A toolkit for integrated vector management in sub-Saharan Africa

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Contents

Abbreviations

CDC	United States Centers for Disease Control and Prevention
DDT	dichlorodiphenyltrichloroethane
ELISA	enzyme-linked immunosorbent assay
HAT	human African trypanosomiasis
IRS	indoor residual spraying
IVM	integrated vector management
LLIN	long-lasting insecticidal net
LSM	larval source management
NGO	nongovernmental organization
PCR	polymerase chain reaction
QA	quality assurance
SMS	short message service
WHO	World Health Organization
WHOPES	WHO Pesticide Evaluation Scheme

Preface

This toolkit for integrated vector management (IVM) is designed to help national and regional programme managers coordinate across sectors to design and run large IVM programmes. It is an extension of earlier guidance and teaching material published by the World Health Organization (WHO): *Handbook for integrated vector management* (*1*)*, Monitoring and evaluation indicators for integrated vector management* (*2*)*, Guidance on policy-making for integrated vector management* (*3*) and *Core structure for training curricula on integrated vector management* (*4*).

The toolkit provides the technical detail required to plan, implement, monitor and evaluate an IVM approach. IVM can be used when the aim is to control or eliminate vector-borne diseases and can also contribute to insecticide resistance management. This toolkit provides information on where vector-borne diseases are endemic and what interventions should be used, presenting case studies on IVM as well as relevant guidance documents for reference.

The diseases that are the focus of this toolkit are malaria, lymphatic filariasis, dengue, leishmaniasis, onchocerciasis, human African trypanosomiasis and schistosomiasis. It also includes information on other viral diseases (Rift Valley fever, West Nile fever, Chikungunya, yellow fever) and trachoma. If other vector-borne diseases appear in a country or area, vector control with an IVM approach should be adopted, as per national priorities. Malaria, as one of the most important vector-borne diseases in sub-Saharan Africa, is the main focus of this document. Programmes targeting other vector-borne diseases can learn from the experiences gained from malaria vector control and presented here.

We hope that the detail provided in this toolkit will help programme managers to design and run effective IVM programmes.

The main text was prepared by Professor Steve Lindsay and Miss Anne Wilson (Durham University), Dr Nick Golding (Oxford University), Professor Willem Takken (Wageningen University), Dr Marlize Coleman (Liverpool School of Tropical Medicine) and Professor Steve Torr (Liverpool School of Tropical Medicine and Warwick University). The authors thank the following people for their contributions to the IVM toolkit, either during workshops in September 2013 and April 2014 or during the WHO Expert Review Meeting in January 2015:

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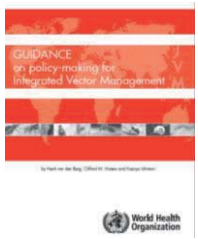
WHO Reference documents for IVM

Handbook for integrated vector management. Geneva: World Health Organization; 2012.	
Monitoring & evaluation indicators for integrated vector management. Geneva: World Health Organization; 2012.	
Guidance on policy-making for integrated vector management. Geneva: World Health Organization; 2012.	
Core structure for training curricula on integrated vector management. Geneva: World Health Organization; 2012.	
Global plan for insecticide resistance management in malaria vectors. Geneva: Global Malaria Programme, World Health Organization; 2012.	

Hi, I am Musa!

I am a vector control programme manager at the central or regional level of a country. I have too much to do and have few resources. Please follow my tips if you are in a similar situation to mine.

Executive summary

Vector-borne diseases are infectious diseases transmitted by mosquitoes, ticks, flies and bugs, which act as "vectors" of the disease-causing pathogens. These diseases contribute substantially to the global burden of disease and disproportionately affect communities in developing countries. There is a high burden of vector-borne disease in sub-Saharan Africa, and many of these diseases are present in the same geographical location. This toolkit focuses on the key vector-borne diseases affecting populations in sub-Saharan Africa: malaria, lymphatic filariasis, dengue, cutaneous leishmaniasis, visceral leishmaniasis, onchocerciasis, human African trypanosomiasis (HAT) and schistosomiasis. It also includes information on other viral diseases (Rift Valley fever, West Nile fever, chikungunya, yellow fever) and trachoma.

IVM is a "rational decision-making process for the optimal use of resources for vector control". The approach contributes to achieving the targets set for control or elimination of vector-borne diseases by making vector control more efficient, cost–effective, ecologically sound and sustainable. IVM is characterized by evidence-based decision-making and collaboration both within the health sector and between sectors. Multiple tools may be used against a single vector-borne disease, or one or multiple tools may be integrated to target multiple vector-borne diseases. IVM also contributes to the management of insecticide resistance in vector populations.

IVM requires strong political support from central governments to succeed, in particular to foster intra- and inter-sectoral collaboration and streamline decision-making and resources. To that end, a steering committee with broad participation from government ministries, nongovernmental organizations (NGOs), industry and community organizations should oversee the national implementation of IVM, led by a focal person who is responsible for the overall national programme. Committees or task forces should be established at lower administrative levels (e.g. district) for planning and implementation. A vector control needs assessment should be conducted to determine the policy, institutional framework and resources available for vector control.

IVM is a flexible management system that is adapted to local conditions. Successful programmes undertake multiple rounds of situational analysis, planning, design, implementation, monitoring and evaluation. A comprehensive assessment of the disease situation, including epidemiology and entomology, local determinants of risk and stratification of risk areas is essential to designing a suitable IVM programme. The outcomes of this assessment and other considerations such as available effective vector control methods, insecticide resistance and cost–effectiveness will determine the choice of vector control intervention. Vector control needs and resources should be mapped (needs assessment) and implementation strategies planned. The programme should also be monitored and evaluated to determine its effect on the disease of interest and to ensure feedback for future planning and implementation. The local disease situation might have to be reassessed periodically.

Vector-borne disease results from the interplay of pathogen, vector, human, animal and environmental determinants. It is important to consider which pathogens are responsible for disease in an area and where the diseases are endemic. It is also important to determine which vectors are present, where and when they occur, their behavioural characteristics and their susceptibility to insecticides. Human determinants that should be investigated include where high-risk groups live, local attitudes and practice towards vector-borne disease, and access to diagnosis and treatment. When human diseases also infect animals, such as HAT, the abundance of reservoir hosts should be considered. Environmental determinants include local ecosystems, land use, weather patterns and vector breeding sites. Studying these determinants and their interactions helps to understand why diseases occur and points to ways in which they can be controlled.

In order to plan vector control interventions and prioritize resources, the distribution of vector-borne diseases and vectors must be known. A disease assessment should be conducted in two stages: a broad analysis with stratification (at regional level) and a local analysis (at district level and below). A broad analysis consists of assessing maps of the endemicity of a disease, epidemiological data at regional level and vector distribution. Regions can then be classified according to the diseases present, their incidence, vector species and ecology. A local analysis involves assessing the micro-epidemiology of the disease, including district or community epidemiology and local environmental and human determinants.

The wide range of vector control tools can be classified broadly into chemical and non-chemical tools for controlling either adult or immature forms of a vector. The tools must be chosen on the basis of their efficacy in reducing epidemiological parameters (prevalence or incidence of infection or disease), although evidence of efficacy against the vector may be useful in some circumstances. A number of other factors should also be taken into account in choosing the tools, as some may be less effective or feasible in certain environments. These factors include vector characteristics (such as insecticide resistance), human and environmental safety, affordability and cost–effectiveness, acceptability and community participation, and implementation and delivery of the intervention.

Resource planning is essential. An inventory should be made of the resources and organizational structures currently available for vector control, and the necessary financial, human and technical resources should be estimated. Costing should generally be conducted at national level on the basis of a strategic plan, with clear terms of reference. A number of web-based tools are available for resource planning.

The factors to be considered in implementation include the optimal timing of a particular intervention, the areas and the entities involved, and monitoring and evaluation. Other aspects of implementation to be considered are the populations to be targeted and the geographical areas and goals of vector control (i.e. control or elimination). Although the main responsibility for IVM is with the health sector, other sectors should be involved, where possible, including the community.

Initially, interventions for which there is the strongest evidence of efficacy should be introduced, if not already done, and should correspond to the local entomology and social behaviour. Interventions for which there is more limited evidence should be tested in small pilot studies before being scaled up. Robust trials with epidemiological outcomes are required for interventions that do not have a WHO recommendation. Such studies require specific expertise and should generally be conducted with the assistance of a research institution.

Vector surveillance should be conducted throughout the IVM programme, although the objectives and parameters measured will depend on the stage of the programme. The commonest measure is the density of mature or immature vectors; other important parameters include insecticide resistance. The factors that should be considered in setting up sentinel sites include the endemicity of the disease, ecological zones, accessibility of sites and use of insecticides in the area. Vector surveillance can be conducted by vector control staff or by communities with the right training and support.

An IVM programme must be monitored and evaluated in order to obtain feedback, determine the impact of the programme, and increase accountability to donors and others. A monitoring and evaluation framework should be established, with indicators for measuring the implementation and success of the programme, and clear timing and sources of data for each indicator. The indicators should be specific to the intervention or the disease, such as the number of long-lasting insecticidal nets distributed or the effect on disease burden, and also specific to the IVM programme, such as the number of staff trained in IVM on top of training in specific diseases such as dengue or malaria. Data management systems are required to manage and integrate the vast quantities of data obtained on entomology, cases, survey results and intervention coverage for use in effective decision-making.

Glossary

The definitions given below apply to the terms as used in this toolkit. They may have different meanings in other contexts.

Anthropophagic	Descriptive of vectors that show a preference for feeding on humans, even when non-human hosts are available
Anthropophilic	Descriptive of vectors that are attracted to humans
Breteau index	Number of containers with larvae and/or pupae per 100 houses inspected
Case detection	One of the activities of surveillance operations concerned with the search for disease cases in a community. Case detection is a screening process, using as indicator either the disease presence of fever or epidemiological attributes such as high-risk situations or groups. Infection detection includes the use of a diagnostic test to identify asymptomatic persons with malaria infection
Case surveillance	Ongoing, systematic collection, analysis and interpretation of disease-specific data and use in planning, implementing and evaluating public health practice
Container index	Percentage of water-holding containers with larvae and/or pupae
Controlled before-and-after trial	Trial in which the outcome of interest (entomology, disease or infection) is measured in both the intervention and the control arm before and after the intervention
Cross-resistance	Where resistance to one insecticide confers resistance to another class of insecticide, even when the vector has not been exposed to the second class insecticide
Decentralization	Political measure to reduce central influence and promote local autonomy
Diurnal	Descriptive of vectors that are active during the day
Exophagy	Tendency of vectors to feed outdoors
Exophily	Tendency of vectors to rest outdoors
Endophagy	Tendency of vectors to feed indoors
Endophily	Tendency of vectors to rest indoors
Environmental management	Modification or manipulation of environmental factors with a view to preventing or minimizing vector propagation and reducing human–

	vector–pathogen contact. May entail environmental modification (permanent environmental change) and/or environmental manipulation (recurrent actions to achieve temporary unfavourable conditions).
Evaluation	Assessment of a programme to determine whether its activities led to the expected outcomes and impact
House index	Percentage of houses with larvae and/or pupae
Insecticide resistance	Property of insects that can survive exposure to a standard dose of insecticide that may be the result of physiological or behavioural adaptation
Insecticide-treated net	Mosquito net that repels, disables or kills mosquitoes that come into contact with the insecticide on the netting material. There are two categories of ITN: conventionally treated nets and long-lasting insecticidal nets (LLINs)
Intra-sectoral	Working within a sector, such as health
Inter-sectoral	Working with other sectors, such as the private sector or non-health ministries
Larval source management	Management of aquatic habitats (water bodies) that are potential larval habitats for mosquitoes, in order to prevent the completion of development of the immature stages
Long-lasting insecticidal net (LLIN)	A factory-treated mosquito net made of netting material with insecticide incorporated within or bound around the fibres. The net must retain its effective biological activity without re-treatment for at least 20 WHO standard washes under laboratory conditions and 3 years of recommended use under field conditions
Logical framework (logframe)	A tool used to improve the planning, implementation, management monitoring and evaluation of projects and programmes. A written plan listing the main elements in a project and showing the logical links between them
Meta-analysis	A statistical technique used to summarize the results of several studies to obtain an average estimate of the efficacy of an intervention
Monitoring	Continuous tracking of programme performance against predetermined objectives and targets
Multiple resistance	Two or more different resistance mechanisms are present in one vector. The different resistance mechanisms may combine to result in resistance to multiple classes of products

Protective efficacy	Percentage reduction in disease or infection in a population that has received an intervention. Calculated as (1 – risk ratio) x 100, where the risk ratio is the risk for disease or infection of the intervention group divided by that of the control group. Risk ratio can be replaced by rate or odds ratio in the equation
Nocturnal	Descriptive of vectors that are active during the night
Randomized controlled trial	A trial in which individuals or areas are randomly assigned to receive either the intervention or the control. This is the best experimental design for determining the efficacy of an intervention
Social mobilization	Raising awareness and motivating people to demand change to achieve a particular goal
Stratification	Classification of geographical areas or localities according to the epidemiological, ecological, social and economic determinants for the purpose of guiding vector control interventions
Subsidiarity	Decisions made at the local level
Systematic review	A review of the literature on a particular topic, conducted in a systematic manner to ensure that it is comprehensive. Usually involves searching databases of publications with defined search terms
Vector surveillance	Collection of entomological data used to plan and assess anti-vector measures. Includes preliminary surveys, regular or trend observations, spot checks and focal investigations
Zoophagic	Descriptive of vectors that show a preference for feeding on animals, even when human hosts are available
Zoophilic	Descriptive of vectors that are attracted to animals

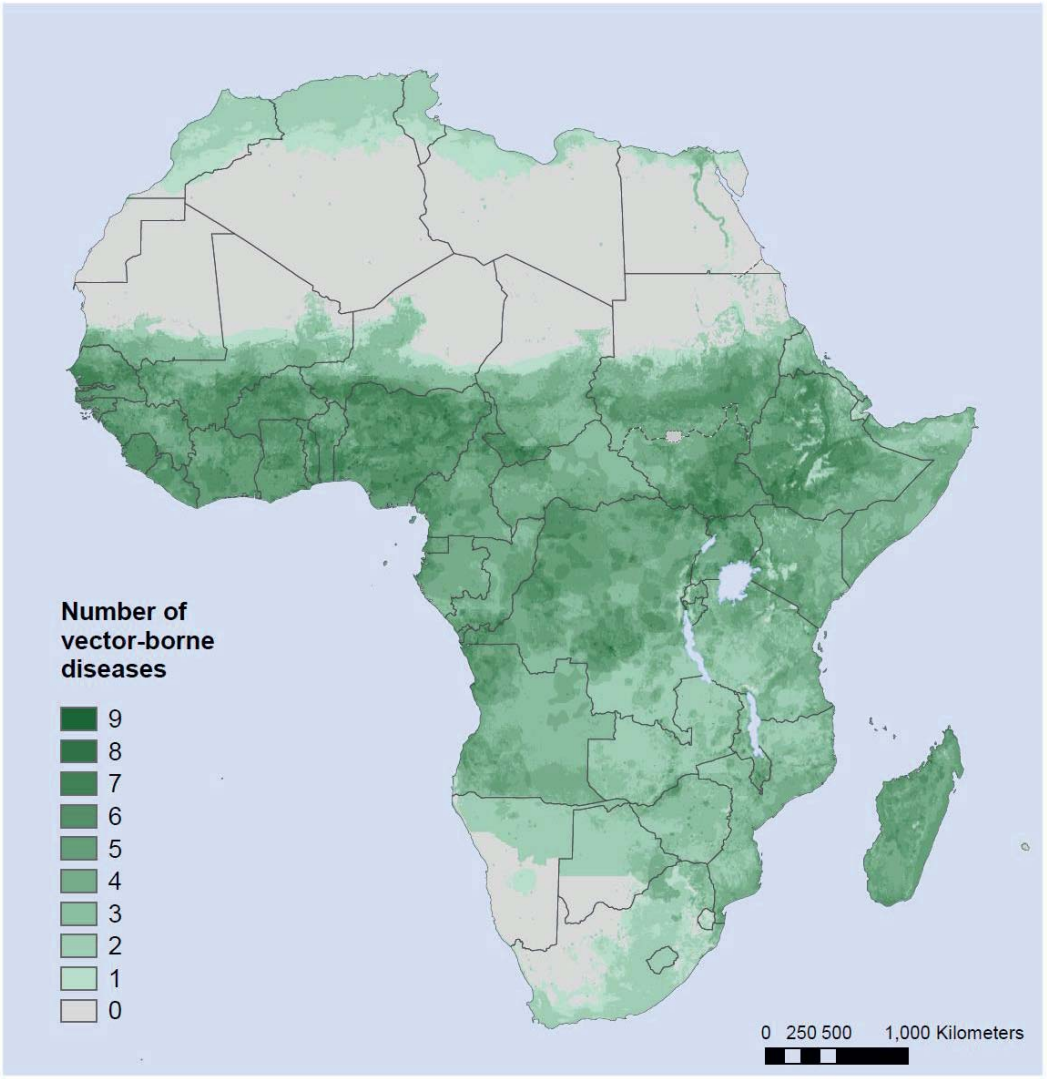
1 Introduction

1.1 Importance of vector-borne diseases

Vector-borne diseases are infectious diseases transmitted by mosquitoes, ticks, flies and bugs, which act as vectors of the disease-causing pathogens. Diseases such as malaria, dengue, leishmaniasis, lymphatic filariasis, schistosomiasis and human African trypanosomiasis (HAT) contribute significantly to the global burden of disease and disproportionately affect communities living in developing countries in tropical and sub-tropical zones. The most important vector-borne disease is malaria; in 2015, WHO estimated that there were 188 million cases of malaria in the WHO African Region, with about 395 000 deaths (*5*). Other vector-borne diseases, such as lymphatic filariasis, leishmaniasis, schistosomiasis, HAT and onchocerciasis, are less deadly but still result in high levels of morbidity (*6*, *7*). Dengue is one of the world's fastest spreading vector-borne diseases, and cases are becoming widespread in sub-Saharan Africa (*8*). These diseases not only affect public health but are also a major cause of poverty and underdevelopment in many countries (*9*).

Vector-borne diseases are widespread throughout sub-Saharan Africa, and many diseases are co-endemic, i.e. co-exist in the same geographical area. Fig. 1 shows the geographical distribution of risk for major vector-borne diseases: malaria caused by *Plasmodium falciparum* and *Plasmodium vivax*, lymphatic filariasis, dengue, cutaneous leishmaniasis, visceral leishmaniasis, onchocerciasis, HAT and yellow fever, which are co-endemic in some areas.

Fig. 1. Global distribution of risk for major vector-borne diseases: falciparum and vivax malaria, lymphatic filariasis, dengue, onchocerciasis, cutaneous and visceral leishmaniasis, human African trypanosomiasis and yellow fever



Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS), World Health Organization

Areas in colour are at risk for at least one disease. The number of diseases that poses a risk is indicated by the colour scale.

1.2 Integrated vector management for disease control

IVM is defined by WHO as a "rational decision-making process for the optimal use of resources for vector control" (*10*) i.e. an adaptive management approach for controlling vector borne diseases. More specifically, IVM is the control of one or more vector-borne diseases (where diseases are co-endemic) using multiple interventions, either chemical or non-chemical or both, selected based on good evidence. IVM also incorporates interventions, actors and, potentially, resources, coordinated between the health and other sectors, including communities, the private sector and non-health ministries, such as agriculture and housing. Thus IVM differs from routine vector control which has been historically heavily reliant on insecticides, is largely vertical, single disease and intervention focused, campaign-based and run solely through the health sector.

The aim of the IVM approach is to help control and eliminate vector-borne diseases by making vector control more efficient, cost–effective, ecologically sound and sustainable. Vector control programmes face a number of challenges, including dwindling public sector human and financial resources, the threat of insecticide resistance, the emergence of new vector-borne disease and pressure to lessen the environmental impact of vector control. IVM can help address these challenges. It can increase the effectiveness of vector control by encouraging the use of local evidence to choose and target vector control, by integrating interventions where appropriate and by collaborating within the health sector and with other sectors. Vector control programmes for a single disease can collaborate with others, thus reducing duplication and overlap and saving costs by making better use of existing human and financial resources. By broadening the range of tools used in vector control programmes, such as environmental management, encouraging the use of different classes of insecticide to attack different life stages of the vector and monitoring the effect of interventions on insecticide susceptibility, IVM may mitigate the threat of insecticide resistance. Many countries are seeing the emergence of new vector-borne diseases and a rise in viral vector-borne diseases, such as dengue, zika and chikungunya. IVM could help disease control programmes to be better prepared for the introduction or re-introduction of diseases through integrated vector and case surveillance. Use of non-insecticide-based control measures might lessen the environmental repercussions of chemical vector control.

WHO has identified the five major elements of an IVM strategy as an integrated approach; evidence-based decision-making; collaboration within the health sector and with other sectors; advocacy, social mobilization and legislation; and capacity-building (*11*). These elements are summarized in Table 1.

Table 1. Elements of an integrated vector management (IVM) strategy

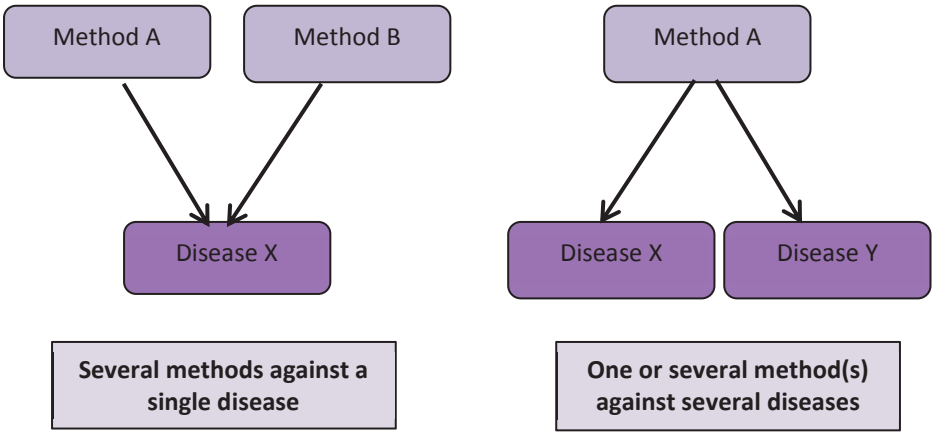
Element	Description
Integrated approach	• Addresses several diseases with vector control tools, often in combination and synergistically • Involves use of chemical and non-chemical methods • Integrates other disease control methods, such as medicines and vaccines
Evidence-based decision-making	• Strategies and interventions adapted to local vector ecology and disease epidemiology and guided by operational research, surveillance, monitoring and evaluation
Intra- and inter-sectoral collaboration	• Collaboration within the health sector and with other sectors (public and private) • Planning and decision-making delegated to the lowest possible level (subsidiarity)
Advocacy, social mobilization and legislation	• Principles of IVM promoted and integrated into policies in all relevant ministries, organizations and civil society • Establishment or strengthening of regulatory and legislative controls for public health • Community engagement and empowerment to increase sustainability
Capacity-building	• Adequate infrastructure and financial and trained human resources at central and local levels • Training and education in place according to IVM curricula

Adapted from reference *1*

Integrated approach

IVM involves the use of a range of proven vector control methods, either alone or in combination; several methods may be used against a single disease, or a single or several methods may be used against several diseases (Fig. 2). The vector control tools may be chemical or non-chemical. IVM can also supplement vaccines, mass drug administration or diagnosis and treatment for integrated disease control.

Fig. 2. Schematic representation of vector control methods used for integrated vector management



In certain situations, IVM can be used for several diseases concurrently, because some vectors can transmit more than one human pathogen (e.g. *Anopheles gambiae* is involved in malaria as well as lymphatic filariasis transmission) and some interventions are effective against several vectors (e.g. long-lasting insecticidal nets are effective against malaria, lymphatic filariasis and leishmaniasis vectors).

Evidence-based decision-making

The selection and use of vector control methods should be guided by knowledge of local vector ecology and the epidemiological situation. IVM programmes should include monitoring and evaluation of the effect on both the vector and the disease in order to resolve problems in implementation and evaluate the impact of the programme. Operational research priorities should be identified and studied to inform the programme.

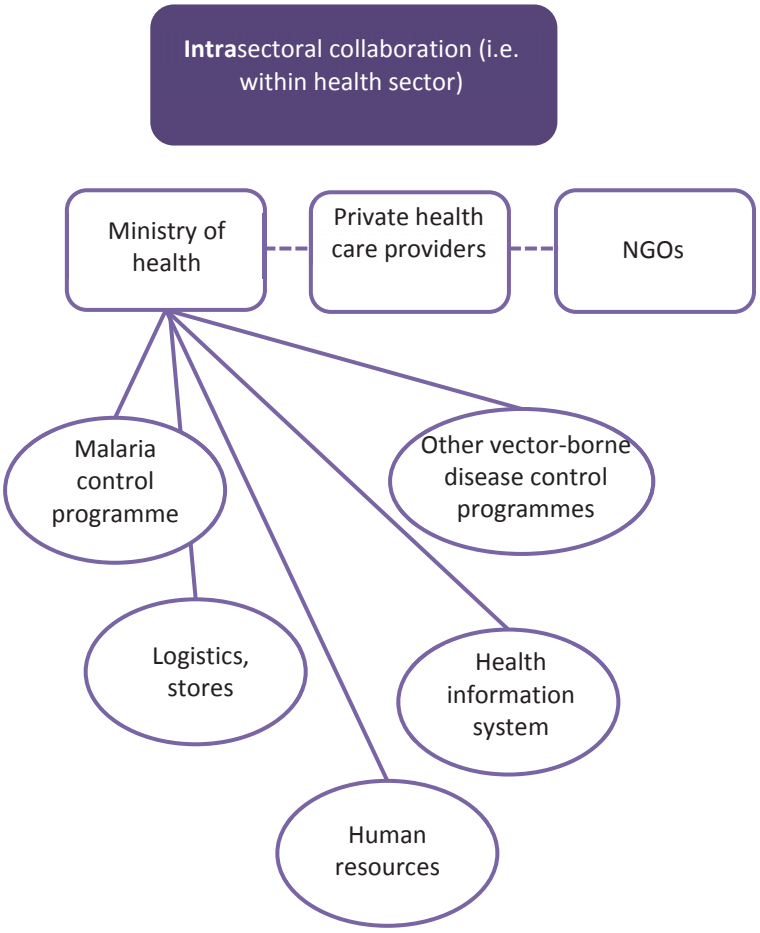
Key point

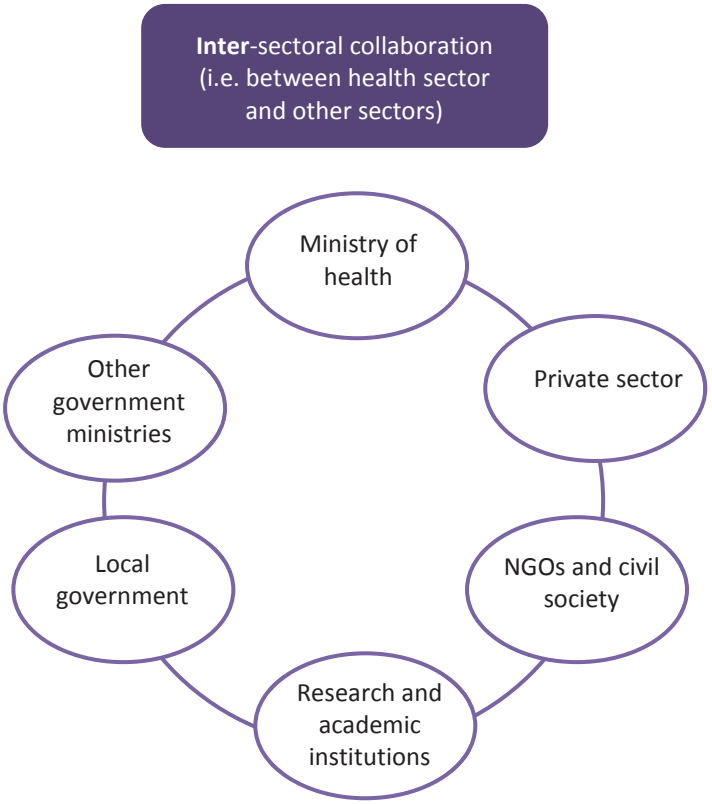
IVM can be used as a strategy for a variety of programme goals, whether the goal is control or elimination.

Collaboration within the health sector and with other sectors

IVM should be collaborative, involving elements of the health sector and other sectors, such as government ministries (e.g. agriculture, education, housing and public works), local government, community groups and non governmental organizations (NGOs) (Fig. 3). Intra- and intersectoral collaboration should be coordinated by a formally established IVM steering committee comprising representatives of different ministries, local government, industry, research and academic institutions, NGOs, civil society and community organizations. This steering committee should clear terms of reference and modus operandi, and access to funding to ensure effectiveness of IVM programmes.

Fig. 3. Hypothetical examples of intra- and intersectoral collaboration between ministries and organizations in IVM





Advocacy, social mobilization and legislation

IVM must be communicated effectively, promoted and integrated into policies in relevant ministries, organizations and civil society. Regulatory and legislative controls for public health should be established or strengthened. The involvement and engagement of communities can help to make vector control more effective and sustainable; therefore, communities should be made aware of the risks of vector-borne disease and take action themselves in the use of preventive measures or vector control around their domestic environment.

Capacity-building

IVM relies on the availability of skilled personnel at national, subnational, district and village levels. It must therefore include a capacity-building programme to upgrade and maintain the knowledge and skills of personnel.

1.3 Integrated vector management over time

IVM should be seen as dynamic and adaptive, as the relative importance of different vector-borne diseases will change over time. For example, as lymphatic filariasis remains only in areas of extremely high transmission, long-term suppression of transmission should result in the elimination of lymphatic filariasis, well before malaria is eliminated. As the prevalence of malaria decreases and transmission is restricted to certain areas, dengue may become the preeminent vector-borne disease. Vector control programmes will then move from widespread control to targeted control, taking into account risk stratification. Eventually, with development, dengue will be better controlled, and mosquito abatement will become the major aspect of vector control programmes, to reduce the biting nuisance of vectors and to remove a platform for emerging vector-borne diseases. This trajectory was seen in the southern states of the USA during the past century. Vector control must be maintained in order to prevent reintroduction of disease.

Fig. 4. Potential scenario of changing disease dynamics with effective control

Section summary

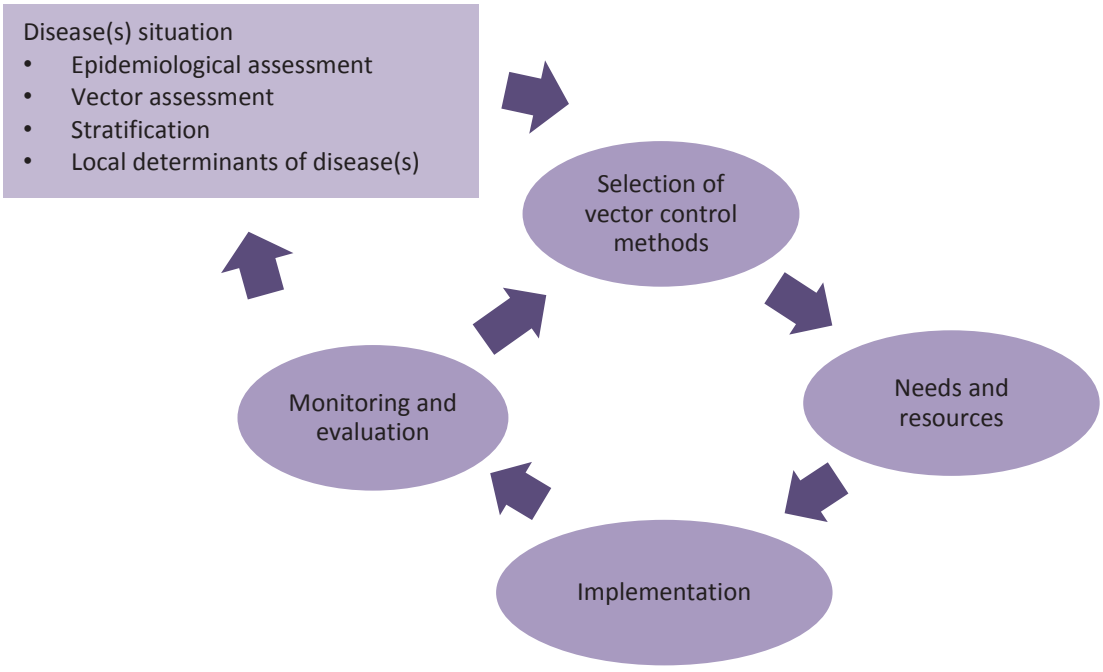
- Sub-Saharan Africa has a high burden of vector-borne diseases, and many diseases occur concurrently in the same geographical location and timeframe.
- The aim of IVM is to make vector control more efficient, cost–effective, ecologically sound and sustainable.
- IVM is characterized by evidence-based decision-making and collaboration within the health sector and between sectors.
- IVM can involve use of several tools against a single disease or of one or several tools against several diseases in an integrated fashion.
- IVM is a dynamic approach, which can be adapted over time to respond to changes in vectors and disease transmission.

2 Framework for planning and implementing integrated vector management

2.1 What steps are required to do IVM?

IVM should involve a cycle of several rounds of situational analysis, planning, design, implementation, monitoring and evaluation (Fig. 5). A comprehensive assessment of the disease situation, including epidemiological and vector assessment, identification of local determinants of disease and stratification of areas at risk is essential for ensuring that the programme corresponds to the situation. Vector control interventions should be selected on the basis of this assessment, knowledge of the efficacy of vector control methods and other considerations, such as insecticide resistance and cost–effectiveness. Needs and resources should be mapped and implementation strategies planned. The programme should be monitored and evaluated to determine its effect on the disease of interest and to allow feedback for planning. The local disease situation might have to be reassessed subsequently.

Fig. 5. Steps in IVM planning, implementation, monitoring and evaluation loop



Modified from reference *1*

Key point

Fig. 5 is the most important illustration in the toolkit, because it shows the steps required for IVM. Each step is explained below.

2.2 Organizational structures

IVM will be possible only if there is strong political will and support at government level. This political commitment will be forthcoming only if a strong case is made that vector-borne diseases affect economic development. It is vital that countries put in place relevant national policies and technical strategies to guide IVM implementation. Therefore, strong advocacy is needed, including information on the burden of vector-borne diseases, their impact on health, the economy and social and cultural aspects (e.g. absenteeism from school and work), the effectiveness of IVM, the benefits of intersectoral collaboration and potential cost savings. This is a long-term strategy that requires political commitment, as IVM will evolve over time as the patterns of vectors and disease change. Therefore, IVM programmes must be approved by the government and run through the department of health and other stakeholders to achieve the aim of reducing morbidity and mortality due to vector-borne diseases.

IVM will work only if there is strong political commitment from the outset. Advocacy for integrated vector-borne disease control must include the government and other stakeholders.

To coordinate efforts, a national IVM steering committee should be established, consisting of senior members of the ministry of health, coordinators of disease programmes (e.g. for malaria, neglected tropical diseases, onchocerciasis), representatives of other ministries (e.g. agriculture, education,

public works), as well as national regulatory authorities, local government, the private sector (including manufacturers, oil and mining companies), academic and medical research institutions and other interested parties such as NGOs and civil society groups (Fig. 6), depending on country context. As far as possible, senior politicians should be involved in establishing and sustaining the IVM programme to ensure intra-and intersectoral collaboration. Advocacy from the ministry of health can make other ministries and stakeholders aware of their own roles and responsibilities in vector-borne disease control, and obtain commitments for action. For example, a ministry of trade and finance may affect vector control by imposing import taxes and tariffs on insecticides and LLINs. Participation on the committee from research institutions is important to evaluate vector control interventions, and regional representation is important for information exchange and to ensure collaborative involvement in activities.

The steering committee should be chaired by the minister of health and should meet regularly. Formal terms of reference should outline the roles and responsibilities of committee members, and to ensure continuity, minimum terms of service set for membership and participation in meetings. Technical working groups with specific expertise and terms of reference could be set up for specific activities, for example to discuss capacity-building or monitoring and evaluation.

Key point

A steering committee must be set up to oversee the IVM programme, comprising members of different disease control programmes and representatives of other sectors.

The work of the IVM steering committee should be guided by a high-level IVM strategic plan. The first version of the plan should be prepared by the ministry of health and then evaluated and reviewed by other stakeholders. The plan should include: the roles and responsibilities of stakeholders, a situation analysis and implementation strategy, cost implications, sources of funding and funding structure, summary of the monitoring and evaluation plan and key points on how the programme will be sustained.

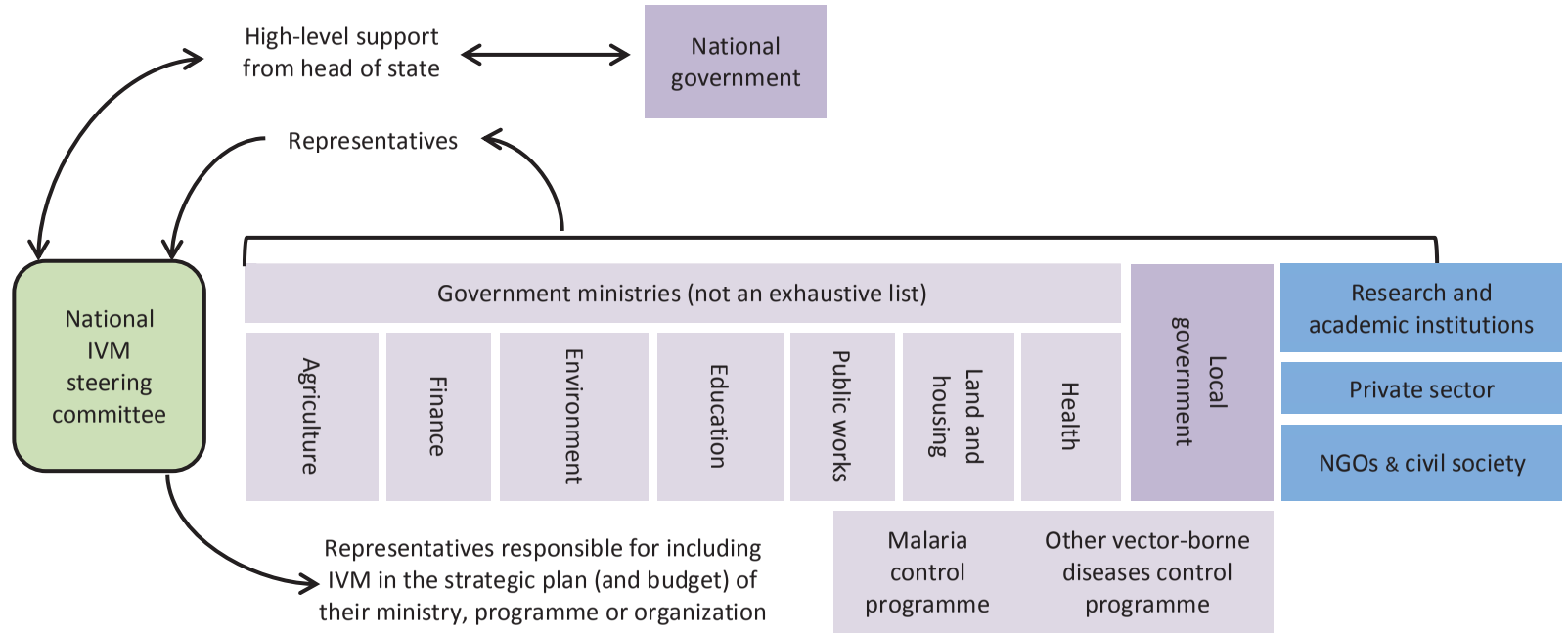
The representatives of each ministry or organization on the committee will then be responsible for advocating for IVM and ensuring that IVM is described in the strategic plans of their own ministries and organizations. This will help them in advocating for funding and allocation of other resources (e.g. human resources or materials) to IVM. Therefore, the first IVM strategic plan should have been

completed 6 months to 1 year before the revision cycles of the strategic plans of individual ministries (usually every 5 years). On the basis of their strategic plans, each line ministry (and other stakeholders) should allocate funds for IVM.

In small countries, such as The Gambia, the IVM steering committee could be backed up by an IVM focal person in each region, whereas in large countries, such as Nigeria, with a decentralized government, the committee shown in Fig. 6 should be replicated at regional level, with representatives from line ministries and other organizations working at that level. The regional committee should therefore also include representatives of regional ministries and organizations and be led by a focal person. An IVM focal person should be assigned at district level in large countries. IVM focal persons at regional or district level will be responsible for coordinating and leading the IVM programme in their region or district. They should work closely with vector-borne disease control programmes in their areas and thus be aware of what is needed. IVM focal people are also responsible for identifying opportunities for intersectoral collaboration, bringing vector-borne disease control programmes together, and increasing community awareness and participation in vector control. At all levels, but particularly at the level of the IVM focal person in regions or districts, it is important to identify stakeholders in the project. Stakeholder analysis tools can be used to identify stakeholders, as well as their interests, power and influence and allow formulation of a stakeholder participation strategy (Annex 1).

Box 1 lists the structures of governance and planning used to support the IVM programme in Morocco.

Fig. 6. Governance arrangements to support IVM programmes



Box 1. Structures and planning for IVM: the Moroccan experience and lessons learnt

1. It is essential to establish a national IVM steering committee.

With the support of WHO, the Ministry of Health of Morocco adopted the IVM approach in 2005. It established a national IVM steering committee to strengthen collaboration among ministries and coordination of the organisational structures of the Ministry of Health. The committee is composed of representatives from key line ministries, such as agriculture, environment, the interior and health, and an academic institution.

2. The national steering committee should have defined terms of reference.

The committee has clearly defined terms of reference, which include studying all aspects of vector control, standardizing control methods, coordinating the activities of various departments with the management at the national level and overseeing projects to promote implementation of IVM.

3. The committee requires strong leadership with expertise in and the ability to advocate for vector-borne disease control.

The Head of the Department of Vector Control is the national focal point for IVM, under the authority of the Chief of the Division of Environmental Health, the Presidency and the secretariat of the committee.

4. The committee should conduct a vector control needs assessment before preparing a strategic plan.

The committee conducted a situation analysis and identified needs in 2007 and then prepared a national plan of action for 2008–2012. The strategy has been implemented gradually in several provinces by raising the awareness of the authorities and local authorities, decentralized services of the ministries concerned, local associations and committees.

5. The IVM steering committee should be replicated at lower levels with locally active stakeholders from civil society and local government.

Steering committees have been set up at regional and provincial levels. The functions of the regional and provincial committees are to raise awareness about IVM, conduct a situation analysis and needs assessment, plan and implement interventions, select appropriate control methods, mobilize resources, monitor and evaluate the impact of IVM and conduct capacity-building. The decentralized services of the ministries of agriculture, the interior, environment, education and health and civil society are represented on these committees. An IVM manual was prepared in 2012 and distributed to all regions and provinces to provide guidance on adopting IVM at decentralized levels.

6. Take advantage of opportunities to advocate for support of IVM.

World Health Day 2014, with the theme of vector-borne diseases, was used to institutionalise the national, regional and provincial committees by a decision signed by several key ministers: the Minister of Health, the Minister of the Environment and the Minister of the Interior.

2.3 Vector control and other needs assessments

The vector control needs assessment process is established in many countries of sub-Saharan Africa (*12*, *13*) and other needs assessments have been conducted for specific diseases, such as under the auspices of the Roll Back Malaria partnership. Such assessments help countries to describe the policy and institutional framework for vector control decision-making, the institutional arrangements to support the vector control programme, the management of vector control operations and the resource base to support operations. We therefore recommend that countries undertake a vector control needs assessment or review the process if one was conducted some time ago.

A vector control needs assessment comprises a situation analysis, an assessment of constraints to implementation of vector control and a needs assessment. The process and items to be considered in a vector control needs assessment are listed in Table 2.

Table 2. Vector control needs assessment

Situation analysis		
Area		What should be considered?
Policy and institutional framework for vector control		General health sector policies Policies by vector-borne disease control programmes Non-health sector policies
Structures, resources and functions	Within the health sector	Place and structure of vector control Inter- and intra-sectoral collaboration and coordination Communication and information flow Human resources
	Other sectors	Financial resources Infrastructure (research, training, technical and operational facilities)
Vector control planning and implementation		Distribution of vector-borne disease and vectors Tools, methods, strategies and coverage Pesticide management needs, safety and environmental issues Intra- and intersectoral collaboration Community mobilization

Needs assessment
Opportunities for strengthening policy for IVM
Opportunities for strengthening institutional frameworks for IVM
Strengthening human resources and systems for vector control
Leadership and governance
Sustainable financing of IVM
Strengthening information systems for IVM
Enhancing implementation: tools, technologies and logistics
Opportunities for community mobilization

From references *12* and *13*

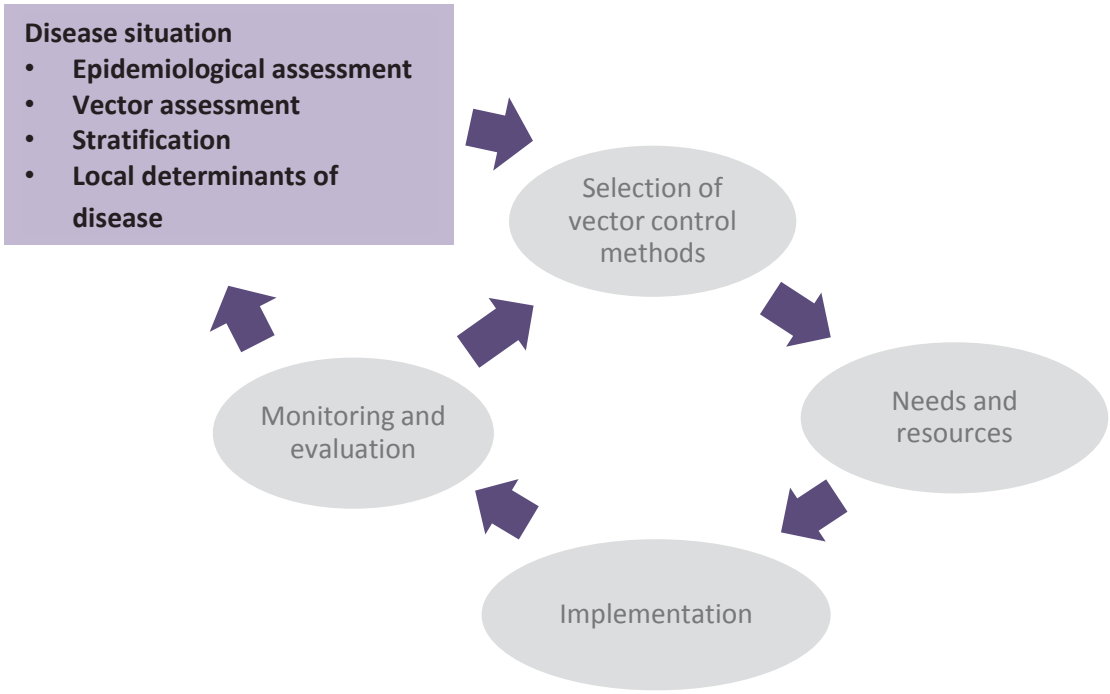
The situation analysis comprises the policy framework, management procedures, institutional arrangements, structures, resources and functions that support vector control activities. These should be assessed at national, regional and district levels. The situation analysis also includes a brief assessment of the burden, distribution and vectors of disease. The sections in this toolkit that describe evaluation of the current epidemiological situation and vector bionomics (e.g. ecology, insecticide resistance) are much more detailed than in a vector control needs assessment; they should be referred to fully, given their importance for evidence-based vector control.

Based on information collected in situation analysis, bottlenecks that constrain implementation of vector control and specific needs can be identified. The needs assessment covers, for example, policy needs (to generate an enabling environment for vector control), institution-building needs (strengthening structures for effective delivery of interventions), managerial needs (decision-making capacity and leadership) and human and financial resources.

Section summary

- IVM should be cyclical, with multiple rounds of situational analysis, planning, design, implementation, monitoring and evaluation.
- Advocacy is required to obtain strong political commitment and support for vector-borne disease control and IVM.
- A national IVM steering committee should be set up to oversee national implementation of IVM; this structure should be replicated at lower administrative levels where necessary.
- The national steering committee should prepare a high-level strategic plan, and the members of the committee should be responsible for introducing specific IVM activities into their own strategic plans and budgets.
- The steering committee should identify opportunities for intersectoral action in planning and implementation of IVM.
- A vector control needs assessment should be conducted to determine, for example, the policy and institutional framework and resources available for vector control in the country.

3 Disease situation analysis



3.1 Introduction

It is important to understand the distribution of vector-borne diseases and vectors in order to plan, control and prioritize resources. An epidemiological assessment requires data on where the diseases are endemic. This is determined by four or five factors, including the pathogen, the vector and human, environmental and, in some cases, animal determinants. Programme managers must consider all of these factors. More information on the determinants of disease is given in Annex 2.

Fig. 7 illustrates the steps in collecting and integrating information. This flowchart splits activities into those that should be conducted at a broad level (national and first administrative level, here termed region) and at a local level (district and below). A broad-level analysis is needed to stratify areas of the country according to the diseases present, disease incidence or risk of infection even if cases have not been reported from the area, vector species and ecology. Locally, the micro-epidemiology of the disease, including human determinants, should be explored.

Fig. 7. Steps in conducting a disease assessment

3.2 Broad analysis

Consider

1. Which vector-borne diseases are endemic, and where are cases occurring? Where are these risks for infection?
2. Are some diseases or infections co-endemic? If so, where are they found?
3. Are there differences in disease risk by geographical area?
4. Which vectors are responsible for transmission, and where are they found?

3.2.1 Step 1. Examine maps of disease endemicity

Maps have been published that indicate the probable geographical distribution of risk for infection for major vector-borne diseases: malaria caused by *Plasmodium falciparum* or *Plasmodium vivax*, lymphatic filariasis, cutaneous leishmaniasis, visceral leishmaniasis, dengue, HAT, onchocerciasis and yellow fever (Figs 8, 9, 12–18). Maps are available for *P. falciparum* and *P. vivax* malaria that represent more epidemiologically relevant quantities, such as the parasite rate and the case incidence rate (*14*).

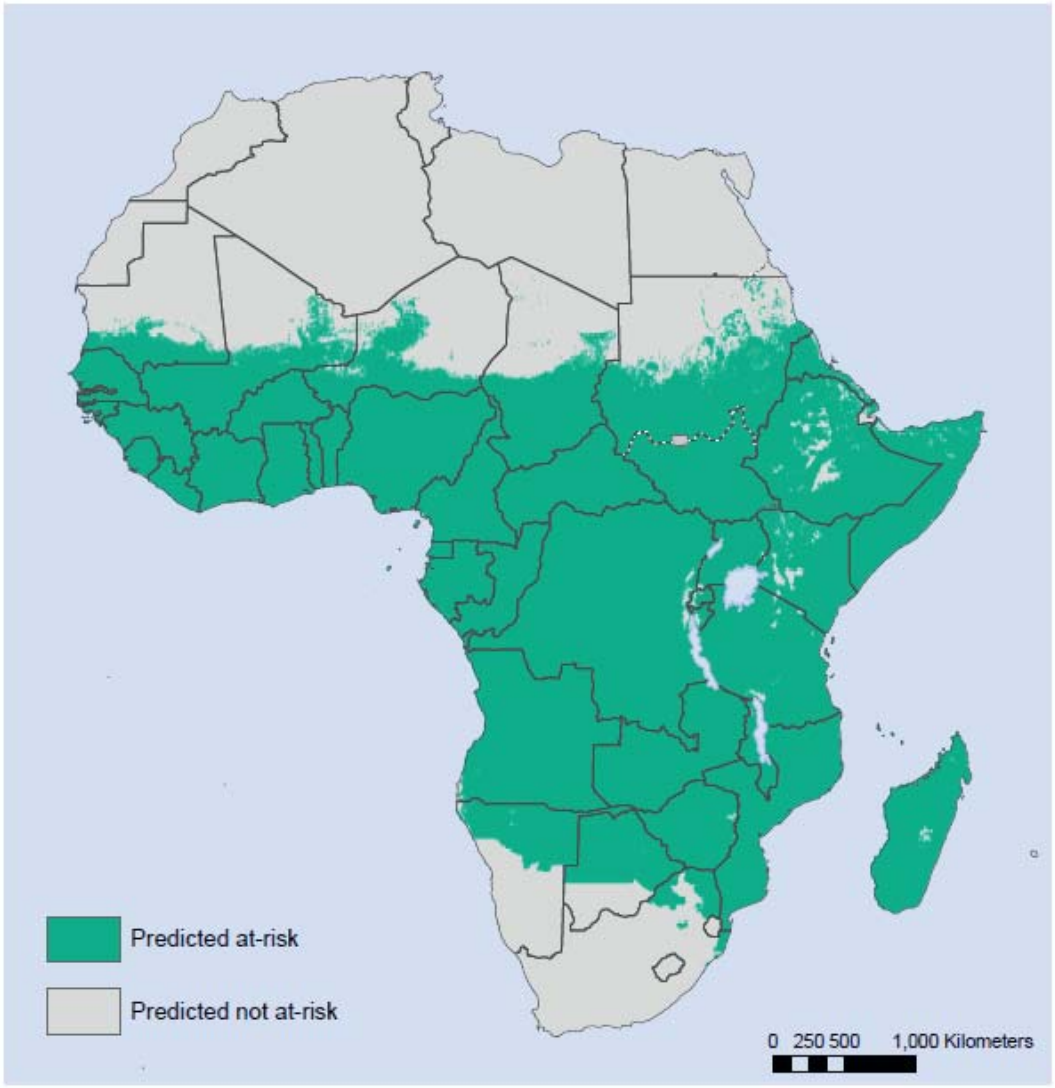
The maps are likely to be most reliable for malaria, lymphatic filariasis and onchocerciasis, as they are based on a large amount of information on subnational disease endemicity. The predicted distributions are less certain for dengue and leishmaniasis, and, as very little information was available for yellow fever, this map (Fig. 18) should be considered to provide only a rough estimate and probably an overestimate of the area at risk for infection.

While these maps show the distribution of infection risk for each disease, diseases and infections may be co-endemic, with more than one disease or infection present in a particular area. Therefore, maps might have to be examined side-by-side to determine whether the population is at risk for more than one infection.

Maps are also available for other vector-borne diseases. Schistosomiasis infection cannot be predicted accurately on a broad scale, because infections are highly focal. Transmission occurs when infected people urinate in water bodies or defecate openly; specific freshwater snails serve as the intermediate hosts of such human–water contact. Maps indicating where schistosomiasis surveys have been done and information on the prevalence of schistosome eggs in urine or stool samples or blood in urine are available for individual countries (*15*). Maps illustrating the distribution of trachoma (active trachoma in children aged 1–9 years and trichiasis in adults) are also available (*16*).

Unfortunately, there is limited information on the distribution of other mosquito-borne viral diseases, such as chikungunya, zika, Rift Valley fever, West Nile virus and o'nyong-nyong virus in sub-Saharan Africa, and maps of infection risk for these diseases are not currently available.

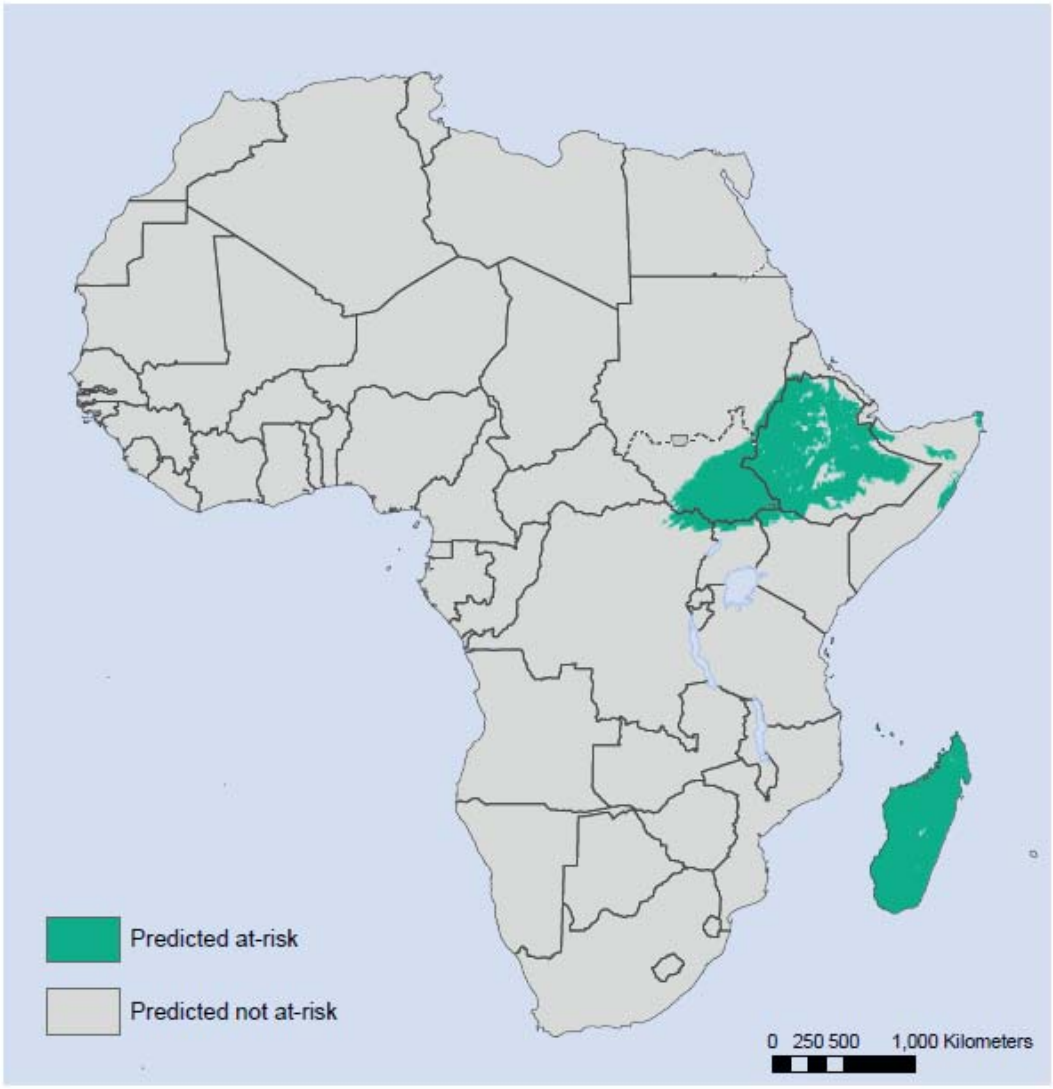
Fig. 8. Distribution of risk for *Plasmodium falciparum* malaria infection in Africa



Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS). World Health Organization © WHO 2015. All rights reserved.

Areas at risk (in green) are those predicted in 2010 to have an annual parasite incidence rate of at least 1 per 10 000 individuals; classified as stable transmission (*14*).

Fig. 9. Distribution of risk for *Plasmodium vivax* malaria infection in Africa



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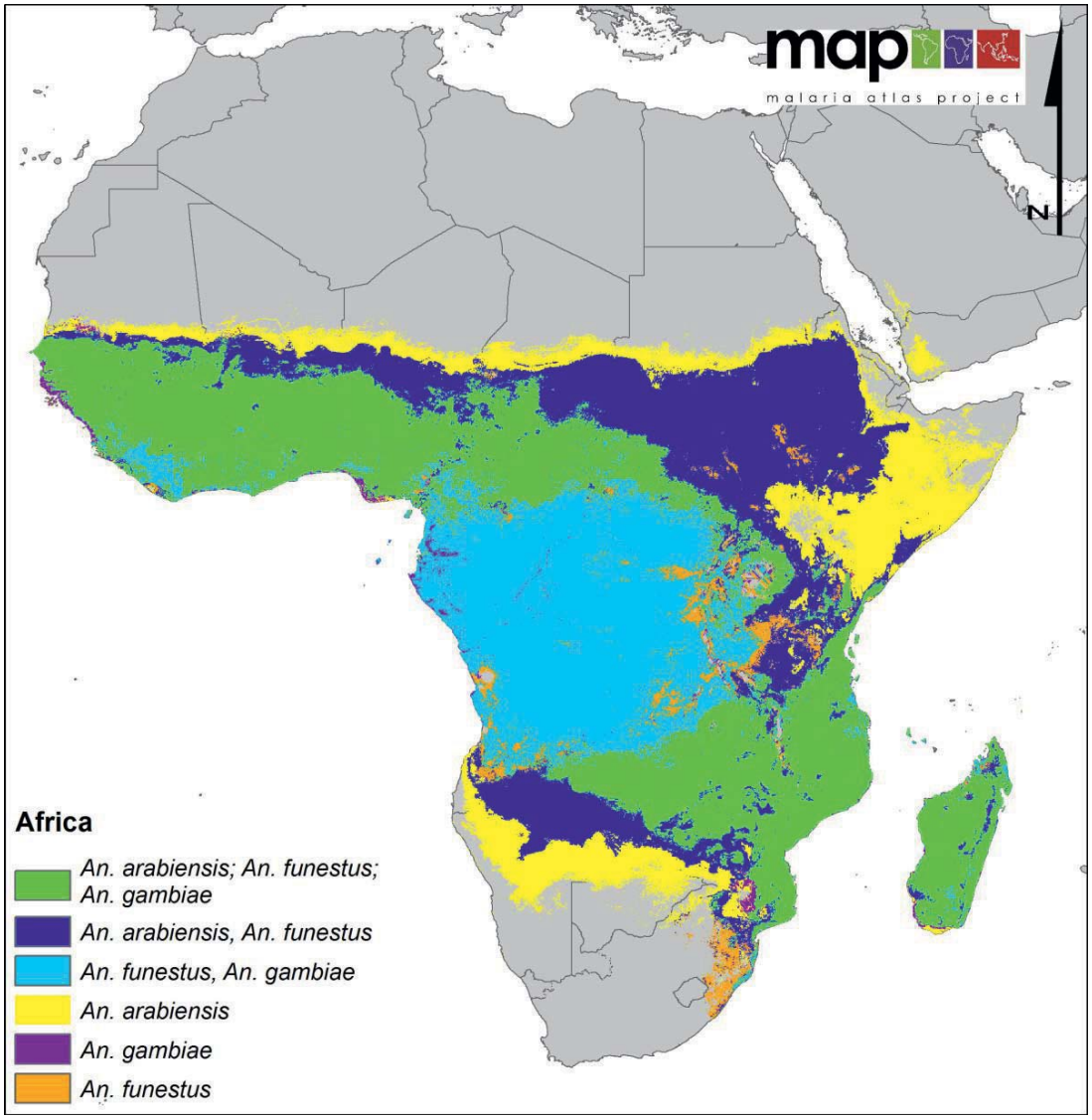
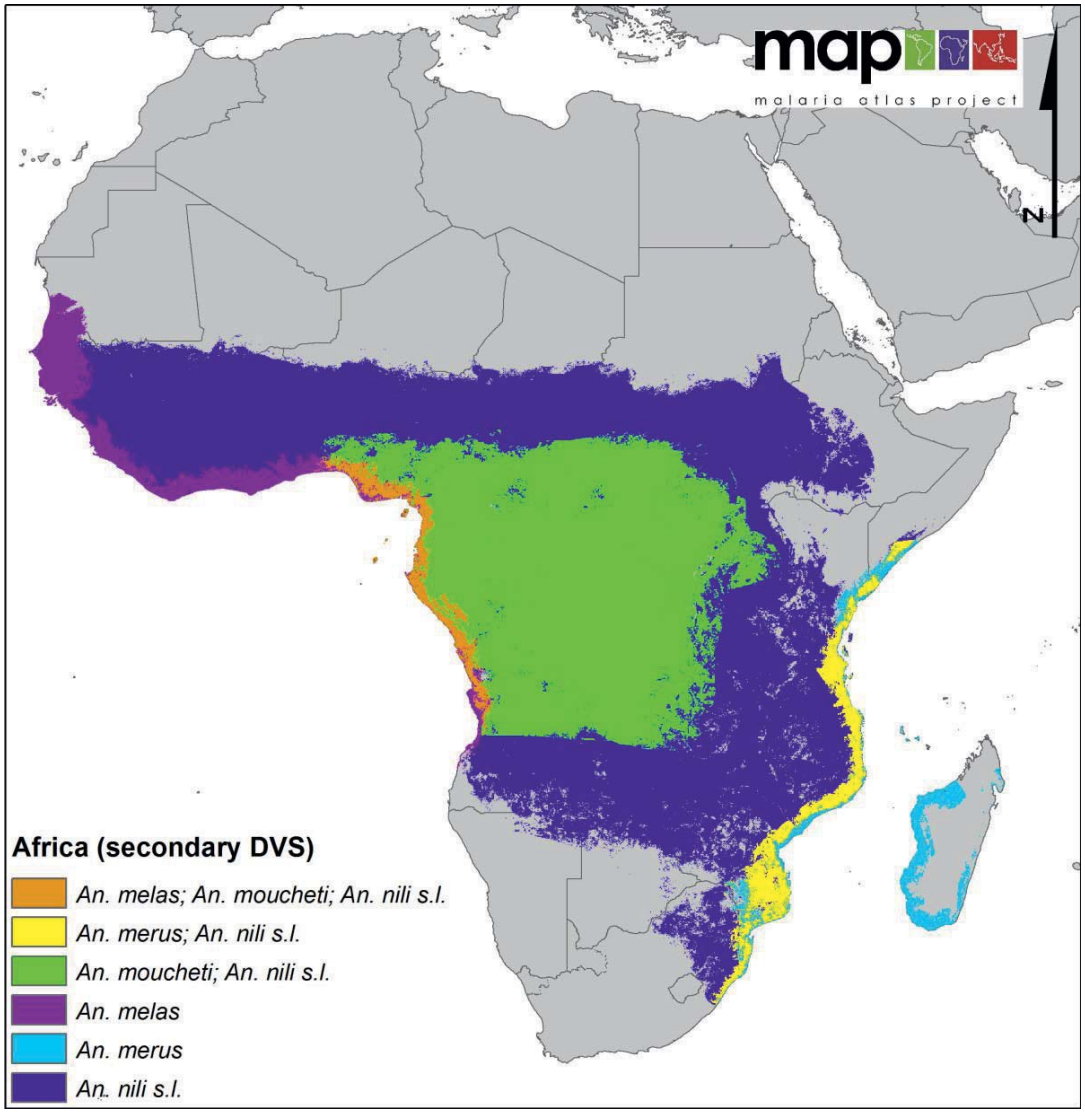
Areas at risk (in green) are those predicted in 2010 to have had an annual parasite incidence rate of at least 1 per 10 000 individuals; classified as stable transmission (*17*)

Fig. 10. Distribution of dominant *Anopheles* spp. vectors of malaria in Africa



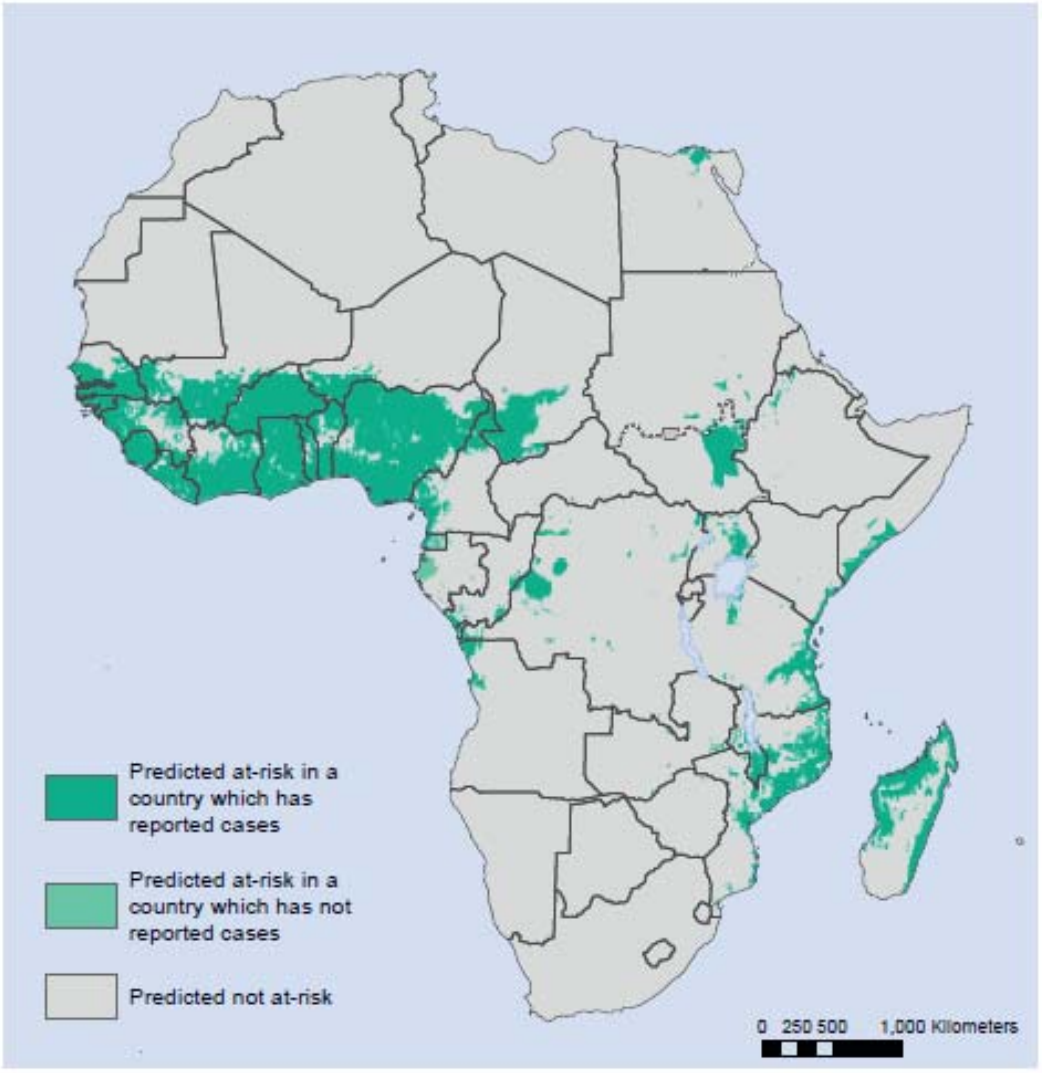
The coloured regions indicated the species considered the most important for malaria transmission in that area. The distribution of these species was estimated from data on mosquito occurrence collected between 1985 and 2009 *(18)*

Fig. 11. Distribution of secondary *Anopheles* spp. vectors of malaria in Africa



The coloured regions indicated the species considered to play a less important role in malaria transmission in that area. The distribution of these species was estimated from data on mosquito occurrence collected between 1985 and 2009 *(18)*

Fig. 12. Distribution of risk for lymphatic filariasis infection in Africa



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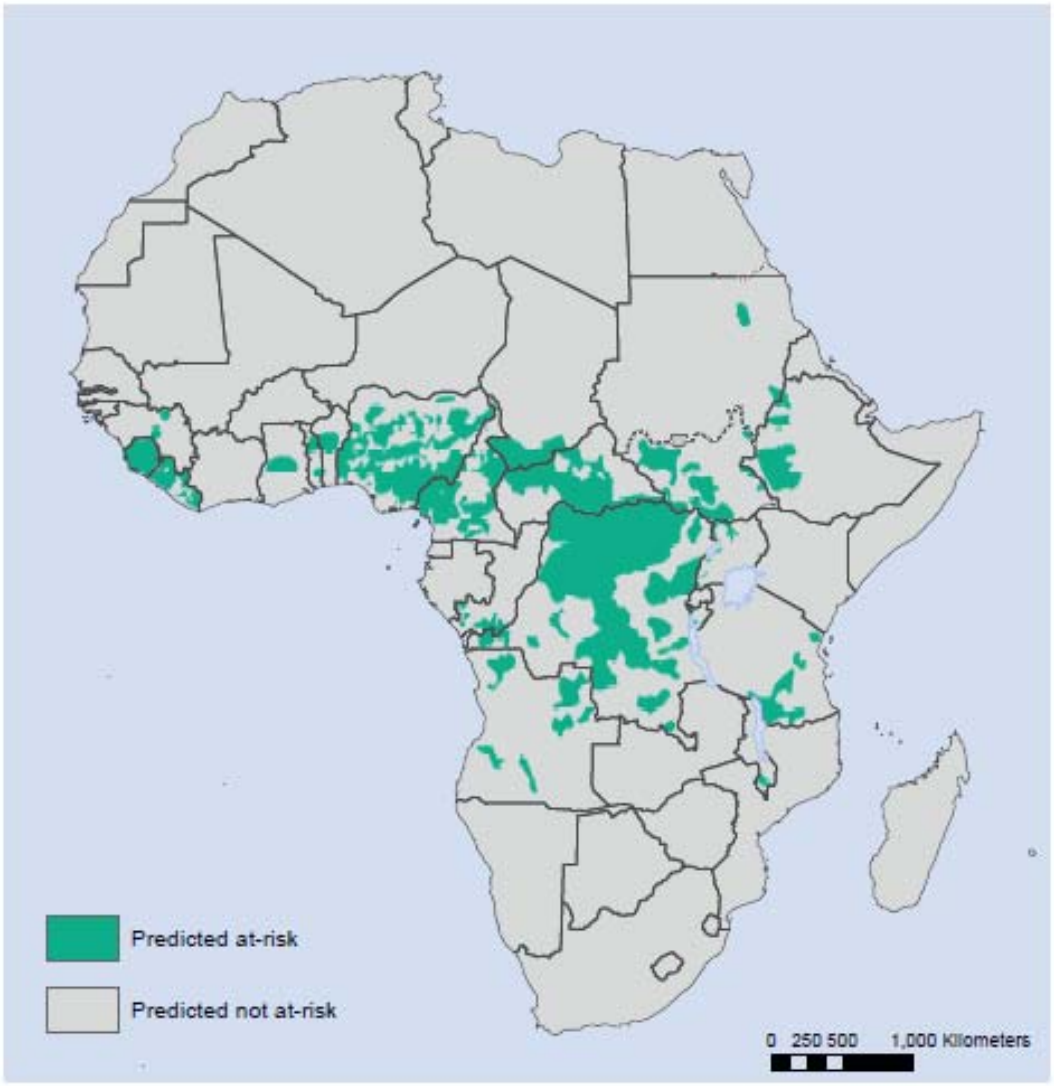
Areas at risk (in green) are those predicted to be environmentally suitable for the disease by Cano et al. (*19*). Areas in light green are predicted to be suitable, but are in countries that are not considered to be endemic for the disease and in which no occurrence was recorded by Cano et al.

Fig. 13. Distribution of risk for onchocerciasis infection in Africa



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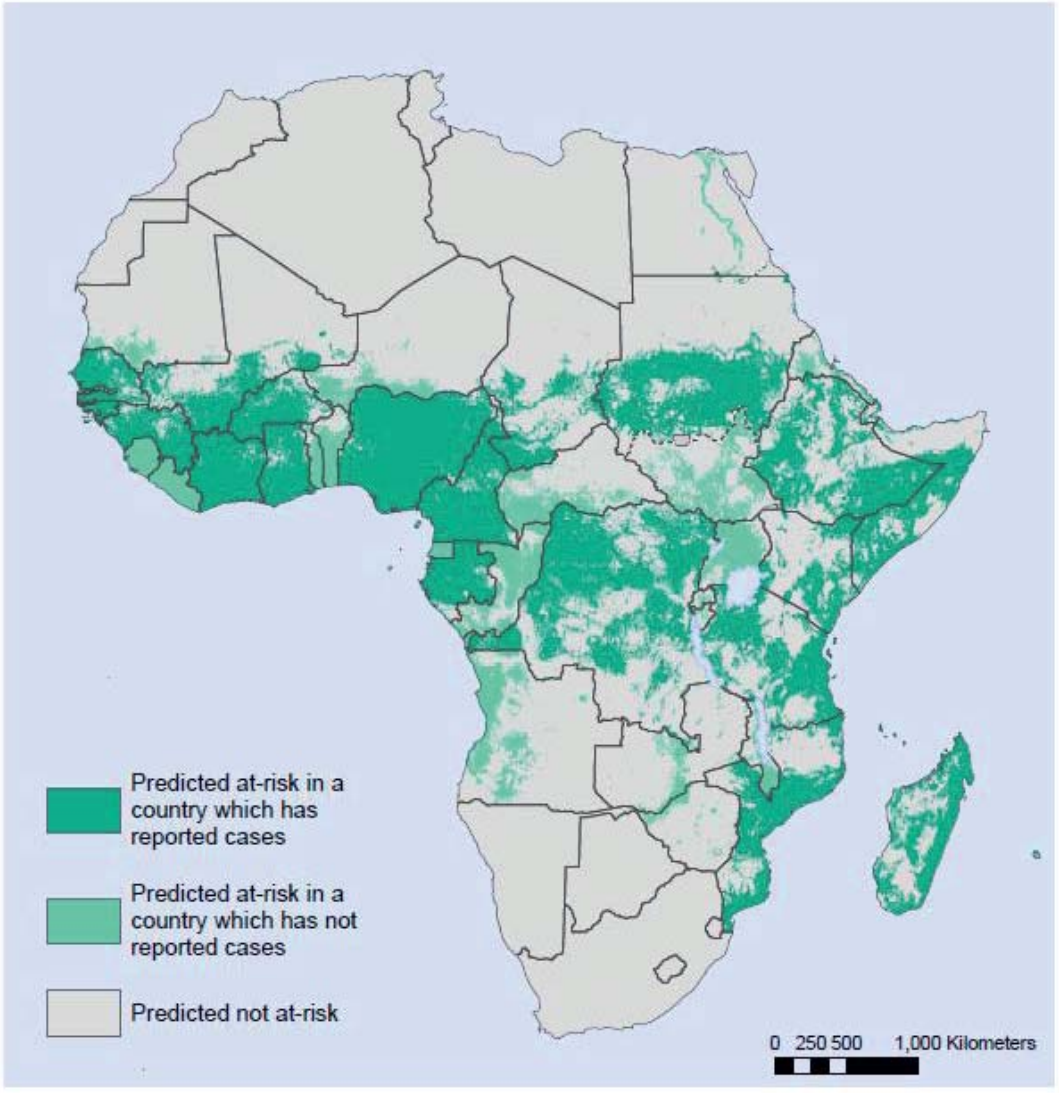
Areas at risk (in green) are those in which control activities were carried out by the African Programme for Onchocerciasis Control between 2006 and 2013 and, in West Africa, regions in which transmission was identified at the end of the onchocerciasis control programme in 2002 (*20*–*22*).

Fig. 14. Distribution of risk for dengue infection in Africa



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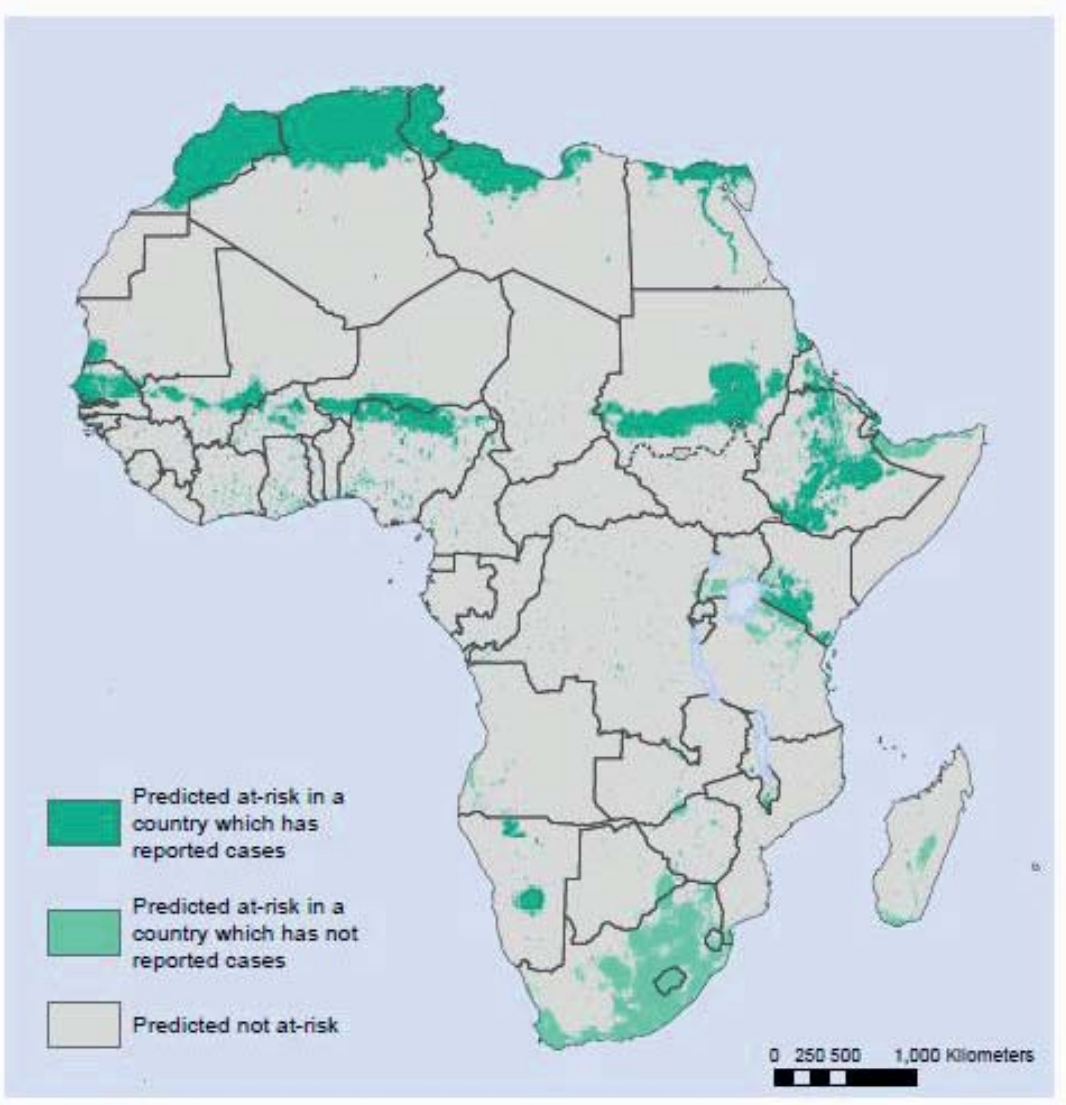
Areas at risk (in green) are those predicted to be environmentally suitable for the disease by Bhatt et al. (*23*). Areas in light green are predicted to be suitable but are in countries that are not considered endemic for the disease and in which no occurrence was recorded by Messina et al. (*24*).

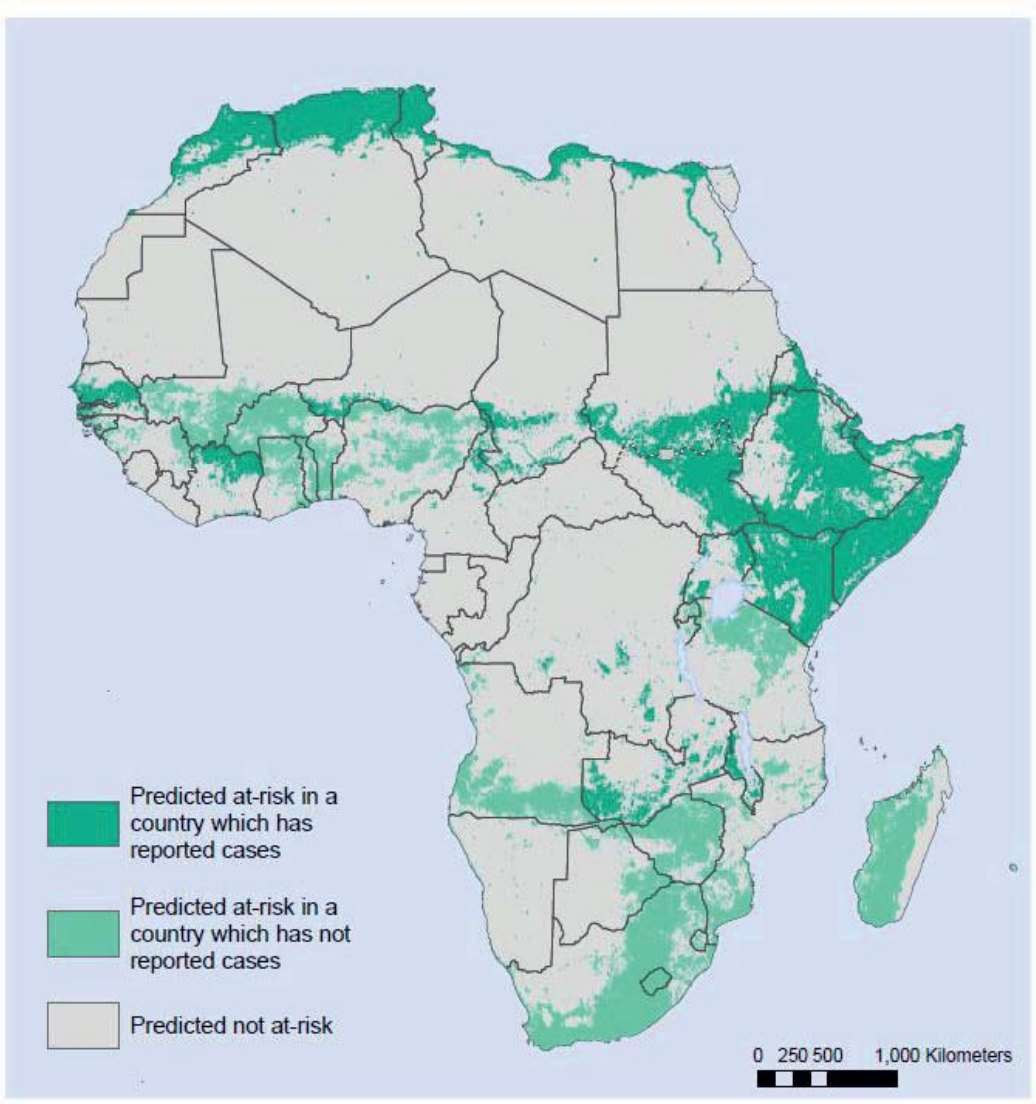
Fig. 15. Distribution of risk for cutaneous leishmaniasis infection in Africa



Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS). World Health Organization © WHO 2015. All rights reserved.

Areas at risk (in green) are those predicted to be environmentally suitable for the disease by Pigott et al. (*25*). Areas in light green are predicted to be suitable but are in countries that are not considered endemic for the disease and in which no occurrence was recorded by Pigott et al.

Fig. 16. Distribution of risk for visceral leishmaniasis infection in Africa



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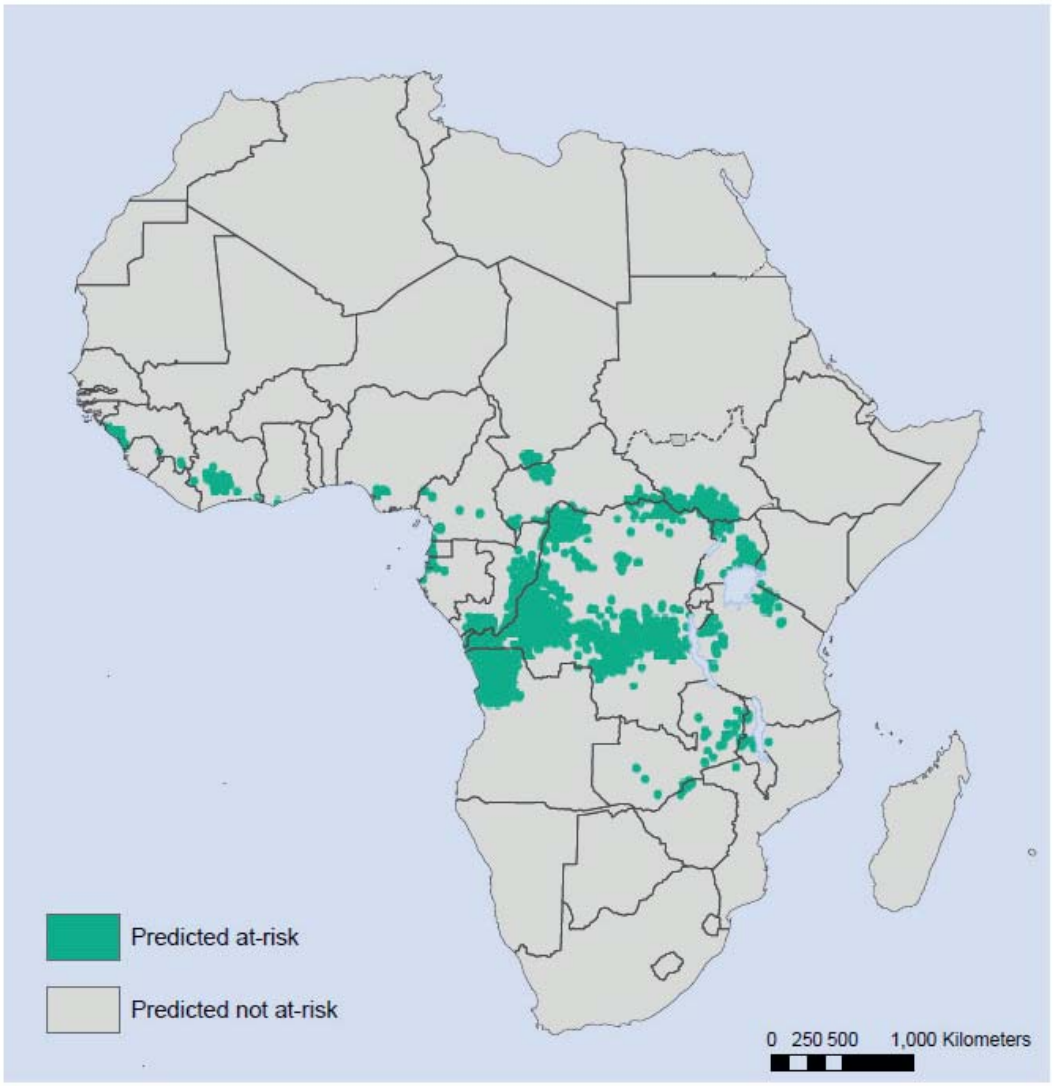
Areas at risk (in green) are those predicted to be environmentally suitable for the disease by Pigott et al. (*25*). Areas in light green are predicted to be suitable but are in countries that are not considered endemic for the disease and in which no occurrence was recorded by Pigott et al.

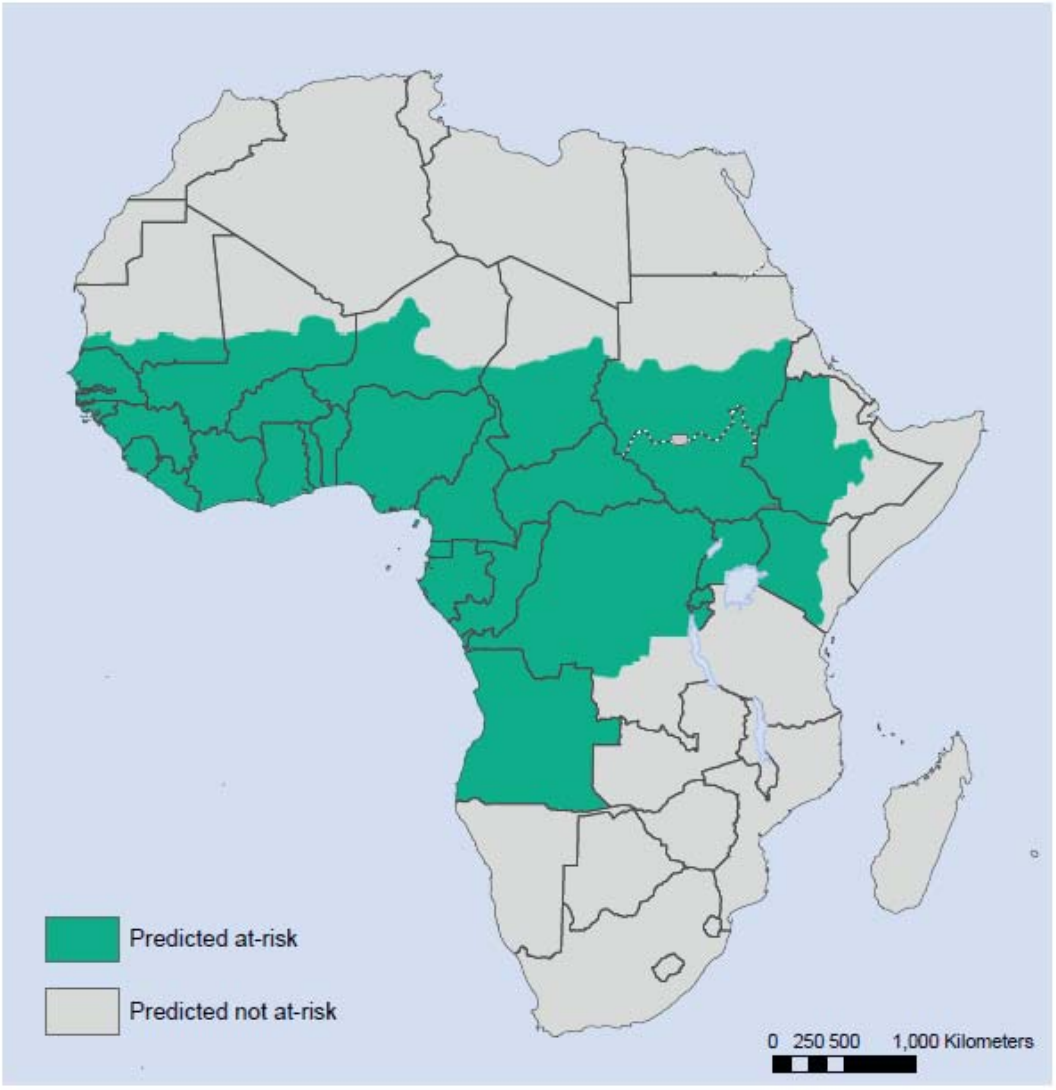
Fig. 17. Distribution of risk for human African trypanosomiasis infection in Africa



Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS). World Health Organization © WHO 2015. All rights reserved.

Areas at risk (in green) are those close to cases identified in 2000–2009 (*26*).

Fig. 18. Distribution of risk for yellow fever infection in Africa



Data Source: World Health Organization Map Production: Public Health Information and Geographic Information Systems (GIS). World Health Organization © WHO 2015. All rights reserved.

Areas at risk (in green) are those considered to be endemic for the disease in 2011 by the United States Centers for Disease Control and Prevention (*27*).

Key point

While maps can be a good guide to risk for infection or disease, they are not fool-proof! Always check the country's epidemiological data. If the maps show gaps or indicate potential pathogen transmission in areas in which you have not looked previously, this might suggest that local surveys and data collection should be done.

3.2.2 Step 2. Investigate epidemiological data (first administrative level)

Maps provide a rough guide to where populations are at risk from infection with vector-borne pathogens at national and first administrative level, but these maps are a guide only and have several limitations. First, although they show areas where populations are at risk for infection, they do not indicate the incidence or prevalence of disease or infection, which is more epidemiologically relevant (such maps are available for malaria (*14*)). Secondly, the risk for infection is not static and can vary during and between years. Thirdly, the risk varies by population within a geographical area. Programme managers should consider whether the distribution of risk shown on the maps seems to be a realistic representation of their local situation. Do the maps highlight gaps in the understanding of disease distribution? Any gaps should be investigated further with surveys or data collection. In the absence of local data, these maps could be used to identify diseases that might be targeted by IVM. Additional epidemiological data are likely to be available in the country and should be consulted.

Epidemiological data can come from public or private health facilities through national health management information systems, community surveys or external sources (Table 3). These data could be used instead of or with the disease distribution maps in this toolkit. When the prevalence or incidence of an infection or disease is known, resources can be targeted efficiently to the most at-risk populations.

Table 3. Sources of epidemiological information on vector-borne disease

Source	Disease(s) covered	Resource
Health management information system	All endemic diseases	Country or programme data
Community surveys	Varies	
Rapid epidemiological assessment or mapping	Onchocerciasis	
Multiple indicator cluster surveys	Malaria	http://www.childinfo.org/mics.html, http://www.micscompiler.org/
Demographic and health surveys	Malaria	http://www.dhsprogram.com/
Malaria indicator survey	Malaria	http://www.dhsprogram.com/, www.malariasurveys.org
Malaria Atlas Project	Malaria	http://www.map.ox.ac.uk/
Global Atlas of Helminth Infections	Lymphatic filariasis and schistosomiasis	http://www.thiswormyworld.org/
Global Neglected Tropical Diseases database	Lymphatic filariasis and leishmaniasis	http://www.gntd.org
NGOs	e.g. Sightsavers, Helen Keller International and The Carter Center (trachoma, lymphatic filariasis, schistosomiasis and onchocerciasis), Médecins Sans Frontières	http://www.sightsavers.org/, www.hki.org, http://www.cartercenter.org, http://www.msf.org/

3.2.3 Step 3. Assess vector distribution and ecology

As well as knowing where there is a risk of infection with a particular vector-borne pathogen, assessment of vector distributions is essential for IVM. This is so that we can tailor the control programme to the individual vectors, which have different biology, ecology and behaviour and so may require the use of different vector control methods. While the maps of disease risk show areas in which suitable vector species are present for each disease, they do not identify which vector species are the most important in each area. Excellent published data are available on the geographical distributions of dominant *Anopheles* vectors of malaria (Figs 10 and 11), but less information is available for other disease vectors. Sources of more information are listed in Table 4. There is currently little information on the geographical distribution of snails as intermediate hosts of schistosomiasis or of flies as vectors of *Chlamydia trachomatis*, given their ubiquity.

Table 4. Sources of information on geographical distribution of disease vectors

Disease	Source of information on vector distribution
Malaria and o'nyong-nyong virus	Figs 10 and 11. More detailed information on the ecology and bionomics (e.g. larval site characteristics, adult feeding and resting) of these species can be found in Sinka et al. (*18*).
Lymphatic filariasis	See Figs 10 and 11 for *Anopheles* vectors shared with malaria. Annex 1 lists primary and secondary vectors by large geographical region (*28*).
Dengue, yellow fever, Rift Valley fever and chikungunya	Maps of the global distribution of the dengue vector mosquitoes *Aedes aegypti* (which also transmit yellow fever and chikungunya) and *Ae. albopictus* are given by Rogers et al. (*29*), although these national maps provide little spatial precision.
Leishmaniasis	The dominant sandfly vectors of leishmaniasis in each endemic country are listed by WHO (*30*). The main transmission cycles of the leishmaniasis, the regions in which they occur and the vector species responsible are described by Ready (*31*).
HAT	Programme against African Trypanosomiasis (*32*) http://www.fao.org/ag/againfo/programmes/en/paat/maps.html
Onchocerciasis	Very little information is available on the dominant blackfly vectors.

Programmes may have published not only maps but also other data on vectors, collected in surveillance schemes. Therefore, it is a good idea to check vector-borne disease control programme reports and information collected by other entities, such as veterinary services, the ministry of agriculture and NGOs.

If the information on disease and vector distributions is patchy in your country, you could identify which ecosystems are present, as this can indicate which vectors and diseases can be expected. There are six main ecosystems – village, urban, rice land, river and estuary, small-scale farming systems and plantations – illustrated in Box 2 (*33*). Usually, a combination of ecosystems is found, for example, in villages near rural settings or where riverine systems adjoin small-scale farming. Determining the ecosystem type in an area is not a shortcut to deciding on control interventions but can be useful for estimating disease risk and opportunities for control (*34*).

Vector distributions and ecosystems also indicate the types of vector-borne disease that may emerge over time or could be reintroduced if they have been eliminated. The maps provided in this toolkit, which predict risk on the basis of environmental suitability (leishmaniasis, dengue and lymphatic filariasis), also indicate areas in which a disease might be reintroduced.

Box 2. Ecosystem as a basis for assessing risk for vector-borne disease (adapted from *33*)

Village ecosystem (major risks: malaria, lymphatic filariasis; minor risks: leishmaniasis, HAT)

Village agro-ecosystems are defined as human settlements comprising ≥ 10 households that form an agriculture-based economic and social entity with certain facilities (e.g. school, health centre, farming cooperative) that benefit the community. Human settlements for the production of food create numerous opportunities for disease vectors to thrive; these are primarily *Anopheles* spp. (malaria and lymphatic filariasis vectors).

Corn crop, Ghana (United Nations photo)

Climatic conditions in sub-Saharan Africa are suitable for vectors at nearly all times of the year, although temperatures in highland areas and rain may be limiting factors.

Urban ecosystems (major risks: malaria, lymphatic filariasis, dengue, chikungunya)

Sub-Saharan Africa is experiencing rapid urbanization, which is often accompanied by poor housing, overcrowding, pollution, lack of waste collection, hygiene and sanitation, difficult access to water, unprotected water reservoirs, weak services, low productivity and widespread economic disparity. Urbanization changes vector ecology and introduces new risks for vector-borne disease. For example, inappropriately designed latrines and open drains provide breeding sites for *Culex quinquefasciatus*, the lymphatic filariasis vector. Market gardens for growing fruits and vegetables and shallow drains provide breeding sites for malaria vectors of the *Anopheles* spp. Water storage tanks and other containers provide breeding habitats for the dengue vector *Ae. aegypti*.

Rice land ecosystems (major risk: malaria; minor risks: lymphatic filariasis, dengue)

Rice-growing areas are found in the floodplains of seasonal rivers, natural wetland areas and man-made irrigation systems (e.g. Office du Niger, Mali; Vallée du Kou, Burkina Faso; Benue river system, Cameroon; and Mwea irrigation system, Kenya). Extension of rice growing into these areas created breeding habitats for malaria vectors (*An. gambiae* s.l.*, An. funestus* and *An. arabiensis*).

Rice plants being removed for transplantation in fields near Tananarive, Madagascar (United Nations photo)

River and estuary ecosystems (major risks: malaria, onchocerciasis, HAT; minor risks: leishmaniasis, west Nile virus, Rift Valley fever, lymphatic filariasis)

Small, fast-flowing streams are breeding sites for blackflies (*Simulium* spp.) that lay their eggs on plants hanging or growing in running water. Several species of riverine tsetse flies are strongly associated with riverine and lacustrine (lake) systems that provide the relatively high humidity required by adults and pupae. Adult flies find blood meals on animals and humans living in or entering these habitats.

Where rivers flow into the sea, mangrove forests provide shelter and breeding sites for vectors adapted to brackish water conditions. For example, the saltwater mosquitoes *An. melas* (West Africa) and *An. merus* (East Africa) can be locally important malaria vectors.

Crops growing on flood plain of River Niger, Bamako, Mali (A. Wilson)

The flood plains of large rivers such as the River Nile, Zambezi River, Congo River and Niger River are used for cultivation of crops including rice, resulting in proliferation of malaria vectors.

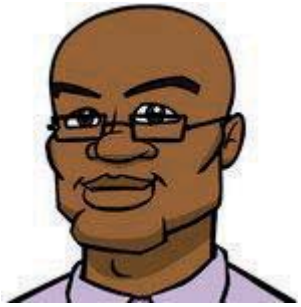
Small-scale farming systems (major risk: malaria, lymphatic filariasis; minor risk: HAT)

Small-scale farming systems are those in which farming is the chief economic activity of fewer than 10 households, with no communal services. Living conditions are often poor and preventive measures may not be used. Communities are often remote and have difficult access to health facilities. Subsistence farming is strongly associated with poverty and vector-borne disease, particularly malaria and lymphatic filariasis. Pastoral and village cattle may be reservoirs of HAT, particularly in East Africa.

Plantations (major risks: HAT, malaria)

Commercial plantation agriculture, such as replacing tropical rainforest with tea, coffee, oil palm, sisal, cocoa or cotton, often causes dramatic changes in the environment. Many vectors have been able to adjust and adapt to these man-made environments, including the malaria vector *Anopheles* spp., which breed in drainage channels, pools and puddles, and tsetse flies (*Glossina* spp.), which find sufficient shade and blood meals from mammals in plantations for survival and efficient transmission of the disease.

Tea plantation, Mbeya, United Republic of Tanzania (UN Photo)



Key point

Urban ecosystems can present new habitats for vectors and drive vector-borne disease. Therefore, it is a good idea to assess the population density in your country and identify rural and urban areas. If you do not have this information, you can access population maps from websites such as the Global Urban–Rural Mapping Project (GRUMP, v1) (http://sedac.ciesin.columbia.edu/data/collection/gpw-v3).

3.2.4 Step 4. Stratify areas according to diseases present and their current incidence

Once the disease situation has been assessed in steps 1–3, programme managers should be in a position to stratify (classify) areas endemic for disease according to their epidemiological and ecological characteristics. Hence, stratification is used to identify areas in which different approaches to disease control are indicated. When a country is endemic for several vector-borne diseases, stratification is more complicated.

Stratification is usually done at the first administrative level (region), the level at which vector-borne disease programmes are usually organized. Stratification of areas should be collaborative, involving programme staff from the regions and other stakeholders, such as NGOs. It is important to use the most current data available on disease incidence and the vector. Stratification should be reviewed regularly to take into account changing disease and vector patterns.

Box 3 describes one method of stratification for vector-borne disease in the United Republic of Tanzania.

Box 3. Example of stratification by diseases present and their incidence in the United Republic of Tanzania

Step 1. Assess maps and list diseases present by first administrative level (region).

Maps indicating risks for infection or the disease endemicity are shown below. Dengue, HAT, *P. falciparum* malaria, onchocerciasis, lymphatic filariasis, schistosomiasis and trachoma (www.trachomaatlas.org) were found to be endemic. Although areas of the country are suitable for transmission of leishmaniasis, no records of occurrence were found and the country is not considered endemic for this disease. The maps do not indicate that yellow fever or *P. vivax* malaria is endemic.

Region	Disease						
	Dengue	HAT	Onchocerciasis	Falciparum malaria	Lymphatic filariasis	Schistosomiasis	Trachoma
Tabora	x	x	x	x	x		
Rukwa	x	x	-	x	x		
Morogoro	x	-	x	x	x		
Lindi	x	-	-	x	x		
Ruvuma	x	-	x	x	x		
Mbeya	x	-	x	x	x		

Be sure to use only up-to-date data on the diseases present or the risk for infection, as the disease situation is likely to change over time, and new vector-borne disease may appear.

Step 2. Find epidemiological data at first administrative level

Possible sources of epidemiological data include both national data and external sources such as the Malaria Atlas Project maps for malaria. The disease(s) that present the highest burden should guide the IVM programme at the first administrative level. Of all the vector-borne disease present in the United Republic of Tanzania, malaria has the highest disease burden. Determine which areas have the highest incidence or prevalence of malaria, and categorize them from highest to lowest for prioritization of intervention. The same process of identifying areas of high and low prevalence should be used to prioritize interventions for all vector-borne diseases.

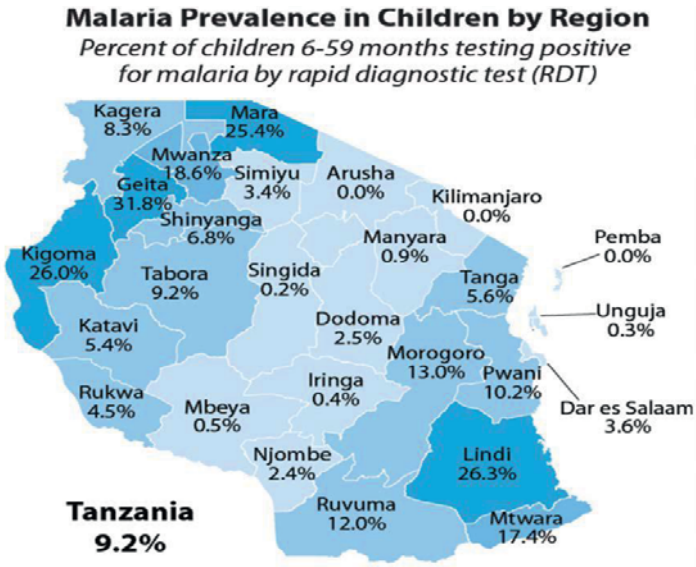


Fig. A: Malaria prevalence in children aged < 5 years from the 2011–2012 Tanzania HIV/AIDS and Malaria Indicator Survey (*35*)

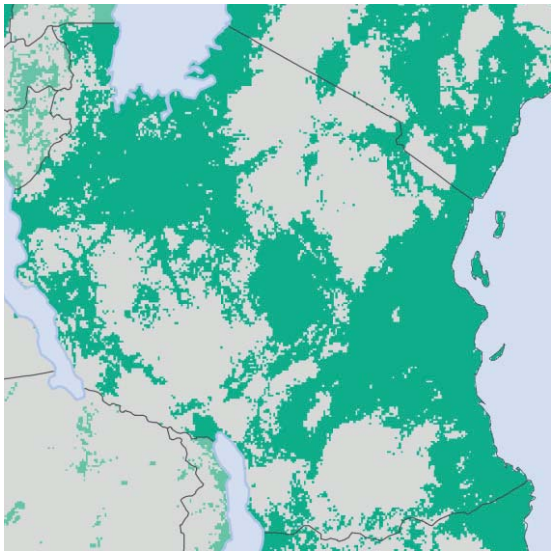


Fig. B: Distribution of dengue infection risk in the United Republic of Tanzania

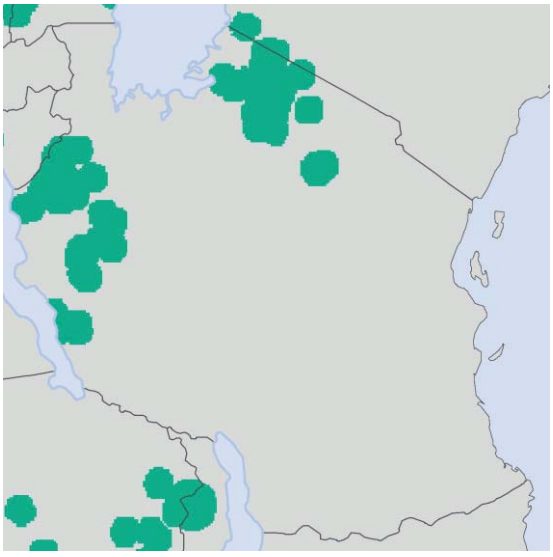


Fig. C: Distribution of human African trypanosomiasis infection risk in the United Republic of Tanzania

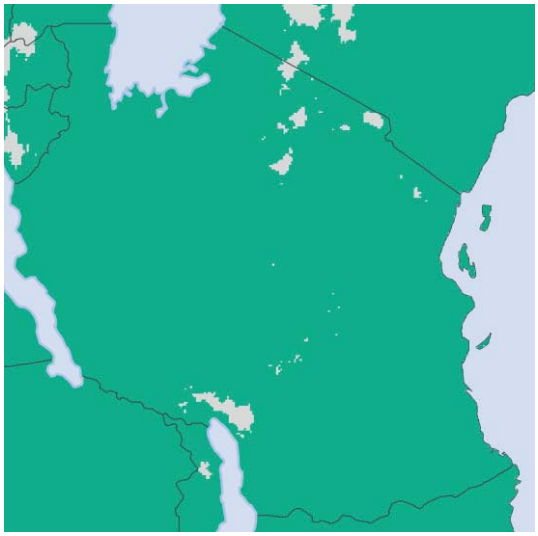


Fig. D: Distribution of *P. falciparum* malaria infection risk in the United Republic of Tanzania

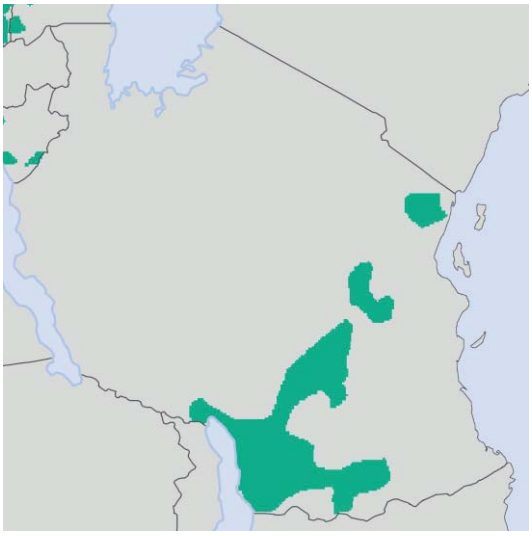


Fig. E: Distribution of onchocerciasis infection risk in the United Republic of Tanzania

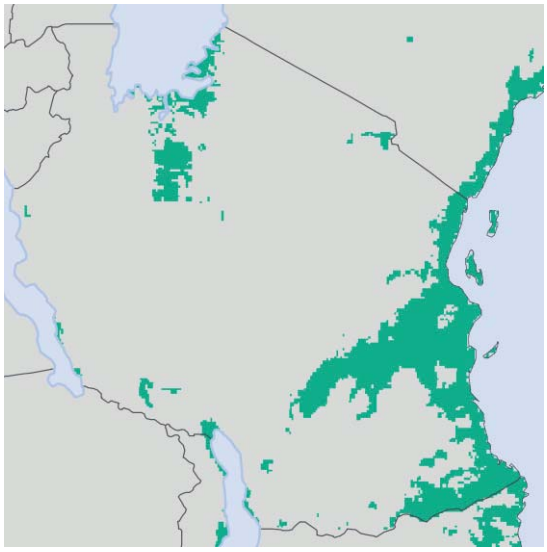


Fig. F: Distribution of lymphatic filariasis infection risk in the United Republic of Tanzania

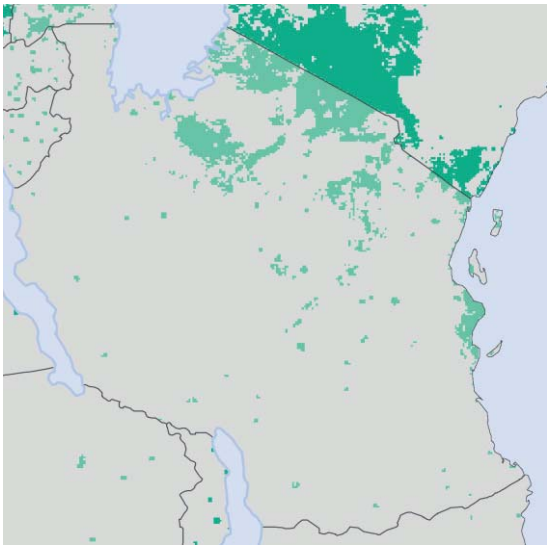


Fig. G: Distribution of cutaneous leishmaniasis infection risk in the United Republic of Tanzania

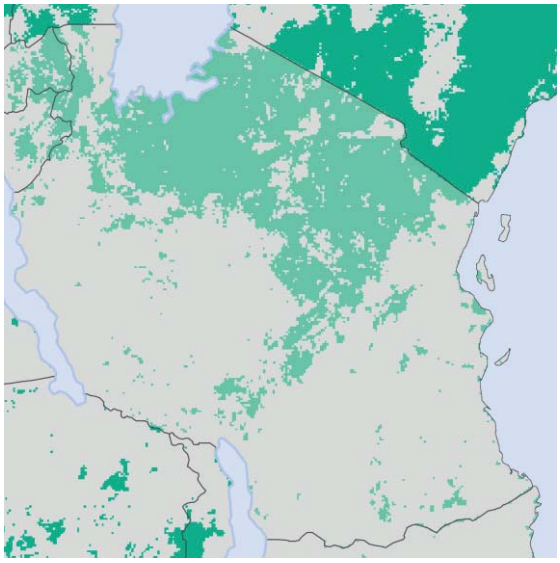


Fig. H: Distribution of visceral leishmaniasis infection risk in the United Republic of Tanzania

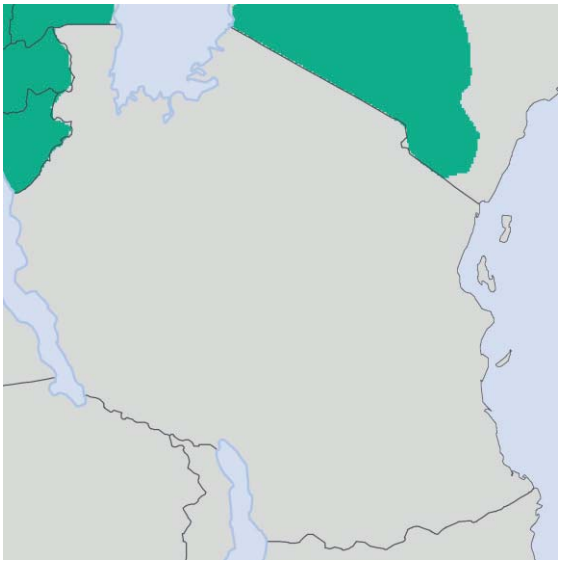


Fig I: Distribution of yellow fever infection risk in the United Republic of Tanzania

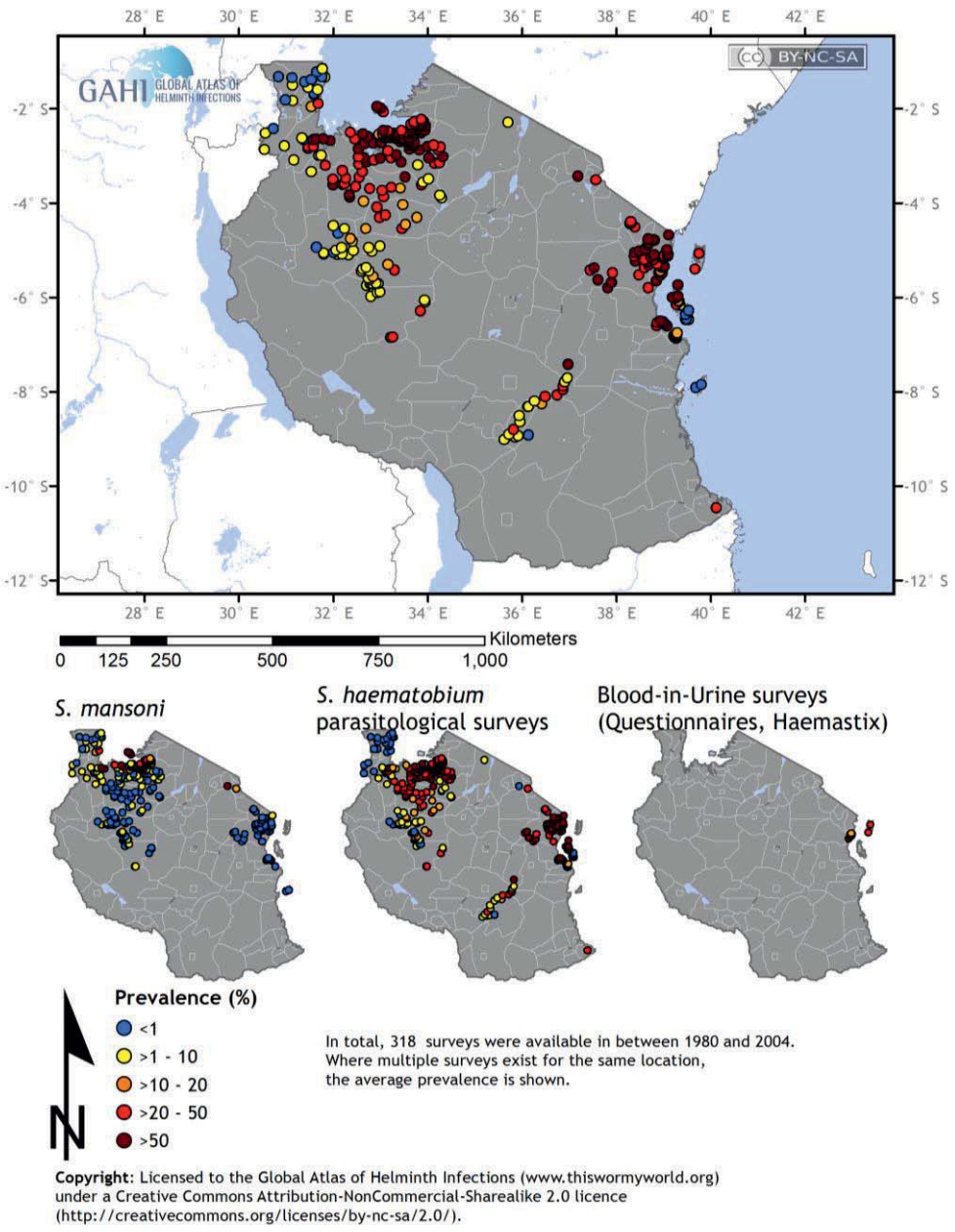


Fig. J: Maximum point prevalence of schistosome infection and location of *S. mansoni* and *S. haematobium* surveys in the United Republic of Tanzania (*36*)

Step 3. Identify the determinants of disease ecology

Determine where diseases occur and how this is related to factors such as population density, socio-economic conditions and the environment (e.g. elevation, land use, water bodies, potential animal reservoirs of infection). Many countries will have some data, particularly with respect to eco-epidemiological types, e.g. tropical Africa savannah, forest and forest fringes, highland and desert fringes. (See Box 2.)

In the United Republic of Tanzania, the risk for dengue is concentrated in highly populated regions, while onchocerciasis occurs in mountainous regions near Iringa. The occurrence of human African trypanosomiasis is correlated to some extent with large game parks and reserves.

Step 4. Assess vector distribution

Using published information or national data, identify the main disease vectors present.

Step 5. Identify potential animal reservoirs

Determine where large concentrations of cattle or wildlife are found.

Step 6. When evidence on disease endemicity is weak or patchy, additional surveys are recommended.

For example, maps indicate the areas of the United Republic of Tanzania that are environmentally suitable for leishmaniasis, although cases have not been reported. Leishmaniasis may nevertheless be present in these areas, and it would therefore be advisable to conduct population-based surveys to confirm the absence of this disease.

3.3 Local (district level and below) analysis

Consider:	Are there differences in disease incidence within regions? Are there other environmental and human factors that should be taken into account?

While stratification at regional level is useful in decision-making and prioritizing resources, the main determinants of vector-borne diseases often show heterogeneity at a finer scale. For example, the determinants may include the concentration of human habitation, at-risk groups such as hunters who are active throughout the night or a major vector breeding habitat such as an area of irrigated rice production. The determinants of disease should therefore be identified and mapped at lower levels of administration (district and below). More information on these determinants is given in Annex 2.

A local analysis consists of two steps. First, local epidemiological data should be assessed, such as incidence figures from health facilities. This can help to locate "hotspots" of disease transmission and give some clues about risk factors for vector-borne diseases. More information on identifying "hotspots" of transmission in order to target IVM interventions is given in section 5.1. Secondly, environmental and human factors that may influence disease on a smaller scale should be identified.

3.3.1 Step 1. Investigate epidemiology (lower administrative level)

Regional vector control programmes should be based on the incidence and prevalence of disease in their region. Sources of data include health management information systems, hospital or health facility records or community surveys (for diseases such as HAT or onchocerciasis, for which patients often do not present at health facilities). Determine whether there are differences in disease incidence or prevalence by geographical area or over time; and consider whether disease incidence or prevalence differs by for example age, sex, ethnic group, occupation, community or whether people use preventive measures. This can help identify human risk factors for disease transmission. If these data are not collected routinely, questions could be added to hospital logs or survey forms. Sudden changes in epidemiological data may be a result of alterations in diagnostic practice or reporting; therefore it is important to rule out this possibility before taking any action.

Surveillance should be strengthened to capture data on emerging or reintroduced infections or diseases.

3.3.2 Step 2. Consider other environmental factors, alternative hosts and human factors that may influence disease

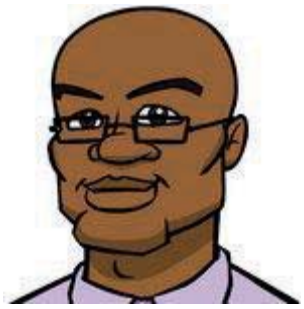
Various environmental and human determinants can influence vector-borne disease (Annex 2). Vector control programmes at district level should be aware of their natural features (e.g. rivers, lakes, forests, wetlands), land use (e.g. plantations, rice or cotton agriculture) and the presence and distribution of alternative hosts (e.g. livestock, wild animals). It may be helpful to think in terms of the ecosystems present, as these will indicate the probable disease–vector complexes, although there may be several ecosystems within a district. More information on common ecosystems is given in Box 2. Areas of economic or socio-political instability, such as camps for displaced people, should also be a priority for vector-borne disease assessment and intervention.

Identifying human determinants of vector-borne disease, such as socio-economic conditions, population movement, practices and attitudes towards vector-borne disease and access to diagnosis and treatment, is important. District vector-borne disease control programmes should be aware of these determinants; however, it may be useful to meet with community stakeholders such as village chiefs, religious leaders and community groups from time to time, particularly if epidemiological parameters change.

Fig. 19. Participatory research: generating a seasonal calendar (photo courtesy of S. Lindsay)

An extension of a simple consultation meeting would be to conduct participatory mapping, whereby people such as village chiefs, religious leaders and community groups help to map variables such as where people live, the patterns of their movements, infrastructure (e.g. roads, locations of markets and schools), vector breeding sites, locations of health services, land use, vegetation and water bodies. Similarly, they could help to draw a seasonal calendar with information on the timing of peaks of disease incidence, when people move (e.g. religious festivals) and the main agricultural activities (e.g. planting, harvesting or movements of livestock) (Fig. 19). Participatory and temporal mapping can help to identify vector-borne disease risks, periods of increased risk and improve targeting of control.

Advantages of such participatory activities are community empowerment, better understanding of disease risks and compliance with control measures. More examples of community participation and its value in IVM are given in section 6, including involvement of schoolchildren in malaria control in Khartoum, Sudan, and section 8, including use of people in the community to conduct larval source management in Dar es Salaam, United Republic of Tanzania.



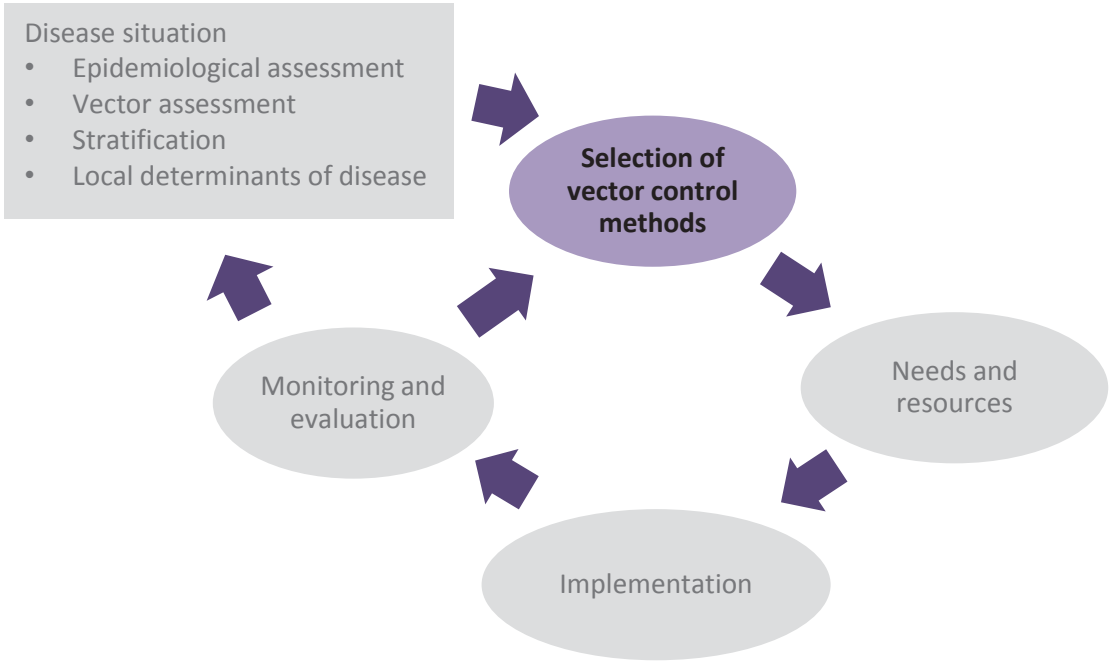
Key point

If there appears to be a "hotspot" of disease, consider that it may be due to failings in the current disease control system before considering additional methods. For example, health centres may be prescribing ineffective drugs, or there may be low coverage or non-compliance with preventive measures.

Section summary

- The distribution of diseases and vectors must be known in order to plan control and prioritize resources.
- A disease assessment should be conducted in two stages: a broad analysis and stratification (at provincial level) and local analysis (district and below).
- A broad analysis consists of assessing maps of disease endemicity, provincial epidemiological data and vector distribution. Programmes can then classify regions according to the diseases present, their incidence, vector species and ecology.
- A local analysis involves assessing the micro-epidemiology of the disease, including district and community epidemiological data and local environmental and human determinants.

4. Selection of vector control methods



The main factor to be considered in choosing a vector control tool is its effectiveness in reducing disease or infection. Other factors that must be considered include vector characteristics (such as insecticide resistance), human and environmental safety, affordability and cost–effectiveness, acceptability and community participation and implementation and delivery of the intervention.

- ✓ Efficacy or effectiveness
- ✓ Vector characteristics including insecticide resistance
- ✓ Human and environmental safety
- ✓ Affordability / cost effectiveness
- ✓ Acceptability and community participation
- ✓ Implementation / delivery of the intervention

4.1 Efficacy against vector-borne disease

There are many vector control tools, which can be broadly classified into chemical-based and non-chemical-based tools for control of either adult or immature forms of the vector. Previous guidance on vector control has not included details of the efficacy of the tools, assuming that all tools are equally effective, which is not the case. In many situations, there is no evidence that some of the vector control tools in common use today are actually effective. This toolkit recommends only those that have been shown to be effective, as one of the central tenets of IVM is to make evidence-based decisions. In assessing the efficacy of vector control tools for each disease, evidence from systematic reviews, meta-analyses and individual studies such as randomized controlled trials and programme data were used. Although there are some interesting developments in novel vector control tools, these are still experimental and therefore are not included in this toolkit.

It is important to choose vector control tools on the basis of their **efficacy against epidemiological parameters** (prevalence or incidence of infection or disease), when possible. Evidence of efficacy against the vector may be useful in some circumstances, but this is not always correlated with impact on disease. In the following sections, vector control tools are separated into three levels:

- those recommended by WHO, for which there is strong evidence of efficacy;
- those for which there is some evidence to recommend their use or to recommend their use in certain settings or populations; and
- those for which there is currently insufficient evidence to recommend their use.

4.1.1 Malaria

Tools recommended by WHO	Tools for which there is some evidence of utility in certain settings or populations	Tools for which there is currently limited evidence of utility
Long-lasting insecticidal nets (*37*, *38*)	House improvement or screening	Space spray
Indoor residual spraying (*39*)	Insecticide-treated sheeting, tents or wall linings	Spatial repellents
Larval source management (supplementary tool) (*40*)	Insecticide-treated clothing or sheets	Topical repellents

WHO-recommended vector control tools against malaria

The core malaria vector control tools recommended by WHO are long-lasting insecticidal nets (LLINs) (*37*, *38*) and indoor residual spraying (IRS) (*39*), which are similarly effective. Larval source management (LSM) (Box 4) is recommended by WHO as a supplementary method in locations where malaria vector aquatic habitats are "few, fixed and findable" (*40*). LLINs and IRS are effective against

indoor biting and/or resting *Anopheles* mosquitoes, while LSM can reduce the densities of mosquitoes that bite and rest indoors or outdoors. There are no other recommended interventions specifically for outdoor-biting mosquitoes; this is an area of active research.

Box 4. Larval source management (adapted from *41*)

Larval source management includes any of the following:

- **Habitat modification:** a permanent alteration to the environment, aimed at eliminating larval habitats. Includes landscaping, drainage of surface water, land reclamation and filling, covering large water storage containers (for example, wells) with mosquito-proof lids and permanent slabs, building covered areas to store potential breeding sites (for example, shelters for tyres) or completely covering water surfaces with a material that is impenetrable to mosquitoes (for example, expanded polystyrene beads)
- **Habitat manipulation**: temporary environmental changes to disrupt vector breeding. Includes water-level manipulation, flushing of streams, drain clearance, shading, proper disposal of garbage, regular emptying and cleaning of domestic containers (e.g. flower pots, animal drinking-water troughs) and exposing habitats to the sun, depending on the ecology of the vector
- **Larviciding**: the regular application of biological or chemical insecticides to larval habitats (Fig. 20)
- **Biological control**: the introduction of natural enemies of mosquitoes into aquatic habitats, e.g. predatory fish, invertebrates, parasites or other disease-causing organisms
- **R**emoval of dangerous man-made aquatic habitats and safe waste disposal

Fig. 20. Larviciding of *Anopheles* breeding sites in the Gambia (photo courtesy of S. Lindsay)

Recommendation on combined use of LLINs and IRS for malaria control

Several studies have been conducted to determine whether IRS confers an additional benefit to that of LLINs. A cluster-randomized trial in the Gambia found no significant additional benefit (*42*); however, a study in the United Republic of Tanzania did show an additional benefit of IRS when used with LLINs (*43*, *44*). The available data indicate that, in settings where there is high LLIN coverage and where LLINs remain effective, IRS may have limited utility in reducing morbidity and mortality from malaria (*45*). WHO recommends that programmes prioritize delivery of either LLINs or IRS at high coverage and to a high standard, rather than introducing the second intervention in order to compensate for deficiencies in implementation of the first (*45*). In a resistance management strategy, however, there may be benefit in using both interventions with a different class of insecticide (i.e. non-pyrethroid) used for IRS (*45*, *46*).

Vector control tools for which there is some evidence of utility in certain settings or populations

Some studies have shown that house modifications, such as by closing eaves, ceilings and installing screening on doors and windows, can reduce the number of mosquitoes in houses and reduce the prevalence of malaria (*47*). A randomized controlled trial in the Gambia showed lower mosquito densities and a lower prevalence of anaemia among inhabitants of screened houses than among unscreened control houses; and fully screened houses (screened windows and doors and closed eaves) were better than partially screened houses (screened ceilings only) (*48*).

Insecticide-treated plastic sheeting including impregnated blankets) may be useful in temporary settlements, such as refugee camps. A randomized controlled trial in refugee camps in Sierra Leone found 61% protective efficacy against malaria of deltamethrin-treated plastic sheeting attached to the walls and ceilings of temporary shelters (*49*). A controlled before-and-after study of insecticide-treated plastic sheeting versus untreated plastic sheeting for construction of temporary labour camps in India showed a 96% (95% CI, 70–99%) reduction in malaria incidence (*50*). Insecticide-treated plastic sheeting should be applied to both the walls and the ceilings of shelters for maximum effect. Plastic sheeting and other insecticidal wall linings may be somewhat effective when used for lining the walls in houses. Though the efficacy of these interventions has not been broadly demonstrated, a randomized controlled trial in India showed a 71% (95% CI, 47–84%) reduction in malaria incidence in a village with deltamethrin-treated plastic sheeting on the walls and ceilings when compared with a village without this installed (*51*).

Insecticide-treated clothing, shawls and bed-sheets have also shown promise in preventing malaria. A study in Kenya showed an 81% reduction in the number of malaria cases among people using permethrin-impregnated shawls (*shukas*) as compared with the control group (*52*). A randomized controlled trial of the use of permethrin-treated clothing and bedding among refugees in Kenya found a 69% reduction in clinical malaria (*53*). Insecticide-treated clothing or sheets are more

effective than topical repellents as they may be used more consistently, although retreatment with insecticides is required at regular intervals.

The public health value of potential tools has not yet been assessed or established, therefore their wide-scale implementation is not currently recommended. For settings in which there is robust evidence of epidemiological impact, pilot implementation may be accompanied by robust monitoring and evaluation in order to guide the continued use or expansion of these kinds of interventions.

Vector control tools for which there is currently insufficient evidence to support their use for malaria

Certain fish species can reduce the density of mosquito larvae by predation in aquatic habitats (*54*); however, a systematic review of studies of use of larvivorous fish as an intervention against malaria showed no convincing evidence that they suppress *Anopheles* larval populations enough to reduce malaria in the local human population (*55*).

Spatial repellents such as mosquito coils are commonly used to reduce mosquito nuisance. Although many studies have shown beneficial effects of mosquito coils on the mortality, deterrence, repellency and feeding inhibition of mosquitoes in both laboratory and semi-field environments, the evidence for clinical outcomes is weak. Research is being conducted on new forms of spatial repellents, such as passive emanators..A meta-analysis of studies of the efficacy of personal repellents against malaria did not show an effect against either *P. falciparum* malaria (protective efficacy, 18%; range, –8% to 38%) or *P. vivax* malaria (protective efficacy, 20%; range, –37% to 53%) (*56*). Given the limited evidence, routine use of personal repellents is therefore not recommended for protecting against malaria although they can help reduce biting nuisance for individuals.

Key points

The core vector control interventions recommended for the prevention of malaria are LLINs and IRS. The selection of these interventions should be based on local epidemiology and entomological information, including the insecticide susceptibility status of local vectors. Larval source management can be a useful supplement, but its use is recommended only in locations where breeding sites are “few, fixed and findable”.

Supplementary interventions that could be considered in an integrated strategy or in specific settings or populations are housing improvements, such as screening, insecticide-treated walling linings, plastic sheeting for temporary structures, and insecticide-treated clothing and bed-sheets.

4.1.2 Lymphatic filariasis

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
Preventive chemotherapy except where *Loa loa* is co-endemic (*57*)	LLINs (anophelines)	LLINs (culicines)
	IRS (anophelines)	IRS (culicines)
	House improvement or screening (anophelines)	
	Larval source management (culicines)	

Vector control tools for which there is some evidence to recommend their use for lymphatic filariasis or in specific settings or populations

The primary intervention against lymphatic filariasis is preventive chemotherapy (mass drug administration) with either ivermectin or diethylcarbamazine citrate in combination with albendazole (*57*). The role of vector control is, however, increasing as part of an integrated strategy, and it is the only effective method in areas where where loiasis is endemic (*58*, *59*). Combining mass drug administration and vector control has several advantages, including supressing transmission without having to identify all foci of infection and minimizing the risk for re-establishment of transmission from infected individuals (*59*).

As malaria and lymphatic filariasis share the same *Anopheles* vector in rural areas, we would expect LLINs to be effective against both diseases. However, this question has not been addressed in a randomized controlled trial. Observational studies in Nigeria and Papua New Guinea have shown that insecticide-treated nets protect against lymphatic filariasis where the disease is transmitted by *Anopheles* mosquitoes (*60–63*), and LLINs may be useful in areas co-endemic for lymphatic filariasis and *Loa loa* where mass drug administration with ivermectin is contraindicated because of serious adverse events (*64*).

House spraying with residual DDT alone interrupted transmission of lymphatic filariasis by *Anopheles* mosquitoes in Indonesia (*65*) and the Solomon Islands (*66*). In both countries, elimination of lymphatic filariasis were by-products of the malaria control programme. Although this evidence is convincing, few studies have been conducted, and the effectiveness on lymphatic filariasis of other insecticides used on IRS has not been rigorously tested. In addition, given the long lifespan of adult filarial worms (estimated to be 4–10 years), IRS would have to be applied consistently for an

extended period (as in the study in the Solomon Islands), which might not be feasible in some settings.

LSM, with a microbial larvicide, by environmental management or with polystyrene beads, has also been shown to be effective against culicine vectors of lymphatic filariasis. These interventions are well adapted to the breeding sites of *Culex* vectors, which predominate in urban and semi-urban environments. Treatment of enclosed water bodies such as latrines with a floating layer of expanded polystyrene beads can prevent mosquito breeding for a long time (*67–69*) (Fig. 21).

Treatment of open breeding sites (e.g. drains) with insecticides such as microbial larvicides (e.g. *Bacillus thuringiensis israelensis* and *B. sphaericus*) (*70–74*) or insect growth regulators (e.g. pyriproxyfen) (*75*) also reduces mosquito breeding. Importantly, several studies have shown the additional benefit of larval source management with mass drug administration on microfilarial infections. In Makunduchi, a town in Zanzibar, United Republic of Tanzania, a single mass administration of diethylcarbamazine citrate combined with treatment of pit latrines with polystyrene beads resulted in a progressive decrease in the rate of microfilaria, from 49% to 3% (*76*). The contribution of vector control to the decrease in microfilaria rate was demonstrated by comparison with another town in which only mass drug administration was used and where the infection resurged 3–6 years later. Biting nuisance was also reduced, which increased public acceptance of the programme (*77*). Several studies in India also showed a beneficial effect of multiple LSM strategies (e.g. larviciding, polystyrene beads and fish) against microfilaraemia (*78–80*).

Fig. 21. Treatment of latrines with expanded polystyrene beads (photo courtesy of J. Ensink)

As house improvements, such as closing the eaves and installing screening, can reduce the entry of *Anopheles* mosquitoes (*47*), this intervention would be expected to be effective against lymphatic filariasis in rural areas.

Vector control tools for which there is currently insufficient evidence to recommend their use for lymphatic filariasis

LLINs and IRS are less effective against culicine vectors of lymphatic filariasis because *Culex* mosquitoes are less susceptible to insecticides than *Anopheles* (*81–83*). For example, Bøgh et al. reported that insecticide-treated bed nets reduced the indoor resting density by 16% for *Cx. quinquefasciatus* and 98% for *Anopheles* spp. (*84*). A study in India did not show an effect of IRS with bendiocarb on the density of *Cx. quinquefasciatus* (*85*). No studies appear to have been conducted of the efficacy of LLINs or IRS against clinical parameters of lymphatic filariasis transmitted by culicines; therefore, there is insufficient evidence to recommend these interventions.

Key points

The following vector control interventions are recommended in combination with mass drug administration for lymphatic filariasis:

- LLINs (and possibly also IRS if there is a commitment to apply it repeatedly for a long time) where anophelines are responsible for transmission
- larval source management where culicines are responsible for transmission.

4.1.3 Dengue

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
Sustained management		
Indoor spraying (preferably with residual insecticides) Perifocal spraying, e.g. around tyres, with residual insecticides Removal of containers Covers on water container Larviciding (insecticides or biological tools) of containers Social mobilization campaigns (education and public relations) Legislation (enforcement and incentives) Environmental management LLINs, insecticide-treated curtains, screening		Aerial and truck-mounted ultra-low-volume space spraying
Epidemic mitigation		
Indoor ultra-low-volume space spraying IRS LLINs, insecticide-treated curtains and screening Legislation (e.g. granting immediate access to premises)		Aerial and truck mounted ultra-low-volume space spraying Topical repellents

Vector control tools for dengue can be categorized into those used for sustained management of vectors and those used for epidemic mitigation, when an outbreak has occurred and the aim is to prevent more dengue cases (*86*). The evidence base for dengue vector control is limited, however, by a lack of methodologically strong studies focusing on entomological endpoints that do not correlate well with infections in humans; thus, it is difficult to attribute any decrease in cases or vector populations to the vector control interventions used. The vector control tools for dengue recommended in this section were critically assessed by experts in dengue as part of the Partnership

for Dengue Control Initiative (*86*) on the basis of WHO-recommended tools (*87*). The experts concluded that they were unable to recommend a specific intervention because of the limitations of the data, in particular the absence of a clear impact on health. Little or no evidence is available on the dengue interventions that have been tested in Africa; therefore, it will be important to learn lessons from countries that have wide experience in dengue control.

WHO-recommended vector control tools against dengue

Sustained management

IRS has been used for sustained management of dengue vectors on only a few occasions. Studies in Cairns, Australia, showed that it could reduce adult female density (*88*) and the risk for dengue virus transmission when used appropriately (*89*, *90*). IRS for dengue control involves selective treatment of harbourage sites for *Aedes* mosquitoes (e.g. in wardrobes, under beds and tables, in dark corners, in laundry areas) with residual insecticides rather than the whole house (*90*).

Perifocal spraying of containers with residual insecticides for control of larvae and adult resting mosquitoes was successful in two *Ae. aegypti* eradication programmes in the Australian Northern Territories in the 2000s (*91*).

Environmental management methods such as removing, washing, bleaching or covering containers with lids, usually in combination, with community mobilization and participation for sustainability have been shown to be effective in many studies (*92–97*). Studies in Latin America have shown beneficial effects of insecticide-treated net covers for containers (in combination with insecticide-treated curtains) on larval and pupal demographic indices (*98*, *99*).

Treatment of containers with chemical (e.g. temephos) or microbial (e.g. *B. thuringiensis israelensis*) larvicides reduced entomological parameters in a number of studies (*100–102*). A systematic review (*103*) included a study in Cambodia that showed 53% protective efficacy (95% CI, 50–55%) of water treatment with temephos against dengue (*104*). In a systematic review of 14 studies of the effectiveness of *B. thuringiensis israelensis* used as a single agent for the control of dengue vectors (*105*), 12 found reductions in entomological indices after an average period of control of 2–4 weeks. In one study in the review, a single case of dengue was found in the area treated with *B. thuringiensis israelensis* and 15 cases in the untreated area when an outbreak occurred (*106*). A study of targeted treatment of productive breeding sites with spinosad and LLIN screens showed lower adult and pupal-based vector indices than with no intervention (*107*).

Larval predators such as larvivorous fish, copepods and insects can reduce *Ae. aegypti* larval indices, although it is not clear whether the effect extends to adult mosquitoes or reduces dengue incidence. A meta-analysis of nine studies of biological control showed an average reduction of 82% (95% CI, 56–93%) in the container index (*103*).

Community mobilisation and participation in dengue control are crucial, as many breeding sites are close to houses and associated with daily activities, and sustainable efforts are key to long-term *Ae.*

aegypti vector management strategies. A number of studies have shown beneficial effects of community-based dengue control, through e.g. education campaigns and social mobilisation (*94*, *108–110*).

An expert panel concluded that legislation should be a component of sustained mitigation programmes (*86*). Legislation for dengue control can include holding citizens and local government directly responsible for failing to deal with breeding sites around houses or making local authorities responsible for maintaining drains, water courses or swamps and canals that are within their administrative limits, and imposing penalties if they do not comply. Legislation has been used to good effect for dengue control in Singapore (*111*), and similar legislation has been effected in other areas, including for example Pakistan, and Sri Lanka.

A systematic review suggested that LLINs, insecticide-treated curtains and screening are effective against dengue (*112*); several of the studies reviewed found reductions in entomological parameters (*98*, *113–115*), and one study reported a strong protective efficacy of insecticide-treated screening against IgM seropositivity (*116*, *117*). Such interventions are usually introduced for sustained management but could also be used for epidemic control. It has been suggested that broad coverage (about 70%) with insecticide-treated interventions in houses is required for a community-level effect against dengue vectors (*115*). A recent study suggests that insecticide-treated curtains may not have an effect on *Aedes* infestation levels in areas where intensive *Ae. aegypti* control measures are already implemented (in this low transmission setting: inspection of premises, larviciding of containers, removal of breeding sites with community participation and indoor and spatial fogging every 7-22 days) (*118*). Another intervention which has shown to be effective in reducing larval density is insecticide-treated water container covers which have been trialled in several studies in combination with insecticide-treated curtains or other interventions (*98*, *99*, *119*, *120*).

A review of the efficacy of biological methods, chemical methods, environmental management and a combination of these methods showed that combinations are the most effective (*103*). Thus, a package of vector control interventions against dengue is advised, ideally combining chemical and environmental or biological and environmental methods that target both the immature and adult stages of the vector.

Epidemic control

Indoor ultra-low volume insecticide application, usually with portable hand-held or backpack sprayers, reduced the number of dengue cases in Iquitos, Peru, when applied early in the epidemic transmission season (*121*). IRS has also been used successfully for epidemic control in Brazil (*89*) and anecdotally in Hawaii (*122*). Conducting interventions in households can be operationally difficult during an outbreak, particularly in large settlements, where it may be difficult to gain access to sufficient houses to achieve high coverage in a short time (*86*). However, LLINs should be used for case isolation of dengue patients in hospitals (*87*).

Vector control tools for which there is currently insufficient evidence to recommend their use for dengue

The expert group recommended use of topical repellents with IRS for epidemic control (*86*); however, no studies with epidemiological outcomes appear to have been conducted of use of topical repellents for dengue control, and a systematic review on malaria suggested that topical repellents do not have a significant impact on disease outcomes (*56*).

The expert review did not recommend use of aerial or truck-mounted ultra-low volume spraying, as it has no sustained impact on mosquito populations and is not cost–effective for routine delivery during outbreaks (*86*, *123*, *124*). Use of aerial or truck-mounted ultra-low volume spraying is often politically motivated, as this is a highly visible intervention. The lethal effect is, however, transient, and mosquito populations recover rapidly; furthermore, the efficacy is variable because droplets may not penetrate inside houses to *Ae. aegypti* resting places (*125*, *126*), especially if householders do not comply with requests to open their doors and windows (*127*).

Key points

For dengue vector control, a **combination** of vector control methods is recommended, ideally with two or more categories (chemical, biological or environmental) and targeting both immature and adult vectors.

4.1.4 Cutaneous and visceral leishmaniasis

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
IRS (where vectors bite or rest indoors) LLINs, insecticide-treated curtains or screening (where vectors bite or rest indoors) Reservoir management (zoonotic and sylvatic cycles)	Environmental modification	

WHO-recommended vector control tools against cutaneous and visceral leishmaniasis

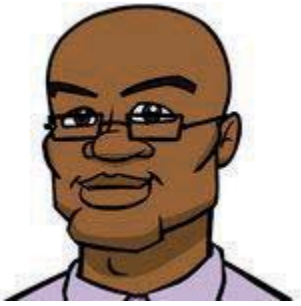
The efficacy of vector control tools against leishmaniasis depends on the parasite, the vector and the transmission cycle. In general, if the sandfly vector bites or rests indoors, LLINs or IRS will be effective. For example, even vectors with a sylvatic cycle may feed or rest indoors, especially if habitat change, increased human activity or urbanisation in sylvatic fringe areas has encouraged domestication of vectors. If the vector feeds or rests outside houses, other strategies should be considered. It is therefore important to understand sandfly biology and human behaviour in a particular setting before planning intervention strategies.

In a systematic review (*112*), three studies of the efficacy of LLINs or insecticide-treated bed nets against cutaneous leishmaniasis transmitted by *Phlebotomus papatasi* or *Phlebotomus sergenti* found high protective efficacy, ranging from 50% to 98% (*128–130*). A study of the efficacy of LLINs against visceral leishmaniasis showed no significant effect on incident *Leishmania donovani* infections or incident cases of visceral leishmaniasis in India or Nepal (*131*); however, transmission probably occurred outside houses, where LLINs would be unable to prevent sandfly–human contact. Insecticide-treated nets provided better protection than untreated nets (*132*), although the mesh size is a consideration: nets designed with large holes to be cooler are more likely to let sandflies through, even if they are treated (*133*, *134*). Other insecticide-treated materials, such as curtains and screening, also reduce vector density within houses (*135–137*), although the evidence for their efficacy against clinical disease is weaker than for LLINs (*136*, *138*).

IRS is also highly effective against cutaneous and visceral leishmaniasis when the vectors rest indoors. For example, randomized controlled trials found a protective efficacy against cutaneous leishmaniasis of 54% (95% CI, 3–78%) in Peru (*139*) and 47% (95% CI, 32–59%) in Afghanistan (*124*). Other studies and evidence from an anti-malaria campaign with DDT-IRS in Peru also found drastic reductions in the transmission of cutaneous leishmaniasis (*140–142*). Evidence from India also suggests that IRS is effective against visceral leishmaniasis, with reductions in the number of cases of

this disease resulting from DDT spraying for malaria control (*143–145*). To control peri-domestic species, outer walls and animal shelters should also be sprayed with IRS, as well as inside houses.

Leishmaniasis can also be transmitted zoonotically by wild animals (sylvatic zoonosis) or domestic animals (domestic zoonosis) that act as reservoir hosts. In some cases, reservoir control is recommended, with or instead of vector control measures. Table 5 lists some of the major parasite transmission systems in sub-Saharan Africa and provides guidance on potential reservoir and vector control methods (More detail is provided in reference *32.*) and studies on reservoir and vector control measures are cited in the table.



Key point

It is important to understand sandfly biology and human behaviour in a particular setting to determine where transmission is occurring or where vectors rest, before you plan intervention strategies.

Table 5. Zoonotic and sylvatic transmission cycles in sub-Saharan Africa and guidance on potential reservoir and vector control methods

Disease	Parasites	Endemic countries in Africa	Reservoir hosts	Reservoir control	Vector control
Visceral leishmaniasis	*Leishmania donovani* and *L. infantum*	Eritrea, Ethiopia (Metema-Humera in the northwestern lowlands; Libo Kemkem and Fogera districts in Amhara regional state and north of Lake Turkana; in the south, the Segen and Woito valleys, the Genale and Gelana river basins and west Moyale at the border with Kenya), Djibouti, Kenya (Machacos, Kitui, West Pokot, Masinga, Meru, Baringo, Turkana), Somalia, Sudan (north: Gadaref, Blue Nile, White Nile, Sinnar, South Kordofan and West Darfur states; south: Upper Nile, Jonglei, Unity States, Eastern Equatoria) and Uganda (northeastern focus: Pokot Department)	*L. donovani*, mainly anthroponotic Foci of zoonotic transmission related to *L. infantum* with domestic dogs as main reservoir	No recommendations	IRS and LLINs Not recommended: spraying of termite hills to control *P. martini*
Visceral leishmaniasis	*L. infantum*	Algeria, Chad, Central African Republic, Egypt, Gambia, Libyan Arab Jamahiriya, Mauritania, Morocco, Senegal and Tunisia	Domestic dogs and wild canines (foxes, jackals, wolves)	Management of domestic and feral dog populations by treatment or culling (*146*, *147*)	Topical insecticide on dogs or insecticide-treated collars may have some benefit (*148*) IRS if species are endophilic
Cutaneous leishmaniasis (few or sporadic cases	*L. tropica*	Algeria, Egypt, Ethiopia, Israel, Jordan, Kenya, Libyan Arab Jamahiriya, Morocco, Namibia and Tunisia	Suspected to be zoonotic Hyraxes are among suspected reservoir hosts.	No recommendations	No recommendations
Epidemic zoonotic cutaneous leishmaniasis	*L. major*	Algeria, Burkina Faso, Cameroon, Chad, Egypt, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Kuwait, Libyan Arab Jamahiriya, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sudan and Tunisia	Four main transmission systems: *R. opimus* (great gerbil) and *P. papatasi*; *Psammomys* spp. (fat sand rats) and *P. papatasi*; *Meriones* spp. (jirds) and *P. papatasi* or *P. salehi*; and *Arvicanthis*, *Tatera* or *Mastomys* spp. and *P. duboscqi* or *P.papatasi*	Studies with poisoned baits to control rodents reduced the number of cases (*149*–*151*). Deep ploughing or other mechanical destruction of rodent habitats has been tested (e.g. *152*) but is expensive and not sustainable.	No recommendations
Zoonotic cutaneous leishmaniasis	*L. aethiopica*	East Africa Highlands: Ethiopia, Kenya, Uganda	Stable foci of low endemicity are maintained by hyraxes (*Procavia*, *Heterohyrax* and *Dendrohyrax* spp.), and the parasite (*L. aethiopica*) is transmitted by *P. longipes* and *P. pedifer*	Small-scale eradication of hyraxes close to settlements	Fogging of hyrax habitats

Tools for which there is some evidence to recommend their use against cutaneous and visceral leishmaniasis

Environmental modification such as cleaning and clearing rubbish from around houses, streets and vacant land, covering cracks and crevices in walls of buildings with plaster, asphalting streets and covering courtyards with bricks, cement or other materials may be effective in preventing sandfly breeding. Studies reported that plastering walls and cracks with lime or mud can reduce the density of visceral leishmaniasis vectors in houses (*153*, *154*), but no epidemiological data were collected. Environmental modification may not be effective as a standalone intervention but should be considered as part of a long-term strategy if sustainability can be achieved.

Key points

If sandfly vectors bite or rest indoors, LLINs and IRS should be effective against cutaneous or visceral leishmaniasis.

Reservoir control methods should be considered if the parasite is maintained in domestic or wild hosts.

4.1.5 Human African trypanosomiasis

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
Traps and targets (insecticide-treated)	Insecticide-treated cattle	
	Aerial spraying	
	Sterile insect technique	

Control of human African trypanosomiasis (HAT) relies on reduction of the parasite reservoir (human and/or animal) as well as vector control. Case detection and treatment has played a major role in efforts against Gambian HAT (*155*). Although vector control can contribute to the control of Gambian HAT it plays a greater role against Rhodesian HAT, which is a zoonosis. The tools available include traps and targets that attract host-seeking tsetse flies, insecticide-treated cattle, aerial spraying of tsetse habitats and the sterile insect technique.

WHO-recommended vector control tools against HAT

Traps and targets (insecticide-impregnated screens) are highly effective against tsetse flies (*156*). They function by simulating hosts and attracting tsetse flies with odorant cues or visual cues, such as size, shape and colour. While traps can be used for surveillance and control, targets are used only for control. Impregnation of the targets or traps with an insecticide makes them highly effective in killing flies upon impact. Various designs have been developed for use against particular target species in particular environments (more detail is given in reference *155*). For example, use of bi-conical tsetse traps was highly effective in Uganda (*157*). Traps are effective, but they are more expensive, difficult to construct and use, more fragile than targets and require regular maintenance.

Sufficient traps must be in place per unit area in order to reduce tsetse fly density. For savannah tsetse species, a density of four traps or targets per square kilometres can reduce HAT effectively (*158*). For riverine species of tsetse fly in Central and West Africa, traps or targets can be placed linearly at a distance of 50 m (*159*); flies are attracted mostly to the colour of the trap or target and odorants are less effective (*160*, *161*).

Smaller insecticide-treated targets, measuring 50 × 25 cm^2, have been found to be highly attractive to riverine species of tsetse fly such as *Glossina fuscipes fuscipes* (*162*, *163*). In contrast, for savannah flies, reducing the target size drastically reduced the number of flies caught (*164*). These small targets (25 × 25 cm) consist of a square of phthalogen-blue polyester cloth attached to fine black polyethylene mosquito netting impregnated with insecticide (Fig. 22). In northern Uganda, small targets reduced *G. fuscipes* populations by more than 90% in 12 months (*165*). In a study of

population screening and treatment with or without vector control by use of small targets in Guinea, the incidence of HAT was lower in the arm including vector control than with screening and treatment alone (*166*). Small targets are easy to deploy because of their size, cheap to manufacture and probably require less maintenance than traps or larger screens. Smaller screens with netting were estimated to improve cost–effectiveness by six times over standard 1 × 1 m targets for control of *G. palpalis gambiensis* and *G. tachinoides* (*162*). The insecticide on the netting is effective for up to 8 months but starts to become less effective after 5 months (*165*).

Fig. 22. Small targets for savannah tsetse fly control (photo courtesy of S. Torr)

Vector control tools for which there is some evidence to recommend their use against HAT

Use of insecticide-treated cattle to control tsetse fly has had mixed success (*166*), with some successful examples (*167*, *168*) and some unsuccessful (*169*, *170*). The uneven results are probably due to differences in the numbers and distribution of treated cattle, the area covered by treated animals and rapid loss of the effective insecticidal dose on the animals. Furthermore, when

alternative hosts such as wildlife are abundant, the flies can feed on them, reducing the effectiveness of the treated cattle (*171*). Insecticide-treated cattle are not used widely because there are few cattle in many foci of Gambian HAT in Central and West Africa, and the intervention requires sustained support from farmers. The measure may be more sustainable if it is used in areas where tsetse flies also transmit livestock trypanosomes that cause *nagana*, such as in Uganda, where Rhodesian sleeping sickness is prevalent (*172*). As tsetse flies preferentially land on the legs and belly of cattle (75–95% of flies), restricting insecticide application to the legs and belly of older cattle can be more cost–effective (*173*, *174*) and reduce the risks to non-target organisms (*175*).

In areas where tsetse flies are widespread, large scale aerial spraying of insecticides has been conducted. Aerial spraying of insecticide has been tried for both Gambian and Rhodesian tsetse but performs better for Rhodesian sleeping sickness where woodland surrounding tsetse habitats is less dense. Suitable concentrations of endosulfan or deltamethrin were sprayed by sequential ultra-low volume aerial spraying over forested habitats, where the flies were killed upon impact with micro-droplets of insecticide (*176*, *177*). Aerial spraying can be effective but is more expensive than traps and targets, and there is concern about the environmental impact of widespread application of insecticides.

Focal and ground-spraying of insecticides of resting sites, such as lower branches and tree trunks, and pupal development sites, such as ant-bear holes and springhare and hyena dens, has been used successfully in a number of locations, including Botswana (*178*) and Zimbabwe (*179*). In the past DDT was used but this is no longer possible due to environmental concerns. More recently, pyrethroids have been tested for bush spraying and shown to reduce tsetse catches and HAT cases (*180*). However, focal and ground-spraying are not widely used nowadays, as regular application over large areas is difficult.

Once tsetse fly populations have been reduced to a low level, release of sterile insects can eliminate the last remaining flies. This technique was used successfully to eliminate tsetse (*G. austeni*) from Unguja Island, Zanzibar, United Republic of Tanzania, between 1994 and 1997 (*181*). This technique may not be suitable everywhere because of its high cost, logistical difficulty, potential reinvasion outside island populations and doubtful feasibility in areas with multiple species. Releasing sterile males may actually increase transmission because males are also vectors of HAT.

4.1.6 Schistosomiasis

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
Preventive chemotherapy with praziquantel		Biological control with fish
Provision of potable water and sanitation		Molluscicidal plants
Health education		
Molluscicides		
Environmental management		

The mainstay of control of schistosomiasis is regular preventive chemotherapy with praziquantel (*57*). Other interventions that may be important in the control and elimination of schistosomiasis include provision of potable water and sanitation, snail control with molluscicides, environmental management, biological methods and health education to change water-use habits, discourage open defecation and urination and encourage attendance for disease screening.

WHO-recommended vector control tools against schistosomiasis

As schistosomiasis results from unsanitary disposal of human waste and the absence of safe sources of water, it is not surprising that provision of safe water and sanitation is associated with a reduction in schistosomiasis (*182*, *183*).

A number of effective tools are available for snail control, including molluscicides and environmental management (*184*). Molluscicides such as niclosamide ethanolamine salt were effective for snail control in schistosomiasis control programmes in China (*182*), Egypt (*183*) and Morocco (*187*, *188*), and niclosamide is recommended by WHO for snail control (*189*). Molluscicides are expensive when used on a large scale, and their use requires skilled personnel, logistics and equipment (*190*). Focal treatment with molluscicides targeted to high-prevalence areas can be used when transmission sites are small and circumscribed. Rapid reinvasion can occur so regular treatment is necessary and it can be difficult to know where and when to treat particularly where contact with contaminated water occurs over a large area (*190*).

Environmental management for schistosomiasis includes increasing the flow rate of water to wash away snails, such as river flushing (*191*), removal of vegetation or drainage at certain times of the year. Environmental management may have some disadvantages; for example, removal of vegetation may affect fish stocks, and increasing the flow rate of rivers may perversely create breeding habitats for *Simulium* (black fly) vectors of onchocerciasis, which prefer fast-flowing water.

Environmental management is important in the creation of man-made habitats, such as dams, artificial lakes, irrigation schemes and aquaculture. Where irrigation schemes are introduced, overhead or drip irrigation may reduce the risk for increasing schistosomiasis transmission associated with traditional surface irrigation (*190*). In irrigated rice-growing areas, multiple cropping or alternate cropping systems can be used to reduce snail habitats (*190*).

Vector control tools for which there is currently insufficient evidence to recommend their use for schistosomiasis control

A number of methods for biological control have been tested. Biological control of *Biomphalaria glabrata* by competitor snails of the Ampullariidae (*Pomacea glauca, Marisa cornuarietis*) and Thiaridae (*Tarebia granifera, Melanoides tuberculata*) families has had some success in the Caribbean (*192–195*); however, there is a risk that the new colonizing snails will become susceptible to the local schistosome, as occurred in Brazil (*196*, *197*). Snail control with fish has been tested in a number of locations, including Lake Malawi and Lake Victoria, but has been largely unsuccessful (*198*).

Several plants contain natural molluscicides (e.g. saponins from *Phytolacca dodecandra* (*199*, *200*) and isoflavonoids from *Millettia thonningii* (*201*)). Experimental studies with these compounds have not, however, led to recommendation for their use, for reasons such as toxicity or difficulty of large-scale production (*184*).

4.1.7 Trachoma

The strategy for control of trachoma consists of **s**urgery, **a**ntibiotics for treatment, **f**acial cleanliness and **e**nvironmental change (SAFE).

Tools recommended by WHO	Tools for which there is some evidence to recommend their use or their use in certain settings or populations	Tools for which there is currently insufficient evidence to recommend their use
Surgery		
Antibiotics		
Facial cleanliness		
Environmental change (environmental sanitation by physical or chemical methods)		

WHO-recommended vector control tools for trachoma

The flies that transmit trachoma can be controlled by environmental sanitation or by physical or chemical methods (*202*). Environmental sanitation includes provision of water and sanitation facilities and promotion of hygiene (e.g. discouraging open defecation, promoting proper disposal of household waste), which has benefits against many other diseases, including childhood diarrhoea. These interventions should therefore be considered a priority. Provision of latrines was shown in a cluster randomized controlled trial to reduce trachoma prevalence by 30% in the Gambia (*203*). Space spraying, spraying of residual insecticide on the outside of houses where flies rest or use of fly traps can be useful but are not considered long-term strategies. Space spraying deltamethrin reduced the prevalence of trachoma by over 80% in a cluster randomized controlled trial in the Gambia (*203*), but continuous repeated spraying will generate resistance in the flies. This is therefore considered only in areas with an unusual temporary increase in transmission risk (*202*).

4.1.8 Onchocerciasis

Onchocerciasis can be controlled by targeting the parasite using ivermectin chemotherapy (*57*) and the vector using vector control measures, in particular larviciding of breeding grounds using chemical or microbial larvicides (Fig. 23). Although the current strategy for onchocerciasis control relies mostly on drugs, it is important to note that the major reductions were brought about by a combination of drug treatment and vector control. Vector control has also re-emerged as an important strategy now that onchocerciasis is targeted for elimination.

Fig. 23. Larviciding for onchocerciasis control, Sanaga River, Cameroon (photo courtesy of D. Baleguel)

Aerial larviciding was responsible for the near-elimination of river blindness from much of West Africa (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Senegal, Sierra Leone and Togo) as part of the Onchocerciasis Control Programme (OCP) between 1974 and 2002 (*204*). After early development of resistance of *Simulium damnosum* to temephos and phoxim, a number of insecticides (chemical and microbial) were used in rotation. Despite the success of the OCP, there has been a resurgence of blackflies in some former Programme countries, indicating that continued vector surveillance is needed.

In 1995, the African Programme for Onchocerciasis Control (APOC) was launched in 19 African countries not covered by the OCP (*205*, *206*). APOC relies heavily on mass drug administration with ivermectin, although activities to eliminate the blackfly vector are used in Equatorial Guinea, Uganda and the United Republic of Tanzania, where vector control is feasible and cost-effective. Ground larviciding with environmentally safe insecticides continued for 2–3 years, concluding in 2005. The African Programme is monitoring the blackfly population in these countries to confirm vector elimination.

4.1.9 Other viral infections

Vector control programmes must remain vigilant for epidemics of arboviruses, which can emerge quickly and infect large numbers of people. Importantly, new human pathogens transmitted by vectors may emerge (*207*, *208*). As these diseases are epidemic, few studies have been conducted to assess whether particular interventions are effective in controlling outbreaks. Some guidance based on expert opinion is given in Box 5.

Box 5. Vector control tools for use against viral infections (except dengue)

Rift Valley fever

Many species of mosquito can act as vectors for transmission of the Rift Valley fever virus, and they vary by region (*209–212*). Among animals, the virus is spread primarily by *Aedes* species, which can acquire it by feeding on infected animals. During periods of heavy rainfall, larval habitats frequently become flooded, enabling the eggs to hatch and the mosquito population to increase rapidly, spreading the virus to the animals on which they feed. LSM is the most effective form of vector control if breeding sites can be clearly identified and are limited in size and extent. During periods of flooding, however, there are usually too many, widely spread breeding sites for larviciding measures to be feasible.

West Nile virus

West Nile virus is found in Africa and maintained in nature in a cycle involving transmission between birds and mosquitoes (*213*, *214*). Humans, horses and other mammals can also be infected. Culicines are generally considered the principal vectors of the virus, in particular *Cx. pipiens*. West Nile virus is maintained in mosquito populations by vertical transmission (adults to eggs). Prevention of human infections depends on an effective IVM programme in the area in which the virus occurs. Studies should be conducted to identify local mosquito species that play a role in transmission of the virus, including those that might serve as a "bridge" from birds to humans. Emphasis should be placed on LSM, including source reduction, water management and larviciding.

Yellow fever

Several species of *Aedes* mosquitoes transmit the yellow fever virus (*215–217*). Mosquitoes carry the virus from one host to another, primarily between monkeys, from monkeys to humans and from person to person. The mosquitoes either breed around houses (domestic), in the forest (wild) or in both habitats (semi-domestic). There are three types of transmission cycle:

- *Sylvatic (or forest)*: In tropical rainforests, yellow fever occurs in monkeys infected by wild mosquitoes. The infected monkeys pass the virus to other mosquitoes that feed on them, and the infected mosquitoes bite humans entering the forest, resulting in occasional cases of yellow fever. Most infections occur in young men working in the forest (e.g. for logging)

- *Intermediate*: Small epidemics occur in humid or semi-humid parts of Africa, where semi-domestic mosquitoes (that breed in the wild and around households) infect both monkeys and humans. Increased contact between people and infected mosquitoes leads to transmission, and many separate villages in an area can have cases simultaneously. This is the commonest type of outbreak in Africa. An outbreak can become a more severe epidemic if the infection is carried into an area populated by both domestic mosquitoes and un-vaccinated people.

- *Urban*: Large epidemics occur when infected people introduce the virus into densely populated areas with many non-immune people and *Aedes* mosquitoes. Infected mosquitoes transmit the virus from person to person.

Eliminating potential mosquito breeding sites and larviciding can reduce the risk for transmission of yellow fever in urban areas. Application of spray insecticides to kill adult mosquitoes during urban epidemics, combined with emergency vaccination campaigns, can reduce or halt yellow fever transmission, leaving time for vaccinated populations to build immunity.

Mosquito control programmes targeting wild mosquitoes in forested areas are not practical for preventing forest (or sylvatic) yellow fever transmission.

Chikungunya

Chikungunya virus is transmitted from human to human by the bites of infected female mosquitoes in a number of locations, including sub-Saharan Africa (*218–221*). The mosquitoes most commonly involved are *Ae. aegypti* and *Ae. albopictus* (*222*), two species that can also transmit other mosquito-borne viruses, including dengue. Both *Ae. aegypti* and *Ae. albopictus* have been implicated in large outbreaks of chikungunya. In recent decades, *Ae. albopictus* has spread from Asia to become established in areas of Africa. *Ae. albopictus* thrives in a wider range of water-filled breeding sites than *Ae. aegypti*, including coconut husks, cocoa pods, bamboo stumps, tree holes and rock pools, in addition to artificial containers such as vehicle tyres and saucers under plant pots. This diversity of habitats explains the abundance of *Ae. albopictus* in both rural and peri-urban areas and shady city parks. *Ae. aegypti* is more closely associated with human habitation and uses indoor breeding sites, including flower vases, water-storage vessels and concrete water tanks in bathrooms, as well as the same artificial outdoor habitats as *Ae. albopictus*. In Africa, several other mosquito vectors have also been implicated in disease transmission, including species of the *A. furcifer-taylori* group and *A. luteocephalus*. There is evidence that some animals, including non-primates, rodents, birds and small mammals, act as reservoirs.

The proximity of mosquito vector breeding sites to human habitation is a significant risk factor for chikungunya and for the other diseases that these species transmit. Prevention and control rely mainly on reducing or treating natural and artificial water-filled containers that support breeding of the mosquitoes. This requires mobilization of affected communities. During outbreaks, insecticides may be sprayed to kill flying mosquitoes, applied to surfaces in and around containers where the mosquitoes land and used to treat water in containers to kill immature larvae.

For protection during outbreaks of chikungunya, clothing that minimizes skin exposure to day-biting vectors is advised. Repellents can be also be used, and people should sleep under LLINs at night. People travelling to areas of risk should take basic precautions, including use of repellents, wearing long sleeves and trousers and ensuring that rooms are fitted with screens to prevent mosquitoes from entering.

O'nyong-nyong

O'nyong-nyong virus is an alphavirus closely related to chikungunya virus but transmitted by anopheline mosquitoes (*An. funestus* and *An. gambiae*). The clinical picture is similar to that of chikungunya (self-limiting febrile illness characterized by headache, rash and joint pain). Secondary hosts have not been formally identified, although antibodies against o'nyong-nyong virus have been found in game animals in sub-Saharan Africa (*223*). There have been sporadic outbreaks in West and East Africa, and a study in coastal Kenya found a seropositivity rate of 56% (*224*). As the vector is the same as that for malaria, the core malaria vector control tools of LLINs and IRS plus LSM in some settings are likely to be effective against o'nyong-nyong.

4.2 Multiple diseases and multiple interventions

In areas where diseases are co-endemic, vector control interventions that are effective against multiple diseases should be used to save costs and ensure greater efficiency. For example, control of *Anopheles* vectors should reduce the occurrence of malaria, lymphatic filariasis, Rift Valley fever, West Nile fever and o'nyong-nyong (*212*, *225*–*227*). Table 6 summarises the recommended vector control interventions to use when diseases are co-endemic. In Table 6, WHO-recommended primary vector control tools are shown in green and supplementary methods in orange.

Combinations of interventions are likely to be more effective against a disease than a single intervention. For example, combinations of interventions with different modes of action (chemical, biological, environmental) targeting immature and adult mosquitoes are recommended for dengue control. Studies of LLINs and IRS for malaria are discussed in section 4.1.1. Unfortunately, for other diseases there are fewer studies of combinations of interventions.

Table 6. WHO-recommended vector control tools, by disease

Intervention	LLINs	Insecticide-treated curtains or house screening	IRS / Peri-focal spraying	House improvement and cleaning peri-domestic environment	Larval source management: Larviciding	Larval source management: Environmental management	Larval source management: Biological Control	Larval source management: Polystyrene beads	Insecticide-treated clothing or sheets	Insecticide-treated sheeting, tents or wall linings	Indoor ultra-low volume spraying	Water and sanitation	Molluscicides	Aerial insecticide	Focal, peri-focal or ground spraying	Insecticide-treated traps and targets	Insecticide-treated cattle
Malaria																	
Lymphatic filariasis (anophelines)																	
Lymphatic filariasis (culicines)																	
Dengue																	
Leishmaniasis	*	*	*														
HAT																	
Schistosomiasis																	
Trachoma																	
Onchocerciasis																	
Yellow fever																	
West Nile virus																	
Rift Valley fever																	
Chikungunya																	
O'nyong-nyong																	

WHO-recommended primary tools in green, supplementary tools in orange

* Where sandfly vectors bite or rest indoors

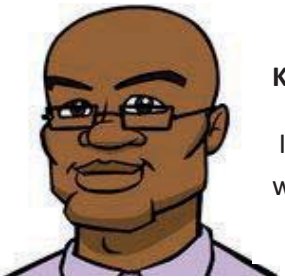
4.3 Vector characteristics, vector insecticide resistance status and risk for development of resistance

Information from an initial assessment of the ecology and behaviour of the target vector species should be used in deciding on vector control tools. Tools may have different efficacy against vector species, depending on their biology, ecology and behaviour. For example, LLINs are more effective in controlling vector species that are more endophagic.

It is also important to consider the susceptibility of the vector to insecticides and the risk for development of resistance by repeated use of insecticide-based vector control. Insecticide resistance, particularly in malaria vectors, is increasing and may eventually threaten the effectiveness of vector control (*228*). There are few, if any, places in sub-Saharan Africa where there is still full susceptibility of malaria vectors to pyrethroid insecticides, which are the only class of insecticide currently used for impregnating bed nets. More information on the types and mechanisms of insecticide resistance, the distribution of insecticide resistance in sub-Saharan Africa in vector species and testing for insecticide resistance is given in section 9.

What interventions should be implemented to mitigate insecticide resistance or maintain effectiveness if insecticide resistance is already present? Insecticide resistance management strategies are available, and technical guidance is available for malaria (for which the threat is greatest) in the Global Plan for Insecticide Resistance Management in malaria vectors (*46*). Additional guidance, including decision trees to support the choice of an intervention, will soon be available in a WHO document to assist countries in preparing plans to manage insecticide resistance. The WHO website should also be consulted, as this is a fast-moving area. In general, insecticide resistance management strategies involve pragmatic use of the available insecticidal tools to reduce selective pressure for resistance, with diversification of the range of interventions used to reduce reliance on insecticides when possible. Lessons might be learnt from experience in agricultural pest management (*229*).

The options for insecticide resistance management include rotation of different classes of insecticide and using combinations of interventions. For rotations, insecticides with different modes of action are used in succession, ideally annually or between spray rounds. Combinations of interventions can reduce selection pressure for resistance, as a mosquito that survives the first insecticide (e.g. a pyrethroid on a net) may then come into contact with additional insecticides used in the house (e.g. another insecticide sprayed on the walls). If LLINs and IRS are combined, an insecticide with a different mode of action to pyrethroids should be used for IRS, such as a carbamate or organophosphate insecticide. While selection of the appropriate insecticide should be guided by the resistance profile and the resistance mechanisms present, other factors such as acceptability, cost and residual efficacy in the particular setting, should also be considered.



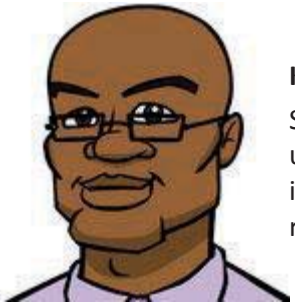
Key point

If LLINs and IRS are combined, IRS must be done with an insecticide with a different mode of action.

Other options for insecticide resistance management, both of which pertain to IRS, are mosaic spraying (use of different classes of insecticides in neighbouring areas) and use of mixtures of different classes of insecticide in a single formulation, so that the mosquito is guaranteed to come into contact with the two classes of insecticide at the same time. Mosaics are not operationally feasible in many settings, and mixture formulations are not yet available.

By increasing the variety of interventions available for vector control, including non-insecticide-based vector control, IVM can make a real contribution to insecticide resistance management and can help to prevent or mitigate insecticide resistance. For example, interventions such as LSM can be used in some settings and for some species to reduce vector density without the need for insecticides, thus reducing selection pressure for insecticide resistance. For example, the risk that vectors will develop resistance to *B. thuringiensis israelensis*, which contains four toxic proteins, is considered minimal (*230*).

The risk for development of resistance is affected by the rate of application of insecticide formulations, the frequency of application and other factors such as the generation time of the vectors. Insecticides used in other programmes and sectors may also contribute to selection pressure for insecticide resistance in disease vectors; therefore, communication should be encouraged between vector-borne disease control programmes and other sectors such as agriculture to determine what insecticides are being used where and when and in what volumes. Insecticides used in one vector-borne disease control programme may have inadvertent effects on other vectors so it is also important that there is communication between different disease control programmes.



Key point

Strategies such as larviciding and environmental management can be used in some settings to reduce mosquito numbers without the use of insecticides and can therefore reduce selection pressure for insecticide resistance.

4.4 Human and environmental safety

Another consideration in deciding on vector control methods is the risk that the intervention poses for human and environmental health. Some known side-effects of vector control methods are listed in Table 7.

Table 7. Side-effects of vector control methods

Method	Side-effect	Importance
Chemical methods		
LLINs and insecticide-treated curtains	Risk for resistance	Important
	Human toxicity	Not important
	Ventilation	Important
IRS	Risk for resistance	Important
	Human toxicity	Somewhat important
	Smell	Important
	Residue on walls	Somewhat important
	Effect on ecosystems	Not important
Indoor ultra-low volume space spraying	Risk for resistance	Somewhat important
	Human toxicity	Somewhat important
	Effect on ecosystems	Not important
Insecticide-treated sheeting, tents and wall linings	Risk for resistance	Important
	Human toxicity	Not important
Insecticide-treated clothing or bed sheets	Risk for resistance	Somewhat important

	Human toxicity	Somewhat important
Insecticidal treatment of habitat, e.g. focal, peri-focal, ground or aerial spraying	Effect on ecosystems	Very important
	Risk for resistance	Important
Insecticide-treated cattle	Human toxicity (food chain)	Somewhat important
	Effect on ecosystems	Somewhat important
Sterile insect technique for HAT	Effect on ecosystems	Important
Insecticide-treated traps and targets	Animal and human toxicity	Somewhat important
	Effect on ecosystems	Somewhat important
Treatment of pit latrines	Effect on ground water	Somewhat important
	Environmental pollution (polystyrene beads)	Somewhat important
Non-chemical methods		
Source reduction	Effect on ecosystems	Not important
Habitat manipulation	Effect on ecosystems	Not important
Irrigation management	Effect on ecosystems	Not important
Design of irrigation structures	None	
House improvement and screening	Reduced ventilation	Somewhat important
Adaptation of pit latrines	None	
Waste-water management	None	
Solid-waste management	None	
Predation	None, if indigenous species used	
Biological larvicides	Risk for resistance	Not important
Repellent plants	Human toxicity	Not important
Removal trapping	None	
Zooprophylaxis	None	
Polystyrene beads	Pollution	Not important

Adapted from *33*

Judicious use of pesticides is essential in view of the development of insecticide resistance, the few new compounds under development, the high costs of many insecticides and possible adverse effects on human health, due to acute or chronic exposure, and on the environment (e.g. other

arthropods, fish). Personnel handling public health pesticides should be trained on safe handling of pesticides and provided with adequate protection. Communities receiving the interventions should be educated to improve compliance and minimise risk of exposure to pesticides. Guidance on decision-making for the judicious use of insecticides is provided by the WHO Pesticide Evaluation Scheme (WHOPES) (*231*). Guidelines on the distribution and use of pesticides should be followed to minimize risks to health and the environment (*232*). Countries should reduce and eventually phase out use of persistent organic pollutants, including DDT, in accordance with the Stockholm Convention on Persistent Organic Pollutants (*233*). IVM offers an opportunity to reduce use of DDT by using alternative insecticides for chemical-based control and diversifying the interventions available for vector control.

Non-chemical methods have limited adverse effects on human health, with the possible exception of certain structural adaptations that introduce changes in human workload or affect the ventilation in houses.

4.5 Affordability and cost–effectiveness

Affordability is another consideration in selecting vector control methods. Affordability refers not only to national or decentralized budgets allocated to health but also to the contributions of other sectors and the willingness of communities to invest time and resources. Cost–effectiveness is a form of economic analysis (Box 6). Few data are available on the cost–effectiveness of interventions other than LLINs, IRS and LSM for malaria control.

Box 6. Cost–effectiveness

Cost effectiveness is a form of economic analysis for comparing the relative costs and effects of two different courses of action. The incremental cost–effectiveness ratio, ICER, is the ratio of the change in costs to incremental benefits of an intervention:

$$ICER = (C1 – C2) / (E1 – E2)$$

where C1 and E1 are the cost and effect in the intervention group, and C2 and E2 are the cost and effect in the control group.

Costs are usually described in monetary units, while the effect is measured in terms of lives, cases or disability-adjusted life years gained or lost.

A 2011 review showed that, from a provider perspective, the median incremental cost–effectiveness ratio per disability-adjusted life year averted was US$ 27 (range, US$ 8.15–110) for insecticide-treated bed nets and US$ 143 (range, US$ 135–150) for IRS (*234*). Despite variations in delivery costs between studies and settings, these interventions were consistently cost–effective against a threshold of US$ 150 per disability-adjusted life year averted. The review could not conclude

whether insecticide-treated bed nets were more cost–effective than IRS; however, three comparisons of insecticide-treated bed nets and IRS showed that bed nets are more cost–effective (*235*–*237*), and one study showed that IRS was more cost–effective than insecticide-treated bed nets where malaria was epidemic (*238*). It should be noted that the cost–effectiveness of IRS and LLINs are not stagnant and depend on a number of factors, including the cost of insecticides, some being considerably more expensive than others; e.g. carbamates and organophosphates are substantially more expensive than pyrethroids.

Behaviour change campaigns and other activities should also be taken into account in calculating cost–effectiveness. Often, these campaigns increase use and coverage to such an extent that, even with the increased cost of additional activities, the cost–effectiveness is higher. Box 7 gives an example of the cost–effectiveness of LLIN distribution and use campaigns in Ghana.

Box 7. Cost–effectiveness of distribution and use of LLINs: evaluation of a universal distribution campaign in Ghana (adapted from *239*)

Ghana undertook national mass distribution of LLINs between May 2010 and October 2012 and distributed 12.5 million nets. The campaign involved pre-registration of individuals and sleeping spaces, distribution of LLINs door-to-door with "hang-up" campaigns by volunteers and "keep-up" behaviour change communication to achieve high, sustained use of the LLINs.

A study was conducted to assess the cost and cost–effectiveness of the campaign in three regions of Ghana (Brong Ahafo, Central and Western) with a before-and-after design. The incremental cost–effectiveness of the "hang-up" component was assessed from data on the extent to which the component was implemented and LLIN use. Economic costs were estimated on the assumption that LLINs would be replaced after 3 years and included the time of unpaid volunteers and household contributions to volunteers.

In total, 3.6 million LLINs were distributed, and 46% of households reported that that they had been hung by a volunteer. The financial cost of the campaign was US$ 6.51 per LLIN delivered, and the average annual cost was US$ 2.90 per LLIN delivered. The campaign cost US$ 6619 per additional child death averted. Hanging nets constituted 7% of the annual cost, although the additional cost was modest because of the use of volunteers.

LLIN use was greater in households in which one or more LLINs had been hung by a volunteer, with more than 1.5 times the odds that the LLIN was used. The additional cost of hanging the nets was US$ 0.23 per LLIN delivered, with a net saving per LLIN used and per death averted.

In this campaign, hang-up activities were estimated to save costs if they increased LLIN use by 10% or more. This suggests that hang-up activities can make a LLIN campaign more cost–effective.

Cost–effectiveness during routine vector control may be different from that during elimination campaigns or epidemics. For example, during intense epidemics, IRS by experienced sprayers is probably the fastest way to contain transmission and is likely to be more cost–effective than LLINs.

The cost of environmental management to combat malaria in copper mining communities in Zambia (clearing vegetation, modifying river boundaries and draining swamps) per disability-adjusted life year averted was US$ 762, with decreasing costs (US$ 32–133) after the 5-year start-up period (*234*, *240*). This intervention is likely to be cost–effective in the long term, despite its high start-up costs.

The cost–effectiveness of LSM has not been studied, although one study estimated the economic and financial costs per person protected per year of large-scale dispersal of microbial larvicides in three ecologically diverse settings (*241*). The cost per person protected by larval control in this analysis was US$ 0.79–2.50, which is comparable to that of other malaria interventions. For example, the cost of IRS was US$ 0.88–4.94 per person protected (US$ 2000), the cost per treated net year of conventional insecticide-treated bed nets was US$ 1.21–6.05 and that of LLINs was US$ 1.38–1.90 (2005 US$) (*242*, *243*).

4.6 Acceptability and community participation

It is important to consider the cultural and social context in which vector control interventions are to be implemented. The acceptability of these interventions by communities ensures correct use of personal protective measures, sustained interest and participation and therefore intervention effectiveness. Acceptability to communities can be assessed by social research methods, such as holding a community forum or a focus group (see Box 32). Three examples of studies in which social research methods were used to determine community acceptability are given in boxes 8–10.

Community participation is an important aspect of the effectiveness of most, if not all, vector control methods. Participation ranges from adherence to use of interventions, such as LLINs, to active involvement in environmental management. Public health education is required before programmes start to ensure that everyone understands what is being done and why. Delivery of interventions should be accompanied by a comprehensive information, education and communication (IEC) and / or behavioural change communication (BCC) campaigns to promote community compliance in terms of usage and maintenance of the intervention. Who is engaged and how depend on local circumstances; in rural Africa, village leaders and sometimes religious leaders are usually consulted and involved from the outset before meetings are held in villages. Community participation is often critical for achieving coverage and for the sustainability of control activities but requires investment in communication, education and training of volunteers.

Box 8. Community acceptance of house screening for mosquito control in the Gambia (*48*, *244*)

An acceptability study was conducted as part of a randomized controlled trial of house screening (either complete, with doors and windows screened and eaves closed, or only ceilings screened) versus control in the North Bank Division, Gambia. Screening reduced the entry of *An. gambiae* at night, with a 59% reduction in fully screened houses and 47% in houses with screened ceilings. The prevalence of anaemia in children in screened houses and screened ceiling houses was almost halved.

Qualitative and quantitative methods were used in the acceptability study. First, focus group discussions were held with a selection of householders in each trial arm to collect information on general perceptions of the types of screening and on the main concerns and benefits. The results of the discussions were used to design a questionnaire, which was filled in by a wider selection of study participants. In the questionnaire, the participants were asked to choose whether to keep the screening they had been allocated, have it removed or have the other type of screening. The study also included "durability surveys" at 6 and 12 months after the screening was installed and assessment of indoor climatic conditions.

Most of the participants recognized that screening stopped mosquitoes and other insects from entering their houses and also animals such as bats and geckos; some participants reported sleeping more soundly as they felt more secure, and the screening prevented dust and dirt from falling on them when there was high wind or rain. The problems identified were difficulty in cleaning the white ceiling netting and damage to screened doors by children and domestic animals. Although 9% of those with fully screened houses and 17% of those with screened ceilings said they made the house hotter, the screened houses were hotter by an average of only half a degree Celsius. When offered a choice of screening, most participants chose full screening, regardless of whether they initially received screened ceilings, full screening or no screening.

Box 9. Community acceptance of tsetse control baits in Arua District, northwest Uganda (*245*)

Tsetse baits (traps or targets) are a method for controlling HAT. Their effectiveness depends to some extent on their acceptance by the community. Previously, negative views of communities towards traps led to damage or theft of traps and ultimately the failure of control programmes.

A qualitative study was conducted to explore knowledge, perceptions and acceptance of tsetse traps and targets in villages in Arua District, northwest Uganda, an area endemic for Gambian HAT. Focus group discussions were held with men and women in villages that had previously had tsetse traps as part of a control programme and in villages in which they had never been used.

The villages that had not had traps previously perceived them negatively, associating them with witchcraft and ghosts, largely because of the positioning of the traps near the river (considered to be the home of ghosts) and unease about who had positioned the traps and for what purpose. Villagers who had previously seen traps reported they had initially felt similarly but now perceived them positively. Most participants were aware of the purpose of the traps, and seeing insects trapped in them appeared to reinforce positive attitudes, particularly among women. Villagers who had been told the purpose of the traps (either by the person setting it up or another community member) said that the information helped them to put aside associations with supernatural powers. Participants expressed willingness and motivation to be involved in tsetse control after villagers in the group previously exposed to traps reported having contributed to tsetse control, for example by maintaining traps and cutting back vegetation around rivers.

This study underlines the need to understand community perceptions of new interventions. Tsetse control programmes should plan and budget for community involvement at all stage e.g. community sensitisation, trap/target deployment and maintenance to ensure that programmes are effective and sustainable.

Box 10. Community awareness and acceptability of microbial larvicides for malaria control in a rural district of east–central United Republic of Tanzania (*246*)

A study was conducted to assess the community acceptability of larviciding in Mvomero District, east–central United Republic of Tanzania as part of a large cluster-randomized, community-supported larviciding trial. Data were collected by household surveys, focus group discussions and in-depth interviews. Data were collected during the baseline year of the trial when participants had not yet been exposed to the larviciding intervention or observed its benefits.

The study participants were generally aware that mosquitoes transmit malaria, and about two thirds of those interviewed understood that larvae breed in water bodies. They had not heard of larviciding as an intervention but were generally receptive to its use after a brief description of the method, which was read to them by the investigator. Some respondents were worried about larvicides being applied to water bodies that are used as sources of drinking-water and for other domestic purposes, and some expressed concern about larvicide being washed away during the rains. Despite a generally positive reaction to larviciding, participants expressed the need for community sensitisation before implementation which would enable community members to understand its benefits and safety to humans, animals, and plants.

Respondents were also asked about their willingness to contribute financially to sustain a larviciding programme. Of the participants in the focal group discussions, 88% said they would be willing to contribute a minimum of 1000 shillings (equivalent to approximately US$ 0.60) to the programme at regular intervals, e.g. every 3 or 6 months. However, some respondents were concerned about proper use of financial contributions from the community after negative experiences with community-supported programmes in the past, when money was not used for its intended purpose. Others said that community members would be more willing to contribute financially once the benefits of larviciding were observed.

4.7 Delivery of interventions

The choice of vector control tool should also take into account the feasibility and logistics of delivering or implementing the intervention. Interventions can be implemented by vector control services or by other sectors or the community with supervision by a vector-borne disease control programme. Some interventions, such as LLINs, can be delivered in various ways, including mass campaigns and continuous distribution through various channels. Delivery or implementation mechanisms may differ for routine and epidemic control. More information on this topic is given in section 5.

WHOPES is responsible for promoting and coordinating the testing and evaluation of pesticides for public health. In its present form, WHOPES has a four-phase evaluation and testing programme for

studying the safety, efficacy and operational acceptability of public health pesticides and preparing specifications for quality control and international trade. Its recommendations facilitate the registration of pesticides by Member States. Currently, WHOPES releases lists of recommended insecticides for IRS, insecticide-treated bed nets, LLINs, space spraying and larvicides, which can be found on the WHOPES website (http://www.who.int/whopes/en/). Countries should use only those products recommended by WHOPES and meeting the quality control specifications. On the basis of WHOPES recommendations, countries can register products with their national regulatory authority.

Although products may have met WHOPES standards, it is the responsibility of national regulatory authorities or procurement agencies (e.g. the President's Malaria Initiative or the Global Fund) to ensure their quality by testing batches before shipment. Batches should be tested in a laboratory certified for good laboratory practice to ensure that the product meets WHO or country specifications. This process is outlined in WHO and other (e.g. Global Fund) procurement guidelines (*247*). The time required for batch-testing should be included in lead times to ensure that there is no delay in releasing products for use in the field.

To ensure that the products delivered to the field are of good quality, guidelines for appropriate storage and shelf lives should be followed. Nevertheless, products that have passed their shelf life can still be used for up to 6 months, as long as batch testing shows they still meet specifications. Quality assurance (QA) procedures should be in place to ensure delivery of high-quality products to the field, such as checking the level of insecticide on a random sample of surfaces sprayed for IRS. An insecticide quantification kit will soon be available for assessing the amount of insecticide on sprayed surfaces. QA indicators should be added to strategic plans and logical frameworks for monitoring and evaluation.

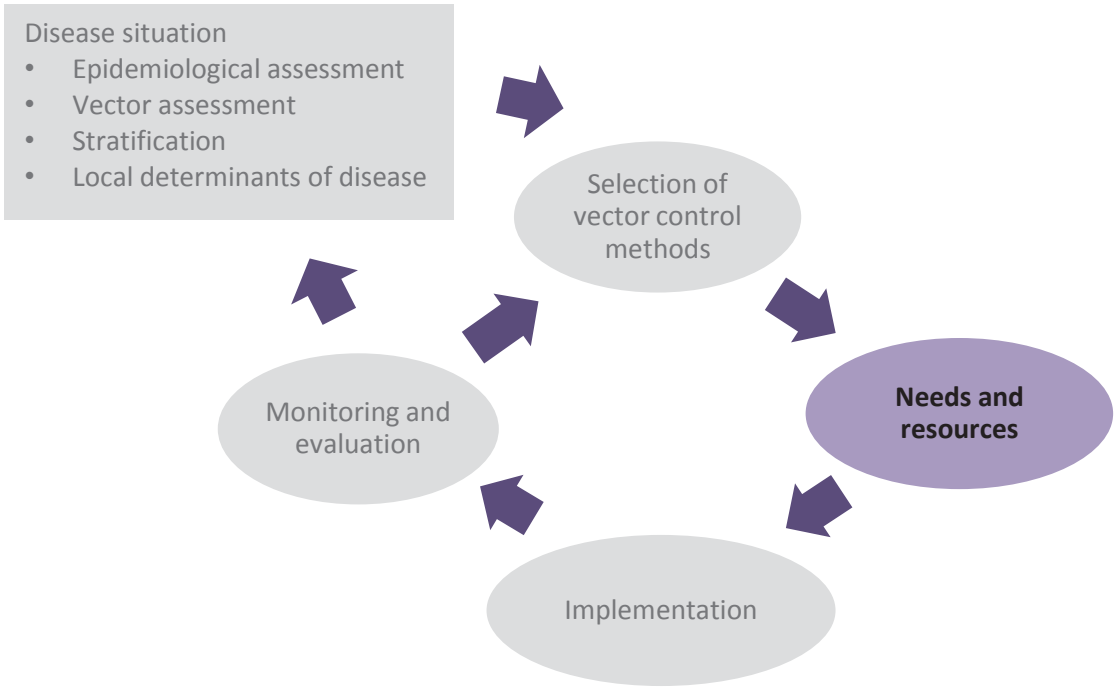
Key points

When selecting the most appropriate vector control method or combination of methods, it is important to consider their effectiveness, the local ecology and behaviour of the target species, the resources available for implementation (human, financial and material), the cultural context in which the intervention will be carried out, the feasibility of applying it in a timely manner and the adequacy of coverage. Countries should use only those products recommended by WHOPES that meet quality control specifications and should test batches before shipment.

Section summary

- There is a wide range of vector control tools, which can be broadly classified into chemical-based and non-chemical based tools for control of either adult or immature forms of the vector.
- Vector control tools should be chosen primarily on the basis of their efficacy against epidemiological parameters (prevalence or incidence of infection or disease), although evidence of efficacy against the vector may be useful in some circumstances.
- Vector control tools may be effective against multiple diseases, for example IRS is useful against malaria, lymphatic filariasis, dengue and leishmaniasis.
- A number of other factors should be taken into account in choosing vector control tools, including vector characteristics such as insecticide resistance, human and environmental safety, affordability and cost–effectiveness, community acceptance and participation and implementation or delivery.
- Only WHOPES-approved products should be used, and batches should be quality tested before shipment.

5. Needs and resources



When the locally appropriate vector control methods have been selected, an inventory should be made of the **financial resources, human resources and infrastructure (research, training, technical and operational facilities)** available for vector-borne disease control at national, regional or district level. WHO publications on needs assessment and the IVM curriculum may be helpful in assessing country capacity and resources (*4*, *12*). The organizational structures in which resources could be used should also be assessed. They are likely to vary by country, region and district, but some suggestions can be made.

Local stakeholders should participate in drawing up the inventory of resources and organisational structures. Possible collaboration with other local programmes or with government services should be discussed, to ensure activities are coordinated and avoid duplication. Potential financial resources include those received from national programmes for vector-borne disease control and from district health offices, local government and other public sectors, the private sector, civil society organizations and the community. The amount and type of resources depend on the diseases and vectors targeted. For example, vectors that breed predominantly in irrigated fields require strong engagement from the agriculture sector, whereas vectors that breed in the peri-domestic environment might require community participation in the removal of breeding sites. Vector control

programmes, other units in the ministry of health and other sectors may contribute to IVM financially; however, other types of resources, including human resources (e.g. expertise or personnel time) and material resources (e.g. equipment, fuel, transport, commodities) are equally important and should be encouraged.

5.1 Financial resources

Costing is usually done at the national level on the basis of a strategic plan, with clear terms of reference. Sources of financing for IVM differ by country, but the major source in many sub-Saharan African countries are funds provided for malaria control by external donors, such as the Global Fund or the President's Malaria Initiative. National funding for vector control, such as from tax revenues or budget reallocation, forms a component in most countries though the proportion of the total budget provided from domestic sources varies from country-to-country. In some countries, the private sector may also contribute to the national budget. Funding from donors is likely to remain disease specific to some extent. However, it is possible to include activities or commodities which cut-across diseases in these proposals such as developing capacity in entomological surveillance, which would be of benefit to other vector-borne disease programmes if the programmes were better integrated. Innovative financing mechanisms such as social insurance should also be considered.

The central government should fund the intersectoral steering committee, as funding by project funds will not be sustainable.

In IVM programmes, costs can be saved by using one intervention against more than one co-endemic disease and by sharing entomological expertise, field visits, transport and equipment more efficiently. Savings can also be made in the long term by using interventions outside the health sector, such as well-constructed drainage channels, which could be a long-term solution to reducing anopheline and culicine larval habitats in urban areas; the cost could be met by the department of public works and not the health department. Encouraging other sectors to contribute resources, particularly financially, will require strong advocacy from the intersectoral steering committee and the ministry of health.

5.2 Human resources and capacity-building

The methods selected for vector control will define the types of human resources needed. For instance, IRS requires trained spraying teams under proper supervision, which often demand substantial financial and logistic support. Local requirements for capacity-strengthening should also be identified. Investment in training and refresher training of staff and volunteers should be promoted. The role of community members, community health workers and agricultural extension workers could be increased relatively quickly by practical short courses on vector biology, ecology

and control methods. The experience of the agricultural sector in training farmers in integrated pest management could be used (see Box 18).

The IVM strategy requires skilled staff at central and local levels. Training, support, career structures and job descriptions should be put in place. Clear career structures which outline competencies and opportunities for advancement are an important incentive for people to seek training and help to retain staff (*2*). For example, in South Africa, Sudan and Zimbabwe, there are clearly defined cadres of public health entomologists with different job descriptions, from national senior entomologist, entomologist at state level and assistant entomologist to mosquito collector (*248*).

Human resources for IVM should be shared within and outside the health sector. Sharing human resources starts with effective communication of IVM objectives, indicators, expected targets and outcomes in the health sector and beyond. Transparency is essential for identifying the most cost–effective way to deliver health services to benefit all involved. Fig. 24 outlines an example of the sharing of human resources within the health sector for IVM with IRS and LSM to control lymphatic filariasis and malaria vectors. Human resources could be shared in a similar way between the health sector and other sectors.

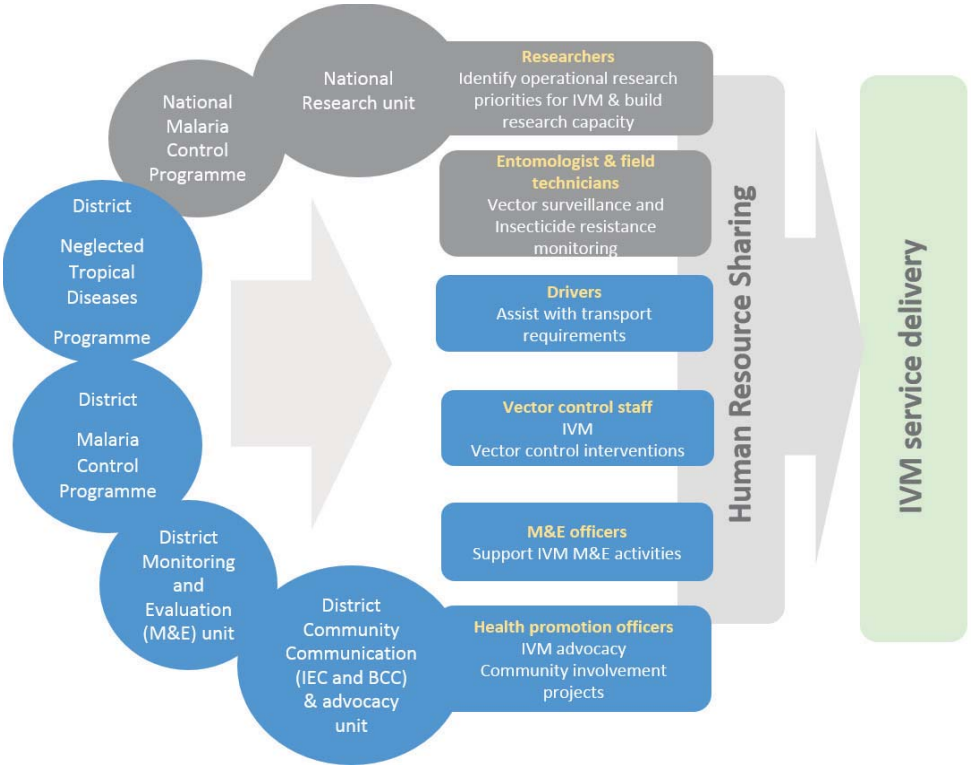


Fig. 24. Example of human resource sharing to support an IVM approach at district level

Capacity-building and supportive supervision should be strengthened. Useful training resources include the WHO *Core structure for training curricula on integrated vector management* (*4*), which gives advice to regions and countries for preparing their own training curricula for IVM. The training document does not duplicate existing specialized courses in medical entomology or vector control, as vector-borne disease programmes are likely to be familiar with these topics.

The training provided should be based on an assessment of what is required by the ministry of health, to ensure that it is directly relevant to the expected skills of the cadre. Gaps in capacity may include project management skills, geographical information systems, mobile communication technology and information communication technology, which are required for effective data collection and entomological and epidemiological response (*248*, *249*). These skills are increasingly being used to refine strategies, to target interventions in space and time (see Box 12 for use of surveillance data to target interventions in South Africa) and to monitor and evaluate their impact (see Box 29 for use of SMS by health facilities to report case numbers). Capacity-building in entomological surveillance is essential for deploying interventions correctly according to vector ecology and behaviour and for evaluating the impact of interventions, including on insecticide resistance.

Collaboration between vector-borne disease control programmes and national universities and other training institutions should be strengthened, perhaps by formal agreements (*249*). National universities or institutions or overseas research institutions could give training in research and other activities. A directory of African institutions that provide training in IVM is available (*250*). It is important to establish a network of training and mentoring opportunities for staff, including public health entomologists and monitoring and evaluation staff. Box 11 gives examples of available medical entomology courses in Africa. Cross-border collaboration, such as the Lubombo Spatial Development Initiative (Box 22), can also be useful for capacity-building, in which the training resources are shared.

Retention of staff and institutional memory on IVM should also be considered. It is important that IVM activities are not solely dependent on key individuals and that training documents and SOPs are developed.

Box 11. Examples of courses in entomology in Africa (*250*)

Master of Science (MSc) course in medical entomology and vector control

The MSc was launched in 2008 by the Blue Nile National Institute for Communicable Diseases at the University of Gezira, Sudan, in collaboration with the London School of Hygiene and Tropical Medicine, the Liverpool School of Tropical Medicine and Witwatersrand University. The course is supported by the WHO Regional Office for the Eastern Mediterranean and was initiated by a resolution of the Regional Committee, in which IVM was endorsed as the regional strategic approach for vector-borne disease control. Over 80 people from 12 countries in the WHO African and Eastern Mediterranean regions have been trained during the past 3 years.

International masters degree in entomology

This course is run jointly by the Institute for Research and Development (Benin), Montpellier University (France), Abomey-Calavi University (Benin) and the Entomological Research Centre of Cotonou (Benin). The topics covered include systematics, biology and ecology of vectors of medical interest and epidemiology and control of vector-borne diseases. In the first 6 years of the course since its inception in 2006, degrees have been awarded to 91 students from 24 countries.

5.3 Infrastructure

Adequate infrastructure is required to plan and implement an IVM programme. Activities should be built around established structures in vector-borne disease control programmes, such the National Malaria Control Programme which is typically the most well-resourced of vector control programmes in sub-Saharan African countries. Infrastructure such as entomological laboratories for vector collection, rearing, identification and bioassays might have to be upgraded, and there should be an insectary, at least at national level, for maintaining a susceptible *Anopheles* colony to test for insecticide resistance (*249*).

Strengthening information systems for IVM should be a priority. Information, communication technology and mobile technology infrastructure should be upgraded for fast, accurate information collection and assessment, for example with tablets for remote collection of data.

5.4 Tools for resource planning

A tool for integrated planning and costing (http://www.ntdenvision.org/resource/tipac_multilingual) could be used to estimate the financial resources required for an IVM programme. This is an Excel program for estimating the costs and funding gaps of public health programmes, including IVM. It can be used with national strategic plans and budgets to plan and coordinate future programme

resources. The program is not a substitute for a plan of action or programme budget, but it can help with resource planning and revising a national plan in the face of resource constraints.

The OneHealth Tool (*252*) can be used to determine the financial requirements for extending malaria interventions, to project health impacts, plan health systems and analyse scenarios and fiscal space. It has been used in a number of countries for national strategic planning and costing. Other vector-borne diseases are not yet included.

Although WHO recommends that one LLIN be distributed for every two people at risk of malaria in order to meet the target of universal LLIN access, many households have odd numbers of people. Therefore, for procuring LLINs, WHO recommends an overall ratio of one LLIN per 1.8 people in the target population (*38*, *253*). A useful tool is NetCALC (http://www.vector-works.org/resources/netcalc-planning-tool/) which can model several scenarios of continuous distribution approaches based on country-specific data, and provides estimations of the ability of various channels (ANC, EPI, school-based distribution, curative care, community-level distribution, and retail) to reach overall universal coverage.

The WHO operational manual for IRS gives guidance on costing, budgeting and financing (*39*). An example of items to be costed in an IRS programme is shown in Table 8.

Decision-making and financial planning for tsetse fly control are complex because of the large number of variables, such as location, timing, strategy and methods. The decision support and costing tools available for HAT vector control include Tsetse Plan (planning community-based operations with bait techniques), Tsetse Muse (planning large-scale control operations with any method) and HAT-trick (operations specifically to control sleeping sickness). All three tools can be downloaded from www.tsetse.org. Shaw et al. (*174*) described the cost of tsetse fly control operations in a hypothetical area of 10 000 km^2 in south-eastern Uganda.

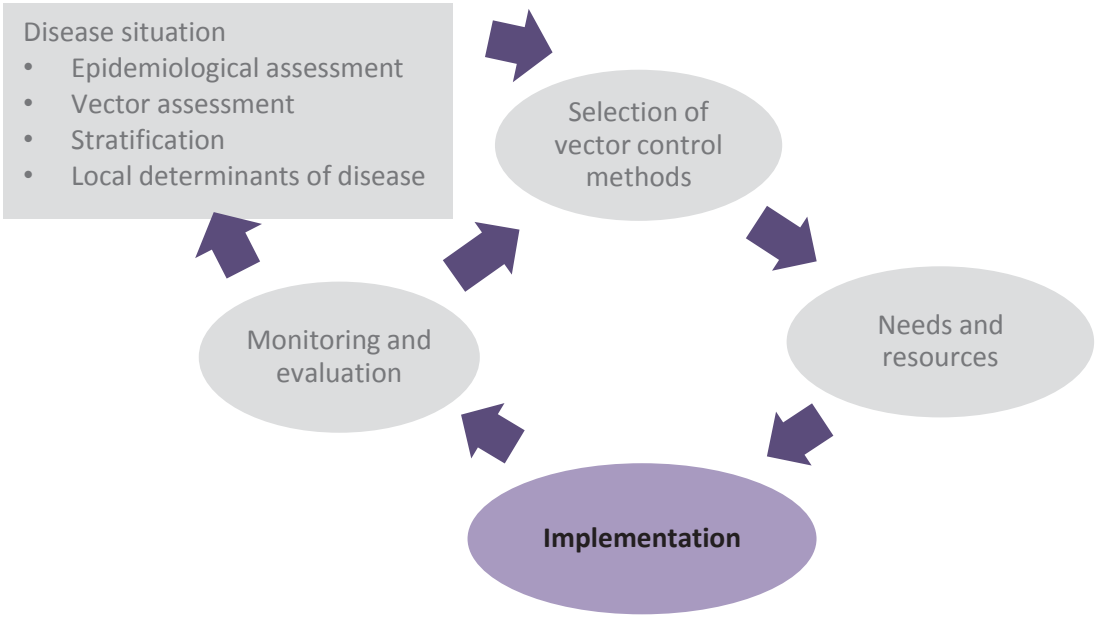
Section summary

- Make an inventory of the financial and human resources and infrastructure available and required for vector-borne disease control at national, regional or district level.
- Resources should be shared with other sectors, depending on the type of interventions.
- A number of tools are available for resource planning.

Table 8. Example of capital and operational budgets for an IRS campaign (adapted from *39*)

Item	No. of units	Unit cost	Total cost
Capital costs			
Baseline epidemiological and entomological review and survey			
Environmental impact assessment			
Compression sprayers			
Equipment, spares and replacement parts			
Tool kits			
Protective sheeting to cover household goods			
Transport: truck or boats for three or four spray teams			
Transport: supervisors' motorcycles			
Transport: coordinators' four-wheel drive vehicles			
Malaria camps, storage and base			
Recurrent costs			
Spray insecticides, including buffer stocks			
Quality assurance and quality control of IRS formulation and of spraying			
Salaries of spray operators for 4–8 weeks (adjusted to minimum wage)			
Personal protection (overalls, gloves, helmets, face shields with screen)			
Collection and disposal of empty sachets and containers			
Travel and per diem for supervisors and coordinators throughout the campaign			
Transport hire and fuel costs			
Annual training of coordinators and supervisors			
Annual training of spray operators			
Annual information, education and communication and campaigns (community mobilization materials)			
Annual review of environmental compliance and pesticides management			
Monthly, quarterly and annual operations management meetings			
IRS data entry and summary reports sheets			
Malaria prevalence surveys (optional)			
Entomological studies and sentinel sites			
Annual post spray review and annual report production			

6. Strategy for implementing integrated vector management



For implementation of IVM, the following points should be considered:

- **what** interventions will be delivered (section 4),
- **where** the interventions will be implemented,
- **when** the interventions will be implemented,
- by **whom** the interventions will be delivered and **how**.

The latter three bullet points are covered in the section below.

6.1 Spatio-temporal targeting

6.1.1 Spatial targeting

IVM means conducting vector control better, by making use of information on where vector-borne pathogens and diseases are, to make more effective use of limited resources and to target interventions to the populations at highest risk. Therefore, specific IVM interventions will probably need to be targeted to specific geographical locations or to "hotspots" of disease. As malaria is still associated with the greatest morbidity and mortality of the vector-borne disease burden in sub-Saharan Africa, areas or populations at risk should be targeted for universal coverage with appropriate vector control, which in most settings is LLINs. IRS and larval source management (LSM)

can be used in a more targeted manner for malaria and lymphatic filariasis control in rural areas. Targeted IVM can be used not only for more strategic use of resources but also for epidemic response, elimination or foci of high insecticide resistance.

Targeting hotspots of disease either routinely or for elimination

Hotspots of disease may exist as areas of higher transmission than in surrounding areas or can appear when transmission has been reduced substantially so that only some foci of transmission remain. For example, although the main intervention for lymphatic filariasis is preventive chemotherapy, there may be some areas in which repeated rounds of chemotherapy have failed to reduce transmission substantially, and it may be appropriate to use vector control measures in addition to standard practice.

A targeted (proactive) IVM approach can be used to direct control activities to small geographical areas where high transmission is expected. (See sections 3 and 9 for sources of information on prevalence/incidence of infection or disease in your country.) This technique should be validated over time in each setting, as it based on the assumption that hotspots of transmission are relatively constant over time. Although this method does not require timely, well-functioning case notification, it does require geo-location of cases and some expertise in identifying the populations at "greatest risk", or hotspots. In resource-poor environments, the geographical locations of cases can simply be plotted on a map to allow programme staff to visualize risk by area. Community participation can be sought to identify breeding sites, and other features, such as health centres, can be mapped. Programmes with greater expertise or links with research institutions can use more complex tools to identify clusters of cases in time and space from existing data. For example, the Malaria Control Programme in Mpumalanga Province, South Africa used open-source software to detect local malaria clusters (*253*), comparing the observed number of cases in a cluster with the expected distribution if the spatial and temporal locations of cases were independent. These methods can help plan public health activities, including targeted intensified measures in any hotspots identified, such as active case detection, early diagnosis and treatment of positive cases, IRS, top-up LLIN distribution, focal larviciding where vector aquatic habitats are few, fixed and findable, and other health promotion tactics.

Targeting outbreaks to prevent epidemics

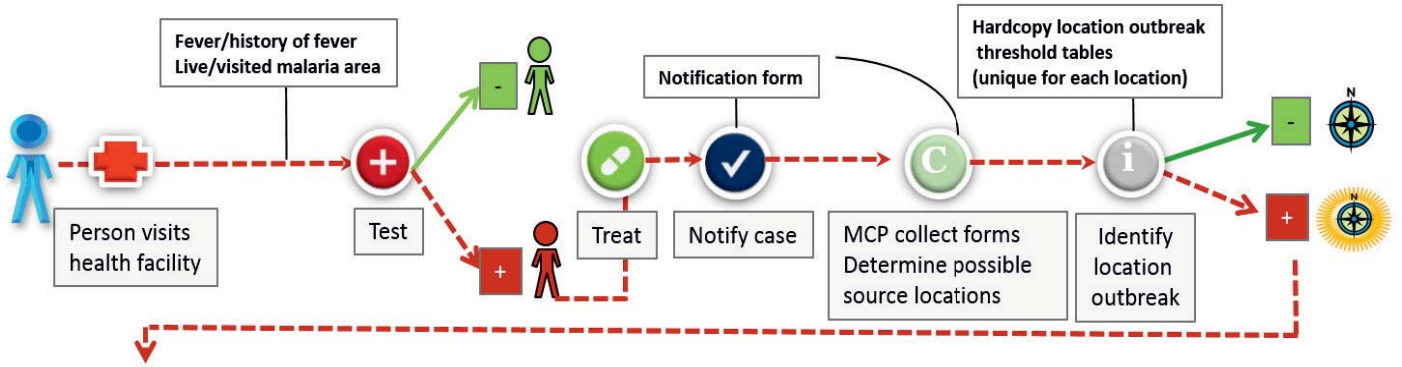
Targeted IVM can be used where transmission is unstable with potential outbreaks or for epidemic response. Its use should be triggered when there are transmission fluctuations in space and time or where population movement brings non-immune people into contact with vector-borne pathogens (e.g. displaced populations in conflict areas).

The approach requires a well-functioning surveillance and health information system with capacity for prompt recognition and reporting of an increase in the number of cases and adequate resources for an integrated, timely response. Cases reported by health facilities are relayed to the vector control programme (passive case detection) (Fig. 25). Often, teams go to the household of a case

and conduct active case detection in the neighbourhood. Predetermined thresholds for each health facility, village or area are used to determine when and where an intervention is necessary. An example of the use of thresholds for outbreak detection in an unstable malaria transmission setting in South Africa is given in Box 12.

In areas at risk of epidemic malaria, IRS may be used as an epidemic response tool, as it has a rapid, reliable short-term impact; in addition, detection and treatment of cases should be strengthened, and LSM could be considered. LLINs are not recommended for epidemic response, although, if access or usage is low in the epidemic area, measures to improve these may be considered.

This approach may not work for all diseases or in all settings. For example, early warning for dengue outbreaks is difficult and not well understand currently. As a result, countries prone to dengue epidemics often implement control measures after the onset of an epidemic, which is in most cases too late to have any impact.



Response

MCP staff, health promotion staff, community members, entomologist and field technitians

- **MCP staff**
  - prioritise outbreak locations for tracing cases
  - verify source locations
  - reactive case detection – test + treat, family and neighbours/special or mass survey
  - case mapping at household level
  - larval source management
  - IRS – if warranted e.g. low coverage
- **Entomologist**
  - vector surveillance, insecticide resistance monitoring
- **Health promotion staff**
  - IEC+BCC activities in effected communities
- **Community members**
  - community mobilization to identify vector breeding sites for management and mapping
  - in case of **epidemic**, distribute personal protection measures

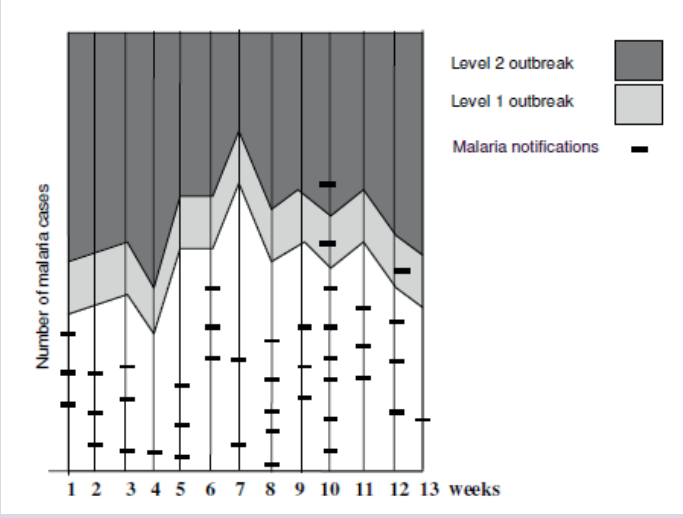
Fig. 25. Use of IVM to target outbreaks

Box 12. Use of case thresholds to identify outbreaks and direct use of targeted IVM (*254*)

A relatively simple system for identifying malaria outbreaks was evaluated in the epidemic-prone rural area of Mpumalanga Province, South Africa, to guide focal malaria control. A system of thresholds for the number of cases triggered malaria control responses. A three-tier system was used, with thresholds at facility, town or village level and the Provincial Malaria Information System. From 5 years of notification data, binomial thresholds were determined for each primary health care facility in the area of Mpumalanga Province at highest risk. Wall charts were drawn that showed outbreak thresholds (outbreak levels 1 and 2), for cumulative charting of daily tallies of confirmed cases against the weekly threshold.

If a threshold was exceeded at facility level (tier 1), the staff notified the malaria control programme, which ensured that stocks of rapid diagnostic tests and treatment were sufficient to manage additional cases. The cases were followed up at household level to verify the probable source of infection. If a threshold was exceeded at town or village level (tier 2), environmental assessment was conducted to identify breeding sites, and larviciding was performed with an organophosphate; IRS coverage was confirmed, and, if the number of cases was sufficiently high at this level for more than one successive week, additional IRS was considered.

An automated electronic outbreak identification system at town and village level (tier 2) was integrated into the Provincial Malaria Information System (tier 3) to ensure that unexpected increases in case notification were not missed. Automatic e-mail alerts to managers at the malaria control programme triggered performance monitoring of tier 2 responses.



The staff had positive reactions to the threshold system, and 84% of health facilities reported outbreaks within 24 h (n=95), 92% within 48 h (n=104) and 100% within 72 h (n=113). An appropriate response to all outbreaks was achieved within 24 h (tier 1, n=113; tier 2, n=46). The binomial outbreak thresholds method performed better than currently recommended outbreak thresholds, such as those recommended by WHO (mean + 2 standard deviations) and CDC (cumulative sum).

Targeting foci of insecticide resistance

Targeted IVM may be useful in the management of foci of insecticide resistance. For example, in areas of high resistance, IRS in addition to LLINs, a mixture of IRS or LLINs with two different insecticides (once available) or use of supplementary methods such as LSM could be used to reduce selective pressure. Such targeting is appropriate for IVM when a blanket approach is not operationally or financially feasible and should be guided by up-to-date information on the susceptibility of vectors to insecticides and resistance mechanisms in the local vector populations.

6.1.2 Temporal targeting

Certain vectors can transmit more than one disease; for example, *An. gambiae* transmits both malaria and lymphatic filariasis, and *Ae. albopictus* transmits both dengue and chikungunya. The vectors of a number of vector-borne diseases increase during the rainy season, offering opportunities for combining operations to increase efficiency, especially where vectors can be controlled by the same or similar interventions. In general, vector populations should be targeted when they are at their lowest densities, before they begin to proliferate, such as at the onset of the rainy season.

Malaria

Universal coverage of all populations at risk of malaria is recommended, and protective measures should be maintained throughout the entirety of the malaria transmission season in order to supress transmission. In areas of moderate or intense seasonal malaria transmission, LLIN distribution or IRS should be conducted before or at the start of the rainy season. LLINs are designed to provide protection for a minimum of 3 years, although field durability varies widely and is often shorter. Most IRS formulations provide protection for 6 months at most, and the residual period depends on the surface sprayed. Thus, where transmission is perennial, two rounds of spraying of an insecticide with 6 months of residual efficacy will be required annually, with more frequent spraying required where residual efficacy is less than 6 months. Spraying should be done at appropriate times to ensure that the protection extends throughout the transmission season. If breeding sites can be located during the dry season, they should be larvicided or removed by environmental management. Communities and the ministry of public works should remove waste and clear drains or build drains before the start of the rainy season. It does not make sense to larvicide during periods of exceptionally heavy rainfall, as many larvae will be washed away and the larvicide diluted. Housing improvement as a long-term investment should be encouraged for sustaining the gains in vector control.

Lymphatic filariasis

Where lymphatic filariasis is transmitted by *An. gambiae*, the same timing of interventions as for malaria control should be used: distribution of LLINs or IRS before the rainy season and targeting of

breeding sites with LSM during the dry season or at the beginning of the rainy season to destroy residual breeding sites. Polystyrene beads to prevent culicines in closed habitats should be deposited at any time except during heavy rains or flooding, when the beads can be washed away.

Cutaneous and visceral leishmaniasis

Interventions against sandflies with seasonal changes in abundance should be targeted at the time of year, before adult vectors begin to increase (*255*).

Onchocerciasis

Larvicides should be applied when the flow rate of rivers is lowest. At this time, the vector population will be concentrated in specific areas, and the cost of larviciding will be reduced.

Dengue

Peak transmission of dengue virus is often associated with periods of high rainfall and high temperatures. Rainfall increases the number of breeding sites available for vectors, and high temperatures increase the frequency with which vectors take blood meals and reduce the extrinsic incubation time.

Some interventions should be in place continually in areas at risk, as a preventive measure. These include LSM (e.g. surveillance of containers for *Ae. aegypti* and treatment or elimination of positive sites) and use of insecticide-treated materials. Other interventions should be reserved for epidemic control, such as indoor ultra-low-volume space spraying conducted in addition to routine interventions.

Human African trypanosomiasis

Vector control interventions should be targeted when tsetse populations are at their lowest. In particular, during the dry season, riverine tsetse will have retracted into dense forest, where they are most easily attacked (*256*). Often, targeted interventions are conducted at the start of the season in which the risk for floods and growth of vegetation are minimal.

6.2 Implementation of integrated vector control

Once the types of vector control tools have been chosen, it is important to consider **how** the intervention will be delivered and by **whom** (vector control programmes, other sectors or community members). These depend on the setting, the resources available, the groups or areas targeted by the intervention and the aims of the programme (e.g. routine control, outbreak or epidemic control, elimination or mosquito abatement). Control programmes should also consider interventions to increase the uptake and correct use of interventions and their sustainability.

High coverage with LLINs and IRS is necessary to have a community-wide impact on transmission. Similarly, in those areas targeted for LSM, interventions should cover a substantial proportion of aquatic habitats. A number of coverage targets have been set and internationally agreed (Table 9). Of particular importance is WHO guidance on achieving universal coverage with LLINs for populations at risk for malaria, which is to use a combination of delivery methods, such as mass free distribution and continuous distribution at various sites, in particular antenatal and vaccination services (*38*). Programmes should follow these recommendations when possible, and their achievement should be tracked and documented as an indicator in a monitoring and evaluation plan.

Interventions that require strong logistical or technical knowledge, such as aerial spraying for tsetse control or indoor ultra-low volume in a dengue epidemic, should be delivered by vector control programmes, which may be able to share costs and resources in delivering interventions. For example, national strategies defining LLIN allocations for malaria vector control could prioritise areas with lymphatic filariasis endemicity.

Cost savings and other benefits can also be achieved when interventions are delivered together, such as the same vector control team performing LSM and IRS or delivery of mass drug administration and LLINs at the same time (see Box 13). Although relatively few LLINs were distributed (38 600), the example shows the feasibility of this approach. Integration of activities not only saves resources but can have synergistic effects on pathogen transmission; for example, integration of active screening for HAT and vector control in the form of small targets had a greater impact on disease prevelance than active screening alone (*259*).

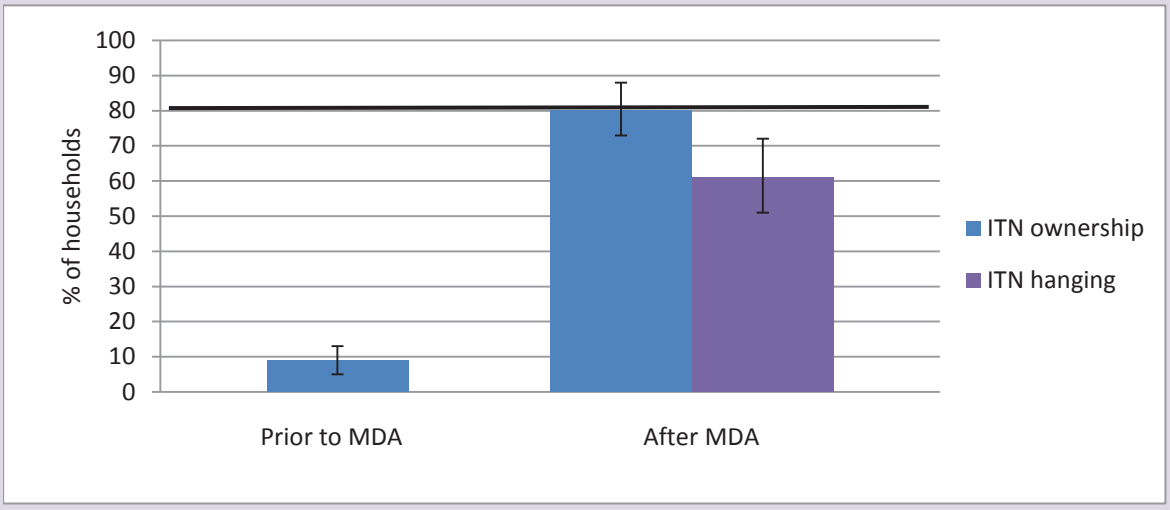
Table 9. Target coverage levels of interventions

Disease	Intervention							
	LLINs	Insecticide-treated curtains or screening	IRS	Larval source management	Indoor ultra-low volume spray	Molluscicides	Traps or targets	Insecticide-treated cattle
Malaria	Universal coverage (*38*)		> 80% (*257*)	As many breeding sites as possible				
Lymphatic filariasis	(Rural transmission) Universal coverage* (*38*)							
Dengue		> 70% (*114*)						
Leishmaniasis	Universal coverage (*38*)		> 80%					
HAT							*Trypanosoma brucei gambiense*: 50 m apart (*159*) *Trypanosoma brucei rhodesiense*: four baits km^2 (*158*)	
Onchocerciasis				As many breeding sites as possible				
Rift Valley fever								Treatment of all domestic livestock
Schistosomiasis						As many water bodies as possible		

Universal coverage is defined as one LLIN per two people, *most likely to be effective at lower coverage (*258*).

Box 13. Integration of LLIN distribution with mass drug administration for lymphatic filariasis and onchocerciasis in central Nigeria (adapted from *260*)

In Africa, anopheline mosquitoes transmit malaria and lymphatic filariasis, and LLINs are likely to reduce transmission of both diseases. Provision of LLINs, in particular to target groups such as children under 5 years and pregnant women, is a major goal. In this study, LLINs were delivered during mass drug administration for lymphatic filariasis and onchocerciasis in central Nigeria in 2004. Community volunteers distributed 38 600 LLINs and at the same time treated 150 800 people with ivermectin and albendazole (compared with 135 600 in 2003). Changes in LLIN coverage and use were assessed in a 30-cluster survey. Of surveyed households with children under 5 years and pregnant women, 80% (95% CI, 72–87%) owned one or more insecticide-treated bed nets, nine times more than in 2003. The graph shows percentage LLIN ownership and use by households with vulnerable sleeping spaces before mass drug administration in 2003 and after mass drug administration in 2004.



Linkage of LLIN distribution with mass drug administration resulted in a substantial improvement in LLIN ownership and use, without adversely affecting drug coverage. The integration meant that the two programmes could share resources and realize mutual benefits. This is one model for rapidly improving coverage with LLINs.

6.3 Involving the non-health sector

The health sector has conventionally been responsible for vector control, and interventions that require strong logistic support, such as IRS, usually require the specialist skills and capacity of the health sector. Each type of intervention need not necessarily be implemented and maintained by the government health sector, however, and offices other than health and other organizations can and should share the responsibility for certain vector control methods or certain areas. Partners such as NGOs, communities, schools, the private sector and public sectors such as agriculture, construction and local government also have important roles in planning and implementing vector control and personal protection. Strong policy support and advocacy from the IVM steering committee is required for intersectoral collaboration. Interventions in other sectors can not only reduce vector-borne diseases but can also help to improve well-being. For example, drainage of wetland areas can reduce biting mosquitoes, and installation of piped water for dengue control rather than storing water in the home is beneficial for women and children. The intersectoral steering committee should create awareness of the important role of the non-health sector in vector-borne disease, for example by highlighting the way dam construction and agricultural irrigation schemes create suitable vector habitats.

Examples of interventions against vector-borne disease that can be initiated outside the health sector are outlined in Table 10. For example, LLINs can be distributed by NGOs but in coordination with NMCP. Drainage schemes to reduce mosquito breeding sites can be implemented for example, by the ministry of public works. Wetlands can be dried by planting eucalyptus trees, which would be the responsibility of the department of forestry, or made unfavourable for the aquatic forms of An. gambiae by regenerating papyrus swamps, which would provide shaded areas unsuitable for this mosquito. Environmental management in agricultural areas, irrigation systems, construction sites, waterways and peri-urban areas could be administered by the agriculture, irrigation and environment sectors and local government (Fig. 26).

Fig. 26 Environmental management by clearing drains to reduce breeding sites (photo courtesy of S. Lindsay)

Schools and work places may be particularly prone to daytime biting vectors (e.g. those of dengue) and should therefore be involved in vector control. Box 14 gives a practical example of the involvement of the Ministry of Education of Brazil in health promotion for primary school children about dengue. Malaria control in Khartoum, Sudan, within the Khartoum Malaria Free Initiative is a good example of the involvement of a number of sectors and community participation in vector control (Box 15). Strong political will and effective intersectoral collaboration have been integral to the success and sustainability of the Initiative. While interventions can be initiated and implemented outside the health sectors, they should be supervised and coordinated by the IVM focal person at regional or district level.

Table 10. Interventions against vector-borne disease could be initiated outside the health sector

Intervention	Ministries or organizations involved in implementation
Health education and promotion	Schools, ministry of education, work places, the media (TV, radio, Internet), drama groups, NGOs, religious and community groups
LLINs, IRS, insecticide-treated sheeting or tents	NGOs, United Nations, vector-borne disease control programmes, private sector, ministry of tourism, women's groups
House improvements and screening	Ministry of housing, NGOs, community members
Drainage	Department of public works, local government
Drain clearance	Youth groups who collect rubbish to sell, community members (Fig. 27)
Drying out of breeding sites	Department of forestry, local government, community groups
Swampland restoration	Department of the environment
Removal of obsolete concrete water storage containers	Department of public works, contractor, local government
Filling and levelling	Department of public works, local government
Maintenance of irrigation channels or flushing	Farmers, ministry of agriculture, irrigation authority
Removal of vegetation from the edges of water bodies	Farmers, community members
Intermittent irrigation	Farmers, ministry of agriculture, irrigation authority
Improved housing	NGOs, microfinance initiatives, department of housing
Larval or snail surveys and application of larvicides or molluscicides	Schools, community groups, municipal corporations, public health staff, farmers
Improvement of environmental sanitation	NGOs, department of public works, local government
Water supply and sanitation	Ministry of water resources, ministry of environment and sanitation, NGOs
Social and environmental responsibility, e.g. tyre disposal	Private companies
Solid waste and container disposal	Rubbish collectors, local government, youth groups, industry
Insecticide-treated cattle	Farmers, ranch owners, veterinary services
Topical insecticide or insecticide-treated collars on dogs	Dog owners, veterinary services or Ministry of Livestock's, local municipalities
Culling of reservoir animals	Community members, veterinary services, local municipalities
Destruction of habitats of rodent reservoirs of leishmaniasis	Farmers, community members, local municipalities

Fig. 27. Drains are excellent breeding sites for culicines and should be cleaned, treated or made inaccessible to vectors (photo courtesy of S. Lindsay)

Box 14. Primary school education as a strategy for dengue control (*261*)

A study was conducted in Botucatu, São Paulo (Brazil), to determine whether education of primary school children could be used as a strategy for dengue control, by empowering the children to be "agents of change" in their communities. The educational intervention consisted of an explanation of the biology and development of the mosquito, information on the disease and the virus, transmission and prevention. In addition, a video on dengue was shown, debates were held, and the children observed the life cycle of the mosquito under a microscope and completed written exercises.

The effect of the intervention was measured by quizzing the children before and after the 2-week programme. Children scored better on the quiz after the intervention, with better knowledge of the life cycle, transmission of dengue by adult mosquitoes, breeding sites (including identifying breeding sites in their homes), control measures and disease symptoms.

While the study could not show whether the intervention had an impact on action being taken against the vector, some studies have shown that such interventions can favour a change in the behaviour of the population, resulting in a decrease in breeding sites.

Box 15. Malaria control in Khartoum, Sudan (*262–264*)

The Khartoum Malaria Free Initiative was launched in 2002 by the State and the Federal Ministry of Health in response to a high malaria burden: in the 1980s and 1990s, malaria was the major reason for outpatient attendance, admission and death in Khartoum. After the Initiative was launched, the total number of malaria deaths decreased by almost 75%, from 1070 in 1999 to 274 in 2004, and the parasite prevalence decreased from 0.78% to 0.04% between 1995 and 2008.

The Initiative has three components; diagnosis and treatment, prevention and epidemic surveillance, and employs 14 trained medical entomologists, 60 public health officers, 180 sanitary overseers, 360 assistant sanitary overseers and 1170 spray staff. The mainstay of prevention is control of the primary malaria vector *An. arabiensis*, which breeds mainly in irrigation canals, pools created from broken water-pipes, water basins and storage tanks. New agricultural schemes and new construction sites continually create more breeding sites. A number of vector control methods have been used:

- Larviciding and environmental management are undertaken by the Initiative.
- Removal of water basins and storage tanks is enforceable by law.
- Regular drying of irrigated fields is compulsory in Government and private irrigation schemes and is supported by the Farmers Union and the Ministry of Agriculture. In 2011, 98% of irrigation schemes were dried for at least 24 hours every week.
- In collaboration with the ministries of Irrigation and Agriculture, any leakage from irrigation canals is repaired, and vegetation around canals is cleared.
- The Ministry of Health collaborates with the Public Works Department to repair or replace broken water-pipes. The Initiative is responsible for surveillance, reporting and transport, while the Public Works Department provides engineers and equipment. By 2004, almost 4 km of water-pipes had been replaced and over 6 km repaired.
- The Initiative has strong community support, generated by the distribution of information leaflets, regular radio broadcasts and television coverage, health education in schools in collaboration with the Ministry of Education, organization of an annual Khartoum State Malaria Day, public meetings and the establishment of malaria control committees and societies.
- 405 schools and 287 000 pupils are involved in mosquito larval control activities.
- While LLINs are not distribution through public campaigns or routine systems in Khartoum, sale in the private sector has been encouraged through low pricing due to tax exemptions for LLINs
- Malaria case management is strengthened by training in malaria diagnosis and case management and provision of antimalarial drugs through a revolving drug fund.

The Initiative has strong political support from both State and federal authorities, and there is close collaboration between the State government, the Federal Ministry of Health and other ministries, including those for education, public works and agriculture. The involvement of other sectors has helped to keep costs low: the total annual cost of the programme (which targets a total population of 2 million in urban areas, 3 million in peri-urban areas and 0.6 million in rural areas) is US$ 600 000 or about US$ 0.10 per person protected per year.

6.3.1 Community participation

All vector control activities need community support and participation; therefore, considerable effort should be put into engaging local communities. Communities can be involved in certain vector control activities, in particular environmental management; for example, community participation can be crucial for source reduction. Examples are given of community participation for dengue control in South America (Box 16) and environmental management for urban malaria control in Uganda (Box 17). As dengue is an emerging problem in Africa, it will be useful to learn from established programmes in South America that incorporate strong elements of community empowerment and intersectoral collaboration. Box 18 shows the example of farmer field schools, in which standard curricula for improving crop yields and reducing pests are tailored to include malaria control, and farmers are empowered to design and evaluate their own control experiments. Box 19 gives an example of community-based trapping for tsetse control in South Sudan, which showed not only benefits against disease but also community empowerment. An excellent example of capacity-building of community-based health extension workers for implementing IRS in Ethiopia is given in Box 25.

Box 16. Community involvement in dengue control (*265*, *266*)

Community-based strategies for dengue control involving intersectoral collaboration, health education, environmental management and community participation have been tested in a number of countries in South America.

"Clean Backyard" strategy, Mexico

In Mexico, the *patio limpio* or "clean backyard" strategy has been used to train community members to identify and eliminate breeding sites, emphasizing the importance of each household in the fight against dengue and the common aim of a dengue-free community. First, a local assembly is held with community members, where the concept is explained, and community leaders known as "block activators" are identified and receive training. The block activators then train community members on their block in identifying and eliminating breeding sites and help them understand the benefits of keeping their house clean. The block activators assess the area under their control each month and attend community assemblies, where the results of surveillance are fed back to the block activators and recommendations made when the expected outcomes are not met. The effect of the strategy on mosquito breeding sites in Guerrero, a state in south Mexico, was assessed during 1 year (2007). The communication strategy included not only training of block activators and community mobilization but also 18 signboards and 130 posters, three daily loudspeaker transmissions in areas such as shopping centres and markets throughout the community and distribution of pamphlets to every household. More than 1000 block activators were identified and trained, each managing an average of 15 households. Of a sample of 5477 backyards, 54% (2918) were designated as "clean" and free of breeding sites. Further analysis revealed that the households that were not visited or assessed by a block activator had a 2.4 times higher risk for dengue than those that had been trained and supervised by an activator. In addition, 80% of trained households were able to identify a breeding site and mosquito larvae at the 3-month follow-up visit. Sustaining the behaviour change was identified as a problem in the follow-up survey at 1 year, which indicated that only 30% of trained households had a clean backyard and were aware of the risks associated with breeding sites.

Action research to stimulate community participation, Santiago de Cuba, Cuba

A quasi-experimental study was conducted in Santiago de Cuba, Cuba, to assess the effect of an intervention to stimulate community participation in dengue control on the basis of entomological parameters. The aim was to mobilize the community to participate in all stages of *Ae. aegypti* control, from problem identification to evaluation. The following steps were followed:

- Formative research was conducted with social research methods (e.g. knowledge, attitudes and practices surveys, focus group discussions, behavioural observations) to design the intervention.
- Community working groups were formed with 10–20 members, including formal and informal leaders, public health workers from the Government vector control programme and doctors and nurses in neighbourhood family practices. The groups were responsible for coordinating local intersectoral action and were asked to find ways of involving the community.
- The groups held meetings with the community to identify needs and priorities for dengue control.
- Action plans were prepared according to the priorities of the vector control teams and community members.

Cont.

A social communication strategy, with face-to-face encounters, community meetings and local mass media, was used to mobilize the community and promote behaviour change with respect to larval source and environmental management, such as covering water storage containers, removing containers that could fill with water and being compliant with the use of temephos in water storage containers. The groups obtained material (cement, wood and nylon) free of charge from the local government to repair water containers and construct covers. The groups also negotiated with Government intersectoral committees for action on larger projects such as repairing broken water-pipes and sealing the foundations of buildings that served as breeding sites. Additionally, risk surveillance was set up and conducted by the community with tools for mapping intra-domiciliary and extra-domiciliary environmental risks.

After the intervention, risk behaviour in households was reduced: keeping uncovered water storage containers decreased from 49% to 3%, and removing larvicide from water containers decreased from 46% to 1% between 2000 and 2002. Entomological parameters were also reduced, with a reduction in the absolute number of positive containers by 75% and a significant reduction from 1.2% to 0.4% in the house index (percentage of houses infested with *Ae. aegypti* larvae or pupae).

Thus, local community working groups were able to engage community members and local government to resolve problems of mutual concern; however, the project was time-limited and its sustainability remains unclear.

Box 17. Community-based environmental management for urban malaria control in Uganda
(adapted from *267*)

Environmental management for vector control involves either habitat modification or manipulation to prevent or minimize vector propagation. A study was conducted to assess the strengths and weaknesses of a community-based environmental management programme for malaria control in two Ugandan cities: Kampala and Jinja. Both cities provide ample breeding sites for malaria vectors. In Kampala, high rainfall results in rapid run-off of large volumes of water that collect in valley bottoms throughout the city; Jinja, being located next to Lake Victoria, has large areas of swamp.

Initially, entomological and clinical surveys were conducted to determine the level of transmission and intensity of infection in different areas of the cities. Four sites were chosen in each city: in Kampala, samples were taken in small valleys with flooded brick pits where clay is collected for brick-making; in Jinja, the sampling sites were close to farmland or swamps.

On the basis of the survey findings, control options were identified, and a participatory approach was used to prepare community action plans specific to the vector ecology at each site. In partnership with local health authorities, the community was mobilized during house visits, and meetings were used to inform and engage communities such as young people, women's groups and brickmakers. Communities selected the packages of interventions that they considered appropriate. For example, in Kampala, communities decided to fill in puddles, drain the brick pits and introduce larvivorous fish into larger water bodies. In the second year of the study, the communities worked with the support of local health authorities, the study team and engineers.

Box 18. Farmer field schools: involving rural communities in malaria control (adapted from *268*)

Agricultural environments can provide ample breeding sites for malaria vectors, as clear temporary water bodies coincide with the time of crop cultivation and there is often a ready supply of human and animal hosts as blood sources in close proximity. Widespread use of insecticides for agriculture may also contribute to resistance in malaria vectors to public health insecticides

Malaria control has been integrated into a complementary intervention in rural development known as "farmer field schools" for integrated pest management. The schools are a form of education in which the concept of learning based on experience is used to build farmers' expertise. During the crop cycle, a group of 15–30 neighbouring farmers meet weekly to make field observations and discuss crop pests, beneficial organisms, plants, soil and environmental conditions. The farmers are encouraged to design experiments (e.g. "What if, instead of spraying, we drain the water to control plant hoppers in rice?"), which are evaluated the following week. These weekly learning cycles strengthen the skills and increase the confidence of farmers, and group dynamics and communication exercises are conducted to strengthen group cohesion, maintain motivation and help the farmers to develop organisational skills. A review of farmer field school experiences indicated positive outcomes, including drastic reductions in use of agro-pesticides, economic benefits and empowerment.

In malarious areas, the integrated pest management curriculum can be amended to include the ecology and control of malaria and to involve farmers and others in the control of malaria in their environment, by integrated pest and vector management. The best-documented pilot study of this approach was conducted in Sri Lanka, where the curriculum has been adapted for the wetland rice ecosystem. Farmers are encouraged to identify malaria breeding habitats by sampling with dippers, to study the mosquito life-cycle by rearing young larvae in water jars covered with mesh, and sampling and identifying adults of the three main mosquito genera at different times and habitats to understand disease vector activity. Farmers also assess the effects of agricultural methods for suppressing mosquito breeding (e.g. alternate wet–dry irrigation of field plots, land levelling at planting) and draw maps of the village environment, with water bodies, crops, houses, etc. to facilitate planning of coordinated environmental management.

Farmer field schools can reduce malaria in four ways: reduced pesticide use reduces selection pressure on malaria mosquitoes; increased awareness and understanding of malaria increases personal protection and treatment-seeking behaviour; increased profits from agriculture are link to improved housing, nutrition, treatment access etc; and environmental management reduces vector breeding and thus transmission of disease.

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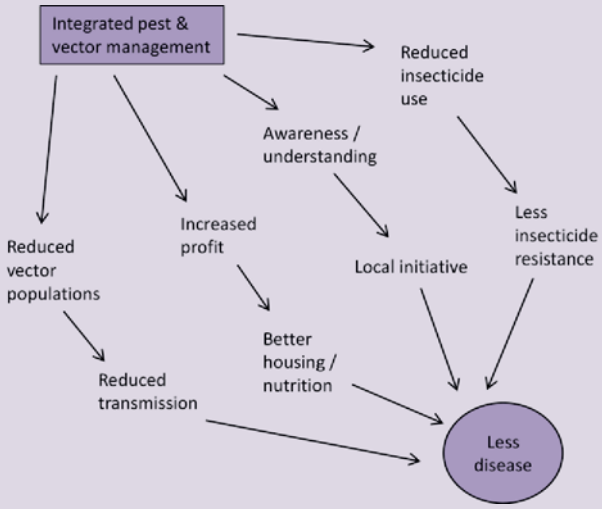


Although this example is from Sri Lanka, the farmer field school concept is established in sub-Saharan Africa for increasing agricultural productivity; thus, the curricula could be adapted to different ecosystems where malaria and other vector-borne disease are present.

Box 19. Community-based tsetse fly trapping in South Sudan (from *269*)

South Sudan experienced a resurgence of HAT in the 1990s. Seroprevalence surveys organized by the Cooperative for Assistance and Relief Everywhere (CARE), the International Medical Corps and the United States Centers for Disease Control and Prevention identified foci of high transmission. In one of these foci (Tambura County), a community-based tsetse trapping project was introduced, alongside mass screening and treatment. Villages participated in making, setting and maintaining more than 3000 pyramidal traps, which were placed near places of increased human–vector contact, including village farm plots, water sources and areas in which people gathered firewood.

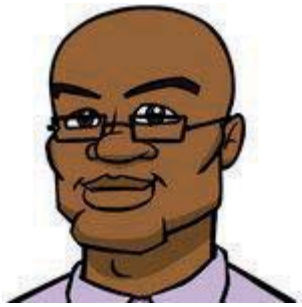
A train-the-trainer approach was used. National health officials were trained in tsetse fly biology and control methods. Community mobilisation was carried out before community selection of 350 volunteers. Volunteers were mainly traditional birth attendants. County health officials and the volunteers prepared village maps marked with sites for trap placement. The volunteers were trained to collect flies from the traps and were given bicycles so that they could collect and submit caught flies to county health officials. County officials, in collaboration with CARE monitored fly density over time. The density of flies caught in traps dropped from 25 per trap per week at the beginning of the project to fewer than 3 flies per trap per week. Importantly, seroprevalence for HAT fell from 9% to 2% between 1997 and 1999. Another benefit of the intervention was that community members learnt about the causes and prevention of sleeping sickness and were more willing to participate in screening and seek treatment.

6.3.2 The private sector

In some areas, it may be beneficial to involve the private sector in IVM, whether in the tourism sector, employer-based vector-borne disease control programmes or social responsibility projects. The tourism sector in particular should be encouraged to invest in vector-borne disease control, as a reduction in these diseases in an area will have a positive impact on the number of visitors. For example, hotels may have some contribution to the introduction of arboviruses or parasite strains from other areas, and should therefore be encouraged to practice source reduction around the premises, surveillance and other measures to prevent the establishment of new strains in the community. Industries such as mines and plantations might run vector-borne disease control programmes in collaboration with local partners or to complement national activities, as in the example of Anglo Gold Ashanti in Ghana (Box 20). Ranches in areas endemic for HAT could be encouraged to implement control measures, such as insecticide-treated cattle (*166*).

Investment in vector-borne disease control has economic and social benefits, and several examples exist showing the cost effectiveness of employer-based malaria control programmes (*270*). Companies can be encouraged to undertake social responsibility projects in communities, such as the support by Marathon Oil of the National Malaria Control Programme on Bioko Island, Equatorial Guinea, which has helped to reduce the malaria burden (*271*). Alternatively, vector control programmes can leverage partnerships with the private sector, as a source of external funding

beyond the non-traditional donors, or to accelerate the uptake of interventions or build on existing control operations by providing financial or human resources, expertise and advocacy. A management guide is available to help companies or organisations operating in malaria-endemic regions of Africa to develop an effective malaria control programme (*272*).



Key point

Vector control programmes should consider partnering with the private sector in vector-borne disease control activities. There are economic (reduced direct and indirect costs of vector-borne diseases) and social (build reputation of company for social responsibility and good corporate citizenship) benefits of businesses investing in VBD control.

Box 20. Business investment in malaria control: Anglo Gold Ashanti in Ghana (adapted from *270*)

The gold mining company Anglo Gold Ashanti is based in Obuasi, Ghana, an area endemic for malaria. In 2004, malaria accounted for 22% of all deaths in the community, and the local hospital and clinics saw as many as 12 000 confirmed and unconfirmed cases of malaria per month. The cost to the company in providing malaria care to workers and their dependants was massive, amounting to approximately US$ 55 000 a month on treatment alone.

To address this problem, the company decided in 2005 to set up an integrated malaria control programme focusing on mineworker housing and infrastructure, as well as surrounding villages. The programme was developed and conducted in partnership with the Ghana Health Service, the Ghana National Malaria Control Programme and the Obuasi Municipal Assembly. It was also aligned closely with Ghana's National Malaria Plan. The programme consisted of vector control (LLINs, IRS and larviciding), diagnosis, treatment of confirmed cases with artemisinin-combination therapy and information, education and communication campaigns.

After implementation of the programme, the number of malaria cases at the mine hospital fell from 6600 cases a month in 2005 to 1150 cases a month in 2009. Absenteeism due to malaria was also reduced: the average monthly number of days of work lost to malaria fell from 6983 in 2005 to 282 in 2009. The average monthly medication cost to the company was also reduced, from US$ 55 000 in 2005 to US$ 9800 in 2009.

6.3.3 Supporting interventions

Once vector control tools have been selected, supporting interventions should be decided on. Communities must be informed about the diseases, their transmission and control methods. Supporting interventions can encourage correct use and care of interventions such as LLINs. For example, LLIN distribution campaigns could be accompanied by distribution of messages for behaviour change through radio spots, posters and leaflets, or may be followed by "hang-up" campaigns, in which community volunteers visit households to hang up nets and distribute messages about the benefits and use of LLINs. Two examples of the use of theatre, songs and dance to inform communities about diseases and control methods and encourage behaviour change are described in Box 21. Text-messaging could also be used to distribute messages and encourage behaviour change (*273*). For example, text-message reminders of visits for intermittent preventive treatment of malaria in pregnancy could be combined with messages on LLIN use (*274*).

Box 21. Use of folk theatre to encourage behaviour change for malaria control (*275*, *276*)

Kalajatha is a popular traditional form of folk theatre in India. It is an effective medium of mass communication in the Indian sub-continent, especially in rural areas where, because of a low literacy rate, many conventional methods such as posters, pamphlets, and electronic media have limited effect.

In 2001, *kalajatha* was used to disseminate health education messages for bio-environmental control of malaria in Tumkur District, Karnataka State, India. The National Institute of Malaria Research and the Community Health Cell in Bangalore jointly initiated the programme, with coordination by an intersectoral committee. Support of local government was obtained. The district health committee headed by the District Commissioner approved the proposal for the programme. The departments of Health, Education, Child and Women's Welfare, Rural Development and Panchayat Raj (local assembly), the Tumkur Science Forum and local political and religious leaders participated in the programme.

Thirty local artists were selected, and a scriptwriter wrote songs, drama and musical drama. The topics covered included the signs and symptoms of malaria, treatment, health facilities, transmission, the role of *Anopheles* mosquitoes and breeding sites of mosquito vectors. The theatre pieces also covered malaria control strategies, focusing on larvivorous fish (*Poecilia reticulata* and *Gambusia affinis*) and environmental management. Community leaders gave consent for the events, and local media publicized the events widely, which also helped to spread the key messages.

The impact of the theatre events was assessed after 2 months with a semi-structured questionnaire, by comparing the knowledge of people who had attended *kalajatha* with that of people who had not. Those who had attended had significantly more knowledge about malaria, its symptoms, transmission and control methods. They could easily associate clean water with anopheline breeding and the role of larvivorous fish in malaria control. A year after the *kalajatha* events, the community participated in releasing larvivorous fish, which resulted in a reduction in malaria incidence (276).

Another example of the use of folk theatre for behaviour change is Netos de Bandim, a youth dance group based in Guinea-Bissau. The group designs community education campaigns with dance, theatre, music, poetry and dialogue to convey public education messages. They have conducted campaigns on HIV/AIDS, cholera and malaria.

In 2011, Netos de Bandim worked with UNICEF to educate over 2000 families in 10 Bissau neighbourhoods about malaria prevention. The leaders of the group learnt about key communication messages to work on with the younger members, who in turn worked in groups or individually to come up with role plays, songs and poetry to help convey the messages. The dance group delivered these behaviour change messages by organising large block parties in Bissau neighbourhoods, which drew large crowds because of the reputation and following of Netos de Bandim. When young people in the community saw the plays, they mimicked the messages and reproduced them daily in their communities as a game, which helped to reinforce the messages.

The project has enabled over 100 young people in the dance group to learn about malaria and to exercise leadership by teaching their community about malaria prevention. The approach also preserves and encourages appreciation of dance forms and other cultural traditions, which helps to promote ethnic tolerance and social cohesion.

6.3.4 Cross-border initiatives

In some situations, it might be worth considering cross-border initiatives for vector-borne disease control. Examples include the Trans-Kunene Malaria Initiative in Cunene and Namibe provinces in Angola and the Kunene, Ohangwena and Omusati regions in Namibia. Another example is the Lubombo Spatial Development Initiative, which was a cross-border collaboration for malaria control between Mozambique, South Africa and Swaziland (Box 22). Cross-border initiatives have also been implemented for control of HAT, such as the regional tsetse and trypanosomiasis control programme between Malawi, Mozambique, Zambia and Zimbabwe in the 1980s (*277*) and Farming in Tsetse Controlled Areas (FITCA) between Ethiopia, Kenya, Uganda and the United Republic of Tanzania in the late 1990s to early 2000s (*278*). Where areas of tsetse infestation cross country boundaries, a coordinated effort is required to control the flies successfully and prevent reinvasion.

Box 22. Lubombo Spatial Development Initiative for malaria control (*278*, *280*)

The Lubombo Spatial Development Initiative was a tri-lateral development programme between the governments of Mozambique, South Africa and Swaziland, which included malaria control as a key component. The Lubombo region comprises eastern Swaziland, southern Mozambique (Maputo province), and north-eastern KwaZulu-Natal. The Initiative was established in 1999 with the signing of a protocol of understanding by the heads of state of the three countries that set up the programme, coordinated by the Malaria Research Unit of the South African Medical Research Council. The tri-national group met quarterly to address any issues. Comparatively strong control programmes in South Africa and Swaziland meant that the focus of the programme was to extend effective control into southern Mozambique, which was an important reservoir of transmission and a point source for imported cases, given the substantial population movement across the region. The programme comprised prompt diagnosis and treatment of malaria and vector control, mainly with IRS. IRS was conducted in southern Mozambique in a staged fashion between 2000 and 2004, and the impact was monitored by annual cross-sectional surveys to assess the prevalence of *P. falciparum* infection, entomological monitoring and malaria case notification in South Africa and Swaziland. Significant reductions in the prevalence of *P. falciparum* were reported in southern Mozambique, with fewer notified cases in South Africa and Swaziland during the same period. The project was so successful that it was extended to Gaza Province in Mozambique, which borders Mpumalanga and Limpopo provinces in South Africa. This brought the contiguous area under malaria control by the programme to more than 200 000 km^2.

Capacity and infrastructure development played a large role in the programme. For example, the malaria control offices of the Initiative worked in close collaboration with provincial health departments in Mozambique. Local staff were trained to coordinate and manage the programme with training and supervision by experts in South Africa and Swaziland. Annual training camps for IRS operators were held before each spraying round to ensure that they were competent and maintained consistency across areas. Health care providers were trained in malaria diagnosis, treatment, monitoring and evaluation. A comprehensive malaria information system with a spatial component was developed, which facilitated planning and monitoring of spraying by providing managers with information on malaria cases and vector control activities. The success of the programme in reducing malaria transmission throughout the target area provides a strong argument for investment in regional malaria control.

Section summary

- For IVM implementation, it is important to consider **what**, **where**, **when** and by **whom** interventions will be implemented, and **how**?
- Vector control can be targeted in space and time, usually against a background of interventions such as LLINs which are usually maintained across multiple years.
- By evidence-based targeting of vector control interventions in space and time, resources can be used more strategically under routine conditions, or areas can be targeted for epidemic control or foci of insecticide resistance.
- The timing of implementation should be considered in order to maximize the effects of the intervention on vectors and disease.
- Interventions that require strong logistical support and technical knowledge are generally implemented by or on behalf of vector control programmes.
- Delivery of several interventions simultaneously can have a number of benefits, including resource savings.
- IVM should involve other sectors in vector control, when possible. Community participation and the skills and resources of private sector companies should be used.
- Regional partnerships such as the Lubombo Spatial Development Initiative can be beneficial in vector-borne disease control.

7. Operational and implementation research

IVM programming should be based on evidence, ideally from sound operational research and surveillance. Countries should identify research questions for operational planning and implementation of IVM. A working group could be set up within the IVM steering committee to identify suitable questions. Types of questions that could be answered by operational research are listed in Box 23, many of which are illustrated with practical examples.

Box 23. Types of questions that could be addressed by operational research

Efficacy	• What is the added benefit of LSM in areas with LLINs for malaria control?
Delivery	• Can community health workers delivering preventive chemotherapy also apply larvicides to breeding sites?
	• Can community groups conduct environmental management?
	• Can community members install, maintain and monitor traps for tsetse flies? (Box 19)
Targeting	• Is targeted IRS for leishmaniasis more effective than blanket spraying?
	• Are people living next to irrigation canals more likely to have malaria?
	• Can geographical information systems be used to target interventions more effectively at district level?
Community mobilization, acceptability, adherence	• How effective are behaviour change communication radio spots for increasing adherence to use of LLINs?
	• Does an educational intervention on dengue transmission and prevention in schools increase the knowledge of pupils and their families? (Box 14)
Cost, cost–effectiveness	• Is IRS by community health workers more cost–effective than by a vector control programme? (Box 25)
Surveillance	• Can mobile technology be used to collect information on cases from peripheral health centres? (Box 29)
	• Can schoolchildren identify rodent habitats for zoonotic leishmaniasis?
	• Can community members operate and collect mosquitoes from window traps?
	• Can community members identify larvae and map and survey larval breeding sites? (Box 27)

To answer these operational research questions, various study designs will be required. Studies of the efficacy of an intervention will be experimental and often randomized. Studies of the feasibility of community delivery of interventions might evaluate training, intervention coverage, cost and use of resources and community satisfaction. Studies measuring adherence will usually evaluate this

using cross-sectional surveys. A good general resource for different types of field trials is *Field trials of health interventions in developing countries: a toolbox* (*281*).

7.1 Efficacy of vector control interventions that are not yet approved by WHO

The efficacy of vector control interventions not yet approved by WHO must be tested in robust trials against epidemiological outcomes. For an intervention to receive a recommendation from WHO it needs to show a public health impact. Entomological outcomes might also be assessed to support the clinical findings. Interventions like LLINs and IRS are often considered to have a community effect on the vector population, killing so many vectors that they reduce the survival of the whole population, thus reducing the proportion of older vectors, which are most likely to be infective. Studies of these interventions are generally cluster-randomized controlled trials, in which communities or geographical areas are randomly allocated to control or intervention. Studies must be conducted rigorously, with adequate sample sizes, so that they can answer the research question. To conduct clinical trials, vector-borne disease control programmes should partner with research institutions in the country or overseas.

Key point

If you wish to test a new intervention, perhaps developed in your country or elsewhere, it is a good idea to partner with academic or research institutes that can share their knowledge on designing, evaluating and analysing complex studies.

7.2 Pilot-testing and scaling up recommended vector control interventions

Interventions approved by WHO, such as WHOPES-approved insecticides for IRS or larvicides for LSM, are based on robust evidence and do not generally have to be tested in randomized controlled trials in a country before use. Nevertheless, local entomological and socio-behavioural parameters must be measured to ensure that, for example, the feeding or resting behaviour of the vectors and community acceptance support the intervention. Pilot testing may be useful to evaluate new or multiple interventions in an area, to monitor and evaluate their effect in a small area (for example, a district) before using them on a wider scale. Small pilot studies provide an opportunity to refine the vector control methods and train staff before wider application.

The minimum type of study recommended for pilot implementation is a controlled before-and-after design, with entomological data collected before and after introduction of the intervention, and at the same times in the control group (which does not receive the intervention).

Each group in a pilot study should comprise one to four clusters of communities or defined geographical areas. As vector density often depends on the weather, in particular rainfall, it is a good idea to collect both meteorological and entomological data. Ideally, there should be a control site, where the intervention is not implemented but entomological measurements are conducted in the same way as at the intervention site; this can control for other factors that might affect the results. A randomized trial is preferable, as with this design each arm of the trial is more likely to have similar villages (or sites in urban areas). For example, a sentinel site could be divided into two areas, which are randomly assigned either to receive the intervention or be a control. If interventions are allocated randomly, baseline entomological data might not have to be collected, although it is good practice to do this anyway if there are only a few clusters.

Collection of entomological data is recommended for at least 4–6 months both before and after the intervention, or for a whole transmission season if possible, depending on the seasonality of transmission and the urgency of vector control. Ideally, the sampling sites for entomological data collection should be selected randomly. The minimum requirements for a pilot study, alongside stricter requirements for a higher-quality study are listed in Table 11.

Table 11. Requirements for a pilot study

Criterion	Minimum requirement	Stricter requirement
Control site	Control site	
Randomisation	Non-randomized allocation of areas to intervention and control	Randomized allocation of areas to intervention and control
Pre-intervention data	4–6 months of baseline entomological data from intervention and control areas	1 year or transmission season of entomological and clinical data from intervention and control areas
Post-intervention data	4–6 months of post-intervention entomological data from intervention and control areas	1 year or transmission season of entomological and clinical data from intervention and control areas
Data collection	Entomological and meteorological (e.g. rainfall)	-
Replication of study units	At least one data unit (e.g. village or area) per arm	More than one data unit (e.g. village or area) per arm or the number of data units required by sample size calculation that will show an effect on entomological and/or clinical indicators
Selection of sites for entomological monitoring	Non-random	Random

The effectiveness of the intervention should be evaluated against entomological criteria. Epidemiological data can be collected, but this often requires a study with a large sample size (with adequate power) to detect an effect. It is recommended that an intervention that reduces adult vector density by at least 50% should be scaled up (*48*, *282*). The results of pilot studies should be used not only to measure the effectiveness of an intervention but also to establish best practices. Sentinel sites can then serve as training sites for regional control programmes if the intervention is used.

Key point

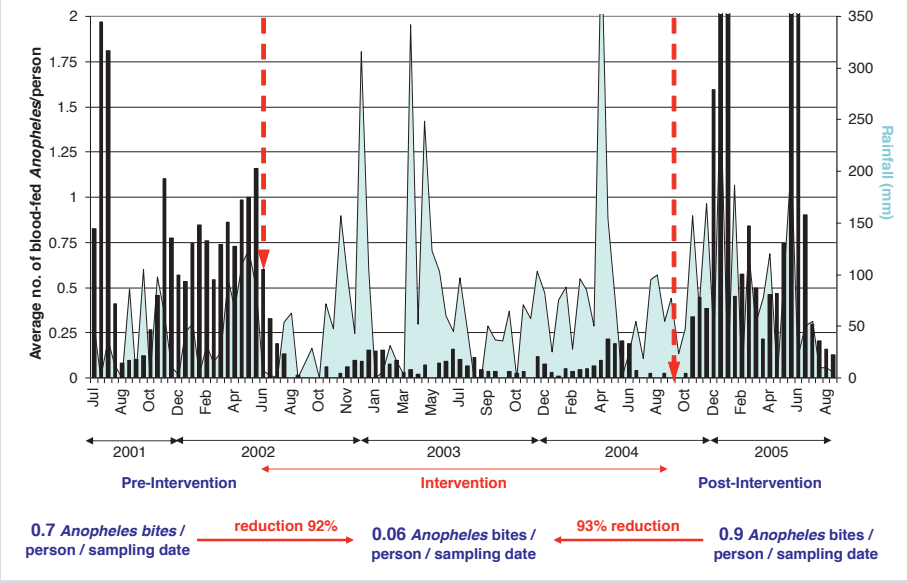
If you have few resources, test the new intervention in two similar locations. Collect baseline entomological data for at least 4–6 months. Then, flip a coin to randomly assign the intervention to one of the two sites. Collect entomological data in both villages for a further 4–6 months.

A simple pilot study with a before-and-after design to assess the effect of microbial larvicides on malaria vectors in Kenya is described in Box 24.

Box 24. Controlled before-and-after study to assess the contribution of microbial larvicides and LLINs to malaria control in western Kenya (adapted from *283*)

A small pilot study of the use of microbial larvicides where LLINs were being used was conducted in a 4.5-km^2 area in and around a large village in rural western Kenya. The design was a non-controlled before-and-after study. From mid-June 2002 to mid-September 2004 (the intervention period), mosquito larvae were controlled with *B. sphaericus* and *B. thuringiensis var. israelensis*. Adult and larval surveys were conducted for 12 months before and after the intervention period. No control site was used.

Application of larvicides reduced the proportion of aquatic habitats containing *Anopheles* larvae from 51% to 7%. The occurrence of late-instar *Anopheles* in habitats was reduced from 39% and 33% before and after the intervention to 0.6% during the intervention. Overall, larviciding reduced *Anopheles* larval density by 95% and human exposure to bites from adult mosquitoes by 92%. The estimated cost of providing this protection to the human population in the study area was less than US$ 0.90 per person per year.



Blood-fed *Anopheles* adults [Williams mean values of *An. gambiae* (97%) and *An. funestus* (3%) combined] per person per sampling date during non-intervention and intervention periods (black bars) in relation to rainfall pattern (blue area, 2-week sum in mm)

7.3 Other research questions

Apart from the efficacy of vector control interventions, other aspects might be interesting for research, such as cost and cost–effectiveness, appropriate targeting of interventions and the feasibility of community-based delivery or surveillance. Box 25 describes a pilot study of the feasibility of community-based IRS, including the resources used, cost, coverage and community satisfaction.

Box 25. Implementation of vector control by health extension workers in Ethiopia (*284*)

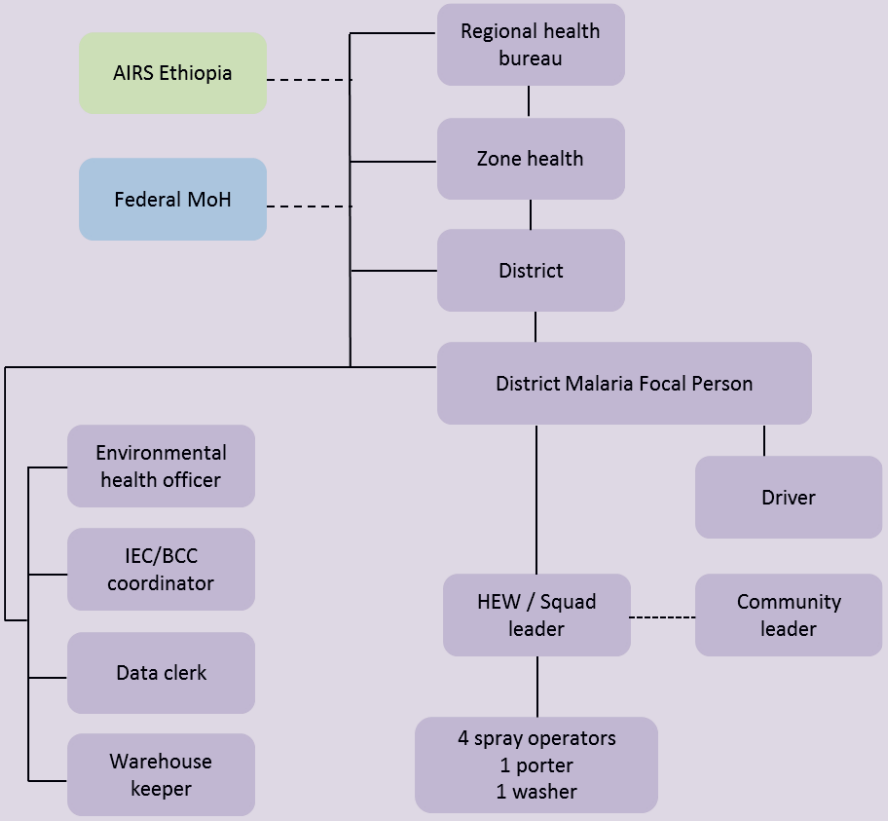
Ethiopia has a health extension programme for increasing access to basic curative and preventive health care in rural areas. The Government has trained about 34 000 community health workers and sent them to village health posts in 15 000 rural *kebele* (smallest administrative unit consisting of about 1000 households), with two health extension workers in every *kebele* of about 5000 people.

IRS is a main component of malaria vector control in some regions of Ethiopia. It is usually applied by spray operators hired from towns, who drive to villages from one of two district operation sites. Many of the operators are unknown in the villages, and the communities do not trust them; furthermore, the cost of travel to the villages and camping equipment can be high. In 2012, the President's Malaria Initiative (PMI) funded a pilot study by the Africa Indoor Residual Spraying (AIRS) project to train health extension workers to conduct community-based IRS in one district.

In the programme, each *kebele* had its own spray squad led by a health worker, who assumed responsibility for managing store rooms, washers, operators, data collection and reporting at sites set up in health posts. The spray squad were four spray operators, a washer or guard and a porter, all of whom were paid and were recruited from the *kebele*. About four squad leaders were supervised by one district expert or team leader, who was supervised by the district malaria focal person in charge of the entire operation. An environmental health officer also closely supervised the operation, and a clerk at the district health office was responsible for daily data entry and reporting.

The roles of the health extension worker were to:

- select capable spray operators and train them in spraying techniques, communication and safe handling of pesticides, in collaboration with district health services;
- consult community leaders to plan the start and end dates of IRS in the *kebele*;
- lead and supervise spraying;
- mobilize the community to cooperate and participate in IRS operations, including ensuring that all households were aware of the spraying and what they should do to make their houses ready;
- educate communities about the benefits of IRS and what to do after their houses have been sprayed; and
- maintain accurate records of activities and use of insecticides.



A train-the-trainer approach was used. Health extension workers were trained for 5 days by district health staff in IRS application, spray pump maintenance, communication skills and messages, and data recording and reporting. Then, in 20 IRS-targeted *kebeles*, the health workers recruited 100 spray operators (five from each *kebele*) and taught them for 6 days, with minimal support from the district health staff or the project.

Over 22 days, the teams sprayed 22 744 structures, representing 98% of all those eligible. No vehicles or camping facilities were required, as the spray operators worked in the villages in which they lived or nearby. Only one vehicle was required for supervision and rapid collection of reports from each *kebele*. More spray operators were required than for usual district-led IRS campaigns: five from each *kebele* rather than a team of 20 spray operators who covered the entire district. The training costs were higher, but the team took less time to complete IRS (22 days versus an average of 31 days for district-led IRS). Community-based IRS was only marginally cheaper than district-led IRS in this pilot study due to an initial outlay on construction of soak pits and equipment for each *kebele*. In the long run, however, community-based IRS will save up to 40% relative to the cost of district-led IRS. The quality of IRS was good, and feedback on the spray operators indicated good performance, perhaps because of a sense of ownership by the health extension workers and spray operators in serving their own communities.

Section summary

- IVM should be based on evidence from surveillance or from operational or implementation research.
- A working group within the intersectoral steering committee should identify operational research questions.
- Operational research can assess the efficacy of interventions, targeting, delivery, new methods of epidemiological or entomological surveillance, cost and cost–effectiveness and community mobilization, acceptance or adherence.
- Interventions that have not been assessed or recommended by WHO should generally be tested in robust, well-conducted randomized controlled trials. Research institutions should be sought as partners if this type of study is to be conducted.
- Interventions approved by WHO but that have previously not been used in a country should be pilot-tested before wide-scale use to assess their effect on entomological parameters.
- The minimum study requirement is a controlled before-and-after design with collection of environmental and entomological data for 4–6 months before and after the intervention and at least one data unit (e.g. village or geographical area) per arm.
- Pilot studies provide an opportunity to determine how to optimize intervention delivery and train staff.

8 Vector surveillance

8.1 Functions

Routine vector surveillance should be conducted throughout the life of an IVM programme. The purpose and objectives of entomological surveillance depend on the stage of the programme. The steps can be classified as preliminary surveys, trend or regular observations, foci investigations, spot checks and vigilance (*285,* Fig. 28).

Preliminary surveys are rapid, short-term surveys with a limited number of techniques to delineate areas with vector-borne diseases and allow planning of control measures. They are generally conducted where little or no information on vectors is available and are a first step in baseline data collection.

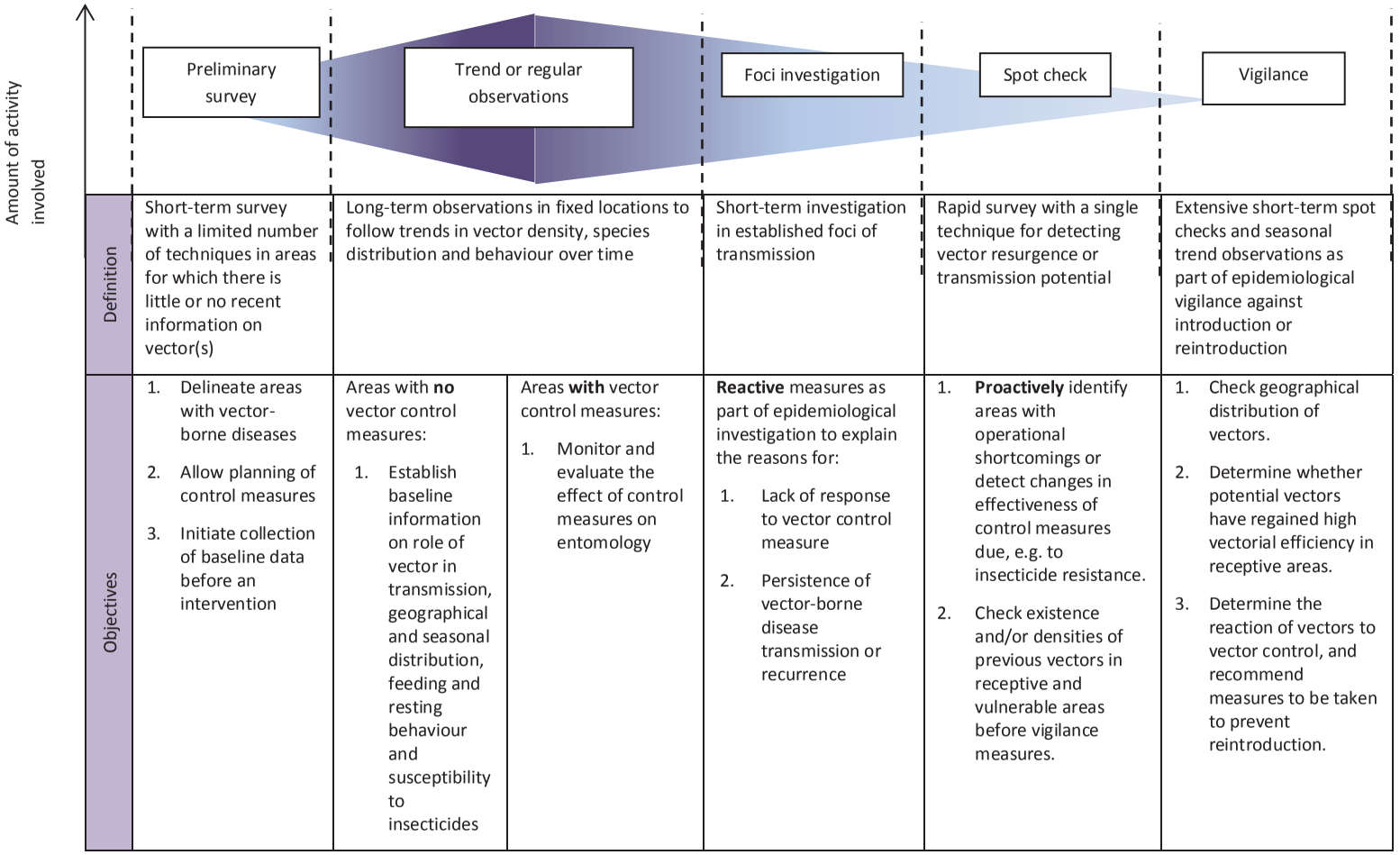
Trend or regular observations can be made whether or not vector control measures are in place. Where there is no vector control, regular observations can be made after the preliminary survey to establish more detailed baseline information on the role of vectors in transmission, geographical and seasonal distribution, feeding and resting behaviour and susceptibility to insecticides. Where vector control measures are in place, regular entomological surveillance is used to monitor and evaluate the effect of programmes on the vector(s), mainly with regard to changes in vector density.

Foci investigation is a short-term, reactive activity conducted as part of a larger epidemiological investigation. The aim is either to determine why vectors are not responding to control measures, for example because of reduced susceptibility to an insecticide, or to investigate the persistence or recurrence of disease transmission. The trigger for an epidemiological investigation might be either clinical (e.g. a hotspot of infection, clinical disease or persistence or recurrence of high levels of infection or clinical disease) or entomological (e.g. no changes in vector density over time despite control measures).

Spot checks are conducted to identify operational shortcomings in vector control measures or to detect changes in the effectiveness of control measures, due e.g. to insecticide resistance. In this case, spot checks should be conducted in areas with high transmission potential, where weaknesses in control measures are suspected or where resistance has been detected. Spot checks can also be used to determine the existence or densities of previous vectors in receptive and vulnerable areas before more comprehensive vigilance measures.

Vigilance refers to entomological surveillance for identifying and responding to the introduction or reintroduction of vectors or disease risks. Surveillance should be conducted in selected localities in areas receptive and vulnerable to new vectors or the reintroduction of vectors during the period of high vector prevalence, and the influx of sources of infection. Preparedness mainly involves identifying the geographical distribution and relative density of vector species and, particularly, identifying newly introduced vector species or pathogens.

Fig. 28. Stages of entomological surveillance (adapted from 286)



Parameters measured	Vector density Vector geographical distribution	Vector density (seasonal) Vector feeding and resting behaviour Vector habitats Infection[a] of vectors Susceptibility to insecticides	Changes in vector density Changes in vector infection[a] rate Susceptibility to insecticides	Vector density Vector infection[a] rate Susceptibility to insecticides Vector feeding and resting behaviour	Susceptibility to insecticides Vector density Vector presence or absence Relative density of vector species Vector geographical distribution Infection[a] of vectors	Vector presence or absence Relative density of vector species Vector geographical distribution Infection[a] of vectors
Where to be implemented	1. Areas designated for vector-borne disease control 2. Areas for which little or no recent information on vectors is available	In fixed sentinel sites (indicator villages) on the basis of information from the preliminary survey. Villages should be sited within a larger area in which parasitological observations are made.	In same sentinel sites as for baseline	For 1, in representative localities in areas with no response to vector control measures For 2, in all locations with persistent or recurrent transmission	For 1, prioritize areas with high transmission potential, where weaknesses in control measures are suspected or where recurrence has been detected. For 2, in selected locations in receptive and vulnerable areas	Selected locations in receptive and vulnerable areas In locations selected from the above for seasonal observations
When to be implemented	Start in season of expected high vector prevalence	As soon as information from the preliminary survey is available	After application of vector control measures	As soon as the epidemiological investigation indicates the presence of active foci of transmission (for 1) or persistence or recurrence of disease transmission (for 2)	For 1, during the season of high prevalence of vectors. taking into account the lapse after application of control measures For 2, during the period of high vector prevalence and during the period of influx of sources of infection into receptive and vulnerable areas	Surveillance during the period of high vector prevalence and the period of influx of sources of infection to receptive and vulnerable areas Seasonal trend observations during the season of high vector prevalence

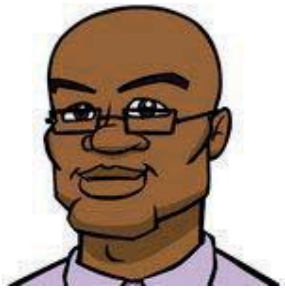
[a] Also infectivity for malaria and lymphatic filariasis vectors.

8.2 Parameters to be measured

The parameters that should be measured during vector surveillance are listed in Table 12. The parameter that is common to all stages of entomological surveillance is the density of adults or immature vectors. Vector density is usually expressed as the mean number of vectors (adults or immature) collected per sample per day, e.g. 30 *An. gambiae* per light trap per night, number of *Phlebotomus orientalis* per room per night, *Ae. aegypti* indices, including the percentage of houses infested with *Ae. aegypti* larvae or pupae. In collections of adult vectors, usually only females are counted, as only females feed on people and can transmit the disease (except for tsetse flies, of which both males and females can transmit infection). Identifying the species of vector is critical and can be done by using established taxonomical keys; in some cases, morphologically identical species can be separated only by molecular techniques, requiring a laboratory. Countries should develop capacity in the use of such techniques. In some situations, it may also be important to measure infection in the vectors, which can be done morphologically, by e.g. microscopic examination of mosquito salivary glands for the presence of sporozoites or by laboratory tests such as reverse-transcriptase (RT) PCR for arboviruses.

If a new vector-borne disease (e.g. West Nile fever, Rift Valley fever or Japanese encephalitis) is spreading, it may be important to assess the competence of local vectors for the new pathogen. If possible, this should be done by vector specialists, or expert advice should be sought.

A number of factors other than vector density should be measured, including the susceptibility of local vectors to the insecticides used for vector control. More information on the measurement of insecticide resistance is given in section 8.7. As the density of some vectors depends on weather patterns, including rainfall and temperature, information on weather should be collected routinely or obtained from meteorological bodies.



Key point

In vector surveillance, it is important to measure latitude and longitude of sampling sites with a global positioning system in order to map vector distribution as well as monitoring insecticide resistance.

Table 12. Parameters that should be measured in a vector assessment in sub-Saharan Africa

Parameter	Questions answered	Measurement method
Vector density	What is the geographical distribution of the main vector species? During which times of the year are the vector species most prevalent? What habitats do the vector species occupy as adults and when immature?	Catches of adult or immature vectors Longitudinal density surveys Species identification (species complex, molecular forms) with identification keys or laboratory tests.
Vector feeding and resting behaviour	What is the feeding behaviour of the vectors (humans, intermediates, indoor, outdoor)? Are there reservoir hosts? Where and when do the vectors rest? When is the vector active?	Laboratory test, e.g. ELISA, to determine the origin of blood meals Animal- or human-baited traps Comparisons of indoor and outdoor biting rates Adult resting catches Repeated vector density catches over 24 h
Infection of vectors	Are vectors infected, and with which pathogen?	Microscopic examination, e.g. sporozoite rate for malaria vectors or laboratory studies, e.g. PCR or ELISA
Insecticide susceptibility	What is the resistance profile of the target vector populations, particularly for those insecticides in use or planned for use?	Bioassays (e.g. WHO tube assay or CDC bottle bioassay) Synergist assays Resistance intensity assay Biochemical enzyme assays Molecular (biological) tests
Efficacy of LLIN and IRS interventions	What is the residual activity of LLINs in the field of sprayed walls?	Bioassay e.g. WHO assay on LLIN or WHO cone assay of sprayed wall

8.3 Methods for sampling vectors

The methods used to sample vectors are listed in Table 13. The method used will depend on the species, the life stage to be collected (adult or immature) and its habitat.

Table 13. Commonly used vector sampling tools, by disease

Disease	Tool	References
Malaria	Human landing catch, CDC light trap, window exit trap, pyrethrum spray catch, animal-baited trap (depends on species host preference), larval sampling, odour-baited trap, tent trap, resting collection (aspirator) (Fig. 29)	*286*, *287*
Lymphatic filariasis	Human landing catch, CDC light trap (*Anopheles*), latrine emergence trap, larval sampling, odour-baited trap, tent trap, ovi trap (culicines)	*28*
Dengue	Larval sampling (Fig. 31), pupal sampling, ovi trap, tyre larvi trap, resting collection, odour-baited trap, gravid trap, aspirator (e.g. battery-powered, Prokopack)	*87*, *288–290*
Yellow fever	Larval sampling, ovi trap	*291*, *292*
Chikungunya	Larval sampling, pupal sampling, ovi trap, resting collection (aspirator or hand-held net)	*293*
Leishmaniasis	CDC light trap, quantitative sticky paper trap, outdoor or indoor resting catch, animal-baited trap (depends on species to be caught), knockdown catch of sandflies resting indoors, funnel trap over animal burrow	*30*, *294*, *295*
HAT	Gambiense HAT (riverine): biconical or pyramidal trap Rhodesian HAT (riverine, Uganda): biconical or pyramidal trap Rhodesian HAT (savannah): odour-baited, episilon, Nzi trap or fly round	*155*, http://www.tsetse.org/
Onchocerciasis	Human landing catch, larval sampling, odour-baited trap, crab catching and examination (*S. neavei*)	*296–301*
Schistosomiasis	Snail surveys	*302*
Trachoma	Fly trap	*202*

8.4 Standard indicators

8.4.1 *Anopheles* (*286*, *287*)

A common sampling tool for estimating the number of mosquitoes entering a house (a proxy for transmission intensity) is the CDC light trap. Its two main advantages are that, when it is placed next to someone sleeping under an LLIN, the person is protected from biting; and it is an unbiased method of sampling as it does not depend on the ability of collectors to catch vectors. These traps are, however, expensive, and the batteries must be charged regularly. A cheaper alternative for estimating the relative numbers of vectors is use of window traps to collect mosquitoes leaving houses; the traps can be emptied by the householders. Indicators for *Anopheles* surveillance are listed in Table 14.

Table 14. Indicators for *Anopheles* vector surveillance

Indicator	Definition	Sampling technique	Formula
Adult			
Indoor resting density	Number of adult female mosquitoes per house per night	Pyrethrum spray catch	= (No. of females ÷ No. of houses) ÷ No. of nights
Human-biting rate	Number of bites a person receives from a specific vector species per night	Human landing catch (collections throughout the night, i.e. 12 h)	= No. of mosquitoes collected ÷ No. of collectors
		Human landing catch (collections for a few hours in the night)	= (No. of mosquitoes ÷ No. of collectors) ÷ No. of collection hours
		Pyrethrum spray catch	= No. of blood-fed females ÷ Total no. of occupants in rooms used for collection
		CDC light trap (approximates to human-biting rate)	= No. of mosquitoes per night per trap
Human blood index	Proportion of blood-fed mosquitoes that fed on humans	Method used to capture blood-fed mosquitoes e.g. pyrethrum spray catch, light trap or window exit trap	= No. of mosquitoes feeding on human blood ÷ Total no. of blood-fed mosquitoes
Sporozoite rate	Proportion of mosquitoes of a given species carrying sporozoites in the salivary glands	Salivary gland dissection, ELISA or PCR	= No. of positive mosquitoes ÷ No. of mosquitoes analysed
Entomological inoculation rate	Number of infective bites received per person per night	Method used to capture blood-fed mosquitoes e.g. human landing catch, pyrethrum spray catch, light trap and window exit trap	= Human-biting rate x Sporozoite rate
Endophagic	Proportion biting	Human landing catch,	= Human-biting rate indoors ÷ (Human-

index	indoors	CDC light trap	biting rate indoors + Human-biting rate outdoors)
Exophagic index	Proportion biting outdoors		= Human-biting rate outdoors ÷ (Human-biting rate indoors + Human-biting rate outdoors)
Microfilaraemic index			= No. of mosquitoes with microfilaraemia ÷ No. of mosquitoes examined
Insecticide susceptibility			See section 8.6
Immature			
Mosquito breeding index	Measure of larval density		= Total no. of larvae and pupae collected ÷ (Total no. of dips performed x No. of breeding sites sampled)
Habitat occupancy	Percentage of positive larval habitats		= No. of habitats with larvae or pupae ÷ Total no. of habitats found

Fig. 29. Clockwise from top left: human landing catch, CDC light trap and window exit trap (photo courtesy of S. Lindsay)

8.4.2 *Aedes*

The key indices for immature *Aedes* vectors are the house index (percentage of houses with larvae and/or pupae), the container index (percentage of water-holding containers with larvae or pupae) and the Breteau index (number of positive containers per 100 houses inspected) (*87*). Pupal demographic indices can also be used, in which the number of *Ae. aegypti* is expressed per person (*87*).

Adult density can be expressed using indoor resting density or human biting rate. Human landing catches are not recommended, as collectors are exposed to dengue, for which there is no prophylaxis.

8.4.3 Sand fly

The key entomological surveillance indicator is sandfly density measured using methods outlined in Table 8.2. Infection rate in sandflies could also be measured as a better proxy for epidemiological outcomes than density alone (*30*).

8.4.4 Black fly

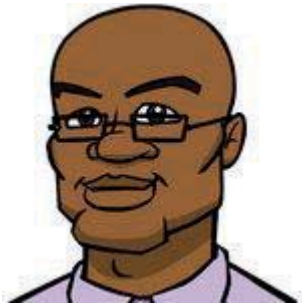
Indicators for black fly surveillance include vector density (number of black fly vectors per trap per unit time), infection rate (proportion of vectors infected with microfilariae) and parous rate (proportion of vectors that have oviposited at least once).

8.4.5 Tsetse fly

Indicators include the average number of flies caught per trap per day, the proportion of blood-fed flies per total number captured and the proportion of flies that are infected with trypanosomes.

8.4.6 Snails

Surveys for snails may be measured as the positivity of water bodies, the density of snails per unit area or the proportion of snails containing cercariae when dissected.



Key point

Skills and resources of entomologists in VBD control programmes could be shared across programmes to expand vector surveillance activities, including monitoring insecticide resistance. This is particularly the case if vector sampling tools, methods or areas where samples are being taken are duplicated across

8.5 Selecting and using sentinel sites

It is recommended that sentinel sites be set up for vector surveillance or existing sites used (if appropriate). During preliminary surveys, vector control programme managers and entomologists should become familiar with the regions in which the programme will be run, including population distribution, eco-epidemiological areas and accessibility. Early reconnaissance will be useful for later, more systematic, extended surveys, when a network of sentinel sites is needed. The considerations to be made in deciding where to set up sentinel sites are listed below (adapted from *285*).

8.5.1 Disease endemicity

Vector control programme managers should ensure that all vector-borne diseases are covered by sentinel sites. Some sentinel sites and surveillance tools might be shared, depending on the disease, such as malaria and lymphatic filariasis transmitted by *An. gambiae* in rural areas.

Observations are generally made in areas of high endemicity. Therefore, in selecting sites, the vector specialists in the programme should work with those responsible for epidemiological information in order to combine knowhow on both entomology and clinical data. As data on infection and disease prevalence or incidence should be collected regularly at sentinel sites, they should be established at existing sites for demographic and health surveillance or close to health centres with established, well-functioning health monitoring information systems. Clinical data collected in parallel with entomological data are useful for monitoring the impact of interventions.

8.5.2 Ecological zones

Sentinel sites should be selected in different ecosystems in the country or region: village, urban, rice land, river and estuary, small-scale farming or plantation. For example, livestock areas may be reservoirs of zoonotic disease, such as Rhodesian HAT.

The eco-epidemiological zones of the country should have been identified as part of the broad disease situation analysis described in section 3. Sufficient sites should be selected so that all ecosystems are covered. Fig. 30 shows ecological stratification of Nigeria for the purpose of siting

sentinel sites. The ecological classification used is: mangrove, forest, forest mosaic and tropical African savannah (Guinea, Sudan, Sahel), with several sentinel sites in each zone.

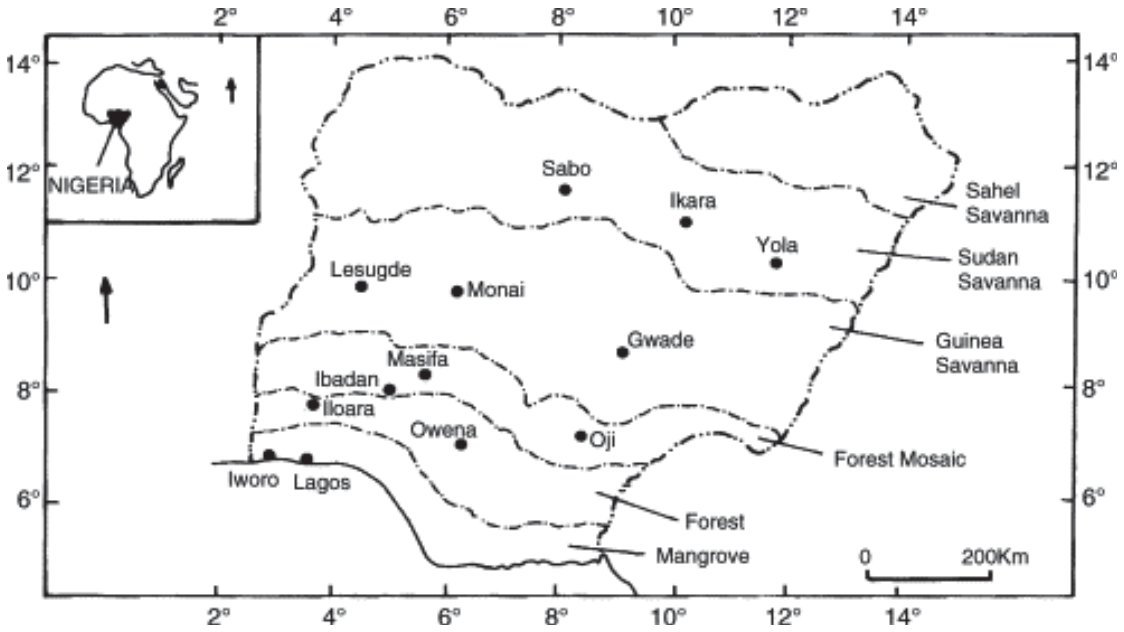


Fig. 30. Ecological stratification of Nigeria for the purpose of locating sentinel sites (adapted from *303*)

Ecological zones should correspond to some extent with areas of vector dominance if vector-borne diseases in the region are transmitted by more than one main vector. In certain types of terrain, there may be a sharp transition from one dominant vector to another, such as in the case of malaria vectors in the Senegambia region. *An. melas* predominates in salt-water mangroves in the Gambia, *An. gambiae* s.s. in Upper River regions and *An. arabiensis* in inland savannah areas of Senegal (*304*).

Seasonal changes in breeding foci affect the distribution and abundance of vectors in an area. For example, in malaria-endemic areas, breeding sites may be widespread and abundant in the rainy season and restricted to perennial streams or swamps in the dry season. If sentinel sites are selected during the rainy season when *An. gambiae* is the dominant vector, a drop in density will be seen during the dry season, and some dry-season foci in which *An. funestus* is the dominant vector may be missed. Thus, sentinel sites and collecting stations within sentinel sites must be selected to obtain a full picture of seasonal incidence, which is related to the type and variation of breeding potential.

8.5.3 Accessibility of sentinel sites

Sentinel sites must be accessible throughout the year so that regular observations can be made. Difficulty in accessing a site to conduct observations, due for example to flooding, should be anticipated. Inaccessibility at a peak time of vector breeding should be avoided.

8.5.4 Volume of insecticides used

Sentinel sites for monitoring insecticide resistance should be in areas with a high incidence of disease or heavy use of insecticides for public health or agriculture, as this is where the threat and potential impact of insecticide resistance are likely to be greatest.

8.5.5 Number of sentinel sites

Vector control programme managers face many challenges, including lack of financial and human resources, transport and time. They may therefore have to compromise between a large number of sentinel sites that are visited less frequently and fewer sites that are visited more regularly and assessed more comprehensively.

Most of the available guidance on insecticide resistance is for malaria vectors, in particular the Global Plan for Insecticide Resistance Management in malaria vectors (*46*). The WHO Regional Office for Africa (*305*) and the President's Malaria Initiative (*306*) have proposed, as an approximate guide, that there should be at least one sentinel site for monitoring insecticide resistance in malaria vectors per every 500 000 nets distributed or 200 000 houses sprayed. This is equivalent to about one site per 1 million people protected, although the exact number will depend on the country. Smaller or less populous countries should generally have one sentinel site per region. Although it is difficult to make strong recommendations, as each country situation is different, a minimum of two sentinel sites is recommended for a representative eco-epidemiological area, with more sites preferable especially if there are multiple vector species in the area.

8.5.6 Number and arrangement of collection points at sentinel sites

Appropriate selection of collection points, for example houses or animal shelters, is critical. The location of adult collection points can be selected purposively or randomly. Purposive selection includes consideration of coverage of different housing types and distances from breeding sites or attractive sites where high vector density would be expected (productive collecting sites). This type of selection allows observation of daily or seasonal shifts or movements in vector populations. For a representative picture of the level of transmission at a sentinel site that is directly comparable over time and between sites, it is best to select collection points randomly. For example, if houses are to be sampled, they can be selected randomly by mapping the study site, numbering the houses and

then randomly selecting several numbers with a random number generator in a computer programme.

Vector control programme managers should also decide how many collection points will be located in each sentinel site, which is generally between two and three. For collection of immatures, the minimum number of aquatic habitats to sample should be defined.

8.5.7 Frequency of sampling

The frequency of sentinel surveillance sampling depends on the capacity and needs of the control programmes, i.e. the vector, the data to be collected and the aim. Generally, species composition and density should be measured every month, at least during the main transmission season, although this may not always be possible. If a site is not well characterized and the seasonality of the vector of interest is unknown, monthly surveys of density and species composition are required. Insecticide susceptibility monitoring should be done every 6–12 months.

The structure and scope of an entomological surveillance system in Sudan are described in Box 26.

Box 26. Entomological surveillance system in Sudan (*285*; unpublished data from the Ministry of Health, Sudan)

Sentinel sites were selected to meet the following criteria:

- sufficient vector density to allow study of vector habits, resting, feeding and distribution (indoors and outdoors);
- representative of different geographical and ecological zones;
- history of vector-borne disease transmission in the area;
- accessibility of site in all seasons;
- types of dwellings and breeding sites present;
- livestock areas considered to represent a potential burden of zoonotic disease; and
- inclusion of urban and rural areas.

Sites were selected at state level, as they fulfilled the criteria listed above. The country has 106 vector surveillance sites, with an average of four to six sites per state, except for large states such as Khartoum, the capital of the country (nine sites) and Gezira State, which hosts the largest irrigated agricultural scheme in Africa (seven sites).

Of the 106 vector surveillance sites, 64 are also used to monitor insecticide resistance. Of these, resistance is monitored annually at 40 of these (irrigation schemes and areas with high use of insecticides such as large cities and camps for internally displaced people and refugees), with the remainder monitored for resistance only every 2 years, as insecticides are used seasonally at these sites.

State and district entomology teams consisting of a senior entomologist and three entomology technicians are responsible for conducting surveys and reporting to the IVM unit at the Ministry of Health. The target vectors for entomological surveillance comprise mosquitoes, sand flies, ticks and snails (when sampling sites border water bodies). Recommended collection methods are used to sample insects and snails. The sentinel sites are visited monthly. State surveys collect information on vector species, vector density (adult and larvae, including *Aedes* mosquito indices), parity rate, biting rate and physiological status.

Data collected at state level are sent to the national IVM unit electronically on a standard form. A subset of the insects and snails collected are sent to national level for additional analysis, including identification and infection rate, with RT-PCR for arbovirus identification. After analysis, the findings are sent back rapidly to state level. The IVM unit regularly supervises all states a minimum of twice a year to make sure that they are conducting vector surveillance as planned. In addition, annual in-service training is given for state staff, and at least three meetings are held each year to discuss progress in vector-borne disease control, including surveillance.


Vector Surveillance Sentinel Sites (106 sites)
Incuding (64 sites) for IR monitoring in Sudan
Egypt
Libya
Chad
Sudan
South Sudan
Ethiopia
Eritrea
Kenya
Uganda
Saudi Arabia
Wady Halfa
Abri
El Selaim
Agaja
El Gaba
Nuri
Elbawga
Elshreek
Sola
El Zedab
S.Shandi
Arbaat
Elshrdi
Sinkat
Haiya
Toker
Dordeeb
El Rad
Halfa Sugar cane
El Thaora
Al Shukria
Dabarposa
Al Kurmuta
Shuwak
El Faw
Al Abbas
Galabat
Doka
Elmahlab
Shambat
Elsimania
Abdila
Shweilh
Tabat
Wad Elneem
Shabesha
Wad Ebnass
Simwata
Singa
Abri Ouf
Assalaya
Wad El Nail
Hay El Zuhor
Agdi
Elazaza
Blang
Elmalha
Malliet
Swdery
Kbkabia
Altwela
Hay Elshreeg
Hay Elwadi
Kass
Adella
Elsika hdeed+Gadeed
Elswagi Elrkabia
El Obeid
El Trda
Albangdeed
Agoas
Elskahdeed
Greea
Watara
Gomeza babekr+Twndty
Tulas
Eldeen
Elhy Elshergi
Rehid Elbrdi
Bram
Abomtareg
Way bila
Sega
Hay Elmsna
Keilak
Talwdi
Abu Gebaiha
Sentinel Sites
State Boundaries
International Boundaries
River Nile
N
0 95 190 380 570 760
Km
25°0'0"E
30°0'0"E
35°0'0"E
20°0'0"N
15°0'0"N
10°0'0"N
5°0'0"N

8.6 Responsibility for vector surveillance

Entomological surveillance is usually carried out by vector control personnel at national and sub-national levels who are responsible for the surveillance of local mosquito populations, analysis of data and eventual decision making. Some programmes additionally rely on trained and supervised community members to supplement surveillance efforts. For example, in Mozambique community members participated in entomological surveillance for monitoring and evaluating IRS with DDT for malaria control (*307*). Window exit traps were installed on six houses with the owners' permission at each of 19 sentinel sites in Zambézia province. The owners were trained to empty the traps daily into labelled specimen jars containing isopropanol and to complete checklists indicating the nights for which the traps were checked. The specimen jars were then collected by programme staff, who assessed species abundance and sporozoite rates, and managed data collected for decision making. Community members have also been involved in monitoring tsetse fly traps and collecting flies in South Sudan (Box 19; *269*). Another example of the involvement of community members in entomological activities is the mapping and monitoring of breeding sites for larval source management in Dar es Salaam, United Republic of Tanzania (Box 27; *308*, *309*).

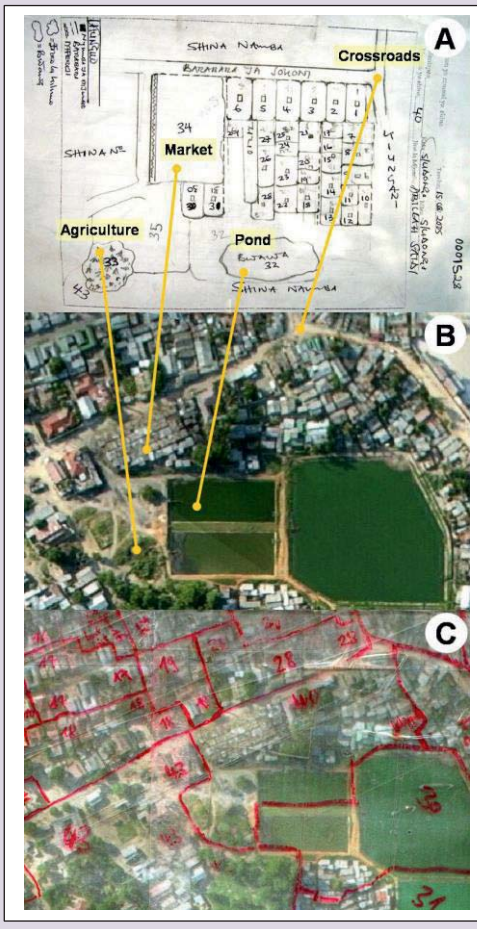
Fig. 31. Larval surveillance using a dipper (photo courtesy of S. Lindsay)

Box 27. Mapping of malaria vector breeding sites for operational larval source management in Dar es Salaam, United Republic of Tanzania (adapted from *309*)

The aim of the Dar es Salaam Urban Malaria Control Programme is to use community members to control aquatic-stage mosquitoes. The Programme in its current form was launched in March 2004 and operates at all five administrative levels of the city: the city council, three municipalities, 15 wards, 67 neighbourhoods and more than 3000 10-cell units. The four upper levels in this hierarchy are responsible for project management and supervision, while monitoring, mosquito larval surveillance and control are organized at the level of the 10-cell units. These usually comprise about 10 houses but can include > 100. Every week, community members monitor and document the larval habitats of mosquitoes, for minimal remuneration. Since 2006, additional community members have been recruited and trained in applying a biological larvicide (*B. thuringiensis* var. *israelensis*) to all potential larval habitats of malaria vectors.

The mapping involves the following steps:

- Community resource draw sketch maps of the 10-cell units, marking plots (and, separately, their characteristics and owners), roads, pathways, drains and other landmarks.
- Technical teams verify the sketch maps from laminated aerial photographs, which are later digitized and analysed with geographical information systems.



Examples of a sketch map, an aerial photograph and a technical map. A. Sketch map. Features include plots with continuous numbering, streets, drains, agricultural areas and ponds. B. The same area on the aerial photo. The yellow lines connect the same features on the map and the photo. C. The same area used for the technical mapping of features, marked with a non-permanent pen.

8.7 Insecticide resistance

8.7.1 Definition

"Insecticide resistance" is the term used to describe the situation in which vectors are no longer killed by the standard dose of insecticide (i.e. they are no longer susceptible to it) or avoid coming into contact with the insecticide. The emergence of insecticide resistance in a vector population is an evolutionary phenomenon. Selection pressure for development of resistance results from use of insecticides for public health and agriculture and may also be driven by household use of insecticides and hydrocarbon pollution (*46*).

Four mechanisms of resistance have been identified: target-site, metabolic, behavioural and cuticular. Target-site resistance involves a genetic mutation that directly reduces binding of the insecticide, e.g. on the surface of nerves, and thereby reduces or eliminates its effect. Metabolic resistance involves a change in the amount or specificity of a metabolic enzyme, so that it detoxifies an insecticide before it reaches the target site. Cuticular resistance consists of modifications in the insect cuticle that prevent or slow the adsorption or penetration of insecticides. In behavioural resistance, a vector adapts its feeding or resting behaviour to avoid contact with the insecticide. For example, there is some suggestion that malaria vectors have adapted to bite outside houses and earlier in the evening when people are not protected by LLINs (*310*).

Cross-resistance occurs when resistance to one insecticide confers resistance to a different class of insecticide, even when the insect has not been exposed to the second. Cross-resistance often occurs when insecticides have a common mode of action; for example, acetylcholinesterase mutations can result in cross resistance between carbamates and organophosphates, or *kdr* mutations result in cross-resistance between pyrethroids and DDT (*46*). When a vector has two or more different resistance mechanisms, they may combine to result in resistance to multiple classes of insecticides.

8.7.2 Testing of malaria vectors

The two main methods for monitoring insecticide resistance in malaria vectors are the WHO tube test (*311*) and the CDC bottle assay (*312*). Either or both types of test may be used, but the results are not directly comparable. In the WHO tube test, mosquitoes are exposed to a discriminating concentration of insecticide on an impregnated paper. Test kits and insecticide-impregnated papers are prepared on behalf of WHO by a collaborating centre, and procedures and conditions for procuring test kits and impregnated papers have been published (*313*). Test procedures should rigorously followed and fully documented including observations on the test used and test conditions such as room temperature and relative humidity.

A mortality rate of < 90% 24 h after the 1-h exposure (2 h for fenitrothion) is considered confirmation of resistance if optimum test conditions are met and control outcomes are within the acceptable range (with test data adjusted accordingly). A mortality rate between 90 and 98%

suggests the presence of resistance, and further investigation is required (*311*). Susceptibility is confirmed if there is a mortality rate of 98% or higher.

Key point

A mortality rate of < 90 is confirmation of resistance if the test is conducted under optimum conditions of temperature and humidity with a minimum of 100 mosquitoes and the control mortality is < 20% and the efficacy of impregnated papers is confirmed with susceptible mosquitoes.

For measurement of the intensity of insecticide resistance, mosquitoes are exposed to a discriminating concentration of insecticide for various times, so that percentage mortality can be plotted over time (time to 50% lethality; see *314* for an example), or to several concentrations of the insecticide for a fixed time, so that percentage mortality can be plotted by concentration (dose for 50% lethality, LD_{50}). The usefulness of this approach for measuring changes in insecticide resistance intensity over time is being evaluated.

When insecticide resistance is confirmed, additional testing should be conducted to identify the mechanism of resistance (e.g. target-site, metabolic resistance, behavioural or cuticular). Countries should approach WHO and research institutes for assistance, as required.

When insecticide resistance is identified at a site, the programme should respond according to the technical recommendations in the Global Plan for Insecticide Resistance Management in malaria vectors (*46*). More sampling may be required in neighbouring areas, as insecticide resistance is often focal, and the presence or absence, the intensity and mechanisms may vary over short distances. Insecticide resistance monitoring data should be interpreted alongside other data, in particular epidemiological data from health management information systems and data on the use and coverage of interventions to obtain a full picture of the situation. Data on the use of insecticides in other sectors, such as agriculture, should also be examined.

More information on the WHO strategy for managing insecticide resistance is given in the WHO Global Plan for Insecticide Resistance Management in malaria vectors (*46*). A framework to support countries in preparing their own plans for monitoring and managing insecticide resistance is being prepared by WHO.

Key point

Insecticide susceptibility monitoring data should be considered with information from other sources, including epidemiological data, intervention coverage and use, and information on insecticides used in other sectors, e.g. agriculture, to obtain a better picture of the drivers of insecticide resistance and its impact on the effectiveness of malaria vector control.

8.7.3 Testing of other vectors

The same techniques used for measuring the susceptibility of malaria vectors, WHO tube assays and CDC bottle assays (*311*, *312*), can be used for other mosquito vectors, including those of lymphatic filariasis and dengue, although care should be taken to use the correct discriminating dose. Publications that provide guidance for testing non-malaria vectors are listed in Table 15.

Table 15. Useful resources for measuring the susceptibility of non-malaria vectors to insecticides

Disease	Vector	Resources
Lymphatic filariasis	*Culex* spp. *Aedes* spp. *Mansonia* spp.	(*28*): Annex 5 gives methods for monitoring and managing resistance to insecticides
Leishmaniasis	*Phlebotomus* spp. (Old World))	(*28*, *315*): Give advice on testing susceptibility to insecticides and strategies for preventing development of resistance
Onchocerciasis	*Simulium* spp. (black fly)	(*317*, *318*)
Dengue	*Ae. aegypti* and *Ae. albopictus*	(*87*): Gives advice on testing susceptibility to insecticides

8.7.4 Current susceptibility to insecticides

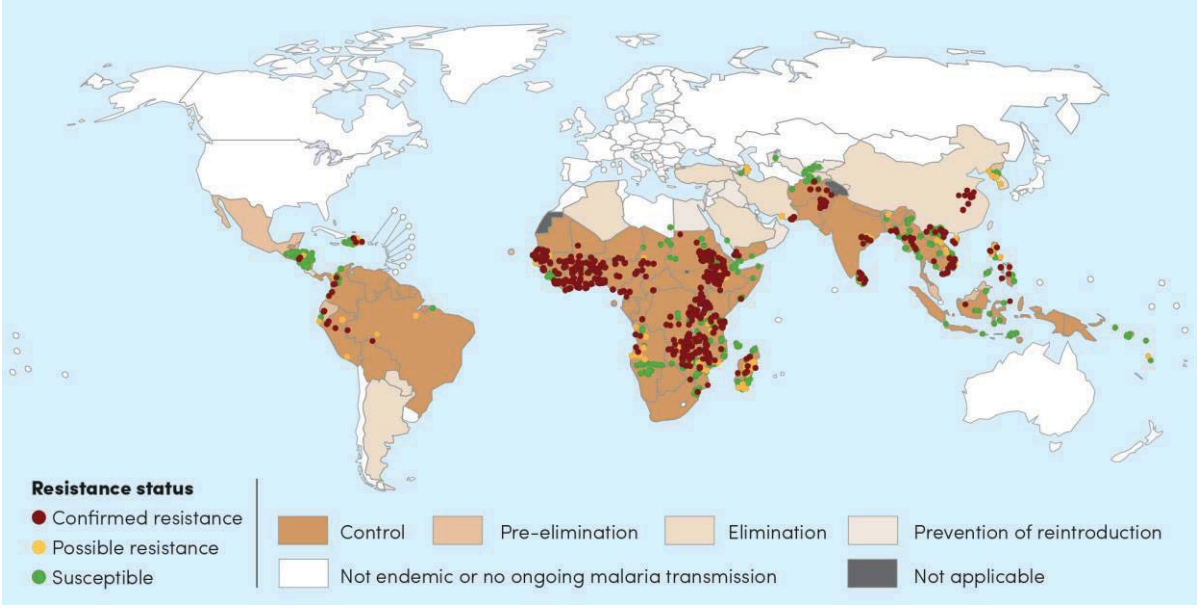
Malaria vectors

Vector control with insecticidal tools, in particular LLINs and IRS, is a critical component of malaria control. Only four classes of insecticide are used as adulticides in IRS: pyrethroids, organochlorines (DDT), organophosphates and carbamates. Currently, pyrethroids are the only class of insecticide available for use on LLINs. The rapid increase in the distribution and intensity of resistance to insecticides in malaria vectors in sub-Saharan Africa is therefore of great concern; resistance has been reported in two thirds of countries with ongoing malaria transmission (*46*) and has been

reported in all the major malaria vectors and to all classes of insecticide, particularly pyrethroids. As yet, there is no strong evidence that resistance is actually compromising malaria control. For example, a recent review did not find that pyrethroid resistance was attenuating the effect of insecticide-treated bed nets on entomological outcomes (*317*); however, the distribution and intensity of resistance are increasing very rapidly in many parts of Africa. Therefore, it is considered only a matter of time until the effectiveness of malaria control is reduced or, at the extreme, that control failure becomes apparent (*46*).

Information on the status of insecticide resistance in malaria vectors can be found in annual WHO World malaria reports. A global insecticide resistance database has recently been established by WHO, and an interactive map of country-level data on resistance is being designed.

Fig. 31. Reported status of pyrethroid resistance in malaria vectors, 2010-2015 (as determined in standard bioassays) (*5*)



Other disease vectors

Insecticide susceptibility in other vector species is less well characterized and documented (*228*). There have been several reports of insecticide resistance in *Cx. quinquefasciatus*, including from Sudan (*318*), Zambia (*319*) and Zanzibar, (*320*), but this information has not been synthesized.

There is no complete information on the susceptibility of sandflies to the range of insecticides used in vector control. Sandfly resistance to malathion and pyrethroids has been reported in Sudan, which is presumably due to intensive use of these insecticides for malaria control and in agricultural practice (*321*), and resistance to DDT has been reported in India (*322*). With increasing use of insecticides for leishmaniasis control, resistance in these vectors should be monitored and management strategies developed.

Use of temephos as part of the Onchocerciasis Control Programme in West Africa led to resistance (followed by resistance to chlorphoxim when the insecticide was changed) (*228*, *323*). Resistance in this species is currently being managed by rotation of temephos, *B. thurigensis israelensis* and permethrin, insecticide use being determined by the rate at which water is flowing in rivers, which are the major breeding sites of these vectors.

Resistance to DDT, pyrethroids and organophosphates is widespread in dengue vectors (*324*, *325*). There is little likelihood that tsetse flies will develop insecticide resistance because of their long life span and low reproductive rate.

8.8 Entomological data management

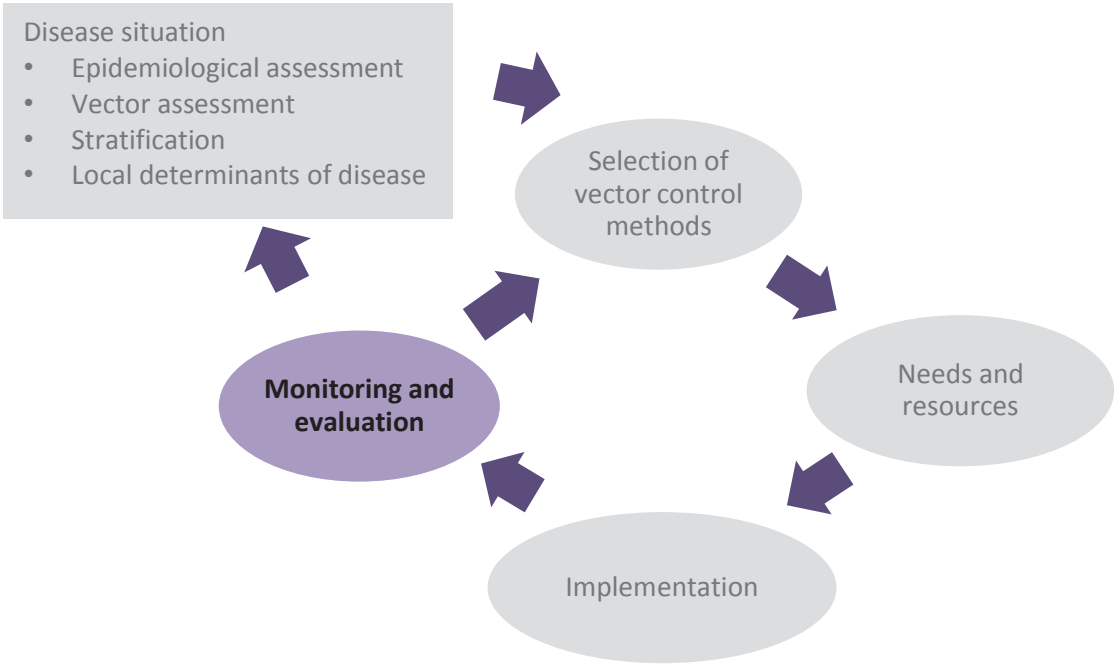
Entomological data should be collected on standard forms, and data should be collated and reported from sentinel sites to district, regional and national programmes in a timely manner.

To ensure proper interpretation of data for decision-making, entomological data should be integrated with epidemiological data (e.g. health management information systems and surveys) and information on intervention coverage. Data can be visualized in the form of maps. More information on integrated data management is given in section 9.7. Data from different vector-borne disease programmes should be reviewed, because use of an insecticide in one programme may have unintended consequences on other vectors or diseases.

Section summary

- Vector surveillance should be conducted throughout the life of an IVM programme, although the objectives and parameters measured will change according to the stage of the programme.
- The most commonly measured parameter is vector density (mature or immature forms), although other parameters are important, particularly insecticide susceptibility.
- Sampling tools vary by vector, although there may be some overlap.
- When setting up sentinel sites, the factors that should be considered include disease endemicity, ecological zones, accessibility and use of insecticides in the area.
- Vector control programme personnel usually conduct vector surveillance, but there are good examples of community involvement in these activities.
- The presence and intensity of insecticide resistance in malaria vectors is increasing, and susceptibility must be measured continuously in sub-Saharan Africa. Insecticide resistance is also present in other disease vectors, including culicines.
- Data management systems should be established to manage and integrate the vast quantities of data generated on entomology, case surveillance, surveys and intervention coverage to allow effective decision-making.

9 Monitoring and evaluation



9.1 Definition

Monitoring is continuous tracking of programme performance and involves checking progress against pre-determined objectives and targets. Monitoring makes it possible to verify whether activities have been implemented as planned, ensures accountability and indicates any problems or constraints, so that corrective action can be put in place. Monitoring is focused mainly on inputs and outputs. Outcomes and impact must be evaluated in order to document periodically whether the programme activities are leading to the expected results in terms of:

- outcomes: for example, intervention coverage or usage or reduction in vector populations; and
- impact: for example, a reduction in mortality or morbidity due to vector-borne disease.

Monitoring and evaluation are linked; for example, monitoring helps to identify possible weaknesses in implementation if the evaluation shows no impact of the programme. While monitoring is continuous, evaluation must be done intermittently, the periodicity varying considerably according to the changes expected in the areas evaluated.

A proposed monitoring and evaluation framework, including illustrative data and indicators for each of the domains (input → process → output → outcome → impact), is shown in Fig. 32.

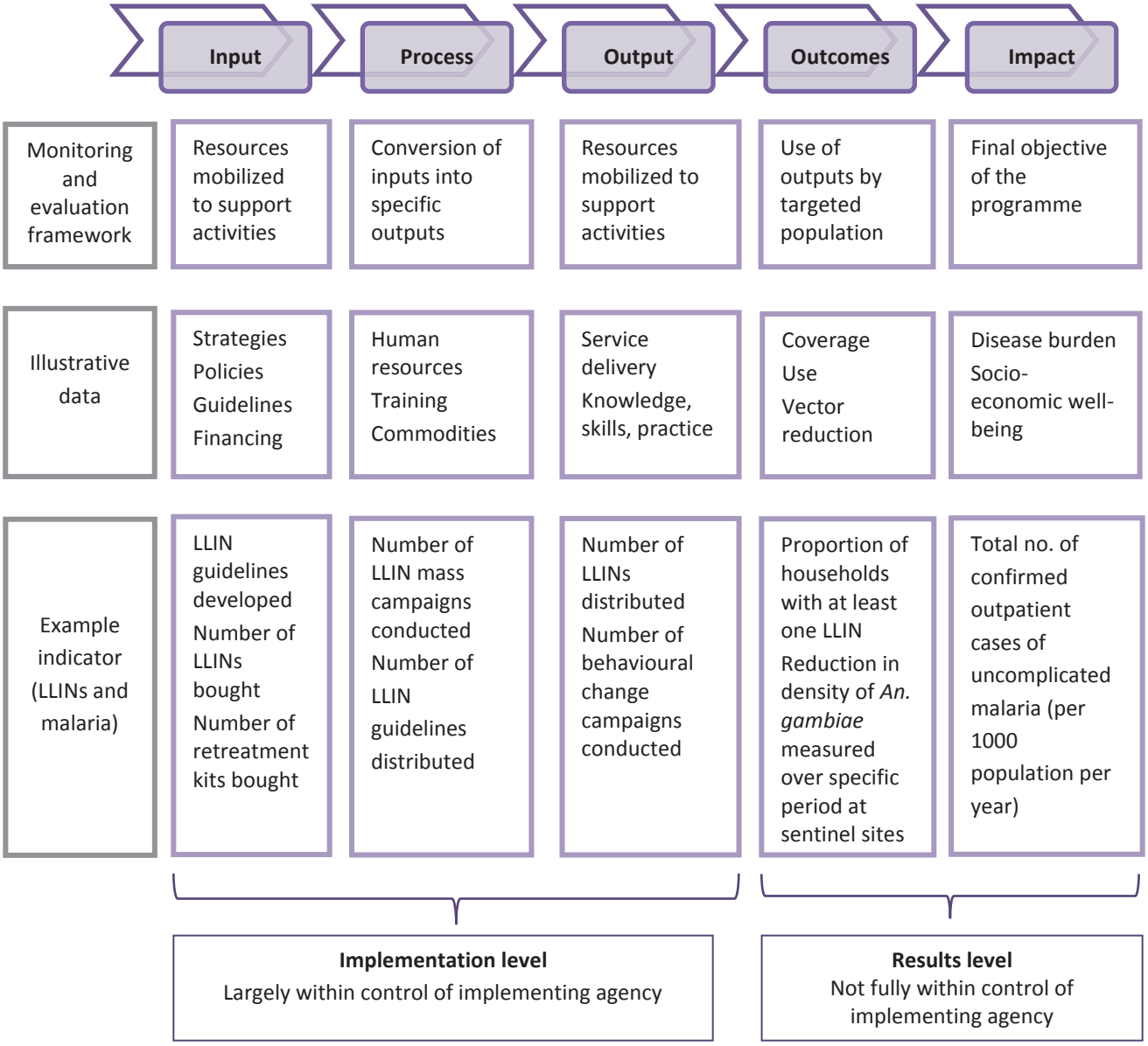


Fig. 32. Monitoring and evaluation framework for IVM programmes (adapted from *326*)

Monitoring and evaluation of IVM are covered broadly in the WHO document on monitoring and evaluation indicators for IVM (*2*). More information on individual diseases is given in the sources listed in Table 16.

Table 16. Sources of more information on monitoring and evaluation of vector control interventions

Disease	Sources of more information
Malaria	Roll Back Malaria Partnership. Framework for monitoring progress and evaluating outcomes and impact (*327*)
	The Global Fund to Fight AIDS, Tuberculosis and Malaria. Monitoring and evaluation toolkit. Malaria (*326*)
	MEASURE. Evaluation (*328*)
	World Health Organization. Disease surveillance for malaria control: operational manual *(329)*
	World Health Organization. Disease surveillance for malaria elimination: operational manual *(330)*
Lymphatic filariasis	World Health Organization. Lymphatic filariasis: monitoring and epidemiological assessment of mass drug administration programme. A manual for national elimination programmes (*331*)
Cutaneous leishmaniasis	World Health Organization Regional Office for the Eastern Mediterranean. Manual for case management of cutaneous leishmaniasis in the WHO Eastern Mediterranean Region (*332*)
Visceral leishmaniasis	World Health Organization Regional Office for South East Asia & Special Programme for Research and Training in Tropical Diseases. Indicators for monitoring and evaluation of the kala-azar elimination programme – Kala-azar elimination in Bangladesh, India and Nepal (*333*)
HAT	Bouchet et al. Key indicators for the monitoring and evaluation of control programmes of HAT due to *Trypanosoma brucei gambiense* (*334*)
Dengue	World Health Organization. Dengue – guidelines for diagnosis, treatment, prevention and control (*87*)
Trachoma	World Health Organization. Trachoma control – a guide for programme managers (*335*)
	Emerson et al. Implementing the SAFE strategy for trachoma control – a toolbox of interventions for promoting facial cleanliness and environmental improvement (*202*)
	Ngondi et al. Trachoma survey methods: a literature review (*336*)
Onchocerciasis	No guidelines available

Yellow fever	World Health Organization. WHO-recommended standards for surveillance of selected vaccine-preventable diseases (*337*)
	World Health Organization. Investigation of yellow fever epidemics in Africa – field guide (*291*)
Chikungunya	World Health Organization and Pan American Health Organization. Preparedness and response for chikungunya virus Introduction in the Americas (*338*)
Schistosomiasis	World Health Organization. Preventive chemotherapy in human helminthiasis. Coordinated use of anthelminthic drugs in control interventions: a manual for health professionals and programme managers (*57*)

9.2 Responsibility for monitoring, evaluation and data flow

IVM is applicable to all vector-borne diseases; therefore, control programmes for different diseases should ideally work to a single IVM monitoring and evaluation plan. Efforts should be made to convince donors of the need for cross disease control by submitting funding requests including more than one disease, where diseases are co-endemic. Initially, however, funding is likely to remain disease-specific, and it is unlikely that monitoring and evaluation of the IVM programme will replace that of disease-specific programmes.

Countries own the IVM monitoring and evaluation plan, as it is for them to assess their programmes. In monitoring and evaluating an IVM programme, each disease-specific programme is accountable to the IVM focal person at national level. At each level (district, region and national), the IVM focal person is responsible for collating data from individual programmes and entering it into the IVM monitoring and evaluation plan.

Data from district level are used to inform vector control activities on the ground. As IVM should be based on local monitoring and evaluation data, proper assessment and use of these data are essential. Data should be collated and sent to regional level, which in turn reports to the national level on the impact of IVM. Often, data are collated and analysed by a central statistics office. Detailed data are generally not used at higher levels, where a strategic overview is required. Feedback loops should operate from national and regional levels, so that information collated is communicated back to the various levels.

Monitoring and evaluation conducted by an external agency such as an academic institution is likely to increase accountability for vector control and ensure unbiased results.

The users of information generated by monitoring and evaluation range from operational staff on the ground to programme managers, the IVM steering committee, country policy-makers, international policy-makers and donors. Information should be disseminated regularly to the intersectoral steering committee and other stakeholders.

9.3 Choice of indicators

Two types of indicator are used in monitoring and evaluating IVM programmes: intervention- and disease-specific and programme-specific. The intervention- and disease-specific indicators include distribution and coverage of the intervention, changes in vector populations and effects on infection or disease. IVM programme-specific indicators include process indicators on training of personnel in IVM and impact indicators of reductions in toxic units of insecticide used. Outcome and output indicators can be borrowed from the disease-specific logical framework (or log frame) that programmes should have in place. The way in which the programme will be evaluated and monitored should be detailed in a plan that includes a log frame, which should include expected reductions in indicators and expected impact of the programme. A hypothetical log frame for monitoring an IVM programme for both malaria and lymphatic filariasis in a rural area with LLINs, IRS and larval source management is shown in Annex 3.

9.4 Evaluation design and attributing change

A number of designs are available for evaluating an IVM programme, which differ with respect to the confidence with which changes in impact indicators can be attributed to the interventions. For example, randomized controlled trials or randomized step–wedge designs are robust and, through randomisation, exclude the influence of other factors on the outcome, providing reasonable certainty that any changes that occurred are attributable to the programme. Most often, however, a longitudinal design (pre- and post- comparison) is used without a control group, in which other factors that influence the outcome may change over time; therefore, attribution of an effect is more difficult. When longitudinal data on disease or infection are used to measure the impact of an IVM programme, it is important to note (and where possible measure) the external factors that might have influenced the outcome, including a parallel programme initiated by an NGO, changes in diagnosis and treatment practices or changes in weather conditions that affect vector abundance. IVM program performance could also benefit from experience gained through Malaria Programme Reviews conducted in WHO African region (*339*).

9.5 Measuring the impact of integrated vector management programmes

The four main impacts of an IVM programme are on disease burden, cost–effectiveness, ecological soundness and the sustainability of the programme (Table 17).

Table 17. IVM Impact indicators, by domain (adapted from *340*)

Impact domain		Indicators
Health		Disease burden (number of cases or infections), mortality from disease, equity
Economic		Cost–effectiveness
Environmental		Insecticide use
Sustainability	Social	Collective action, organization, networking, community acceptance
	Institutional	Intersectoral collaboration, local involvement
	Political	Access to government, resource allocation, policy change, continued resource allocation

9.5.1 Effect on disease burden

It is important to measure the effect of a programme on disease burden, including morbidity or mortality. A standard definition of clinical disease (including diagnostic confirmation where possible) should be used to allow comparison between sites and countries. Recommended case definitions are given in the disease-specific documents listed in Table 16.

Sources of data on infection or disease, depending on the country and the disease, are listed in Box 28.

Box 28. Data sources for measuring effect on disease morbidity or mortality

Population based: censuses, civil registration and vital statistics (deaths and causes of death), health management information system, population-based surveys (demographic and health surveys, multiple indicator cluster surveys), active case detection strategies, integrated disease surveillance and response system

Institution-based: individual records (public and private health facilities), service records (public and private health facilities), resource records, school or employer absentee records, school or other institution surveys

Others: NGO data, agricultural records

When the outcome of interest is death from the disease, the information can be collected from civil registration and vital statistics in some countries.

Data on disease incidence can be obtained from health management information systems and collated from public and private health facility records or from the integrated disease surveillance and response system, if the disease is captured in this system (*341*). Data are generally compiled weekly or monthly at health facilities and then reported up a vertical chain, with further aggregation at each level of the health system (district, region), until they reach the most central level. Collection of data in this way is known as passive case detection, i.e. patients seek care at health facilities, and the cases are recorded by a health worker and reported to the appropriate epidemiological

surveillance system. This system captures only a proportion of cases, as access to health care is often limited, some patients may not seek care, and patients attending private health facilities are often missed. The passive case detection system is only as effective as the health system in which it is embedded. The important aspects are, for example, that case reporting is based on confirmed diagnoses as a standard, and the data are of high quality and complete and are reported in a timely manner to allow rapid action against focal vector-borne diseases, in particular malaria and dengue. Support and supervision for quality control of the surveillance system are also necessary. Despite the potential failings of a passive case detection system, epidemiological data collected in this way can still be used to measure trends. There are some excellent resources on disease surveillance for malaria control and elimination that could be used for other vector-borne diseases (*329, 330*; *342*). An example of a malaria sentinel surveillance system in Ethiopia based on case reporting by a selected number of health facilities, rather than the health management information system, is shown in Box 29.

Box 29. Sentinel surveillance system to monitor malaria trends in Oromia Regional State, Ethiopia (adapted from *343*)

Ethiopia's national malaria control strategic plan includes the goals to eliminate malaria transmission in low-transmission areas and achieve zero malaria deaths by 2015. In order to plan interventions and monitor progress towards these goals, a robust surveillance system is necessary, in particular to quickly identify changes in malaria transmission, morbidity and mortality and, given the focal nature of malaria transmission in some areas of Ethiopia, to identify transmission hotspots.

Ten malaria sentinel sites were set up in Oromia Regional State in 2010 to collect data on indicators of malaria morbidity and mortality. Ten primary health care units were selected, each serving a catchment area of approximately 25 000 people and consisting of district (*woreda*) health centres and associated satellite community (*kebele*) health posts.

Most health centres are located in urban areas and are usually staffed by health officers, laboratory technicians, pharmacists and midwives. Most have inpatient facilities and are the first referral point for severe malaria cases from the health posts. The health posts are located in rural areas and are staffed by health extension workers, who are salaried staff generally drawn from the communities that they serve. These health workers can diagnose malaria with a rapid diagnostic test and provide artemisinin combination therapy to confirmed cases.

The criteria for selecting sentinel primary health care units were decided at a national stakeholder meeting:

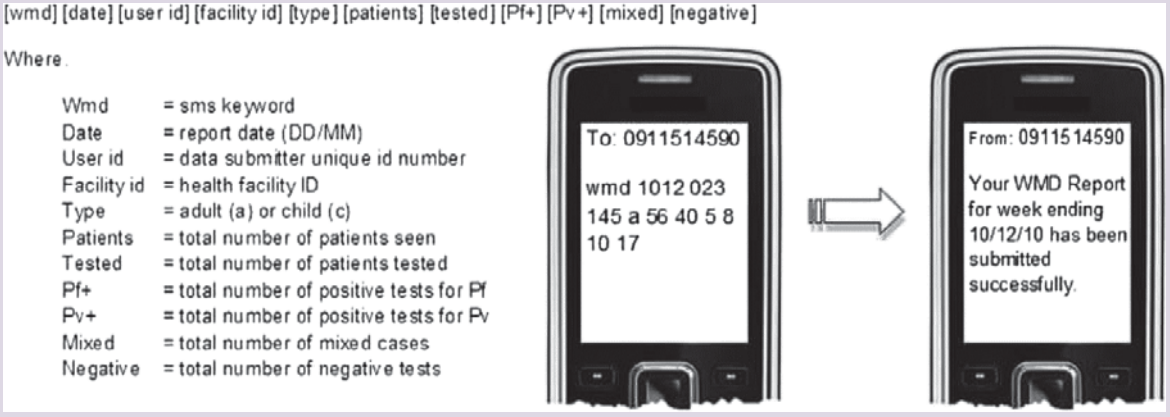
- presence of an outpatient clinic in which an average of at least 50 patients are seen per day;
- laboratory capacity to diagnose malaria by microscopy;

- capacity to provide artemisinin combination therapy as first-line treatment for uncomplicated malaria during the visit;
- designated personnel responsible for data collection and reporting at the facility during the visit;
- situated at < 2000 m above sea level in a malaria transmission area; and
- electricity and year-round access by road available.

Initially, the health centres were the focus of each sentinel site, but after about 2 years, data were being collected and reported from 10 health centres and their 73 satellite health posts.

At the health centres, data were collected from an outpatient department register and a laboratory register. The outpatient register collected information on patient age, residence, history of fever, laboratory tests requested, laboratory results for malaria and relapsing fever (e.g. microscopy or rapid diagnostic test), species-specific diagnosis (i.e. uncomplicated malaria, severe malaria, other), drugs prescribed, inpatient admittance, death and referral to higher-level facilities. At health posts, data were collected from the routine register of fever and malaria patients.

The sentinel facilities send aggregated weekly data by SMS to a central database server.



Mobile phone displaying data reporting format used at health post level

To reduce potential error, a number of logic checks are in place, so that if numbers sent in by SMS from health facilities are implausible a request for resubmission is sent. Once the SMS data are compiled on the central server, web-based reports can be generated, allowing users to view the data in near real-time for assessment of expected and actual malaria cases occurring in the defined area. Alerts can be set up so that both managers and staff at primary health care units receive an SMS or e-mail if the number of cases exceeds a predefined threshold for that health facility.

For the purposes of quality control, surveillance staff visited health centres (initially every 2 weeks) and, with staff, extracted relevant ("gold standard") data from the registries for comparison with the SMS data. The overall concordance was high and improved over time (about 15 weeks).

Use of SMS for reporting surveillance data thus allows accurate tracking of malaria trends. Small-scale sentinel surveillance with enhanced supervision and rapid reporting mechanisms are a viable alternative to relying solely on data collected through the routine health management information system.

Alternatively, active case detection strategies can be used, in which health workers visit communities and actively screen the population to find cases. Active case detection is useful when a disease is rare or occurs in isolated clusters, when patients do not present to health facilities (e.g. for an asymptomatic or stigmatized disease) or for determining the disease incidence in a specific subpopulation. For example, lymphatic filariasis is usually identified in population-based surveys for microfilaraemia or antigenaemia (*57*). Resources can be shared among vector-borne disease control programmes for conducting surveys. For example, lymphatic filariasis and onchocerciasis surveys could be conducted together. More accurate estimates of malaria incidence or parasitaemia in children < 5 years of age can be obtained by conducting population-based surveys. Examples of active case detection techniques that have been used effectively for leishmaniasis are given in Box 30.

Box 30. Active case detection strategies for measuring disease burden (adapted from *30*)

House to house search:	Health workers visit houses and screen every household member for disease.
Camp approach:	Health workers set up a camp in a village, e.g. at a central point or school, and, after a community awareness campaign, invite community members to attend the camp for screening.
Index case approach:	A positive (index) case is identified, and households near the index case are screened for cases.
Incentive-based approach:	An incentive (monetary or other) is given to health volunteers who facilitate case detection.

9.5.2 Cost and cost–effectiveness of integrated vector management programmes and comparison with standard practice

IVM is expected to be more cost–effective than conventional vector control programmes because it reduces duplication among disease-specific programmes, and evidence-based use of a diverse range of vector control tools is likely to result in more effective control. However, this needs to be systematically assessed by programmes and an increased evidence base on cost effectiveness of IVM versus conventional programmes will help to build the advocacy case for IVM.

The aim of cost–effectiveness analysis is to determine whether mortality or morbidity can be prevented to a greater extent at lower cost with IVM or with conventional vector control. The first step should be to determine the costs of implementing an IVM programme and routine vector control. To ensure complete coverage of costs, an "ingredients" approach can be used, i.e. listing the costs of different activities by category rather than listing total costs or total expenditures. For example, programme costs include capital costs (vehicles, equipment, buildings) and recurrent costs (personnel, operating expenditures, training, media campaigns, information, education and

communication). All costs must be included, such as for supporting interventions like community engagement campaigns and interventions. Costing with the ingredients approach can be done with the open-source software Cost-It, available on the WHO-CHOICE website (*344*).

The cost–effectiveness of an IVM strategy is measured by comparing the cost of preventing a death or case of disease or infection (incidence or prevalence) with that in a conventional vector-borne disease control strategy (see Box 31).

Box 31. Hypothetical example of cost–effectiveness (cost per case averted) (adapted from *345*)

A conventional malaria vector control programme in a district, involving use of LLINs, is being replaced by an IVM programme with LLINs, larviciding and drainage of surface water. The first step in comparing the cost–effectiveness of the two programmes is to determine how effective the programmes were in preventing malaria cases. Before any vector control, there was an average of 1500 malaria cases. With the conventional vector control programme, there were 1000 malaria cases in the district; with the IVM programme, the number of malaria cases in the district fell to 500.

The next step is to look at the costs of the programmes. The conventional programme cost an average of US$ 25 000 per year, while the IVM programme cost US$ 40 000 per year. To calculate the cost per malaria case prevented:

Programme	Cost (US$)	No. of malaria cases prevented	Cost per malaria case prevented (US$)
Conventional programme	25 000	1500 – 1000 = 500	25 000 / 500 = 50
IVM programme	40 000	1500 – 500 = 1000	40 000 / 1000 = 40

The cost per malaria case prevented was US$ 40 in the IVM programme and US$ 50 in the conventional programme. The IVM programme was therefore more cost–effective than conventional vector control. Thus, although the conventional vector control programme was cheaper, it was not cost–effective.

The simplified example in Box 31 refers only to malaria. It is important to determine the impact of programmes on the number of cases of disease or death due to all vector-borne diseases in an area. For example, if an area is endemic for both malaria and lymphatic filariasis, the costs and benefits (cases or deaths averted) of each programme alone should be compared with the costs and benefits of the combined IVM programme. When costing an IVM programme, it is good practice to subtract any cost savings made by the prevention of cases, such as inpatient treatment costs, although this information might be difficult to obtain.

Comparisons of the costs and effectiveness of conventional and the IVM programmes can be made in two ways: before and after the intervention or between geographical areas in which the two types

of programmes (conventional and IVM) are being used concurrently. More information on performing a cost–effectiveness analysis is available (*346*).

When the cost–effectiveness of an IVM programme is evaluated in its early stages (for example in year 1 or 2 of implementation), it is important to bear in mind that start-up costs are likely to be higher than long-term costs; therefore, the cost–effectiveness might initially appear to be lower than that of a long-standing conventional vector control programme. High initial start-up costs but increasing cost–effectiveness over time were observed in an analysis of environmental management and house modification for malaria control in copper mining communities in Zambia in the 1920s and 1930s (*240*).

9.5.3 Reduction in insecticide use and comparison with standard practice

Insecticide-based interventions such as LLINs and IRS are the mainstay of vector control for many vector-borne diseases; however, diversification of the tools used in IVM might help to reduce insecticide use, thus reducing the risk for insecticide-resistant vectors, environmental effects and adverse effects on health. This risk can be assessed systematically by comparing the number of toxic units of insecticide used per disease case averted with standard vector control and with IVM. The measure "toxic units of insecticide used" rather than simply the volume of insecticide is maintained because some insecticides are more toxic than others. To measure this indicator, programmes must keep good records of the insecticides used. Further information on calculating the number of toxic units of insecticide used per disease case averted can be found in the WHO booklet on monitoring and evaluation indicators for IVM (*2*).

9.5.4 Sustainability of the programme

The sustainability of an IVM programme can be measured in a number of ways. The WHO document on indicators for monitoring and evaluation recommends determining whether there is a strategy to ensure continued mobilization of resources for vector control (*2*). An interview or survey should be conducted with the government bodies concerned and a copy of the relevant strategy document obtained. The 'institutional memory' of vector-borne disease control programmes can be assessed by determining for example whether there are standard operating procedures and training documents to ensure continuation of activities if key staff retire or leave the programme.

Programmes with more resources may also be interested in the social, institutional or political impact of the programme, as these aspects will influence whether the IVM programme will be sustained. For example, community acceptance is a social impact of a programme: if interventions or programmes are not acceptable to the community, their success and sustainability will be jeopardized. Measuring the social, institutional or political impact of a programme will require specialized quantitative and qualitative techniques. More information on social research methods is

given in Box 32 and elsewhere (*347*, *348*). Practical examples of use of these techniques to assess community participation and intersectoral action are given in boxes 33–35.

Box 32. Social research methods for measuring social, institutional and political impacts of IVM programmes (adapted from *349*, *350*)

Social research methods reveal certain aspects of programmes in greater depth. They help answer the questions "How?" and "Why?". The methods most commonly used in monitoring and evaluation are:

Focus groups

A group of 8–10 individuals is brought together to discuss a particular topic for 60–90 min. The discussion is guided by a facilitator, who usually has a topic guide that lists the topics to be covered and guides the discussion by asking open-ended questions such as "What is your opinion of the new vector control programme?". The discussion is either tape-recorded or recorded by a dedicated note-taker. It is important to consider who will participate in a focus group, as people are more likely to interact well if they see other participants as being like themselves. Group interaction often reveals data and insights that might be less easily accessed in a one-to-one discussion.

In-depth interviews

Interviews vary by the degree of structure. In unstructured interviews, the pace, subject and questions depend on the interviewee. Structured and semi-structured interviews follow a series of guiding questions. In structured interviews, the interviewer asks the questions strictly according to the guide, so that every respondent is asked exactly the same questions in the same order. Semi-structured interviews are more common, in which the interview guide is followed more loosely, and the interviewer is freer to probe the respondent. Interviews can be conducted by telephone or in person.

Observations

There are two main types of observation: participant observation and direct observation. In participant observation, observers become members of the community or population they wish to observe. The observer participates in activities and observes how people interact with each other and other organizations. Participant observation may be difficult in the context of a programme, unless the observer is external. A more useful technique may be direct observation, whereby the observer watches activities but does not participate in them.

Document review

Programme documents, such as policies, meeting minutes, correspondence and routine records on clients or services, are a useful source of information on programme activities and processes and can help generate questions to be answered with other qualitative methods. Document review has the advantage that activities that were performed in the past can be reviewed, and recall is not a problem as the documents were produced at the time of the event.

Analysing qualitative data

Qualitative data, whether from a focus group discussion or interviews, should be examined to identify the main themes, how often the themes occur and how they are related, i.e. whether patterns are appearing. There are software packages to help organize and analyse qualitative data, such as NVIVO, ATLAS.ti and EZ-text (which can be downloaded for free from the CDC website: http://www.cdc-eztext.com/). It is often interesting to compare themes and patterns between groups or individuals. For example, a focus group of

farmers who have to dry their fields once a week according to new IVM policy might have different views about the programme than members of a community.

Survey research

The first step in survey research is to design the survey. Careful consideration should be given to the questions to be asked, how to ask them and the order in which they should be asked. Questions can be closed (requiring a simple yes or no answer) or open-ended (requiring longer, free-text answers). Surveys can either be administered in person during an interview, or the respondent can fill in the questionnaire. It is also important to consider how the respondents will be sampled: by probability sampling (e.g. simple random sampling, systematic random sampling) or non-probability sampling (e.g. convenience sampling or purposive sampling).

Box 33. Qualitative assessment of community-based vector control in Malindi, Kenya (adapted from *351*)

Community involvement is extensive in the National Malaria Control Strategy in Kenya. The Municipal Council of Malindi created an environmental and mosquito control activity mandate under the national primary health care programme in which community groups, partly supported by Government funds, are responsible for environmental management and malaria control activities. They treat ditches, make and sell LLINs, drain stagnant water, organize clean-up campaigns, make and sell repellent *neem* soap and organize community campaigns such as "Malaria Mosquito Day".

A study was conducted with "key informant" interviews, focus group discussions and a "stakeholder" meeting. The aim was to determine which malaria control activities the community groups were involved in and to identify successes and obstacles to vector control. "Key informants" from the Ministry of Health, the Municipal Council of Malindi and the Ministry of Culture and Social Service, Gender and Sports were identified and interviewed by facilitators trained in participatory techniques. The "stakeholder" meeting involved representatives of community groups, NGOs, businesses and public offices responsible for organizing vector control in Malindi. Focus group discussions were held with eight community groups selected randomly from among 19 groups that played a role in mosquito control. The focus group discussions covered the roles and responsibilities of community groups in vector control, operational constraints to effective control and challenges. The discussions were led by a facilitator and recorded by a note-taker. All discussions were recorded and then transcribed and explored to generate categories and explanations in a thematic framework. Data collected with the three methods were compared to determine whether similar themes emerged.

Challenges were identified that are potential barriers to the sustainability of community-based vector control. Support from the Municipal Council was identified as an important enabler. Before 1999, municipal support was provided in terms of training and guidance, equipment, monitoring and supervision, and the regularity of control activities decreased after withdrawal of this support. The community groups reported that such support and supervision were motivating factors, making them feel recognized and appreciated. Another barrier that was identified was that projects did not generate sustainable income (e.g. insecticide-treated bed net manufacturing and sales); volunteerism could not be sustained in the absence of income generation when the community group members themselves were poor.

Box 34. Measuring and evaluating intersectoral action (adapted from *345/352*)

Intersectoral action is a key aspect of an IVM programme, whereby actors and organizations in different sectors take action together against a vector-borne disease. It is therefore important to assess how intersectoral action works and to learn from the experience. The materials used by WHO to generate case studies on intersectoral action for addressing social determinants of health provide excellent guidance for describing and assessing intersectoral action. Some important questions are listed below.

Approaches

What mechanisms and tools were used to support intersectoral action? For example:

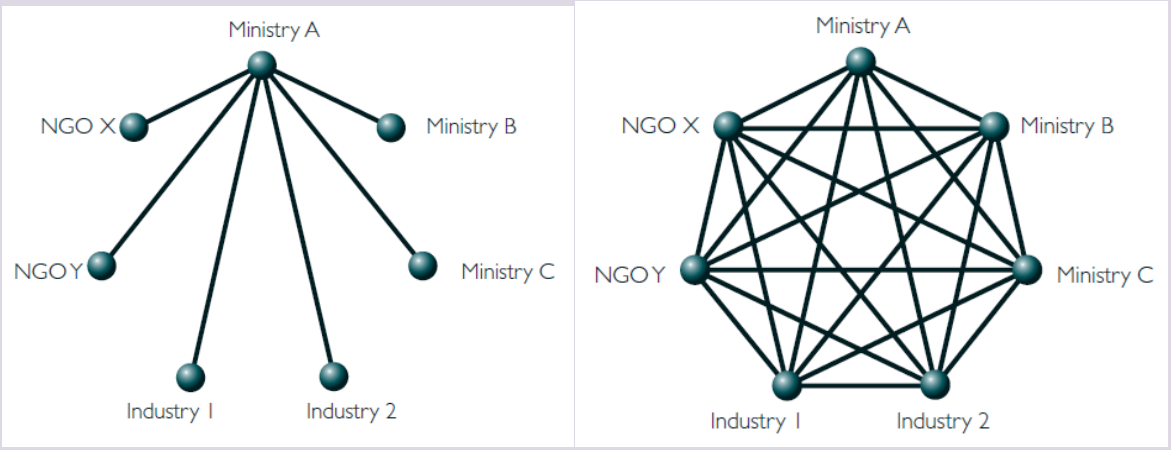
- information, e.g. research, knowledge transfer, communication, evaluation results;
- institutional arrangements or mechanisms, e.g. national commission;
- financial mechanisms, e.g. source of funding, budgeting structure;
- legislation and regulation;
- accountability frameworks or monitoring mechanisms; and
- planning and priority-setting.

What is the structure of the intersectoral action, programme or policies? For example:

- Which principal actors were responsible for influencing the policy decision, its implementation and evaluation? What role did they play? NB: This role can be beneficial or non-beneficial.
- What was the role of the health system or sector in terms of leadership, coordination etc?
- What is the best description of the level of integration? (See Box 35 for categories of integration.)
- Were participatory mechanisms involved? What were those mechanisms? Who participates, and what are their motives? Participation can be categorized as follows:

Classification	Explanation
Informing	To provide the public with balanced, objective information to assist them in understanding the problem, alternatives, opportunities or solutions
Consulting	To obtain public feedback on the analysis, alternatives or decisions
Involving	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered
Collaborating	To collaborate with the public in each aspect of the decision, including finding alternatives and identifying the preferred solution
Empowering	To place final decision-making in the hands of the public

- What was the model for the relationship? Examples of models of relationships are shown below. Informal relationships could be depicted with dotted lines.



- Were there budgeting and financing mechanisms to promote intersectoral action? What were these mechanisms, e.g. funding pools? Which sector or entity proposed the mechanism, and how was it set up?

Impact and lessons learnt

- What were the responses to the process and outcomes, given their expectations?
- How did the perspective of the health sector or other sectors change?
- Did concern about vector-borne disease become a stronger issue with the public, other sectors or the government due to this initiative?
- What is the impact or role of data or evidence on vector-borne disease in stimulating action?
- Which structures, mechanisms, platforms and incentives work well or poorly, and why?
- How could implementation have been improved?
- How can specific barriers be overcome, including those related to funding, budgets, personnel and skills mix?

Box 35. Example of measuring intersectoral action for malaria control in Ghana (adapted from *352*)

A simple method for assessing intersectoral action is that of Owusu et al. (*353*), who examined the degree and determinants of intersectoral action among organizations working in malaria control in two districts of Ghana, one urban and one rural. The researchers interviewed people in 32 core institutions (16 in each district) engaged in malaria control in Kumasi metropolis and Ahafo Ano South district, including institutions in the health sector, in the agriculture, education, environment, economic and finance sectors and in community groups. Institutions were selected on the basis of a document review and consultation with representatives of the Ghana Health Service, which oversees implementation of health policies and programmes. The personnel interviewed included service providers, administrators, service users and community members (including local politicians).

The researchers used a simple classification of the different levels of intersectoral collaboration:

Score	Classification	Explanation
0	No awareness	Institution has no knowledge of another institution's malaria programmes.
1	Awareness	Institution has knowledge of another institution's malaria control programmes, but does not participate in their activities.
2	Communication	Institution has knowledge of another institution's malaria programmes and shares information on their activities.
3	Cooperation	Institution has knowledge of another institution's malaria programmes and shares not only information but also ideas to guide and modify their own planning and activities.
4	Collaboration	Institution has knowledge of another institution's malaria control programmes, shares both information and ideas and also jointly plans and modifies delivery of service by mutual consent.

The representatives of each institution were asked to rate their degree of integration with the other institutions on this scale, and the results were put into a matrix, which allowed the authors to compare how well each institution thought they integrated with other institutions (self-reported degree of integration) and the how well other members of the network thought the institution integrated (group-reported degree of integration).

9.6 Framework for quality assurance

Quality assurance (QA) is the implementation of systematic and well planned activities to prevent sub-standard services or products. Although this approach is commonly used in the manufacturing and other commercial industries, until now QA has not been well defined in the context of vector control. However, increasing pressure for greater accountability from donors and other stakeholders is prompting disease control and elimination programmes to move toward more formal and transparent methods of communicating: service quality standards; the methods by which the probability of a successful programme outcome are increased; methods for performing monitoring checks and assigning quality scores to assess programme performance, and standardized protocols that delineate how problems are identified and the feedback loops in place to effectively correct them.

Good QA is a proactive approach for maximizing resources to increase the likelihood of programme success. Resources are valuable; suboptimal quality outcomes and lack of impact can be attributed to lack of QA during the input, process and output phases of the programme. Whether or not the planned outcomes and impact are achieved, the QA approach ensures sufficient information for the strategic and operational levels of a programme to either support the current strategy or make the necessary changes. This type of structured approach to identifying strengths and weaknesses in programme stages can lead to innovative ways of dealing with challenges and avoiding the potentially devastating consequences of poor vector control management.

The success of the IVM approach depends on QA of individual interventions alone (Fig. 33) and in combination. Implementing multiple interventions without knowledge of the effectiveness of properly performed single interventions may not be cost effective or lead to better impact. Managers and stakeholders at strategic and operational levels should drive the QA agenda in order to gather knowledge to support effective IVM. Communities at risk, who are the primary beneficiaries, should be consulted to understand their expectations.

Fig. 33. Quality assurance of indoor residual spraying: filter paper on the wall is used to measure insecticide application (photo courtesy of S. Lindsay)

Planning the QA of an IVM approach starts at the strategic level with preparation of a QA framework document and operational guiding documents (Fig. 34). The aim of the framework document is to define the quality of IVM, describe the methods to be used to ensure the quality throughout IVM and set out action plans. The more detailed guidelines will break down the process in detail and facilitate operations.

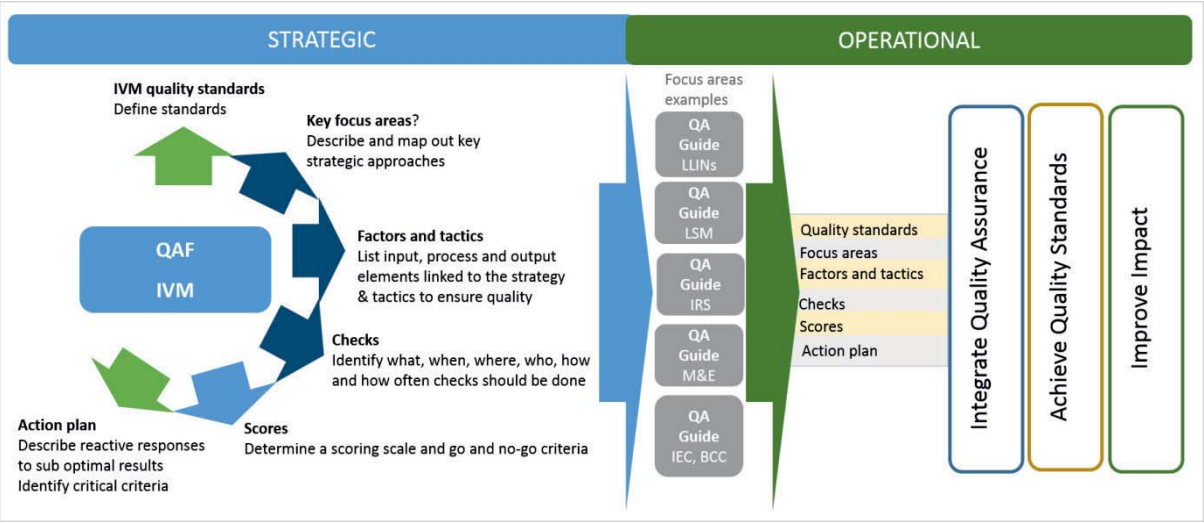


Fig. 34. Quality assurance planning at strategic and operational levels

Fig. 35 is an extract from a QA guide, with one IRS quality standard (> 80% room coverage), advocacy as an example focus area for this standard, input, process and output factors associated with success, tactics to minimize the risk for failure, checks, scoring and proposed corrective action if required. Many vector control programme objectives, activities, indicators and targets will be covered in a QA framework and guide. Duplication of effort should be prevented; it is advisable that a dedicated person be responsible for preparing a QA framework and guide.

IRS standards	Focus areas	Factors	Tactic	Checks	Score	Action
>80 % room coverage	IRS advocacy	**Input** Funding Personnel Transport Equipment Timing Tools Etc.	Annual planning Budget Operational plan Meetings and formal agreements	Adequate budget for personnel, equipment, materials and tools. *Programme Manager.* Annually - April Advocacy plan finalized Formal agreement with health promotion section to share transport. *Programme Manager.* Annually - April. Follow up meetings June, August Meetings with community leaders in each village. *District Vector Control Programme Managers* - August Health promotion materials available. Vector Control Programme *Procurement Officer* - July Equipment tested and available. *District vector control programme manager assistant* -July	Green (no action), orange (action) or red (no go). This is for all scores.	If budget was not approved, discuss possible sharing of further resources with other sections within the health system Determine reasons. Emergency workshop and meetings to facilitate plan and agreements Determine reasons. If time constraints bring all community leaders to one venue. Determine reasons. Decide on alternatives and contact other sections or departments for assistance Faulty equipment requires immediate fixing or alternative arrangements to borrow equipment from other sections or departments.
		Process Acceptance Understanding	Survey	90% will agree spray operators to enter their house 90% understand why IRS is important		Determine reasons for low scores. Rectify where possible e.g. revise all materials and tools for the next season. Emergency community meetings.
		Output Communities reached	Survey	100% of all targeted communities reached.		Visit communities not reached. Determine reason for low numbers.

Fig. 35. Example of a section of QA guidelines for IRS, with advocacy as a focus area for achieving good room coverage

9.7 Data management

Surveillance of disease and vectors will result in a vast quantity of data for monitoring and evaluating a programme. Data on entomology, epidemiology, interventions and other factors such as meteorological information must be integrated. In order that these data can be used to their full advantage for reporting to donors, measuring progress and impact and evidence-based decision-making, a data management system (Fig. 36) should be established.). Outputs of the system include results of queries (e.g. what was the coverage of LLINs in a district during the last universal coverage campaign), reports and also potentially maps if the programme has geographic information system capability. These outputs can be used be operational staff and programme managers to trouble-shoot, adapt and problem solve. They can also be used to advocate to policy-makers and for reporting to funders.

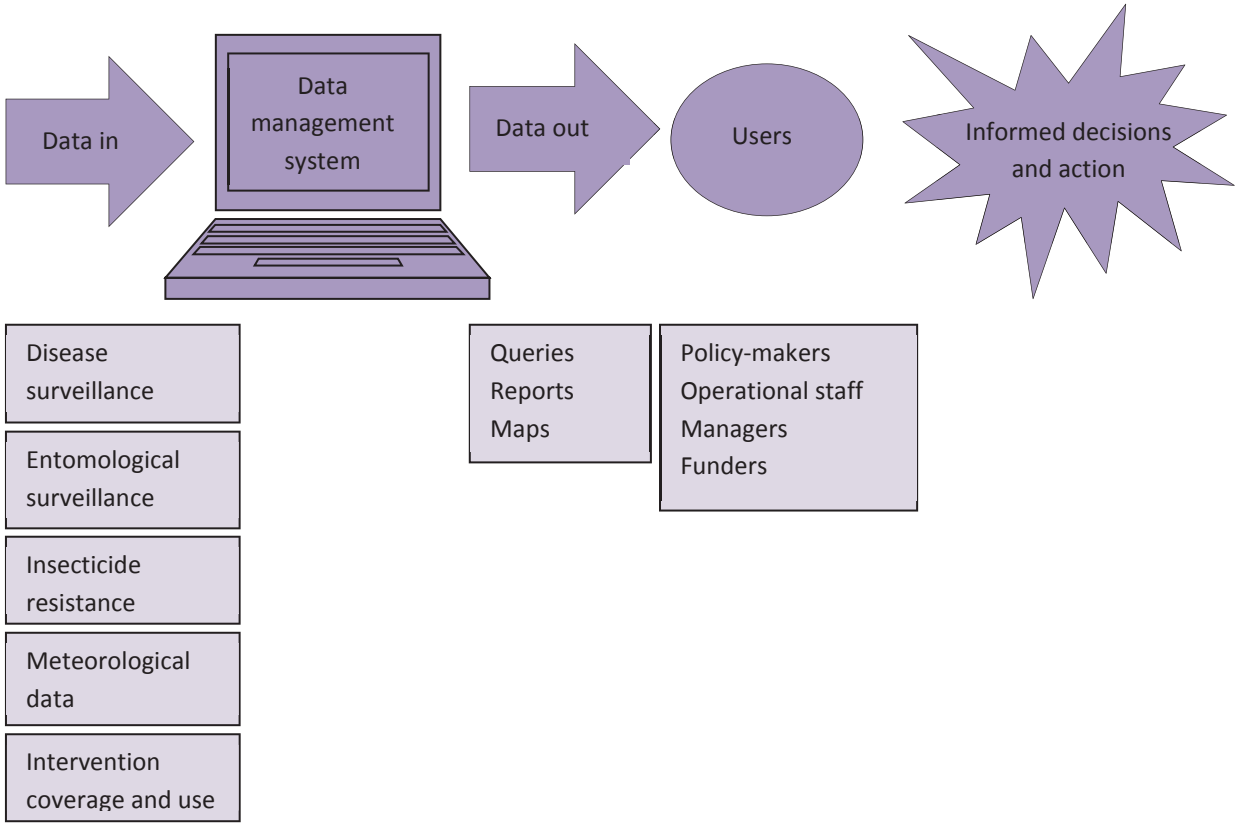


Fig. 36. Integration of data in a data management system

An excellent summary of a health management information system is provided by the WHO Regional Office for the Western Pacific (*354*). While this handbook emphasises case data and the Expanded Programme on Immunization, many of the concepts are valid for vector control programmes.

The first step is to consider the role of users in the hierarchy (Table 18) and the indicators they need to perform their function.

Table 18. Function of each programme entity by administrative level

Administrative level	Function
Village	Case finding, service delivery, entomological surveillance, information, education and communication, behaviour change communication, outbreak identification and response
District	Monitoring (case management, entomology, interventions) and supervision, operational planning, outbreak identification
Region	Evaluation, strategic planning (where appropriate), programme planning
National	Policy formulation, strategic planning

The data collected and reported in the data management system should tie in with the indicators you are interested in for monitoring and evaluation of the IVM programme. The sources of information for the numerator and the denominator and the frequency of data collection should be considered. For example, for an indicator of LLIN coverage, the number of vouchers distributed during enumeration is the denominator and the number of LLIN distributed (vouchers redeemed) is the numerator. In order to measure disease incidence in a district, the number of cases presenting at district health centres is the numerator and the district population (census) is the denominator.

Not all data needs will be met by routine data collection, as mentioned above. Specific surveys may be required to collect data that are used less frequently or for only certain subsets of the population.

It is important to consider the lowest level at which computers will be used for data management, which depends on the budget, the ability of staff to enter data, the technical assistance available for maintaining the system, data security and the compatibility of software with existing hardware.

At lower levels, data are usually collected and processed on paper, although this depends on the setting. For example, field data can either be collected on paper or some control programmes may issue personal digital assistants or smartphones for electronic collection. Data collection tools should be designed carefully and pilot-tested before distribution. They should be kept simple. Data consolidation and management at district, regional and national level should ideally be computerized, and the data management system should be supervised by staff with technical expertise and access to computers and appropriate software.

Data should be recorded and managed so that it flows from the periphery to central level and then aggregated data fed back to peripheral levels. For example, data collected at individual sampling sites by field entomologists might be summarized in weekly reports by the district manager, who will then report to regional authorities, who will report to national managers, perhaps monthly. There may be non-health sector users and suppliers of data in this hierarchy. Data on insecticide use in the agricultural sector should be provided by the ministry of agriculture and assessed with data on insecticide resistance in disease vectors.

The frequency with which data are reported to the next hierarchical level depends on the requirements of users and how often a phenomenon is observed; for example, weekly reports on larval abundance or an annual report on LLIN coverage. As the data move up through the hierarchy, they will be summarized more and more to provide a good overview. The most detailed data should be kept at source, and reporting requirements should be kept to a minimum (*354*).

Training should be conducted to maintain data collection and management at a high standard. Training should include completion of forms, computer input, data analysis, interpretation and use (*346*).

For dissemination of data, consideration should be given to the users, what information should be disseminated, how often it should be disseminated and in what format, such as a written report, at a formal meeting or by another means (Table 19).

Table 19. Data dissemination activities (adapted from *354*)

Example of report or activity	To whom it is be disseminated	Mode of dissemination	Frequency of dissemination
Annual malaria report	Government statistics office Secretary for health Malaria control programme managers and staff (including region and district) Implementing partners, e.g. NGOs Donor representatives	Publication Meeting	Annual
Malaria incidence by region	National malaria control programme staff Health facilities Implementing partners, e.g. NGOs	Telephone E-mail	Monthly
District entomology field team meeting	Field technicians District entomologist	Meeting	Weekly
Intervention team meeting	Subdistrict supervisors Technicians	Meeting	Weekly (for IRS and time-limited LLIN campaigns)

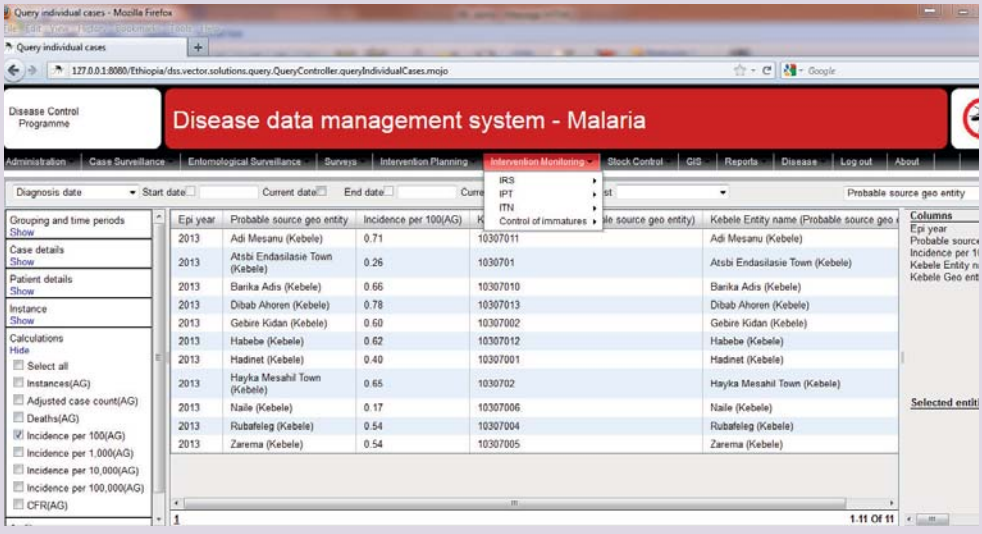
At each level (district, region, national), data should be assessed and interpreted and fed back to inform operational activities. Data collectors must be motivated to ensure the sustainability of the data management system and the production of high-quality data. Motivation can be increased by providing regular feedback (positive and negative) on data outputs.

An example of a computerized disease data management system in which data on entomology, case reports, surveys and intervention coverage are integrated is outlined in Box 36.

Box 36. Example: Innovative Vector Control Consortium disease data management system

The Innovative Vector Control Consortium has issued a disease data management system that facilitates monitoring and evaluation of vector-borne disease control programmes. Currently, the system covers monitoring and evaluation of malaria, dengue and visceral leishmaniasis and allows the addition of other vector-borne diseases. The system has been fully tested and is being used in a number of programmes, including malaria control programmes on Bioko Island, Equatorial Guinea, Ethiopia and Zambia and in a visceral leishmaniasis control programme in India.

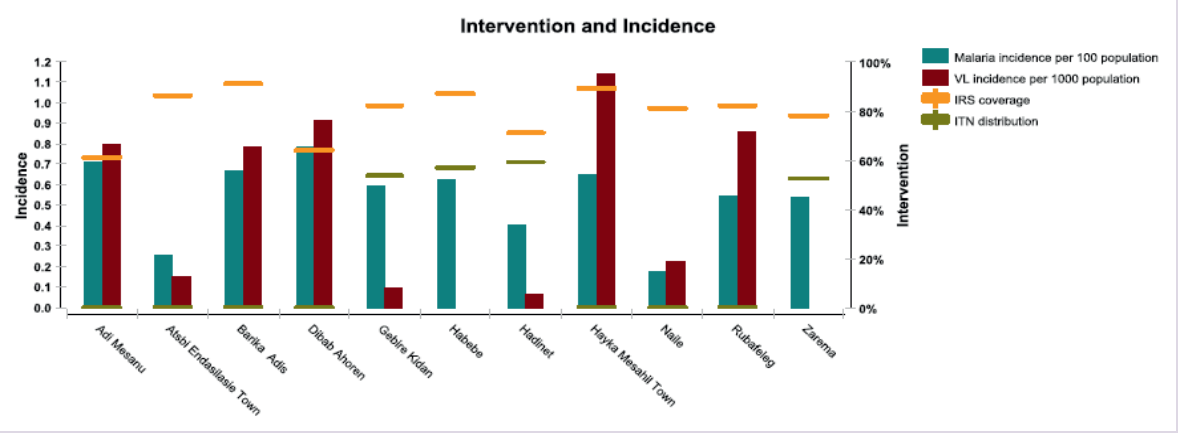
The system is based on open-source software, which can be installed on a central server and accessed with an Internet browser from remote computers. It is a modular system that captures information on case surveillance, entomological surveillance, surveys (for example malaria indicator surveys) and intervention monitoring. It also includes modules for intervention planning and stock control. Data can be put into the system either directly or imported, which is useful if a programme has historical data, if programme staff generate data in a different format or if they do not have online access to the disease data management system.

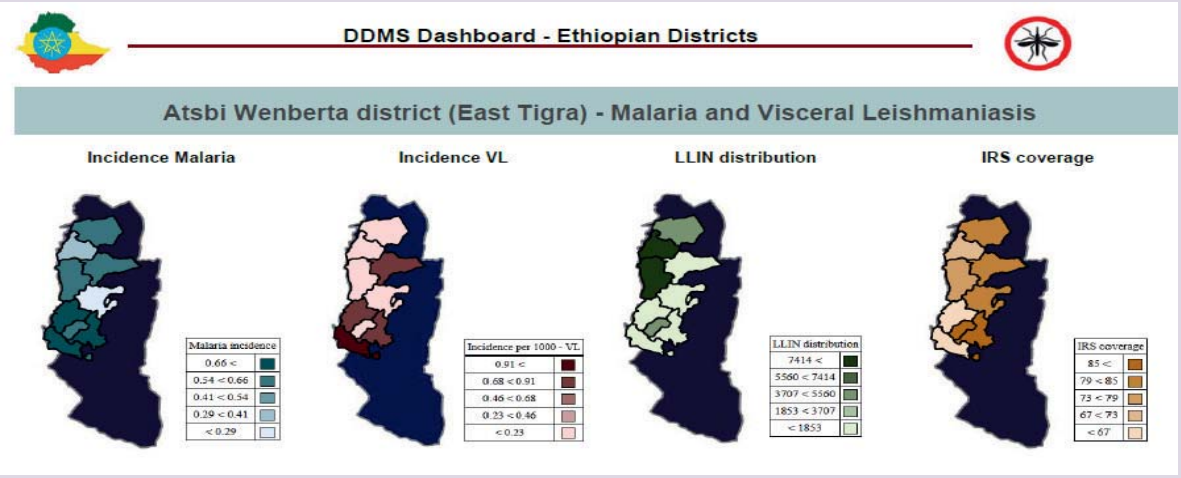


Screenshot of disease data management system interface and query builder (Data are fictitious.)

The system can also support decision-making. Data can be queried and reports generated easily, with clear visuals, including graphs and maps. As reports created online are interactive, the underlying data can be accessed. Maps can be used to show differences in intervention coverage, entomological indicators or clinical cases by geographical area as polygons or individual points, such as larval abundance at sampling sites when these have been located with a global positioning system. In addition, thresholds can be entered into the system to automatically flag and send e-mail alerts if, for example, the number of cases in an area increases, giving an early sign of an epidemic.

The system was developed by the Liverpool School of Tropical Medicine and the Innovative Vector Control Consortium, and the team can provide training and technical support. Full country ownership of the system is preferred, however, and a technically competent country programme staff member can be trained in several weeks to administer and run the system, with little additional support.





Screenshot of reports, showing multi-disease capability (The data used to generate these reports are fictitious.)

9.8 Deciding whether to change, continue or stop integrated vector management

As the dynamics and goals of a programme change over time (e.g. control versus elimination), the IVM programme must also change. Decisions about changing, continuing or stopping use of an IVM tool should be based on a thorough evaluation by the intersectoral steering committee, which will advise the relevant departments. Decisions should be made after the effect of the intervention on epidemiological and entomological outcomes has been assessed, with information on parameters such as cost, cost–effectiveness, human resources and feasibility. It is important to consider the receptivity and vulnerability of an area to disease transmission before stopping interventions, as there may be high risk of disease resurgence even in areas where there have been substantial reductions in disease transmission (*355*).

Section summary

- Monitoring consists of continuous tracking of programme performance and checking progress against predetermined objectives and targets.
- Evaluated outcomes and impact are used to determine whether the programme activities were successful.
- Disease specific programmes are likely to have their own monitoring and evaluation plans but these data should be collated into an IVM specific plan which covers intervention/disease-specific indicators and IVM programme-specific indicators (e.g. cost effectiveness, sustainability, intersectoral collaboration etc.).
- Vector control activities under IVM should be within a QA framework.
- Data management for monitoring and evaluation is very important; data on disease surveillance, entomological surveillance, meteorological information and intervention coverage and use should be integrated.
- A decision to change, continue or stop vector control should be based on a thorough evaluation.

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Annex 1. Example stakeholder analysis for including drain rebuilding and maintenance in an IVM programme

Step 1: Identify key stakeholders

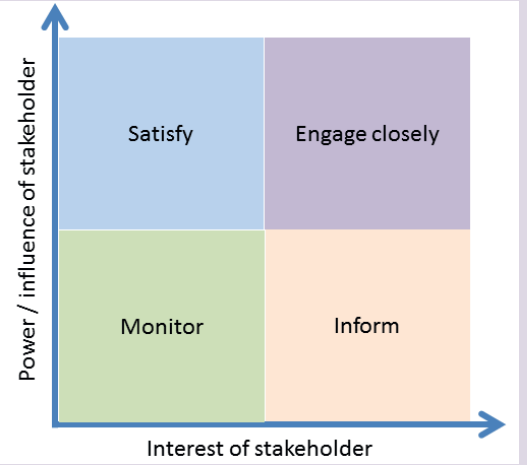
The first step is to brainstorm who your key stakeholders are in the IVM programme. A stakeholder is a person or organisation that has something to lose or gain from a project. They can be people who are affected by the programme, those who have influence or power over it or have an interest in its successful or unsuccessful conclusion.

Step 2: List key characteristics of stakeholders

The characteristics of each stakeholder should be detailed – in particular the name of the specific person in the organisation/group you are dealing with and the role of the stakeholder.

Step 3: Prioritise your stakeholders

Prioritise your stakeholders by considering their power/influence over the programme and their level of interest. The matrix shown below will help you to think this through. The power and level of interest of the stakeholders should influence the action taken with regards to this stakeholder. For example, powerful and important stakeholders should be engaged closely, while stakeholders with less power and importance may only need to be monitored.



Step 4: Understand your stakeholders

The next step is to brainstorm what you know about your stakeholders. How do they feel about the IVM programme? What motivates them e.g. emotion, finance? Who or what influences their opinion of the IVM programme? Is their opinion based on good information? What is the best method of communicating and engaging with them? What resources do they have? How will you gain their support of the IVM programme or manage their opposition?

Step 5: Develop a plan of action

Finally you should develop a plan of action with regards to your stakeholders. You should document the actions taken, who will be responsible for the action and by when/with what regularity.

Stakeholder	Person	Role	Power or influence	Interest	Action taken	Responsible	Timeline
Ministry of Health		Delivers health services					
Ministry of Finance	Mr Ali	Determines level of financial support to other government ministries	High	Low	Lobby for increased funding for Ministry of Public Works	IVM focal person and vector-borne disease programme managers	August
Ministry of Public Works	Mr Abass	Building and maintenance of drains	High	High	Lobby and educate decision-makers about the health benefits of filling and drainage. Ensure that filling, drain rebuilding and maintenance are priorities and are conducted in areas with high vector-borne disease incidence.		
Community leaders	*Shehia* leaders	Mobilize community support	High	Low	Engage community leaders to promote health benefits of clean environment	District head of vector control in the national malaria control programme	
Community group	*Kigogo* women's group	Involved in regular "clean-up" days	Low	High	Encourage more regular clean-up days, provide support for clean-up days, including promoting health benefits and mass media		
Private refuse collectors		Refuse collection for a fee	Low	High	Encourage refuse collectors to look for opportunities to make money from garbage disposal and recycling.	District-level IVM focal person	
Landlords	NA	Responsible for upkeep of housing and collecting rent from tenants	Low	Low	No action	-	-
Tenants	NA	Tenants	Low	Low	Ensure that tenants are reached through community education.		
Tax department	Mr Msellem	Responsible for tax collection	High	Low	Lobby for more efficient tax collection		

Annex 2. Local determinants of disease

Introduction

Vector-borne diseases depend on a complex interaction between pathogens, vectors, humans (animals in some cases) and the environment (Figure A2.1). It is important to consider these determinants and their interactions to understand why diseases occur and how to control them. The different interactions result in wide variation in the time and space in which diseases occur. The geographical distribution of diseases such as malaria may be stable over time, while that of others, such as dengue, may vary from year to year. Diseases may also be distributed unequally in the population due to differences in risk of individuals and communities. Typically, 80% of a disease burden is experienced by 20% of the population (*1*). For example, in malaria-endemic areas, people who sleep close to breeding sites tend to have a higher risk for exposure.

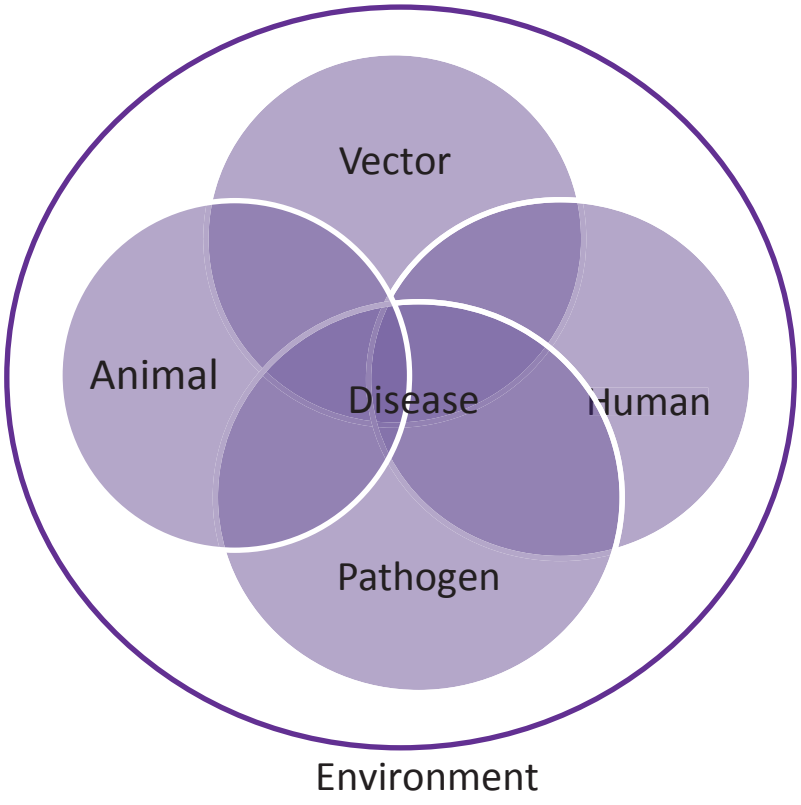


Figure A2.1. Five categories of determinants of vector-borne disease

Many determinants of disease exceed the mandate of conventional vector-borne disease control programmes, such as irrigation systems, urban development, sanitation and housing. These important determinants require coordinated action with other sectors and local communities.

Pathogen-related determinants

The first step is to consider which parasites or pathogens cause disease and identify where vector-borne diseases are endemic in an area. It is also important to consider the medical options available for prevention (e.g. vaccines or preventive chemotherapy) and treatment of the disease. Some questions for consideration are listed in Table A2.1.

Table A2.1. Pathogen-related determinants of disease

Question	Rationale
Which vector-borne disease are endemic in the area?	A central tenet of IVM is the use of evidence to plan and implement vector control. The maps in this toolkit indicate the distribution of vector-borne diseases. They should be supplemented by epidemiological data to prioritize control at lower levels.
What medical options are available for disease prevention?	Vaccines and preventive chemotherapy are available for some vector-borne diseases. A vaccine is available for yellow fever (although it is mainly for travellers and may not be available for most residents of endemic countries), and vaccines are being developed for some other diseases. Preventive chemotherapy is the mainstay of control for a number of vector-borne diseases, including onchocerciasis and lymphatic filariasis. For malaria, intermittent preventive treatment of malaria in pregnancy with sulfadoxine-pyrimethamine is recommended by WHO in areas of moderate-to-high transmission (*2*). WHO also recommends seasonal malaria chemoprevention for children aged 3–59 months in areas of highly seasonal malaria transmission in the Sahel subregion (*3*).
Which parasites or pathogens cause disease?	Diagnostic capacity should be built to distinguish between parasites, such as *P. falciparum* and *P. vivax* and co-infection within e.g. *Leishmania* and HIV.
What medical options are available for treatment?	Effective treatment is available for some diseases; WHO guidelines on choice of drug and dosing should be followed. Where drug treatment is available, vector control programmes should be aware of whether the existence of drug resistance and whether counterfeit or sub-standard drugs are a problem. Effective drugs are not available for some diseases, e.g. dengue fever, and only supportive care is provided.

Vector–related determinants

The dominant vectors of vector-borne disease should be identified. The vector distribution maps in this toolkit can be used but should be supplemented with national data, such as data from sentinel surveillance sites. The relative abundance of vectors in an area should be assessed continuously, as vector populations are rarely constant, and new vector species may be introduced such as *Ae. albopictus,* an efficient vector of chikungunya. The questions that can elicit information on vectors are listed in Table A2.2.

Table A2.2. Vector-related determinants of disease

Question	Rationale
What are the main local vectors?	The main vectors must be identified in order to adjust control programmes. As the species composition of vectors may change over time, for example due to climatic and environmental change, regular re-assessment is necessary.
Where and when do they occur?	Vector control must be targeted to the areas and the times in which the vector is present. The presence of suitable habitats and seasonal changes in weather such as temperature or rainfall determine vector abundance.
What are the behavioural characteristics of vectors (e.g. diurnal activity pattern, endophily, anthropophily)?	Vector characteristics determine the efficacy of some control methods. For example, insecticide-treated nets are effective against indoor, night-biting mosquitoes; while IRS is effective against mosquitoes that rest indoors. Some vectors feed on both humans and other animals, so that the vector can be controlled by targeting the secondary host. For example, *Glossina* (tsetse flies) of the morsitans group, which are responsible for transmitting Rhodesian HAT, can be controlled by treating cattle with insecticides. The behavioural characteristics of vectors should be assessed regularly over time, as vectors may adapt in response to control measures.
Where and when do the vectors breed?	Larval stages of vectors cannot run or fly away and so may be suitable targets for vector control, provided that breeding sites are “few, fixed and findable”. It is therefore important to identify where and when vectors breed and consider vector control tools against this stage. For example, larval source management can be used against mosquito larvae for control of malaria, and dengue or sandfly vectors that breed in rodent burrows can be targeted by residual insecticide.
Are they susceptible to insecticides?	It is important to monitor the susceptibility of vector populations to insecticides, because, if their susceptibility is reduced, vector control may be less effective. Not only the presence of insecticide resistance but also the specific mechanisms involved and the intensity of resistance should be investigated.

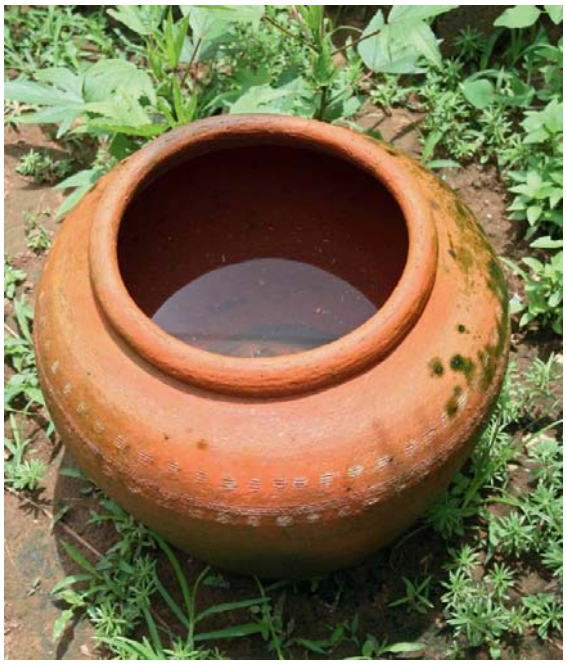


Figure A2.1: Water storage jars provide excellent breeding sites for *Aedes* mosquitoes (photo courtesy of S. Lindsay)

Human-related determinants

Human determinants can influence: the coexistence of vectors and human, such as in poor housing conditions or population movement into new areas; disease transmission, such as in the absence of preventive measures; and the infectious reservoir, which consists of population groups that are less resilient because of poor nutrition or co-morbid conditions and have poor access to health care and effective treatment.

The control programme manager should identify the human determinants that are present and how they combine to place some population groups at greater risk for vector-borne disease and to favour transmission. These population groups should be targeted as a priority. Many of these determinants will require the involvement of other actors both within and outside the health sector.

Table A2.3 lists some questions that can elicit information on the most important human determinants.

Table A2.3. Human-related determinants of disease

Question	Rationale
Where do the high-risk groups live?	This information can be derived on a large scale from the disease distribution maps in the toolkit (section 3). On a smaller scale, programmes should identify probable hotspots of disease. These could be dynamic, such as disease outbreaks in areas of economic or socio-political instability. Others could be identified routinely, from health centre records, which, with participatory mapping and community consultation, is an effective method for determining risk factors.
Where is infection most likely to occur?	It is important to understand whether transmission occurs in houses, during travel or at work. This will require understanding

	of population movement and vector behaviour in the high-risk areas.
Are some population groups more susceptible due to socioeconomic status, co-morbid conditions, age or sex?	Low socioeconomic status is often associated with poor economic resilience (e.g. no savings), poor nutrition, poor resilience against disease, poor housing conditions, high population density and overcrowding and poor sanitation and hygiene. These are all risk factors for vector-borne disease transmission. Disease control measures and support should be targeted to these communities. Co-morbid conditions such as malnutrition and HIV infection make individuals more susceptible to infection with vector-borne pathogens and greater morbidity and mortality as a result. These conditions should be identified in the population and addressed.
What are local practices and attitudes towards vector-borne disease?	It is important to determine how local communities perceive and understand vector-borne diseases, as this may affect their practices and behaviour, such as water storage methods, which can increase their risk for dengue (Fig. A2.1), outdoor defecation, which can increase their risk for schistosomiasis or trachoma, or washing and bathing in contaminated water (Fig. A2.2). Risk is also related to non-use or poor adherence to preventive measures such as LLINs.
What is their access to diagnosis and treatment?	Health service capacity differs by location. In some countries, there is less capacity in rural and remote areas than in more populated areas. Other barriers to access include awareness of disease signs and symptoms, physical distance between health facilities (public and private) and communities, cost (for e.g. travel, user fees), gender dynamics and acceptability. People may seek care in the formal public or private health sector, from pharmacies and drug sellers or from traditional healers, with differences in the accuracy of diagnosis and effective treatment. Different groups, such as children and adults, may seek care in different sectors or use several sectors. The importance of compliance with medication should be emphasized.

Fig. A2.2. Increasing the risk for schistosomiasis by collecting water from a potentially contaminated source, Lake Victoria, Kenya (photo courtesy of S. Lindsay)

Environment-related determinants

Understanding the environment in which vector-borne disease hotspots are found can help control programme officers to target interventions in space and time. For example, in areas of seasonal transmission, LLIN distribution and IRS are best practised at the beginning of the rainy season. Questions related to the environment are listed in Table A2.4.

Table A2.4. Environmental determinants of disease

Question	Rationale
What are the local ecosystems?	Vector species are adapted to specific ecological settings; more information on ecosystems and the prevalence of vector-borne disease complexes is given in Box 3. Recognizing the different ecosytems gives a rough idea of what vectors are present and their abundance; e.g. lower numbers of *An. gambiae* are found in forest and urban areas than in rural areas. The dengue vector *Ae. aegypti* often breeds in water storage tanks and discarded containers in urban areas.
How is land used?	The way in which land is used for agricultural purposes can alter vector habitats and increase the risks for vector-borne disease (Fig. A2.3). For example, commercial forest plantations create habitats suitable for tsetse flies, and intensive agriculture (e.g. cotton growing) with heavy pesticide use can result in insecticide resistance in local vectors. Irrigation often increases mosquito populations, which can lead to more cases of malaria in areas of unstable transmission, where people have little or no immunity to malaria parasites, such as in the African highlands and desert fringes. In areas of stable malaria transmission, irrigation generally does not affect malaria rates, because of changes in the dominant vector species and also wealth generation in these areas that results in better housing and greater use of personal protective measures (*4*). Urbanization alters breeding sites and can lead to increased prevalence of vector-borne diseases such as dengue.
What are the local weather patterns?	The life cycle of many vector species depends on rainfall and temperature. Establishing the seasonality of disease transmission indicates when it is best to initiate control activities. In areas of intense seasonal transmission, for example, LLIN distribution or mass drug administration should be done at the beginning of the rains. In seasonal malaria chemoprevention, up to four doses are recommended during the malaria transmission season (*3*). Larval source management with larvicides may suppress larval habitats during the dry season in areas with cool seasons, as in parts of southern Africa (*5*). In areas where epidemics of dengue or malaria occur, it may be possible to prepare for outbreaks by closely monitoring the rainfall patterns. Vector control interventions should be in place throughout the epidemic period.
What is the extent and distribution of the breeding habitat?	Information on where vectors breed, whether the habitat is aquatic, the number of breeding sites, their extent (e.g. flood plains or large-scale rice irrigation) and whether they are relatively fixed and permanent will determine whether larval source management is a potential control option.

It is combinations of interactions among pathogens, vectors, humans and the environment that determine the range and abundance of vector-borne diseases. Understanding these complex interactions allows programme managers to understand why the diseases occur and points to ways in which they can be controlled.

Fig. A2.3. *Anopheles* breeding sites in irrigated ditches (photo courtesy of S. Lindsay)

Animal-related determinants

A number of vector-borne diseases are zoonoses (diseases that also occur in animals). Therefore, it is important to determine whether wild or domestic animals are carriers of vector-borne pathogens. For example, in parts of Ethiopia, visceral leishmaniasis is transmitted by sandflies from rock hyrax to people living in villages situated on river banks or rocky hills, the natural habitats of rock hyrax. Identifying settlements at high risk for zoonotic diseases allows targeting of control. Questions that might help in identifying high-risk communities are listed in Table A2.5. It might be helpful to discuss these questions with local veterinarians and wildlife experts to obtain up-to-date, locally appropriate information.

Table A2.5. Animal-related determinants of disease

Question	Rationale
What are the common species of wildlife in the area?	Wildlife are infected with many different pathogens, some of which may also infect humans. Birds, rodents, small mammals and ruminants can all act as reservoirs of infections for human diseases. For example, rhodesiense sleeping sickness can be caught from wild ruminants (Fig. A2.4), while gambiense sleeping sickness is primarily a human disease.
What are the common domesticated animal species?	In certain situations, domesticated animals can harbour vector-borne disease pathogens; e.g. cattle can be reservoirs of infection for HAT.

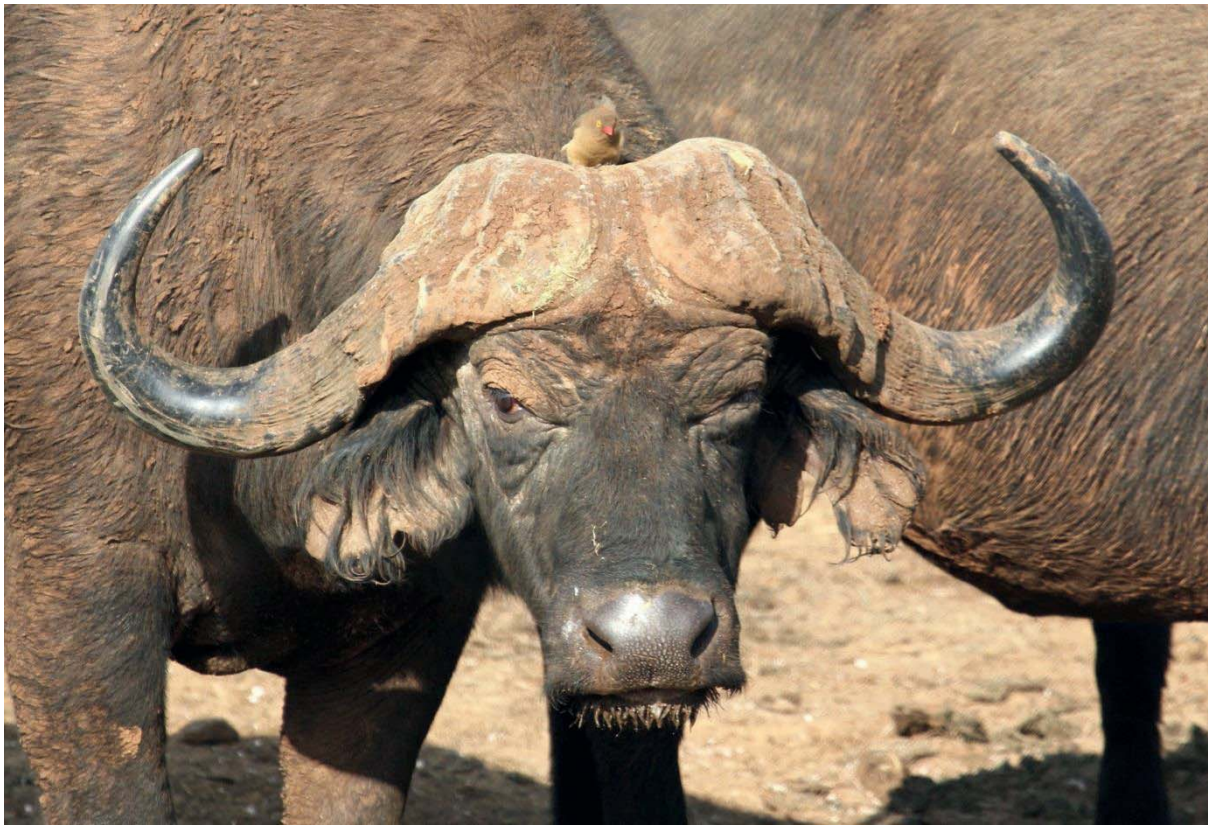


Fig. A2.4. Savannah tsetse flies commonly feed on buffalo (photo courtesy of S. Lindsay)

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Annex 3. Example logical framework for monitoring and evaluating an integrated vector management programme for malaria and lymphatic filariasis in a rural area

Goal	Area	Impact Indicators	Data type	Data source
Reduced morbidity and mortality from malaria and lymphatic filariasis with IVM in a cost–effective, ecologically sound manner	Morbidity and mortality from malaria	Total number of confirmed outpatient cases of uncomplicated malaria (per 1000 population per year)	Numerical	Health facility records
		Mortality rate among children < 5 years (per 1000 live births per year)	Numerical	Vital statistics
		Slide or rapid diagnostic test positivity rate at health facility level	Numerical	Health facility records
		Malaria parasite prevalence	Numerical	Representative household surveys (demographic and health, multiple indicator cluster, malaria indicator)
	Lymphatic filariasis infection	Antigenaemia prevalence in endemic populations	Numerical	Household surveys
		Antigenaemia prevalence among children < 5 years	Numerical	School or household surveys
	Cost–effectiveness	Reduction in cost per case of disease averted per year	Numerical	Programme reports
	Ecological soundness	Reduction in toxic units of insecticide used per case of disease averted per year	Numerical	Programme reports
	Sustaining resources for vector control	Strategy in place to ensure continued mobilization of resources for vector control	Logical	Minutes of IVM steering committee meetings

Outcome	Outcome indicator	Data type	Data source
Risk for transmission and effect on vector	Reduction in density of *An. gambiae* measured over specified period at sentinel sites	Numerical	Entomological surveys at sentinel sites
Maintain high coverage and use of LLINs	Proportion of households with at least one LLIN	Numerical	Household survey
	Proportion of pregnant women sleeping under LLINs	Numerical	Household survey
	Proportion of children < 5 years sleeping under LLINs	Numerical	Household survey
Maintain high coverage with IRS in targeted areas	Proportion of targeted households sprayed in past 12 months	Numerical	Household survey
	Proportion of targeted sleeping rooms sprayed in past 12 months	Numerical	Household survey
Target a high proportion of productive breeding sites of vectors of both diseases with environmental management or larvicide	Proportion of productive breeding sites drained or treated with larvicide	Numerical	Entomological surveys at sentinel sites

Output	**Output indicator**	**Data type**	**Data source**
Universal distribution of LLINs through appropriate channels	Number of LLINs distributed through mass campaigns	Numerical	Programme reports
	Number of LLINs distributed through health facilities	Numerical	Programme reports
	Number of nets retreated with insecticide	Numerical	Programme reports
	Number of BCC campaigns conducted to encourage correct use of LLINs		
Indoor residual spraying in the targeted areas	Number of HHs (or rooms) sprayed in specified time frame (e.g. last 12 months)	Numerical	Programme reports
	Percentage of targeted HH covered by IRS	Numerical	Programme reports

	Volume of insecticides used in specified time frame (e.g. last 12 mth)	Numerical	Programme reports
Larval source management of vector breeding sites using draining or larviciding	Number / volume of breeding sites that have been drained or treated with larvicide in specified time frame	Numerical	Programme reports

Process	Process indicator	Data type	Data source
Intervention-specific			
LLIN	Number of people trained in distribution and retreatment	Numerical	Programme reports
	Number of distribution points (community and health facilities) established	Numerical	Programme reports
	Number of LLIN guidelines distributed	Numerical	Programme reports
	Number of meetings held with stakeholders	Numerical	Programme reports
	Number of mass distribution campaigns	Numerical	Programme reports
IRS	Number of target households mapped	Numerical	Programme reports
	Number of spray operators trained	Numerical	Programme reports
	Number of IRS guidelines distributed	Numerical	Programme reports
Larval source management	Number of productive breeding sites identified	Numerical	Programme reports
	Number of larviciding operators trained	Numerical	Programme reports
	Number of larval source management guidelines distributed	Numerical	Programme reports
IVM and system-specific			
Training in IVM	Number (and percentage) of staff trained in IVM	Numerical	Programme reports

Human resources	Number (and percentage) of staff with job descriptions that make reference to vector control	Numerical	Programme reports
Advocacy, communication and social mobilization	Number (and percentage) of sites at which campaigns on behavioural change on vector control were conducted	Numerical	Programme reports
	Number (and percentage) of villages in which communities have been mobilized for vector control	Numerical	Programme reports
Planning and implementation	Number (and percentage) of sentinel sites with functioning vector surveillance and insecticide resistance monitoring	Numerical	Programme reports
Operational research	Number (and percentage) of operational research priorities in vector control that have been addressed	Numerical	Programme reports
	Number of operational research outcomes on vector control that have been used in implementing programmes	Numerical	Programme reports

Input	Input indicator	Data type	Data source
Intervention-specific			
LLIN	LLIN guidelines prepared	Logical	Programme reports
	Number of LLINs purchased	Numerical	Programme reports
	Number of retreatment kits purchased	Numerical	Programme reports
IRS	Number of spray equipment sets purchased	Numerical	Programme reports
	Volume of insecticide purchased	Numerical	Programme reports
	IRS guidelines prepared	Logical	Programme reports
Larval source management	Larval source management guidelines prepared	Logical	Programme reports

	Volume of larvicide purchased	Numerical	Programme reports
	Number of spray equipment sets purchased	Numerical	Programme reports
IVM and system-specific			
Policy	National IVM policy in place	Logical	Programme reports
	National policy on pesticide management in place	Logical	Programme reports
	National strategic and implementation plan on IVM in place	Logical	Programme reports
Institutional arrangements	National steering committee on IVM in place	Logical	Programme reports
	National coordinating unit on vector control in place	Logical	Programme reports
Capacity-building	Certified training courses in IVM and judicious use of pesticides in place at national or regional level	Logical	Programme reports
Organization and management	Standards for professions and careers in vector control and public health entomology in place	Logical	Programme reports


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