aligned, for example on spray timing, structures (organograms) etc. • Inadequate human resource and transport constraints affect VBD control; this includes a moratorium on human resource hiring that prevented essential posts from being filled; • Insufficient information on the gaps and needs across all the VBDs, outdated policy and technical guidance on some VBDs and lack of community engagement strategy for all VBDs; Some policies are not implementable in South Africa context, for example, yellow fever policies and quarantine facilities, an outdated guide on yellow fever and plague; • Poor coordination of stakeholders and partners to support VBD control at all levels (national, provinces and districts); • Inadequate supervision of vector control activities in provinces and districts due to multiple reasons (shortage of staff and vehicles); Duplication of effort that may affect the quality of work and accountability, for example, EHP functions across departments; • Gap in community knowledge, attitudes and practices (KAP) towards malaria and other VBDs; • Gaps in vector control decision making, certification and quality control of pesticide application, monitoring of worker safety, public awareness program, and safe disposal of pesticide-related waste;	• A VBD strategy aligned with best practice and current international standard i.e. IHR and WHO Strategy. Endorsement of Vector control Strategy and action plan by the SA government will lead to new resource allocation to flight priority VBDs; • Establishing a centralized unit that drives policy housing entomologists, epidemiologists and parasitologists; • Developing community engagement and empowerment strategy to promote scale-up and utilization of vector control interventions; • Formalizing inter/intersectoral coordination mechanism at all levels (national, province and districts) with a clear mandate and membership with representatives from different sectors, local authority/municipality and community to support VBD control • Strengthening the network of institutions with a clear mandate and agreement on data sharing to cater for VBDs priorities, and enable integrating malaria with other VBDs; • Conduct KAP for all VBDs and findings used to develop SBCC messages; revise current malaria Communication Strategy (2017-2022) to define a coordination mechanism at all levels and to align with the objectives of the Elimination Strategic Plan (2019-2023) & SA master plan for NTD (2019-2025); • Developing guideline for public health pesticide; certified training of decision-makers on sound management of public health pesticides; and health monitoring of spray operators will contribute to strengthening pesticide management; • Centralizing procurement of vector control equipment e.g. spray pumps and spare parts;
Tools, technologies and logistics of interventions		
Strengths	**Weaknesses**	**Opportunities**
• Many years of programmatic experience with IRS operation and MDA chemoprevention against schistosomiasis, and these interventions are still very effective; • Provinces implementing the entomological survey and resistance monitoring; • Ongoing research activities implemented by various research institutions will contribute to the knowledge of VBDs; • Development of DHIS2 malaria tracker to strengthen surveillance;	• Coverage for IRS declining due to financial constraints and operational bottlenecks; No vector control against vector-borne NTD diseases. Preventive chemotherapy for NTD such as Schistosomiasis not done due to drug shortage; • Newly introduced surveillance tools for malaria elimination lack SOPs to ensure quality application; • Suboptimal system for quality assurance/ quality control of IRS and winter larviciding; • Current research activities are not well coordinated to address gaps in VBD knowledge and operational challenges;	• Renewed effort to promote vector control in alignment with new guidance (GVCR 2017-2030) and adoption of South Africa Vector control Strategy will strengthen VBD control; • Conditional Grant provides an opportunity to fill in gaps in human resources, introduce new tools and approaches for surveillance (e.g. traps to replace HLC) and vector control; • Revising and updating SOP for VBD control and surveillance will strengthen systems to support VBD control; • Developing a national VBD research agenda to guide research activities to address priority needs and operational bottlenecks;

Entomological surveillance and M& E for vector control		
Strengths	Weaknesses	Opportunities
• Provinces conduct entomological surveillance of malaria vectors with support from partners such as research institutions; • Good understanding of malaria vector bionomics and current status of insecticide resistance; • Training opportunity for entomology available through local institutions, partners and regional network (E8 cross-border initiative); • Epidemic Preparedness and Response plans exist at all levels (national, provinces and districts);	• The surveillance system has both human and financial resource gaps that limit its ability to achieve the goal for elimination of local malaria transmission and control of other VBDs; insecticide resistance not done in all sentinel sites; • No monitoring of Culicine mosquitoes or other vectors (e.g. Aedes species diversity, snail or nuisance bedbugs), and vectors of other VBDs; • No malaria / VBDs specific components of EPR;	• Strengthening the capacity for surveillance for elimination through the deployment of surveillance officers, training for all personnel on malaria elimination, and allocating resources for case and foci investigation, response, and clearance; • Finalizing malaria DHIS2 entomology tracker to integrate standardize reporting of all program data, entomology, vector control and entomology; • Extending malaria DHIS2 tracker to include other VBDs; • Building capacity for malaria EPR planning at national, provincial and district level; • Conducting an inventory for institutions and entomologists working on different VBDs (part of VCNA) and devise a mechanism to support surveillance for all VBDs; • Collaboration between entomologist in government and research institutions/universities to enable molecular and virological investigations.
Funding		
Strengths	Weaknesses	Opportunities
• Vector control is mainly funded by the government of SA. Limited funding from external sources and multilateral organization through E8 and MOSASWA initiatives (funded by Global Fund, USAID) or private sector	• Investment in VBDs other than malaria has suffered from serious neglect; • Funding for malaria elimination strategy 2012-2018 was inadequate.	• Costing of the VBD strategy and completion of a business plan to ensure support is available for VBD control in South Africa; • Advocating for sustained political and government support to implement VBD/IVM Strategy through an intersectoral committee;

Annexe 2: Key principles of IVM strategy, description and status of implementation in South Africa

The 5 principles of IVM will guide the implementation of vector control activities. Full implementation of these principles ensures comprehensive consideration of all the factors that are critical to the sound management of the local vectors of human diseases and ensure a sustainable and significant reduction in the diseases that they transmit. The current situation of vector control for each principle of IVM is summarized below (Table below).

Key principles of IVM strategy, description and status of implementation in South Africa

IVM principle	Description of the principle and current status in South Africa
1. Advocacy, social mobilisation and legislation	Adopting a VBD control strategy that is based on the five IVM principles in the development of policies, strengthening regulatory and legislative controls for public health and empowerment of communities. Community acceptance and compliance is key to the uptake of interventions.
	An insecticide-based approach to vector control is the major intervention used for VBDs, especially malaria. Regulatory and legislative measures to control the use of pesticides for public health and agriculture exist but the capacity to enforce the measures need to be strengthened, especially the aspects of safe use and disposal of chemical waste. Sustained political support and funding is key to the successful implementation of a VBD strategy that supports the elimination agenda. IRS is the main malaria vector control method used in South Africa. This intervention is supplemented by winter larviciding in certain areas. However, there are no malaria-specific health promotion focal points in affected provinces and community involvement in vector control activities is minimal. Information, Education and Communication (IEC) campaigns are conducted by provincial health promotion units during IRS campaigns only. NDOH and PMEP shall explore approaches to advocate for continued political support for the elimination of VBDs. A mechanism to promote advocacy will include setting up an intersectoral committee to enhance sectoral coordination and collaboration, identifying influential persons for advocacy and political leverage, and exploiting public events such as National Malaria Day to advocate and raise awareness of VBD elimination.
2. Intra- and inter-sectoral collaboration	Collaboration within the health sector and with other sectors is key for successful implementation of a VBD control strategy. This considers all options of collaboration within the department of health and with other government departments, the public at large and private sectors. Sharing and optimizing the use of resources, building capacity for planning, monitoring, and decision-making at the lowest possible operational level are important.
	Collaboration for vector control is critical because activities conducted by other sectors may have a direct or indirect impact on VBDs. The South Africa Malaria Elimination Committee (SAMEC) is a technical advisory group on malaria elimination. The SAMEC mandate should be clarified, terms of reference revised and its membership reconstituted to ensure multi-sectoral representation and a mix of skills to support the operationalization of the VBD control Strategy. The successful implementation of a VBD control strategy requires political support and sustained funding, and this should be taken into consideration in the process of revamping SAMEC.
3. Integrated approach	Targeted use of different vector control methods, alone or in combination, to control vector-borne disease or multiple diseases. This may include chemical and non-chemical interventions.
	Currently, malaria vector control in South Africa is based on an IRS mosaic approach in which pyrethroids are used for painted brick-built structures while DDT is used for traditional mud-walled and cement–brick structures. IRS is supplemented by winter larviciding on a limited scale. LLINs are not widely used in South Africa. New tools and approaches for vector control, coupled with the smart deployment of current interventions based on evidence, is necessary for optimization. New tools are necessary given the current biological threats – insecticide resistance and outdoor transmission of malaria – which pose a challenge to malaria control.
4. Evidence-based decision making	Seek to adopt strategies and interventions to local entomology, epidemiology, and sociology as informed by surveillance, routine monitoring and evaluation, and operational research.
	Each of South Africa's malaria-endemic provinces has several entomology teams with essential physical infrastructure to support vector surveillance and quality analysis for IRS. The collection of entomological data is however not done systematically due to several reasons including inadequate human resources, especially at the senior/managerial levels. Currently, the endemic provinces do not have a senior entomologist with the requisite skills required to effectively plan and manage vector surveillance, data collection, and analysis for decision-making. The biology and bionomics of malaria vectors are well characterized in South Africa. Information on other VBDs, particularly mollusc intermediate host of Schistosoma and arbovirus vectors is outdated and limited to a few studies conducted by research institutes. A national research agenda should be developed in consultation with relevant sectors and stakeholders, to include priority research areas to better understand vector-borne diseases prevention and control and to guide operational activities.
5. Capacity building	Call for development of adequate human resources, training and career structures at national and local levels to support VBD control, development of essential physical infrastructure, provision of financial resources and strong partnership.
	In South Africa, trained human resources at national, provincial and district/ municipality levels for VBD control are limited to malaria. Essential physical infrastructure – insectaries and laboratories – exist in some provinces to support malaria vector control. In line with the Vector Control Strategy and GVCR 2017-2030, the country will conduct a comprehensive vector control needs assessment to identify priority needs and capacity gaps to be addressed to strengthen vector control and accelerate to malaria elimination and prevention of VBD outbreaks. As a matter of priority, each provincial malaria elimination program should appoint a senior public health entomologist to manage vector surveillance, monitoring and evaluation activities for malaria and other VBDs.

Annexe 3: Proposed malaria entomology structure that can be expanded to all VBDs

Level of Health system	Responsible officer	Tasks
National	National Public health Entomologist (1)	Estimation of commodities and logistics; Training and mentoring of provincial entomologists; Supervision of vector surveillance and lab/insectary activities; Data review and signing off for entry into the database;
Province	Provincial Entomologist (1) Laboratory technicians (2) Entomology Assistants (5) Data Manager (1)	Estimation of commodities and logistics and ensuring adequate supplies; Training of provincial entomology teams in mosquito sampling and storage methods; Running vector surveillance; Processing mosquito specimens for species identification, human blood index and sporozoite infection rates, arbovirus testing and quality control of IRS and other interventions; Supervising & monitoring entomology activities and submit data to national Liaison with and submission of mosquito specimens to diagnostic support institutions and laboratories
District/ Municipality	Entomology Team leader (1) Entomology team of 4 vector collectors	Collection and appropriate storage of mosquitoes and other vectors before submission to diagnostic support labs and institutions; Conduct vector ecology, bioassay, susceptibility studies and larviciding;

Annexe 4: Examples of potential operation research questions for consideration in South Africa

The NDOH in consultation with provincial program managers and stakeholders such as research institutions will develop a national research agenda for VBD and prioritize specific questions that address operational bottlenecks in the implementation of VBD control. Below is a list of potential operational research questions for consideration.

- What is the extent of bedbug infestations and how does this affect IRS uptake in affected communities?
- Can the IRS applied for malaria prevention be used to control nuisance bedbugs?
- Can larvicide be used to control both malaria mosquito's larvae and snail – intermediate host of schistosomiasis?
- What is the current distribution of Bulinus globosus and Biomphalaria pfeifferi in relation to the distribution intestinal and urogenital schistosomiasis?
- Can geographical information systems and mapping be used to target interventions more effectively at the district level?
- Is larviciding by the community more cost-effective than by a vector control program?
- Can community members identify and map snail and mosquito breeding habitats to inform targeting of interventions?
- What are the efficient methods/techniques for sampling Anopheline and Aedes vectors in South Africa?
- National distribution profile of rat fleas/ rodents, tsetse flies and ticks and their insecticide susceptibility profile;
- Arbovirus vector distribution, vector competence; the burden of disease and clinical epidemiology in humans at sentinel sites; geographic distribution; reservoir hosts and sentinel animals; control strategies for vectors (insecticides, larvicides, repellents, bed nets etc./vaccination of animals/humans; remote sensing prediction modelling based on the actual surveillance

Annexe 5: Interventions and their vector targets.

Component	Intervention	Vector targets	Vector-borne diseases
Chemical control	LLINs	Anopheles, Culex, Aedes, Phlebotomus	Malaria, leishmaniasis, LF, dengue
	IRS	Anopheles, Culex, Aedes, Phlebotomus	Malaria, leishmaniasis, LF, dengue
	Larviciding	Anopheles, Culex, Aedes, Phlebotomus, Biomphalaria snail	Malaria, leishmaniasis, LF, dengue, schistosomiasis
	Space spraying	Anopheles, Culex, Aedes, Sandfly - Phlebotomus sp, Tsetse fly - Glossina sp,	Malaria, LF, leishmaniasis, dengue, RVF, Trypanosomiasis,
	Household products	Anopheles, Culex, Aedes, Phlebotomus	Malaria, leishmaniasis, LF, dengue
Biological control	Larval control	Anopheles, Culex, Aedes, Phlebotomus	Malaria, leishmaniasis, LF, dengue, schistosomiasis
	Predators and competitors	Anopheles, Culex, Aedes, Phlebotomus, Biomphalaria snail	Malaria, leishmaniasis, LF, dengue, schistosomiasis
Genetic control	Sterile Insect Technique	Tsetse fly	Trypanosomiasis,
Mechanical	House screening	Mosquitoes, house flies	Malaria, filariasis, trachoma
	Baited traps	Tsetse flies, Aedes, cockroaches	Trypanosomiasis, Dengue
	Sticky paper traps	Sand flies, houseflies	Leishmaniasis, trachoma
Environmental management and sanitation	Environmental manipulation and modification	Anopheles, Culex, Aedes, Phlebotomus, Biomphalaria snail	Malaria, leishmaniasis, LF, dengue, schistosomiasis

Annexe 6: Insecticide Resistance Management Plan

Insecticide Resistance Management in Vector-Borne Diseases Program

National scale-up of vector control interventions for malaria and other VBDs will necessarily be accompanied by an increase in the use of insecticides.

General Objective

The overall objective of IRMP is to maintain the effectiveness of existing insecticidal vector control interventions, despite the threat of resistance. This can be achieved by preventing and/or delaying resistance development to insecticides or helping regain susceptibility in malaria vector populations where local vectors are already resistant. The IRMP is an integral part of the vector control and surveillance, monitoring, and evaluation components of the 2019–2023 Malaria Strategic Plan document.

Specific IRM objectives

1. To build provincial entomology capacity that can efficiently monitor entomological indicators including IR and the quality of malaria vector control interventions.
2. To monitor changes in entomological parameters by time, place and interventions.
3. To monitor the quality and performance of vector control interventions.
4. To develop and implement a plan for rotation of insecticides with different MOA as part of the IRM strategy.

Implementation framework for entomological monitoring

Objective 1: To build provincial entomology capacity

Strategy	Activity	Responsible	Partners	Timeline				
				2023	2024	2025	2026	2027
Update SOPs	Revise data collection tools and test SOP	NMEP	PMCP, NICD, SAMRC	X				
Build entomology capacity	Establish sentinel sites	NMEP, PMEP	NICD, MRC	X	X			
	Make insectaries & labs functional	NMEP, PMEP	NICD/ WRIM, UP-ISMC, SAMRC	X	X			
	Establish/fill vacancies of district entomology teams	NMEP, PMEP	NICD, SAMRC	X	X			
	Employ senior provincial entomologist at the MSc level or higher in each province	NMEP, PMEP	NICD, SAMRC	X	X			
	Train / retrain employed field entomology technicians	NMEP, PMEP	NICD/ WRIM, SAMRC	X	X	X	X	X
	Train / retrain employed Lab technicians in molecular and biochemical methods	NMEP, PMEP	NICD/ WRIM	X	X	X	X	X
	Establish National and provincial entomology databases	NDOH, NMEP, PMEP	NICD	X	X			
	Make available equipment, supplies and logistics	NMEP, PMEP	NICD/ WRIM	X	X	X	X	X

Objective 2: To monitor changes in entomological parameters

Strategy	Activity	Responsible	Partners	Timeline				
				2023	2024	2025	2026	2027
Monitor entomology indicators[1]	Conduct entomology surveys monthly	PMEP, NMEP	NICD/ WRIM, UPISMC, SAMRC	X	X	X	X	X
	Identify collected mosquitoes	PMEP	NICD	X	X	X	X	X
	Test mosquitoes for HBI & sporozoite rates	PMEP	NICD	X	X	X	X	X
	Sample breeding sites for larvae	PMEP	NICD/ WRIM, UPISMC, SAMRC	X	X	X	X	X
	Procure susceptibility test kits	PMEP, NMEP	NDOH, WCO. SAMR	X		X		X
	Conduct susceptibility tests	PMEP, NMEP	NICD/ WRIM, UPISMC, SAMRC	X	X	X	X	X

Objective 3: To monitor the quality and performance of vector control interventions

Strategy	Activity	Responsible	Partners	Timeline				
				2023	2024	2025	2026	2027
Monitor quality of interventions	Procure cone bioassay kits	PMCP, NMCP	NICD/ WRIM/ SAMRC	X	X			
	Rear known susceptible mosquito colonies	PMCP	NICD/ WRIM/ SAMRC	X	X	X	X	X
	Conduct cone bioassays for IRS quality annually	PMCP, NMCP	NICD / SAMRC	X	X	X	X	X
	Conduct exit window trapping to measure IRS performance	PMCP, NMCP	NICD / SAMRC					

Description of key IRM activities

Revise vector control Strategy, protocols and SOPs for priority VBDs: This IRM monitoring plan is made up of three activities that shall be monitored simultaneously: entomology/vector monitoring, IR monitoring and monitoring the quality of vector control interventions. In this regard, the national IRS Strategy, data collection tools and IRS implementation plans are now aligned with these Vector Control Strategy. Malaria vector surveillance will continue on Anopheles mosquitoes. Also, surveys on culicine mosquitoes, particularly Aedes and mollusc (intermediate host of Schistosoma) will be initiated to determine bionomics and status of insecticide susceptibility. Aedes aegypti is the pre-eminent vector because of its ability to transmit YFV, ZIKV, CHIKV and the DENVs in urban and peri-urban settings. It is also the one culicine vector for which surveillance can be integrated with the malaria surveillance program, at least in malaria-endemic parts of the country and through Port Health surveillance programs. Febrile disease surveillance and specific arbovirus surveillance need an expanded case definition and also include areas not endemic to malaria. The vectors of the other important VBDs i.e. West Nile, Sindbis, and Rift Valley fever, require different approaches for sampling and screening for viruses, not compatible with malaria surveillance and control methods, and this will mostly be done through NICD disease diagnosis and surveillance programs.

Build entomology technical and infrastructural capacities: Existing human and infrastructural resources will provide a base to support surveys of priority VBDs. The current situation will improve as NDOH makes progress towards strengthening entomological capacity for implementation of the proposed Vector Control Strategy (Strategic objective 3).

Establish a network of entomological sentinel sites: Vector surveillance and monitoring of insecticide resistance of priority Anopheles will be conducted in established sentinel sites in provinces where malaria is still a problem, particularly targeting areas with the persistent transmission. Survey of arboviral vectors such as Aedes and Culex mosquitoes will be conducted to establish a baseline. This survey will target provinces that frequently report cases and or areas with a high risk of importation of arbovirus diseases. This information is needed as part of the preparation for a response in case of an outbreak of arboviral diseases in South Africa.

Ensure access to field and laboratory equipment and infrastructure: There are entomology laboratory/insectary infrastructures with limited facilities and equipment. These all need to be strengthened so that the basic entomological methods can be carried out in each province (mosquito rearing, WHO bioassays, species identifications, biochemical assays for sporozoite infection and blood meal analysis). The NICD, situated in Johannesburg, has adequate capacity for advanced malaria entomology work (such as identifying IR mechanisms using qPCR and microarray techniques), as well as diagnostic testing for arboviruses and parasites. Treated papers for susceptibility tests are purchased each year from Malaysia through the WHO/country office.

Ensure access to field and laboratory supplies and logistics: The three provinces where malaria is still a problem have sufficient equipment for anopheline mosquito collection, rearing and testing. Additional equipment (e.g. CDC light traps, sticky paper & saliva traps) will be needed for sampling adult cuisine mosquitoes such as Aedes and Culex. The PMEPs will continue to procure sufficient field and laboratory mosquito collecting, rearing and testing materials and equipment. These include mosquito collection traps, mosquito rearing and processing kits, susceptibility testing kits, cone bioassay kits, laboratory chemicals/reagents, and transport, SOPs, protocols and data collection tools.

Monitoring of insecticide resistance

The provinces will use the WHO insecticide susceptibility bioassay.[13] The WHO insecticide susceptibility bioassay is a test where mosquitoes are exposed to known concentrations of an insecticide for a fixed period at the end of which the number of fatalities is recorded. The test is designed to distinguish between susceptibility and resistance to insecticides in adult mosquitoes based on the WHO standard discriminating dosages.

Types and frequency of susceptibility testing: Vector susceptibility to all four classes of insecticides recommended for public health use by WHO will be tested annually, if stable vector mosquito populations are detected. Areas, where the same insecticide is used for both vector control and agricultural purposes, may require a more intensive monitoring schedule because of the potential for additional selection pressure on vector populations from agriculture. The types of susceptibility test and process are summarised in Annexe 7. Susceptibility test results together with other relevant information will be used to inform decisions on the choice of insecticide for vector control. Schematic for insecticide resistance monitoring and testing methodology for malaria mosquitoes is summarize below (Fig. 1.1).

Monitor entomology indicators

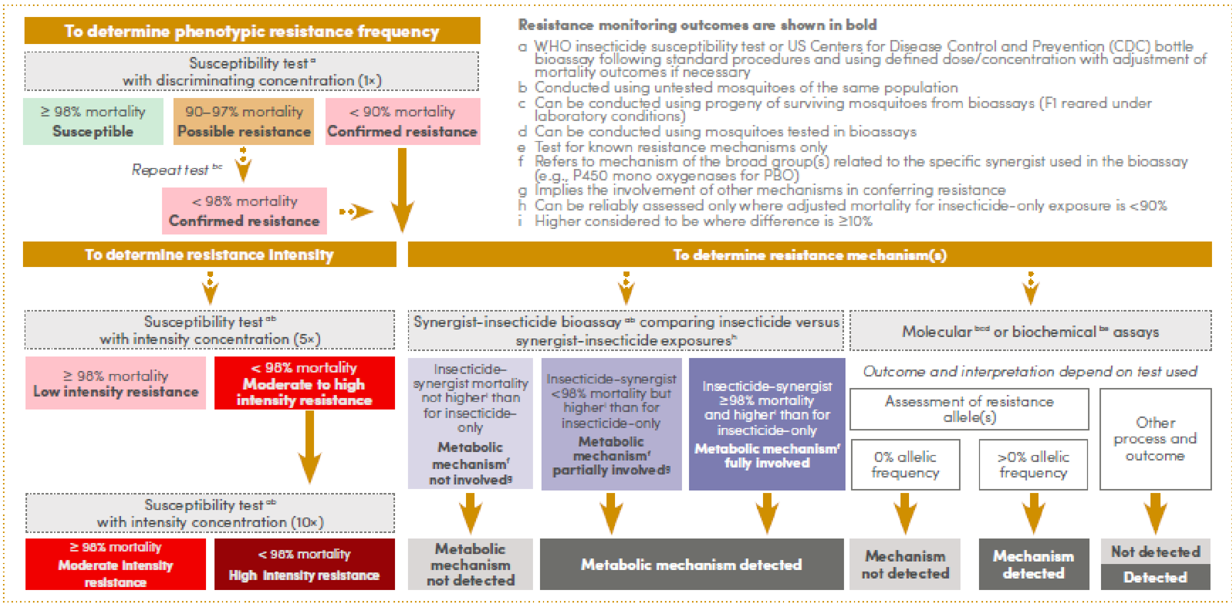
Entomological surveys provide essential information regarding changes in vector bionomics for vector control interventions. The surveys are designed to gather both basic required information as well as additional complementary data. However, because South Africa has an efficient IRS program, mosquito populations are very small and difficult to find. The typical entomological indicators measured in countries to the north are not likely to be achievable here.

13 WHO (2016). Test procedures for insecticide resistance monitoring in malaria vector mosquitoes. Geneva, World Health Organization, 2013

Essential information: Ideally, the following basic information should be collected annually, coinciding with rain and transmission season, from areas where local transmission is known to occur. Indicators marked with asterisk become difficult to measure when vector population are very low and difficult to find:

- Anopheline/culicine vector species present in the targeted areas;
- Indoor and outdoor resting habits of the anopheline/culicine vectors;
- *Adult density: Number of vectors/ house/night; Number of vectors/person/night; and Number of vectors/trap/night
- *Human blood index: Number of mosquitoes positive for human blood/Total number of mosquitoes examined.
- Habitat occupancy: The percentage of positive larval habitats. Habitat occupancy = the number of habitats with larvae or pupae/ Total number of habitats found.
- Larval density: Total larvae collected/ Total number of dips. Useful to monitor the efficacy of larviciding.
- Cone contact bioassays: To assess the quality of spraying operations and to evaluate the duration of residual effect (persistence) of a given concentration of an insecticide on sprayed surfaces.
- Susceptibility test results for indicators needed to support IRS decisions

Figure 1.1: A schematic on insecticide resistance monitoring in malaria vector mosquitoes



Insecticide resistance indicators to support IRM decision

- Resistance status – confirmed (<90% mortality, confirm mechanism); possible (90-97% mortality – repeat test); susceptible (≥98% mortality);
- Resistance intensity – high (<98% mortality at 10x discrimination concentration); moderate to high (<98% mortality at 5x DC or ≥98% mortality at 10x DC); and low intensity (≥98% mortality at 5x DS);
- Proxy for metabolic resistance (synergist + insecticide) – no involvement, partial involvement, full involvement (see Fig. 1.1 for details);

Additional information: The following further information should be collected periodically and in collaboration with research and academic institutions if large, stable populations of vectors are found:

- the behaviour of local vector species regarding the time of feeding and preference for indoor or outdoor, and human and animal feeding;
- the sleeping habits of the human population in relation to the feeding habits of the vector;
- ecological data on the breeding habits of local vector species;

Monitor IRS program performance

In malaria elimination, cases of persistent or renewed transmission, as ascertained by parasitological data, cannot be confirmed entomologically by finding mosquitoes that are infected. The entomological criterion appropriate for monitoring IRS performance towards complete interruption of transmission and elimination of malaria is the elimination or reduction of man-vector contact and the shortening of the life of malaria vectors to such a degree that the extrinsic cycle of the parasite in them is not completed. The entomological assessment could, therefore, aim at assessing the amount of man-vector contact and the probability of survival of any vectors found to visit sprayed houses and feed within. The main practical methods for this purpose are the determination of man-biting rates inside and outside houses, and window-trapping of mosquitoes leaving sprayed houses after biting their inhabitants.

Monitor quality of interventions

Wall Bioassays: The quality of IRS applications, insecticide dosage and persistence on treated surfaces is qualitatively measured by WHO cone bioassay using susceptible mosquito strains maintained in an insectary.[14] The wall bioassay test, which determines the rate of decay of IRS product will be conducted within two weeks after spraying and thereafter every month until the reduction of effectiveness based on WHO protocols.[16]

Basic requirements for provincial entomological monitoring

A provincial entomological monitoring program should include the following:

- Trained personnel with supervisors having MSc or equivalent level of entomological training and experience.
- Reliable and available insecticide-free transport for mosquito collection teams.
- A laboratory with dissection microscopes, mosquito identification keys, mosquito traps and supplies (these should include entomological collection equipment, bioassay tubes).
- A laboratory with equipment and supplies for routine PCR identification of vector mosquito species and biochemical assays for blood meal identification and sporozoite infections and appropriately trained technical staff to carry out these procedures.
- Access to WHO bioassay papers for susceptibility assays;
- An insectary with appropriately trained staff to look after a colony of an appropriate (local species) insecticide susceptible mosquito strain, for cone bioassays and to serve as controls in resistance monitoring using standard bioassay methods for quality control and other laboratory procedures. Handling and processing of arbovirus mosquito vectors will need appropriate biosecurity/biosafety infrastructure through NICD;
- Where capacities are deficient or not available, technical assistance and training are warranted. Local staff should develop needed skills while working with the technical experts. Promising personnel should be selected by the NDOH or PMEP to receive long-term training to further bolster local capacity;
- A vector control technical committee to advise the program based on evidence generated from entomology monitoring activities;
- A written entomology monitoring and evaluation plan with a budget;
- A data management and reporting system;
- A work plan based on the monitoring and evaluation plan;
- A reference research laboratory for identification of resistance mechanisms using molecular and biochemical tools; and
- A reference laboratory for isolating and identifying arboviruses and parasites.

Prevention and Mitigation of Insecticide Resistance

Based on experience in agriculture, resistance management approaches have been proposed to prevent or delay the emergence of resistance by removing selection pressure or by killing resistant mosquitoes. These include mixtures of insecticides, mosaic spraying, rotations of insecticides and deployment of multiple interventions in combination. Approaches for prevention, mitigation and management of vector insecticide resistance are summarized below (Table 1.1) as indicated in GPIRM.[15] The IRM strategies can easily be incorporated into programs, based on an IVM approach.

NDOH will use results of vector surveillance and resistance testing to monitor the evolution of IR and make operational decisions on selection efficacious interventions and strategies to prevent resistance taking consideration of other factors (Fig. 5). Knowledge of resistance mechanisms is important for understanding cross-resistance and select alternative active ingredients for rotation. Understand the geographical spread of resistance and the associated mechanism is useful to inform targeting of specific interventions. Currently, malaria control in South Africa's three malaria-affected provinces is based on an IRS mosaic approach in which pyrethroid is used for selected modernised structures while DDT is used for more traditionally-built structures. Carbamates are also used for IRS in some instances. Introduction of future innovative tools will require prioritization and targeting to accommodate the uniqueness of innovation and high cost of new products (see examples, Table 1.1).

14 WHO (2011). Malaria Entomology and Vector Control. Guide for Participants, World Health Organization, Geneva
15 WHO (2012). Global plan for insecticide resistance management in malaria vectors. Geneva, WHO. Malaria Entomology and Vector Control. Guide for Participants 2011. Geneva

Table 1.1: Insecticide resistance management options to prevent and mitigate resistance

IRM strategy	Description and example in malaria vector control
Rotations of insecticides with different modes of actions	This involves switching between insecticides with different modes of action at pre-set time intervals, irrespective of resistance frequencies. The theory is that resistance frequencies will decline (or at least not increase) during the period of non-deployment of insecticides with a specific mode of action. • All WHO prequalified LLINs contain a pyrethroid insecticide, either alone or combined with the synergist PBO, while one net contains a pyrethroid and a pyrrole. • IRS formulations are prequalified from four out of five insecticide classes currently covered by a WHO policy recommendation. • WHO prequalified new third-generation IRS molecules will make rotation possible
Mixtures	These are formulations that combine two or more insecticides with different modes of action. Effective deployment of a mixture requires that the presence of resistance to all insecticides in the mixture is rare so that any individual that survives exposure to one insecticide is highly likely to be killed by the other insecticide or insecticides. Several vector control products with a mixture of the class of insecticides include: • Pyrethroid + Pyrrole - LLIN with a WHO interim recommendation. • Pyrethroid + Juvenile hormone mimic - LLIN under WHO evaluation. • Pyrethroid + Neonicotinoid IRS formulation with WHO prequalification.
Mosaic spraying	This involves the use of spatially separated applications of different classes of insecticides with different modes of action against the same vector. It can take two forms, the fine-scale mosaic where two insecticides are used in different dwellings within the same village or the larger scale mosaic where different insecticides are used in different geographical areas like villages or towns. This creates a high likelihood for insects within a single generation to come into contact with both insecticides, thus reducing the rate of resistance selection, provided that multiple resistance within the vector population was extremely rare. Available options: • WHO prequalified IRS and larvicide formulations based on different modes of action are available for public use.
Combinations of interventions	This approach exposes the vector population to two different modes of action through the co-deployment of different interventions in the same place. Pyrethroid-only LLINs combined with a non-pyrethroid IRS (where both are at high coverage) is a potential IRM approach, although there is little evidence to indicate that such a combination of interventions will lead to additional epidemiological impact relative to one intervention deployed at high coverage.

Annexe 7: Insecticide Susceptibility Testing Methodology

Mosquito collection methods: The following collection methods are listed here with their inherent limitations:

- Human landing catches (either all-night catches or limited night-time catches, indoors/outdoors – presents a security problem for the collectors as well as payment of S&T. Useful when vector populations are high). The risk to persons conducting HLC can be minimized by using the double Shannon trap method; [16]
- Indoor pyrethrum spray catches (with IRS coverage of over 80%, this technique is not likely to be productive);
- Indoor/outdoor resting (currently ceramic and black plastic pots are being tested for their efficacy in providing an attractive resting place for vector mosquitoes);
- Window exit traps (were used effectively in KZN in the past. Needs traps to be made.)
- CDC light traps (tested in southern Africa and found not effective for Anopheles); CO2-baited CDC light traps (light is optional) are very useful for nocturnal culicines and outdoor sampling of Anophelines, but not for the diurnal Aedes aegypti, which would benefit from Biogents suction traps, designed specifically for Ae aegypti and Ae albopictus. Needs a CO2 source and usually only used at night, the advantage is that mosquitoes do not escape if not emptied before dawn;
- Odour-baited traps (improved traps are now available) will be tested at various localities and compared with CO2 baited net traps. Thus far, Biogents traps, adding odour bait as well as CO2 has proven quite effective for collection of Ae aegypti and other day biters in South Africa;
- Cattle kraal collections (productive for vectors that will feed on cattle as well as humans. Security at night may be a problem.
- Experimental huts (only useful in areas where the natural populations are large)
- Pit-trap collections (useful for collecting outdoor-resting Anopheles mosquitoes. Pits need to be maintained)
- Larval collections (difficult for An. funestus group);
- Tent/net traps with CO2 baiting. Effective against a wide range of mosquitoes, the disadvantage that they have to be emptied before dawn.

The challenge is finding an appropriate collection method that will allow some data to be obtained on vector populations such as Anopheles and Culicine that are in many instances vanishingly small.

Mosquitoes for testing: The age, physiological status and gender of mosquitoes are all factors that can influence the results of the susceptibility tests. Also, the number of vector mosquitoes collected in the field is likely to be small given South Africa's IRS program. For these reasons, susceptibility testing will be conducted on non-blood fed females, aged between 3–5 days post-emergence from either larval collections or the F1 progeny of wild-caught female mosquitoes. Larval collections will ideally be made from several different breeding sites to avoid sampling individuals from single egg batches. Likewise, wild-caught females will also ideally be collected from several different locations to ensure a broadly representative sample of the local population.

A third but less favoured option will be to use wild-caught females directly but as stated above, it may not be possible to collect sufficient numbers for direct testing. In this case, it is necessary to record the physiological status of the adults before testing (i.e. whether unfed or blood-fed, semi-gravid or gravid). The females may be sustained with sugar-water until the tests are carried out.

Mosquitoes to be used for molecular and biochemical assays for species identification, virus isolation and further characterization of resistance mechanism should be used fresh, or stored at –80˚C, or in liquid nitrogen for later use.

Sample size: 150 adult female mosquitoes are required per insecticide to conduct a single set of WHO bioassay tests (4 replicates of 25 mosquitoes each). An additional 50 mosquitoes will serve as "controls" (i.e. 2 replicates of 25 mosquitoes each not exposed to insecticide). If it is not possible to collect enough mosquitoes on a single occasion (if working with wild-caught females for instance) then it is possible to store live mosquitoes until sufficient numbers have been collected. The mosquitoes will be provided with access to a sugar meal until the bioassay can be carried out. After tests, all survivors and at least 20% of those killed in bioassay tests for any given insecticide will be appropriately labelled and stored on silica gel or in ethanol for identification using PCR.

Ambient conditions: If possible, tests will be carried out at 25 °C ± 2 °C and 80% ± 10% relative humidity. During the 1-hour exposure period (2 hours for fenitrothion) and the subsequent 24-hour holding period, both the temperature and relative humidity will be monitored and the maximum and minimum values recorded at the start of the exposure period and again at the end of the 24-hour holding period. Throughout the test, the exposure and holding tubes should be held in a vertical position. The temperature should never be allowed to exceed 30°C.

16 The human sits inside a small net as bait; this is covered by a larger net trap for the mosquitoes that are attracted to the live bait. A second person, suitably clothed to avoid bites, can be utilised to collect the trapped mosquitoes as they arrive or the bait person wearing protective clothing and exit the inner tent to make the collections.

Multiple-use of impregnated papers: The efficacy of impregnated papers declines with the number of uses and the number of mosquitoes tested. The current recommendation is that no insecticide-impregnated paper should be used more than 6 times, the equivalent of exposing around 150 mosquitoes.

Calculation of mortality rates: The mortality of test sample will be calculated by summing the number of dead mosquitoes across all four exposure replicates and expressing this as a percentage of the total number of exposed mosquitoes: Observed mortality = Total number of dead mosquitoes / Total sample size x 100. A similar calculation will be made to obtain a value for the control mortality. If the control mortality is above 20%, the tests must be discarded. When control mortality is greater than 5% but less than 20%, then the observed mortality has to be corrected using Abbot's formula, as follows: (% observed mortality – % control mortality) / (100 – % control mortality) x 100 If the control mortality is below 5%, no correction is necessary.

Interpretation of susceptibility test results:

- Mortality in the range of 98–100% indicates susceptibility.
- Mortality of less than 98% is suggestive of the existence of resistance and further investigation is needed.
- If the observed mortality 90-97%, the presence of resistance genes in the vector population must be confirmed.

Annexe 8: Monitoring and evaluation process and outcome indicators.

Category	Process indicator	Outcome indicator
Policy and Institutional framework	• Vector control needs assessment (VCNA) completed; • National ISC steering committee for multi-sectoral engagement constituted and functional; • Terms of reference for the intersectoral committee (ISC) on VBD developed; • Focal person for VBD identified at the national level; • Focal person for VBD control identified at provincial (endemic for VBDs) / implementation level; • ISC ad-hoc technical committees constituted with clear TOR to support VBD strategy; • National and district cross-border committees for malaria/VBDS constituted and functional;	• National VBD strategy in place; • National policy / guideline on pesticide/ insecticide life-cycle management (including QA/QC and waste disposal) in place/ updated; • National guideline/protocol/SOPs for vector surveillance and control of endemic and emerging vector-borne diseases in place; • National ISC on VBD in place and functioning; • Technical working group on VBDs in place and functional; • Focal person for VBD identified/recruited and functioning; • The Nation and provincial DOH fully functional and addressing all VBDs in the country; • National basic and operational research priorities on VBD control revised/updated;
Organization and management	• Taskforce constituted to conduct VBD workforce appraisal, revise job descriptions and operating procedures; • Taskforce constituted to develop professional standards on vector control and public health entomology;	• National malaria entomology and vector control workforce appraised and enhanced to meet identified requirements across all relevant sectors; • Number (and percentage) of targeted staff with job descriptions that refer to vector control; • Standards for professions and a career track vector control and public health entomology in place;
Planning and implementation	• Required resources for the implementation of VBD control are costed and mobilized; • Required staffing levels and competencies for VBD identified; • Epidemiological and vector data disseminated and utilized for decision-making and impact evaluation; • Institutions to carry out Basic and operational research identified; • Technical support provided to programs to address vector control operational bottlenecks (e.g. utilize results of basic/ operational research, VBD mapping for targeting of interventions, KPA survey findings used to improve community outreach, etc.)	• National strategic and implementation plan on IVBD in place; • Number (and percentage) of targeted staff trained on VBD control/ health education; • National entomological/vector surveillance system strengthened and integrated with health information systems to guide vector control; • Number (and percentage) of targeted sentinel sites with functional vector surveillance and insecticide resistance monitoring; • Number (and percentage) of operational research priorities on vector control that have been addressed; • Number of basic/operational research outcomes on vector control that have been utilized by VBD program; • KAP survey on malaria and priority VBDs completed and findings used to inform vector control programming;

(Footnotes)

1 Indicators aligned to WHO 2019 Malaria Surveillance, Monitoring and Evaluation: An operational manual, WHO Geneva

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