

# NATIONAL GUIDELINES ON INTEGRATED VECTOR MANAGEMENT

JUNE 2020



Government of Nepal  
Ministry of Health and Population  
Department of Health Services  
**Epidemiology and Disease Control Division**  
Teku, Kathmandu



2020

# NATIONAL GUIDELINES ON INTEGRATED VECTOR MANAGEMENT

JUNE 2020



Government of Nepal  
Ministry of Health and Population  
Department of Health Service  
**Epidemiology and Disease Control Division**  
Teku, Kathmandu



# TABLE OF CONTENTS

FOREWORD	v
ACKNOWLEDGMENT	viii
ACRONYMS AND ABBREVIATIONS	ix
<hr/>	
1. INTRODUCTION	1
1.1. Background	1
1.2. Objectives	2
1.3. Target audiences	2
<hr/>	
2. VECTOR CONTROL IN DISEASE CONTROL AND ELIMINATION	3
<hr/>	
3. INTEGRATED VECTOR MANAGEMENT	7
3.1. Key elements of IVM strategy	7
3.2. Organisational structure to support IVM	9
3.3. Global vector control response	12
<hr/>	
4. SITUATION ANALYSIS: VECTOR-BORNE DISEASES IN NEPAL	17
4.1. Malaria	17
4.2. Lymphatic filariasis	19
4.3. Dengue and chikungunya	21
4.4. Kala-azar	22
4.5. Scrub typhus	23
4.6. Japanese encephalitis	24
<hr/>	
5. VECTOR CONTROL TOOLS	25
5.1. Insecticide treated nets (ITNS)	25
5.2. Indoor residual spraying	30
5.3. Space spraying	32
5.4. Larval source management	34
5.5. Personal protection	37
<hr/>	
6. SELECTION OF VECTOR CONTROL METHODS	39
6.1. Vector control across multiple diseases	40
6.2. Disease specific recommendation on vector control tools	42

<b>7. ENTOMOLOGICAL SURVEILLANCE</b>	<b>49</b>
7.1. Techniques for monitoring adult vectors	49
7.2. Techniques for larval collections	53
7.3. Molecular xenomonitoring	56
7.4. Indicators for entomological surveillance	56
<b>8. INSECTICIDE RESISTANCE</b>	<b>61</b>
8.1. Resistance in malaria vectors	61
8.2. Insecticide resistance management in malaria vectors	67
8.3. Responding to insecticidal resistance	69
<b>9. IMPLEMENTATION OF VECTOR CONTROL INTERVENTIONS</b>	<b>73</b>
9.1. IRS	73
9.2. Space spray	83
9.3. Larviciding	90
<b>10. MANAGEMENT OF INSECTICIDES</b>	<b>95</b>
10.1. Safety of users, operators and the environment	97
10.2. Disposal of remains of insecticides and empty packaging	103
10.3. Insecticide disposal	105
<b>ANNEXES</b>	<b>109</b>
Annex 1: Daily reporting form for spray operator	111
Annex 2: Daily/weekly reporting form for spray team leaders	112
Annex 3: Summary monthly reporting form for district IRS coordinators	113
Annex 4: Spray team leader and IRS supervisor's checklist	114
Annex 5: Estimating insecticide products for indoor residual spraying	116
Annex 6: Calculation for amount of insecticide required for each tank load	117
Annex 7: LLIN monitoring and supervision checklist form	128
Annex 8: List of WHO prequalified vector control products: LLIN	119
Annex 9: List of WHO prequalified vector control products: IRS	120
Annex 10: List of WHO prequalified vector control products: Larvicide	121
Annex 11: List of WHO prequalified vector control products: Space spray	122
Annex 12: List of banned pesticide in Nepal	123
<b>REFERENCES</b>	<b>124</b>



Ref. No:

Ref. No:

Government of Nepal  
Ministry of Health and Population  
Department of Health Services



Phone No. +977-14255796  
Fax No. +977-14262268  
Email: ewarsedcd@gmail.com  
Website: edcd.gov.np

Pachali, Teku  
Kathmandu, Nepal

Date: 11 June,2020

## FOREWORD

Vector control has been the key interventions for control of malaria and kala-azar in Nepal. Emergence of new vector borne diseases (VBDs) such as dengue, chikungunya and scrub typhus possess significant challenges to the national program. Routine reliance on insecticide use further pose environmental and population health threat, along with risk of resistance among the vectors.

This national guideline on Integrated vector management (IVM) has been prepared with the objective of providing a toolbox of vector control methods and standards for the program managers to control the vector borne disease. It emphasizes on evidence-based recommendation on the use of vector control intervention for control of VBDs. The guideline will also support the donor agencies and procurement agencies in selecting standard commodities required for the vector control program.

IVM is a rational decision-making process to optimize the use of resources for vector control. I am confident that the guideline will support the health workers to implement vector control in the context of the integrated vector management. I want to congratulate the Director of the EDCC in providing leadership to the team in developing this important document. I would also sincerely thank World Health Organization, technical working group, national and international experts who provided technical contribution to development of this guideline.

This document will be one of the important referral documents and will be useful to all the stakeholders of health and non-health sectors for vector control and management.

.....  
**Dr Dipendra Raman Singh**  
Director General  
Department of Health Services  
Ministry of Health & Population



Government of Nepal  
Ministry of Health and Population  
Department of Health Services  
**EPIDEMIOLOGY AND DISEASE CONTROL DIVISION**

Phone No. +977-14255796  
Fax No. +977-14262268  
Email: ewarsedcd@gmail.com  
Website: edcd.gov.np

Pachali, Teku  
Kathmandu, Nepal

Ref. No:

Date: 11 June,2020

## FOREWORD

---

It gives me immense pleasure to write a few words on the publication of this important standard guidelines on integrated vector management.

Although integrated vector control in some form or other has been practices in Nepal since malaria eradication era, it was felt that a comprehensive document be available which would provide evidence-based recommendation on vector control tools.

In Nepal, the prevalence of the vector borne disease like malaria, kala-azar, dengue, scrub typhus ranges from the lowlands of the terai region to the high-altitude regions. The epidemiology of these vector borne disease varies considerably on account of ecology, vector bionomics, economic, socio-cultural and behavioral factors. The planning for vector management thus requires proper knowledge about the of local vectors bionomics and their response to the control measures. The intention of this manual is to provide guidance to the health program managers at national, provincial, and local level on concept of integrated vector management (IVM), relevant information about entomological surveillance, techniques, insecticidal resistance and implementation of the vector control tools like IRS, LLINs, larviciding and space spraying.

The global technical strategy of malaria 2016-2030 highlights the need to maximize the impact of the vector control; maintain adequate entomological surveillance and monitoring; manage insecticide resistance and strengthen capacity for vector control.

Furthermore, only with strong vector control capacity, effective coordination among stakeholders and community participation, we will be able to implement the IVM. I hope this guideline will provide us with the standards to plan the vector control activities more efficiently in years to come.

I would like to thank all the experts who provided technical inputs for development of this national guidelines on integrated vector management. I would especially thank the team from World Health Organization for providing technical support for developing this important document.

**Dr Basudev Pandey**

Director

Epidemiology & Disease Control Division

Department of Health Service

Ministry of Health & Population





Government of Nepal  
Ministry of Health and Population  
Department of Health Services  
**EPIDEMIOLOGY AND DISEASE CONTROL DIVISION**

Phone No. +977-14255796  
Fax No. +977-14262268  
Email: ewarsedcd@gmail.com  
Website: edcd.gov.np

Pachali, Teku  
Kathmandu, Nepal

Ref. No:



Date: 11 June, 2020

## FOREWORD

---

It gives me great pleasure to be a part of this important guideline on vector control. Vector control in some form has been used since the malaria eradication era in Nepal. The development of this guideline is even more important given emergence of newer vector-borne diseases, growing urbanization and increased reliance on insecticide for vector control.

The intention of this manual is to provide technical and operational information on the implementation of the vector control tools, entomological surveillance and insecticidal resistance management. It also provides a clear guidance on implementing the integrated vector management from the central to the local level. I hope this guideline will provide us with the standards to plan the vector control activities more efficiently in years to come.

I would like to thank all the experts especially the WHO team for proving the technical support for development of this national guidelines on integrated vector management.

**Dr Prakash Prasad Shah**  
Chief  
NTD & VBD Control Section  
Epidemiology & Disease Control Division  
Department of Health Service



Government of Nepal  
Ministry of Health and Population  
Department of Health Services  
**EPIDEMIOLOGY AND DISEASE CONTROL DIVISION**

Phone No. +977-14255796  
Fax No. +977-14262268  
Email: ewarsedcd@gmail.com  
Website: edcd.gov.np

Pachali, Teku  
Kathmandu, Nepal

Ref. No:

## ACKNOWLEDGEMENT

---

The Director General, Department of Health Service, Ministry of Health and Population expresses sincere gratitude to all the reviewers of this guideline, the members of the Technical Working Group and particularly to WHO Country Office for Nepal for developing this comprehensive National Guidelines on Integrated Vector Management.

### List of Contributors:

1. Dr Basudev Pandey, Director, EDCD.
2. Dr Bibek Kumar Lal, Ex-Director, EDCD.
3. Dr Prakash Prasad Shah, Chief, NTD & VBD Control Section, EDCD.
4. Dr Anup Bastola, Chief Consultant Tropical medicine, STIDH.
5. Mr. Ghana Shyam Pokhrel, Ex-Chief, Surveillance and Research Section, EDCD.
6. Dr Dilli Ram Sharma, Ex-Chief, PQPMC/MoLD.
7. Mr. Lila Bikram Thapa, Sr. PHO, NTD & VBD Section, EDCD.
8. Mr. Uttam Koirala, PHO, NTD & VBD Section, EDCD.
9. Mr. Pradip Rimal, PHI, EDCD.
10. Mr. Uttam Raj Pyakurel, VCI, NTD & VBD Control Section, EDCD.
11. Mr. Krishna Raj Pandey, Statistical Officer, EDCD
12. Mr. Shishir Kumar Pant, Entomologist, VBDRTC.
13. Mr. Shambhu Nath Jha, Sr. Entomologist, PMU-EDCD.
14. Mr. Dinesh Koirala, Sr. M&E Coordinator, PMU-EDCD.
15. Dr Suman Thapa, Sr. Technical Advisor-Malaria, SCI-GF.
16. Dr John Mulenga Chimumbwa, International Consultant.
17. Dr Rajpal Yadav, Scientist, VEM/NTD, WHO/HQ.
18. Dr Bhupender Nagpal, Technical Officer, NTD, WHO/SEARO.
19. Dr Henk van den Berg, WHO Consultant.
20. Mr. Sheikh Majeed, M&E Officer, WHO.
21. Dr Usha Kiran, NPO-NTD, WHO.
22. Dr Subhash Lakhe, NPO, CDS, WHO.
23. Dr Lungten Z. Wangchuk, Team Lead, Scientist, CDS, WHO.

## ACRONYMS AND ABBREVIATIONS

---

<i>Ace-1R</i>	insensitive acetylcholinesterase
AI (a.i)	active ingredient
ANC	ante-natal clinic
BCC	behaviour change communication
CDC	US Centers for Disease Control and Prevention
CFR	case fatality rate
CS	capsule suspension
DDT	dichlorodiphenyltrichloroethane
DP	dustable powder
DT	tablet for direct application
EC	emulsifiable concentrate
EDCD	Epidemiology and Disease Control Division
EPI	expanded programme on immunization
EW	emulsion oil in water
EWARS	early warning and notification system
FAO	Food and Agricultural Organization
FCHV	Female Community Health Volunteer
FFS	farmer field school
FFP	filtering face piece
GFATM	Global Fund for AIDS, TB and Malaria
GLP	good laboratory practice
GMP	Global Malaria Programme
GPIRM	global plan for insecticide resistance management in malaria vectors
GR	granule
GST	glutathione-S-transferase
GVCR	global vector control response
HIV	human immune-deficiency virus
IEC	information, education and communication
IPM	integrated pest management
IRM	insecticide resistance management
IRS	indoor residual spraying
ITN	insecticide treated net

IVM	integrated vector management
JE	japanese encephalitis
<i>kdr</i>	knockdown resistance
LLIN	long-lasting insecticidal net
LMIC	low middle income countries
LSM	larval source management
LV	low volume
M&E	monitoring and evaluation
MDA	mass drug administration
MoA	Ministry of Agriculture
MoHP	Ministry of Health and Population
MoSD	Ministry of Social Development
MR	matrix release
NTD	neglected tropical diseases
PPE	personal protective equipment
PHD	provincial health directorate
RBM	Roll Back Malaria Partnership
SC	suspension concentrate
SC-PE	suspension concentrate polymer enhanced
ULV	ultra-low volume
UNICEF	United Nations International Children Emergency Fund
USAID	United States of America International Development
VBD	vector-borne disease
VBDRTC	Vector-Borne Disease Research and Training Centre
VC	vector control
VCI	vector control inspector
VCNA	vector control needs assessment
WG	water dispersible granules
WG-SB	water dispersible granules packaged in water soluble bags
WHA	World Health Assembly
WHO	World Health Organization
WHOPES	WHO Pesticide Evaluation Scheme
WP	wettable powder
WP-SB	wettable powder packaged in water soluble bags
WT	water dispersible tablet

# 1. INTRODUCTION

## 1.1 BACKGROUND

Vector-borne diseases pose a major threat to the health of societies around the world. They are caused by parasites, viruses and bacteria transmitted to humans by mosquitoes, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, snails and lice. Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. The major global vector-borne diseases of humans include malaria, dengue, lymphatic filariasis, schistosomiasis, chikungunya, onchocerciasis, Chagas disease, leishmaniasis, Zika virus disease, yellow fever and Japanese encephalitis. Other vector-borne diseases such as human African trypanosomiasis, Lyme disease, tick-borne encephalitis and West Nile fever are of local importance in specific areas or populations.

More than 80% of the global population live in areas at risk from at least one major vector-borne disease, and with more than half at risk from two or more. The risk of infection for certain viral pathogens is particularly high in towns and cities where *Aedes* and *Culex* mosquitoes proliferate because of favorable habitats and close contact with human beings. Morbidity and mortality rates are often disproportionately high in poorer populations. Vector-borne diseases exert an immense toll on economies and restrict both rural and urban development.

Vector control is the main method for tackling many of the world's major vector-borne diseases. When effective methods of targeting mosquitoes, flies, ticks, bugs, and other vectors that transmit pathogens are well implemented, lives have been saved and the health of millions has been protected. Many existing vector control interventions are known to be effective against multiple diseases, so combining vector control programmes to simultaneously tackle several diseases could offer more cost-effective and therefore sustainable disease reductions. Despite the availability of effective interventions for many of these diseases, lack of resources prevent their effective control.

## 1.2 OBJECTIVES

The objectives of developing this guideline are:

- To develop a multisectoral approach to the vector control at the national and local level.
- To provide evidence-based recommendations on the appropriate choice(s) of vector control options.
- To support the programme managers in effective implementation and management of vector control interventions.
- To provide information and guidance to programme managers on entomological tools and surveillance.

## 1.3 TARGET AUDIENCES

The guidelines have been developed primarily for programme managers, health professionals, environmental health services professionals and for the field level staff for implementing the vector control activities at the local level.

The guidelines are also intended for use by Ministry of Health and Population, Ministry of Finance, international development partners, NGOs, donors and funding agencies to support decision-making on the selection of interventions and procurement of appropriate vector control products.

## 2. VECTOR CONTROL IN DISEASE CONTROL AND ELIMINATION

The role of arthropods in the transmission of diseases to humans was first elucidated in the late 19th and early 20th centuries. Since effective vaccines or drugs were not always available for the prevention or treatment of these diseases, control of transmission often had to rely principally on control of the vectors. Early control activities included the screening of houses, the use of mosquito nets, the drainage or filling of swamps and other water bodies used by insects for breeding, and the application of oil or Paris green to breeding places. Following the discovery of dichlorodiphenyltrichloroethane (DDT) in the 1940s and subsequent discovery of other insecticides, the focus of malaria vector control shifted to the deployment of insecticides to target both the larval and adult stages of mosquito vectors.

Targeting the vectors that transmit disease-causing pathogens is an effective preventive approach against most important vector-borne diseases. Interventions that reduce human–vector contact and vector survival can suppress and even halt transmission. History provides clear examples of when rigorous vector control has led to significant reductions in disease burden. Major declines in malaria, onchocerciasis and Chagas disease have been largely due to strong political commitment and substantial investment in vector control. Malaria reduction and elimination was achieved in some areas through intensive spraying with DDT in the 1950s and 1960s and, more recently, through the widespread scaling up of insecticide-treated mosquito nets and indoor residual spraying. For Chagas disease, elimination of domestic vectors by indoor residual spraying and housing improvements together with enhanced blood screening of donors and supportive treatment for those infected have been impactful in southern countries of South America. Vector control was applied effectively against dengue and yellow fever in the Americas (1950s–1960s), and was effective against dengue in Singapore (during the 1970s and 1980s) and Cuba (during the 1980s and 1990s).

It is well established that effective vector control programmes can make a major contribution towards advancing human and economic development. Vector control interventions have one of the highest returns on investment in public health. Aside from direct health benefits, reductions in vector-borne diseases will enable greater productivity and growth, reduce household poverty, increase equity and women's empowerment, and strengthen health systems.

Optimal impact from strengthened vector control is predicated on high-quality implementation, requiring appropriate deployment, coverage, uptake and use. Many countries continue to experience an ongoing high burden or risk of vector-borne diseases because of inadequate delivery of vector control interventions, resulting from limited investments. There are numerous examples of where upsurges have resulted from weakening of control programmes, particularly for malaria and dengue. The lack of sustainable and targeted financing has been underpinned by many factors, such as poor coordination within and between sectors, weak or non-existent monitoring and evaluation systems, and limited sustainable and proven interventions for certain vectors and situations. In addition, most countries suffer from a dire lack of public health entomology capacity. The result is that the full impact of vector control has not yet been achieved, even though this is often the best-proven or the only available preventive measure against most vector-borne diseases.

The need for a comprehensive approach to vector control to counter the impact of vector-borne diseases have become more urgent. The unprecedented global spread of dengue and chikungunya viruses and outbreaks of Zika virus disease and yellow fever in 2015–2016 clearly highlight the challenges faced globally. Transmission and risk of vector-borne diseases are rapidly changing due to unplanned urbanization, increased movement of people and goods, environmental changes and biological challenges, such as vectors resistant to insecticides and evolving strains of pathogens. Rapid, unplanned urbanization in tropical and sub-tropical areas renders large populations at risk of emergence and expansion of arboviral diseases spread by mosquitoes. Many countries are still unprepared to address these looming challenges.

Alignment of national programmes to optimize implementation of interventions against multiple vectors and diseases will maximize the impact of available resources. Health systems must be prepared to detect and respond quickly and effectively to changes. This response requires not only the availability of effective, evidence-based control interventions, but also well-trained government staff who can build sustainable systems for their delivery.



## Economic cost of vector control

The economic burden of vector-borne diseases to society is significant. For governments in endemic countries, this includes the costs of vector control activities and of case management. For households, this relates to expenditures towards personal protective measures and/or treatment as well as the income loss due to reduced productivity or time off work due to illness or care giving to sick household members. From a macroeconomic perspective, vector-borne diseases have been associated with lower economic development.

Available evidence indicates:

- Malaria has been found to be associated with slower economic development. From 1965 to 1990, the economies of countries with malaria grew 0.25–1.3% less per capita per year than countries without malaria.
- Over a period of 25 years, gross domestic product per capita growth in countries not affected by malaria was more than five times higher than in countries affected by a heavy malaria burden.
- In 2015, a total of US\$ 2.9 billion was invested in malaria control and elimination activities. Malaria has also been shown to cost on an average nearly US\$ 3 per case to households in direct treatment-seeking expenses, far exceeding the international minimum level of income of US\$ 1.90 that is the benchmark for extreme poverty met by 750 million people worldwide.
- The global cost of Chagas disease was estimated to be about US\$ 7 billion per year in 2013, including lost productivity. Cost of treatment ranges from less than US\$ 200 to more than US\$ 30 000 per person per year in endemic countries and exceeds US\$ 40 000 in the United States of America.
- Human African trypanosomiasis in the Democratic Republic of the Congo costs affected households in a typical rural community more than 40% of their annual household income.
- In Bangladesh, India, Nepal and Sudan, 25–75% of households affected by visceral leishmaniasis experience some type of financial catastrophe in obtaining diagnosis and treatment, even when tests and medicines are provided free of charge.
- The estimated aggregated global cost of dengue illness was US\$ 8.9 billion in 2013.
- The total economic benefit from productivity loss averted is estimated for the period 2011–2020 and 2021–2030 to be respectively for Lymphatic filariasis: USD 10.5 billion and USD 13.8 billion, for schistosomiasis: USD 5.5 billion and USD 11.9 billion and for onchocerciasis: USD 1.19 billion and USD 2.11 billion.

## Economic benefits of vector control

- Increased coverage of insecticide-treated nets in Africa has been reported as the most important driver of the decline in malaria prevalence between 2000 and 2015, accounting for an estimated 68% of the 663 million clinical cases averted since 2000.
- The overall reduction in malaria case incidence was estimated to have saved a total of US\$ 900 million in malaria case management costs to governments sub-Saharan Africa; nets alone were estimated to have contributed to a total gross saving of US\$ 610 million.
- The decline in malaria mortality risk between 2000 and 2015 contributed to increase life expectancy at birth by 1.2 years.
- The economic value of reduced mortality risk between 2000 and 2015 is estimated at US\$ 1810 billion in sub-Saharan Africa and at US\$ 2040 billion globally. It is anticipated that achieving the goals in WHO's Global Technical Strategy for Malaria 2016–2030, which relies heavily on effective vector control, would save 10 million lives and generate more than US\$ 4 trillion of additional economic output with a global return on investment of 40:1 and for sub-Saharan Africa of 60:1.
- Insecticide-treated nets and indoor residual spraying against malaria are affordable and highly cost-effective, with estimates of US\$ 2.20 and US\$ 6.70 per person protected per year, respectively.
- For dengue, the cost per DALY averted by vector control ranges from US\$ 334 per DALY averted by larval control in Cambodia to US\$ 779–US\$ 1604 per DALY averted by adult mosquito control in Brazil.

# 3. INTEGRATED VECTOR MANAGEMENT

The vector control policy and strategies by WHO have undergone successive changes since the mid-1950s, eradication of malaria that heavily relied on insecticide residual spraying indoors. Following the challenges faced during the implementation of insecticide-based programmes, in 1997 the World Health Assembly Resolution WHA 50.13 called upon WHO Member States “to take steps to reduce reliance on insecticides for control of vector-borne diseases through promotion of integrated pest management approaches and adaptation of viable alternative methods of disease vector control.” This led to the evolution of an integrated vector management approach to control vector-borne diseases.

Integrated Vector Management (IVM) is a rational decision-making process to optimize the use of resources for vector control. It requires a management approach that improves the efficacy, cost effectiveness, ecological soundness and sustainability of evidence-based vector control interventions with the available tools and resources. Integrated approach is vital in successfully combating vector-borne diseases.

## 3.1 KEY ELEMENTS OF IVM STRATEGY

The key elements of an IVM strategy are shown in Table 3.1. These elements should be supported by legislation and regulation. IVM is a step towards an integrated disease management approach that incorporates all components of disease control, including vector control, prevention, treatment and human vulnerability.

**Table 3.1: Key elements of an IVM strategy**

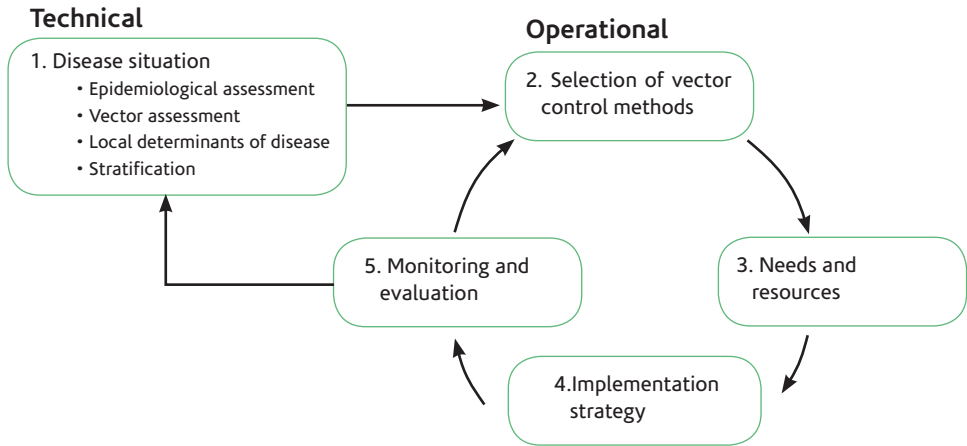
No.	Element	Description
1.	Advocacy, social mobilization and legislation	Promotion and embedding of IVM principles in designing policies in all relevant agencies, organizations and civil society; establishment or strengthening of regulatory and legislative controls for public health; empowerment of communities
2.	Collaboration within the health sector and with other sectors	Consideration of all options for collaboration within and between public and private sectors; application of the principles of subsidiarity in planning and decision-making; strengthening channels of communication among policy-makers, vector-borne disease programme managers and other IVM partners
3.	Integrated approach	Ensure rational use of available resources by addressing several diseases, integrating non-chemical and chemical vector control methods and integrating with other disease control methods
4.	Evidence-based decision-making	Adaptation of strategies and interventions to local ecology, epidemiology and resources, guided by operational research and subject to routine monitoring and evaluation
5.	Capacity-building	Provision of the essential material infrastructure, financial resources and human resources at national and local level to manage IVM strategies on the basis of a situational analysis

### 3.1.1 IVM planning

Planning for IVM starts from analyzing the situation on the ground in terms of policy, strategy and disease epidemiology; and thereafter, generates an IVM plan through logical framework steps by addressing the questions in Table 3.2.

**Table 3.2: Planning and implementation of vector control**

Questions	
Targets	Which diseases and vectors will be the main targets? What are the main vectors?
Mapping	Which areas are at high risk for disease? Which areas VBDs are co-endemic? Will subsets of the human population be targeted?
Methods	How can the risks for disease be reduced? Which vector control methods are available? Which interventions are optimal?
Participation	What contribution will local health services and other sectors make? How will communities participate?
Funding	How will the available financial and human resources be utilized? Who will fund community engagement to support deployment of interventions?



**Fig 3.1:** Steps in IVM planning, implementation, monitoring and evaluation loop.

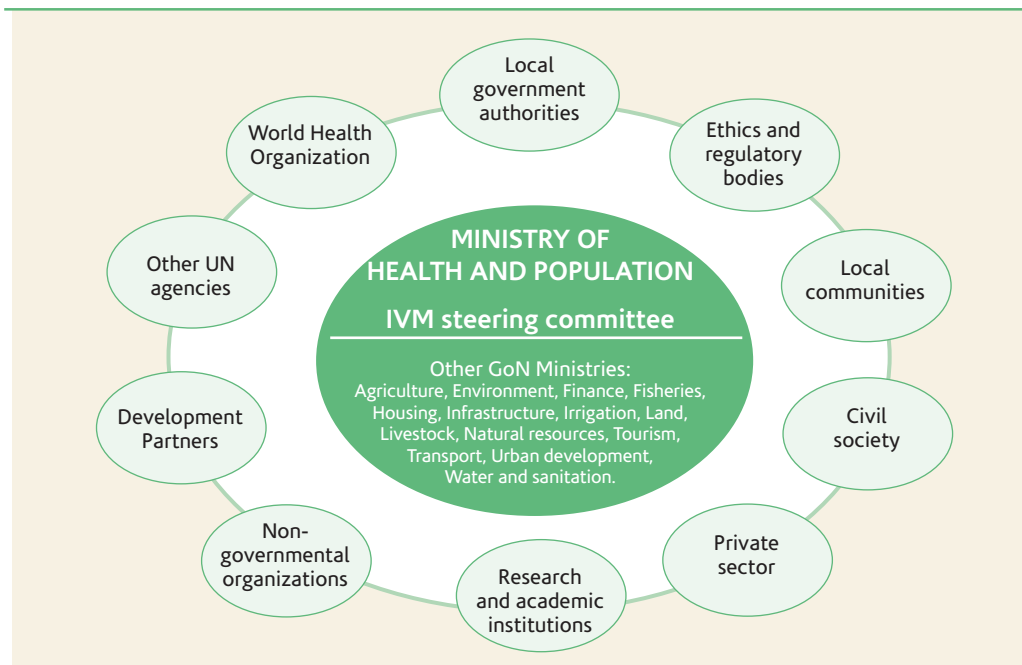
IVM should involve a cycle of several rounds of situational analysis including understanding of vectors, disease transmission, vector control tools, planning, design, implementation, monitoring and evaluation (Fig 3.1).

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 local 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.

Implementation strategies should be planned and needs and resources assessed. The programme should be monitored and evaluated to determine its effect on the disease for programme improvement. And the impact on disease needs to be reassessed subsequently.

### 3.2 ORGANISATIONAL STRUCTURE TO SUPPORT IVM

IVM will be possible only if there is strong political will and support at government level. To coordinate efforts, a national IVM steering committee (Fig 3.2) should be established to develop and oversee the IVM implementation plan. The steering committee should be chaired by the Ministry of Health and Population (MoHP) supported by technical working groups with specific expertise. The work of the IVM steering committee should be guided by a high-level IVM strategic plan which should include: the roles and responsibilities of stakeholders, situational analysis, implementation strategy, cost implication, sources of funding and funding structure, monitoring and evaluation plan and sustainability of the IVM plan.



**Fig 3.2: Intersectoral representation on IVM steering committee.**

The representative of each ministry or organization on the committee will then be responsible for advocating IVM and ensuring that IVM is incorporated in the strategic plans of their own ministries and organization. This will help in advocating for funding and allocation of other resources to IVM.

The IVM Steering committee and the technical working group should be formed at the provincial and local level.

### 3.2.1 Roles and responsibilities

Strengthening collaboration between the health sector and with other sectors is important because often the non-health sector is unaware of how their actions or inactions contribute to VBD. The primary stakeholders of IVM are the communities that will benefit from improved vector borne disease control. The designation of responsibilities for key IVM stakeholders by service delivery level is presented in Table 3.3. The stakeholders can be expanded as per need and situation.

**Table 3.3: Roles of various sectors in IVM implementation**

Sector/agency	Roles
MoHP	<ul style="list-style-type: none"> <li>• Establish inter-sectoral partnerships and networks.</li> <li>• Set strategic directions and conduct overall evaluation.</li> <li>• Advise on policy and institutional arrangements.</li> <li>• Supervise planning and implementation and monitoring and evaluation.</li> <li>• Ensure preparedness to coordinate emergency response.</li> <li>• Mobilize resources for IVM.</li> </ul>
EDCD/VBDRTC MoSD/PHD/ Local level health office	<ul style="list-style-type: none"> <li>• Planning, implementation, supervision, monitoring, and evaluation of IVM interventions.</li> <li>• Plan and implement local IVM strategy.</li> <li>• Set agenda on research priorities to promote vector control and IVM.</li> <li>• Monitor impact of vector control interventions on malaria and other VBDs.</li> <li>• Coordinate implementation of operational research.</li> <li>• Conduct vector surveillance and monitoring.</li> <li>• Conduct epidemiological and vector assessment and stratification.</li> <li>• Support outbreak investigation and response.</li> <li>• Capacity building in entomological surveillance.</li> <li>• Prepare curricula and training of trainers.</li> <li>• Provide training, education, and raise awareness.</li> </ul>
Ministry of Agriculture	<ul style="list-style-type: none"> <li>• Farmers carry out integrated pest management (IPM) activities through farmer field school (FFS) extension program.</li> <li>• Coordinate and monitor the impact of the application of chemicals on food products.</li> <li>• Ensure the safe use, application and disposal of agricultural chemicals to protect human and animal health and environment.</li> <li>• Provide guidelines for life-cycle management of chemicals.</li> <li>• Strengthen regulation of public health pesticides and life cycle management.</li> <li>• Develop and disseminate operational guidelines on the management of pesticides for public health.</li> <li>• Ensure the quality of public health insecticides and application equipment in line with WHO standards.</li> </ul>
Water Resources development	<ul style="list-style-type: none"> <li>• Maintain, design dams and canal system.</li> <li>• Create small check-dams away from human settlements.</li> <li>• Conduct health impact assessment for new project and conduct periodic health evaluation of completed projects.</li> </ul>
Department of water supply and sewage	<ul style="list-style-type: none"> <li>• Repair leakages to prevent pooling.</li> <li>• Restore taps, divert wastewater to pond/pit, stagger water supply.</li> <li>• Mosquito-proofing of water harvesting devices, repair sluice valves.</li> </ul>
Local governments	<ul style="list-style-type: none"> <li>• Implement, supervise, and monitor IVM interventions.</li> <li>• Provide adequate fund for coordination of activities.</li> </ul>
Road and building sector	<ul style="list-style-type: none"> <li>• Adhere to vector control strategy in planning, excavations and construction.</li> </ul>
Ministry of urban development	<ul style="list-style-type: none"> <li>• Implement building by-laws, improved design to avoid undue water lodging, screening for insect proofing.</li> <li>• Issue building permits after public health clearance.</li> </ul>

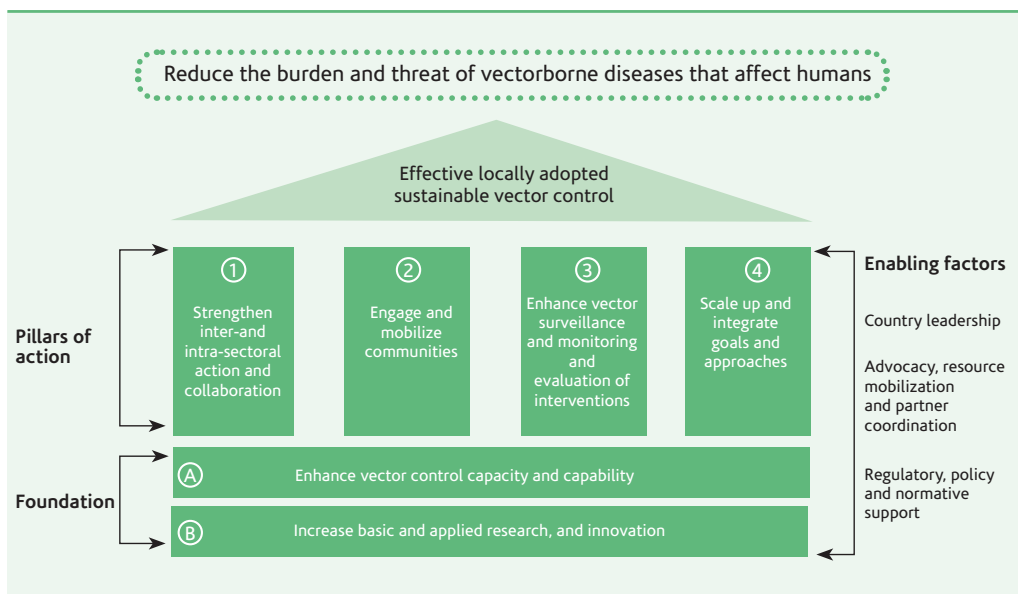
Community, faith-based organizations and civil society organizations (CSOs)	<ul style="list-style-type: none"> <li>• Participate in implementation of IVM interventions, e.g., LLIN distribution and IRS mobilization.</li> <li>• Conduct advocacy, social mobilization, SBCC, and community sensitization.</li> <li>• Support active community participation in control and prevention of VBDs.</li> </ul>
Private sector	<ul style="list-style-type: none"> <li>• Manufacture and procure quality vector control products.</li> <li>• Participate in implementation of IVM interventions.</li> <li>• Support health education campaign in coordination with MoHP.</li> </ul>
WHO, UNDP, UNICEF	<ul style="list-style-type: none"> <li>• Provide technical and normative guidance on IVM strategy, monitoring and evaluation of interventions.</li> <li>• Capacity building.</li> </ul>
GFATM, donor agencies	<ul style="list-style-type: none"> <li>• Provide resources for IVM interventions.</li> <li>• Monitor and evaluate interventions.</li> </ul>
Research Institutions and Universities	<ul style="list-style-type: none"> <li>• National Research Agenda as a guide to conduct research on diseases.</li> <li>• VBDs and assess impact of IVM interventions on VBDs.</li> <li>• Train vector control staff and provide technical support.</li> </ul>
Media and Communication Sectors	<ul style="list-style-type: none"> <li>• Support advocacy and communication program under various ministries to highlight the public health and socio-economic impact of VBDs.</li> <li>• Promote utilization of interventions.</li> <li>• Raise the profile of and demand for IVM interventions through targeted, well-designed advocacy and communication campaigns and activities.</li> <li>• Advocate for increased resources allocated for VBD control.</li> <li>• Promote IVM as a means of vector control.</li> </ul>

### 3.3 GLOBAL VECTOR CONTROL RESPONSE

In 2017, WHO adopted the Global Vector Control Response (GVCR) 2017–2030 as a new advocacy strategy to strengthen vector control worldwide and countries are called upon to update and harmonize their national vector control strategic plans in line with the generic framework. It builds on the basic concept of integrated vector management with a renewed focus on improved human capacity at national and subnational levels and adds a new element of mobilization of resources for vector surveillance and control. There is an emphasis on strengthening infrastructure and systems (e.g. sustainable development, access to potable water, adequate solid waste and excreta management) particularly for areas vulnerable to vector-borne disease upsurges.

The GVCR acknowledges that effective locally-adaptive and sustainable vector control will be achieved by strengthening inter and intra sectoral collaboration, involving all constituencies in a social movement (public, private civil society, religious leaders, traditional healers, local leaders and academia) to fight VBDs.





**Fig 3.3:** Global vector control response model

The GVC model (Fig 3.3) consist of two foundation elements and four pillar of action to reduce the burden and threat of vector borne disease.

The foundation elements of effective and locally-adaptive vector control systems depend on:

1. Enhanced human, infrastructural and health system capacity within all locally relevant sectors for vector surveillance and vector control delivery, monitoring and evaluation,
2. Increased basic and applied research to underpin optimized vector control, and innovation for development of new tools, technologies and approaches.

The four key areas (pillars) to attain effective locally adapted and sustainable vector control are aligned with integrated vector management, and include:

1. **Strengthening inter and intra-sectoral action and collaboration,**
2. **Engaging and mobilizing communities,**
3. **Enhancing vector surveillance and monitoring and evaluation of interventions,**
4. **Scaling up and integrating tools and approaches.**

## **1. Strengthening inter and intra-sectoral action and collaboration**

Reduction of disease burden through vector control is a shared responsibility of all members of society. Effective coordination of vector-control activities is required between health and non-health sectors will maximize efficiencies and have greater impact than isolated, uncoordinated activities and harness the diverse capital available in various areas.

Key stakeholders should be convened into an task force/steering committee whose mandate is to oversight, coordinate and strengthen the vector control programme. Membership should also extend to local authorities and communities as well as stakeholders from other constituencies such as development partners and the private sector. Supporting committees, working groups or networks should be formulated as per needs identified by the core members. Roles and responsibilities of all members should be clearly defined to differentiate decision-makers from partners, with competing interests proactively managed.

## **2. Engaging and mobilizing communities**

Communities play a major role in and are key to the success and sustainability of vector control. While coordination between many stakeholders is required, vector control is critically dependent on harnessing local knowledge and skills within communities. Community engagement and mobilization requires working with local residents to improve vector control and build resilience against future disease outbreaks. Where appropriate participatory community-based approaches are in place, communities are supported to take responsibility for and implement vector control.

## **3. Enhancing vector surveillance and monitoring and evaluation of interventions**

The capacity of vectors to transmit pathogens and their susceptibility to vector control measures can vary by species, location and time, depending on local environmental factors. Vector control must therefore be implemented on the basis of up-to-date local data generated by appropriate methods.

Vector surveillance should be routinely conducted at representative sites in areas where vector-borne diseases are endemic as well as those with low or no ongoing transmission but receptive to pathogen transmission. Monitoring of coverage and implementation quality of vector control interventions are essential to maintaining vector control effectiveness.

## **4. Scaling up and integrating tools and approaches**

A key action to maximize the public health impact of vector control is the deployment and expansion of interventions appropriate to the epidemiological and entomological context. Proven and cost-effective vector control interventions include long-lasting insecticidal nets, indoor residual spraying, space sprays, larvicides and environmental management for specific target vectors.

### 3.3.1 Goals of GVCR

The global vision is the world free of human suffering from vector-borne diseases through effective locally adapted sustainable vector control.

As part of this vision, the response sets ambitious yet feasible global targets aligned with the disease-specific strategic goals and Sustainable Development Goal 3.3. All the national strategic plan for the vector control should be aligned with this global target for vector response (Table 3.4).

**Table 3.4: Goals of the global vector control response**

Goals	Milestones		Targets
	2020	2025	2030
Reduce mortality due to vector-borne disease globally relative to 2016	By at least 30%	By at least 50%	By at least 75%
Reduce case incidence due to vector-borne diseases globally relative to 2016	By atleast 25%	By atleast 40%	By atleast 60%
Prevent epidemics of vector-borne diseases*		In all countries without transmission in 2016	In all countries

\* *Rapid detection and curtailment of outbreaks to prevent spread beyond the country*

### 3.3.2 Priority activities and monitoring for GVCR

The estimated cost for implementation of the Global Vector Control Response 2017 – 2030 equates to an average of US\$ 0.05 per person per year at risk from at least one vector-borne disease, with variation by burden and risk as well as other local factors such as income level. These costs for workforce, coordination and surveillance represent a relatively modest investment in relation to implementation of core interventions, such as insecticide-treated nets (US\$ 1.27 per person protected per year), indoor residual spraying (US\$ 4.24 per person protected per year) and community-based activities for dengue prevention (estimated to exceed US\$ 1.00 per person protected per year). Thus, implementation of the GVCR is still cost effective than the current vector control tools available and should be a national priority.

To achieve global targets, the country must initiate process to monitor progress of the activities listed in the Table 3.5. Achievement of the targets and milestones set out in this response will need significant investment from both international and domestic sources to strengthen vector control capacity and capability, research and innovation, cross-sectoral coordination, community involvement, and surveillance and monitoring systems. Initial assessments will be required to establish the baseline and to verify the indicators and targets set.

**Table 3.5: Priority activities for implementation of GVCR**

Priority activities	
National vector control strategic plans developed/adapted to align with global vector control response	
FOUNDATION	A National vector control needs assessment conducted or updated and resource mobilization plan developed (including for outbreak response)
	A National entomology and cross-sectoral workforce appraised and enhanced to meet identified requirements for vector control
	A Relevant staff from Ministries of Health and/ or their supporting institutions trained in public health entomology
	A National and regional institutional networks to support training/education in public health entomology and technical support established and functioning
	B National agenda for basic and applied research on entomology and vector control established and/or progress reviewed
Priority activities	
PILLARS	1 National inter-ministerial task force for multisectoral engagement in vector control established and functioning
	2 National plan for effective community engagement and mobilization in vector control developed
	3 National vector surveillance systems strengthened and integrated with health information systems to guide vector control
	4 National targets for protection of at-risk population with appropriate vector control aligned across vector-borne diseases

## 4. SITUATION ANALYSIS: VECTOR-BORNE DISEASES IN NEPAL

The terai and inner terai of the country near to the borders have always been endemic for vector-borne diseases. With increased population movement, urbanization, environmental changes, and improved surveillance of diseases, VBDs are being reported from areas where it was not prevalent, including higher altitude districts. The major VBDs and vector bionomics are discussed in sections below.

### 4.1 MALARIA

*Plasmodium vivax* is the predominant species in Nepal followed by *Plasmodium falciparum* is the other important species. While the relative proportion of *P. vivax* cases have been increasing from 71% in 2010 to 95% in 2018, the proportion of *P. falciparum* is correspondingly on the decline from around 29% in 2010 to 5% in 2018. *P. malariae* and *P. ovale* are sometimes detected among patients returning from Africa.

#### Vector bionomics

Malaria is transmitted by bite of a female *Anopheles* mosquito. The mosquitoes that transmit malaria breed in relatively clean water and the immature stages thrive better in water at temperatures ranging from 23-36° C.

The first efforts to survey the mosquitoes and identify the vectors of malaria in Nepal were initiated in 1952. 44 species of *Anopheles species* have been identified in Nepal based on morphological characteristics.

*Anopheles fluviatilis* is now the primary malaria vector in Nepal, *Anopheles annularis* and *Anopheles maculatus complex* are the secondary malaria vectors. *Anopheles maculatus complex* members are seasonal malaria vectors in the mountain region of Nepal. *Anopheles minimus* once considered a vector of malaria in Nepal, is now totally eliminated due to deforestation and effective control using DDT.

### 1. *Anopheles fluviatilis*

**Distribution:** Widely distributed in the foothill areas, terai, forest belt of inner terai and also in the upper river valley upto 2,000 meter.

**Breeding places:** Breeds typically in slow running streams, seepages and irrigation channels; also recorded from rice fields and shallow wells. During heavy rains the breeding of *Anopheles fluviatilis* is often flushed out.

**Resting habits:** Rests indoors in human dwellings and cattle sheds.

**Biting time:** Generally, enters houses at dusk and completes feeding before midnight.

**Feeding preferences:** This species is in general highly anthropophilic.

**Peak density** is observed in the mountain valley after monsoon (July-December), before and during monsoon in inner tarai and following monsoon in forest area.

**Flight range:** Limited flight range.



Fig 4.1: *Anopheles fluviatilis*

### 2. *Anopheles maculatus complex*

In Nepal, *Anopheles maculatus willmori* (sibling species of the *maculatus complex*) is a vector of malaria. *Anopheles maculatus complex* is a sporadic vector breeding in semi-shaded streams and seepages and is associated with persistent high-altitude malaria transmission in many hilly districts. Sporozoite-positive specimens were found at 2,000 meter in Gum valley in Mugu district (mid-western region) during 1969 and in inner and outer terai in 1993 and two districts of the central region - Dhanusha and Sindhuli.

**Distribution:** Usually in valleys and in hilly areas.

**Breeding places:** Shadowy and slow flowing clean water, seepages and rice fields.

**Resting habits:** Primarily zoophilic with 87% high preference for animal blood to just 13% human blood (anthropophilic).

**Biting time:** From 6 pm (early evening) to 2 am at night but greater intensity around 9 pm.

**Feeding preferences:** exophagic/exophilic.

### 3. *Anopheles annularis*

Distribution: is an inefficient vector, breeding in stagnant water and implicated as less important malaria vector in Nepal

Breeding places: Breeds in still waters with abundant vegetation in a variety of water bodies; also breeds in wells, moats, tanks, borrow pits, rice fields and other water bodies such as lakes and stream margins with vegetation.

Resting habits: During day time rests in houses, cattle sheds and mixed dwellings, and rests outdoors in small numbers.

Biting time: Peak biting activity takes place from 7 pm to 5 am.

Feeding habits: A zoophilic mosquito; biting on man is infrequent.

Flight range: Normally up to 1 km.

### 4. *Anopheles minimus*

Distribution: Usually found in the forested belt of terai and inner terai (lower valleys between Churia and Mahabharat ranges). After rounds of DDT spraying in 1960s, it had disappeared due to its high susceptibility.

Breeding places: *Anopheles minimus* breeds in shaded slow flowing streams with grassy margins, swamps, ditches, channels, shallow earth wells; occasionally found to breed in borrow pits, rice fields and seepage from flowing water.

Resting habits: Rests in houses and cattle sheds, preferring to rest on the lower portions of walls.

Biting time: Peak biting activity occurs from 6 pm to 2 am.

Feeding habits: A highly anthropophilic species, and therefore a very efficient vector of malaria.

Flight range. Normally 0.5 km but can disperse up to 2 kms from the original locality.



Fig 4.2: *Anopheles minimus*

## 4.2 LYMPHATIC FILARIASIS

Lymphatic filariasis is a public health problem in Nepal. The disease is more prevalent in rural areas, predominantly affecting low income populations. The major intervention currently in Nepal include mass drug administration with albendazole and DEC, morbidity reduction and behavior change communication activities.

## Vector bionomics

*Wuchereria bancrofti* is the only recorded parasite that causes Lymphatic filariasis in Nepal.

The vectors of lymphatic filariasis are mosquitoes belonging to several genera: *Anopheles*, *Culex*, *Aedes*, and *Mansonia species*. The mosquito *Culex quinquefasciatus*, an efficient vector of the disease, and has been recorded in all endemic areas of the country.

Unlike the transmission of malaria and arboviruses, a large number of bites from infectious mosquitoes is required to initiate a new infection with microfilaraemia. Many factors contribute to the inefficient transmission of lymphatic filariasis. Firstly, microfilariae do not multiply in the mosquito body; Second, only those mosquitoes that survive more than 10 days to complete development from L1 stage to L3 stage. The third-stage infective larvae (L3 stage) migrate through the hemocoel to the mosquito's proboscis and can infect another human when the mosquito takes a blood meal. Third, the larval stage-L3 are deposited on the skin and have to find their way into the bite wound rather than being injected with the mosquito saliva like malaria sporozoites.

Distribution: *Culex quinquefasciatus* breeds in association with human habitations. It is the most common house frequenting mosquito.

Breeding places: Breeds in any type of habitat ranging from fresh and clear to brackish, turbid and polluted water in ground pools, ditches, drains, sewage, septic tanks and in various kinds of artificial containers (bottles, cans, flower pots, vases, bowls, jars, cement tanks).

Resting Habits: Enter houses for feeding at night and for resting during daytime. These mosquitoes rest in dark corners of walls, on hanging objects, cobwebs, inside shoes, cupboards, under cots, tables and chairs.

Biting time: Blood feeding takes place within 24-48 hrs after mating from sun set until dawn. Highest peak is in late night or third quarter of night. It is endophagous as well as exophagous.

Feeding habits: Highly anthropophilic; but also attacks birds such as fowls and other domestic animals.

Flight range: Average flight range of *Culex quinquefasciatus* is about 2-3 km. Males are weak fliers.



Fig 4.3: *Culex quinquefasciatus*



### 4.3 DENGUE, ZIKA AND CHIKUNGUNYA

Dengue fever is rapidly emerging in Nepal and now present in both urban and rural areas. Dengue disease was first reported in Nepal in 2004 and several major outbreaks have occurred since then, with a significant impact on public health. The dengue virus is a Flavivirus with four serotypes. DENV 1 and DENV 2 are most often implicated in the outbreaks that have occurred in the country.

Zika virus (ZIKV) is a Flavivirus with single stranded RNA related to yellow fever, dengue, West Nile, and Japanese encephalitis viruses and is transmitted by *Aedes* mosquitoes primarily by *Aedes aegypti* which is widely distributed in Nepal. However, no clinical cases of zika virus is reported in Nepal.

Chikungunya is a viral illness caused by the chikungunya virus which is classified in the family Togaviridae, genus Alphavirus. The disease resembles dengue fever and is characterized by severe, sometimes persistent, joint pain (arthritis), as well as fever and rash.

#### Vector bionomics

The vectors of dengue in Nepal are *Aedes aegypti* and *Aedes albopictus*. Chikungunya and Zika are spread by the bite of an *Aedes* mosquito, primarily *Aedes aegypti*. The *Aedes albopictus* can be easily separated from *Aedes aegypti* based on presence of white strips down the center beginning at the dorsal surface of the head & continuing along the thorax of *Aedes albopictus*.

Distribution: The density of *Aedes sp* is more during monsoon and post-monsoon season. In dry area or water scarcity areas, the vector density is linked to water storage practices.

Breeding places: *Aedes aegypti* is the main vector in urban, semi-urban and rural areas. *Aedes aegypti* mosquitoes prefer to breed in man-made containers such as water storage containers, water tanks (cement tanks, overhead tanks, underground tanks), exterior extensions of building, coolers, discarded buckets, bottles, tyres, and coconuts shells in which water stagnates for more than a week. In unfavorable



Fig 4.4a: *Aedes aegypti*



Fig 4.4b: *Aedes albopictus*

conditions, the eggs can be viable for over a year in a dry state, which allows the mosquito to re-emerge after winter or dry spell. The eggs (up to 100-120) are laid singly on damp surfaces just above the water line.

*Aedes albopictus* mosquitoes prefer to breed in natural habitats like tree holes, latex collection cups of rubber plantations, leaf axils of pine apple plants, coconut shells.

Resting Habits: *Aedes aegypti* prefers to rest in dark corners of the houses, on dark clothes, umbrellas, under furniture & beds, shelves, coolers, behind hangings, shoes, besides house hold articles, curtains but rarely on walls.

*Aedes albopictus* mosquito rests outside in bushes, shrubs, long grasses in and around peri-domestic situations but sometimes found in domestic conditions as well.

Biting habits: *Aedes albopictus* feeds on different vertebrate hosts including human being. It is also a day-biter.

Biting time: *Aedes sp.* mosquitoes are active and feed during the day time. Females feed on blood and carry the virus that causes dengue from human to human. The *Aedes aegypti* mosquito prefers to bite humans and is easily disturbed by the movement of host during feeding. *Aedes* mosquito often bites several persons to feed to repletion. During the process *Aedes* may infect several persons in the same household or in close proximity, resulting in clustering of cases.

Feeding habits: The species is strongly anthropophilic having high preference for human blood.

Flight range: Average flight range of *Aedes* is 100-400 meters.

## 4.4 KALA-AZAR

In the countries of the SEAR, Kala-azar occurs mainly in India, Bangladesh and Nepal. Kala-azar is a major public health problem in Nepal. The first cases of Kala-azar were reported in Nepal as early as in 1960s.

Kala-azar is a vector-borne disease caused by the parasite *Leishmania donovani* which in Nepal is transmitted by the sand fly *Phlebotomus argentipes*.

### Vector bionomics

*Phlebotomus argentipes* thrives best in alluvial soil, in areas with relatively controlled temperatures, high humidity, presence of large cattle populations and usually at altitude of 600 m. However, kala azar cases have been reported in the hilly regions with higher altitudes of the country in last few years.

Sand flies are troublesome nocturnal pests. They infest dwellings during the night time and take shelter during the day in holes and crevices in walls, holes in trees, caves, stables and store rooms. The females alone bite as they need a blood meal every third or fourth day for ovi-positioning.

They have tendency and preference to feed on cattle blood than human blood. Transmission can occur after a heavy build-up of the sand fly population because the sand fly shifts from cattle to humans only after it has exhausted the option of a blood meal from cattle. Sand flies can hop short distances but cannot fly, although slow wind movement could assist flight. Sand flies seldom reach a height of more than 2 meter and are generally confined to within 50 meter of their emergence site.



Fig 4.5: Sand fly

The highest risk of disease transmission for Nepal is in the months of June to October when the humidity is high and densities peak.

## 4.5 SCRUB TYPHUS

Scrub typhus is caused by gram negative obligate intracellular coccobacillus, *Orientia tsutsugamushi*, which is transmitted by the bite of larval trombiculid mites. The presence of scrub typhus in Nepal was officially confirmed in 2015. In 2015, a total of 101 cases were reported from 16 districts. By 2018, 50 districts have reported 1058 scrub typhus cases.

Approximately 5 to 14 days after being bitten by an infected mite, patients begin to exhibit manifestations of non-specific flu-like symptoms, fever, rash, eschar at the bite site and headache.

Risk groups: Agricultural workers, people living in houses with shrubs/ bush nearby, and travelers in areas with potential exposure to mice and mites, for e.g. camping, rafting, or trekking.

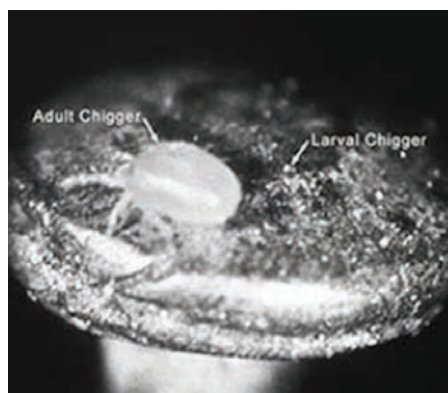


Fig 4.6: Adult and larval chigger (mites) on the head of the pin

(Source: <https://www.cdc.gov/typhus/scrub/index.html>)

### Vector bionomics

Humans acquire the disease from the bite of an infected trombiculid mite (chigger). The mites are both the vector and reservoir of the disease. The mite is very small (0.2 – 0.4 mm) and can only be seen through a microscope or magnifying glass. The larva is the only stage that can transmit the disease to humans and other vertebrates.

## 4.6 JAPANESE ENCEPHALITIS

Japanese encephalitis (JE) is a mosquito borne zoonotic viral disease. The virus is maintained in animals, birds, pigs, particularly the birds belonging to family Culicidae (e.g. cattle egrets, pond herons etc.) which act as the natural hosts. Pigs and wild birds are reservoirs of infection and are called as amplifier hosts in the transmission cycle, while man and horse are accidental or dead host. The virus does not cause any disease among its natural hosts and transmission continues through mosquitoes primarily belonging to *Culex* species. Female mosquito can transmit JE virus to a healthy person after biting an infected host with an incubation period ranging from 5 to 14 days.

### Vector bionomics

The vectors of JE are mosquitoes are *Culex* species. In Nepal, *Cx. tritaeniorhynchus*, *Cx. vishnui* and *Cx. pseudovishnui* are found.

**Distribution:** These mosquitoes are usually found in rural rice growing and pig-farming regions but can also be found at the outskirts of cities in close proximity to human populations.

**Breeding places:** They prefer to breed in rice fields. A conducive ecosystem comprising of irrigation canals, rice fields, ponds, ditches and lakes favour JE vector breeding particularly in rural areas. However in semi urban areas, breeding of *Culex vishnui* group of mosquitoes found in small ponds and ditches with water hyacinth and other aquatic plants.

**Resting habits:** Main vectors of JE are outdoor resting.

**Biting time:** JE vectors are crepuscular in nature.

**Feeding habits:** JE vectors are mainly exophilic and endophagic in nature.

**Flight range:** Flight range varies from 1 to 3 km.



Fig 4.7: *Culex* mosquito

## 5. VECTOR CONTROL TOOLS

The Government of Nepal is highly committed to the control and elimination of VBDs, including malaria, lymphatic filariasis, dengue, kala-azar, Japanese encephalitis, chikungunya and scrub typhus. To achieve the nationally and globally set goals, the country is committed to scaling up of VBDs control and prevention interventions and achieve universal access to all at risk communities. The IVM strategy is an opportunity for planning comprehensive and integrated strategies targeting reduction of human-vector contact and disease transmission the VBDs.

Many tools are available for vector control. Some are for personal protection, while others are for public health good. The effective tools of vector control are divided into five broad categories:

### 5.1 INSECTICIDE TREATED NETS

An insecticide-treated net (ITN) is a mosquito net which is impregnated with an insecticide. It repels, disables and/or kills mosquitoes coming into contact with insecticide on the netting material. With the arrival of new types of nets, the term ITN was re-introduced by the Global Malaria Programme as the umbrella term for all nets treated with an insecticide, insect-growth regulator and/or synergist. The term LLIN is only being used for ITN classes for which physical and chemical durability have been comprehensively demonstrated against the WHO thresholds of 20 washes and 3 years of use in the field. In practice, this means that only nets treated with a pyrethroid insecticide alone are presently referred to as LLINs in the WHO *Guidelines for malaria vector control documents*.

Ordinary mosquito net can be treated by dipping in a water with WHO-recommended insecticide. To ensure its continued insecticidal effect, the net should be re-treated after three washes, or at least once a year.

A factory treated mosquito net are made with netting material that has insecticide incorporated within or bound around the fibres. The net must retain its effective biological activity against vector mosquitoes for at least three years in the field

under recommended conditions of use, avoiding the need for regular insecticide treatment. For this reason, WHO stresses the use of the long-lasting insecticidal nets instead of the conventional ITNs.

Insecticide treated nets work both by (i) protecting the person sleeping under the net (individual level – personal protection) and by (ii) extending its effect to an entire area (community level– mass effect). Personal protection operates by preventing contact between the mosquito and the person under the net. The ‘mass effect’ occurs when the insecticide in the net actually kills the mosquito that touches it, therefore affecting the vector population and lowering the overall intensity of transmission in the targeted area.

**The WHO policy recommendation currently only covers pyrethroid-only nets and pyrethroid-PBO (piperonyl butoxide) nets**

- Pyrethroid-only LLINs prequalified by WHO are recommended for deployment as a core intervention in all malaria-endemic settings.
- Pyrethroid-PBO nets prequalified by WHO are conditionally recommended for deployment instead of pyrethroid-only LLINs where the principal malaria vector(s) exhibit pyrethroid resistance that is: a) confirmed, b) of intermediate level\*, and c) conferred (at least in part) by a mono-oxygenase based resistance mechanism, as determined by standard procedures.

\* *Defined as 10–80% mortality in standard WHO susceptibility tests.*

### 5.1.1 WHO specifications of LLINs

WHO prequalified LLIN should be procured by national malaria control programme and partners for malaria control. To ensure procurement of good quality LLIN, it is highly recommended that pre- and post- shipment quality testing should be requested and potential suppliers should cover the cost for testing.

The LLINs are tested for various essential parameters:

- a) Active ingredient including its identity tests and content,
- b) Wash resistance index for the active ingredient,
- c) Physical properties:
  - Netting mesh size: Average number of complete holes per unit area (holes / cm<sup>2</sup>),
  - Bursting strength: Defined as the maximum pressure that can be applied to a given surface area of netting before it bursts under the strain. The minimum bursting strength for acceptable netting materials is 250 kPa,
  - Denier: An indication of the weight (and therefore the strength) of the thread. A denier of 100 and more is strong and often recommend.

- d) Fabric weight (mass /m<sup>2</sup>) as declared by the manufacturer,
- e) Storage stability at elevated temperature,
- f) Flammability by 45° angle test and a vertical test (EN 1102 method).

*Note: shape, size and colour are not part of the LLIN specifications and procurers are free to specify these according to their choice.*

The WHO Prequalified LLINs are listed in Annex 8 and also available at <https://www.who.int/pq-vector-control/prequalified-lists/en/>.

### 5.1.2 Achieving universal coverage with LLINs

To achieve and maintain universal LLINs coverage, a combination of mass free net distribution through campaigns and continuous distribution through multiple channels is practiced.

Mass campaigns are the only proven cost-effective way to rapidly achieve high and equitable coverage. Complementary continuous distribution channels are also required because coverage gaps can start to appear almost immediately post-campaign due to net deterioration, loss of nets, and population growth.

Mass campaigns should distribute 1 ITN for every 2 persons at risk of malaria. However, for procurement purposes, the calculation to determine the number of ITNs required needs to be adjusted at the population level, since many households have an odd number of members. Therefore a ratio of 1 ITN for every 1.8 persons in the target population should be used to estimate LLIN requirements, unless data to inform a different quantification ratio are available. Campaigns should also normally be repeated every three years, unless available empirical evidence justifies the use of a longer or shorter interval between campaigns.

Continuous distribution through ANC and EPI channels should remain functional before, during and after mass distribution campaigns. School based distribution should be discontinued in campaign years to avoid over-supply of LLINs.

In addition to mass campaigns, the distribution strategy can include following channel:

- ANC, EPI and other child health clinics: These should be considered high-priority continuous LLIN distribution channels. Currently, ANC distribution is practiced in the country.
- Schools, faith/community-based networks, and agricultural and food-security support schemes: These can also be explored as channels for LLIN distribution in complex emergencies.
- Occupation-related distribution channels: In some settings where the risk of malaria may be strongly associated with specific occupations (e.g. forest/ farm



workers and their families, migrants, miners, soldiers and forest workers). In these settings, LLIN distribution is currently practiced in the country.

- Private or commercial sector channels: These can be important channels for supplementing free LLIN distribution through public sector channels. LLIN products distributed through the private sector should be in coordination with the national malaria program.

**Top-up campaigns:** LLIN distributions that take into account existing nets in households and provide each household only with the additional number of nets needed to bring it up to the target number are not recommended. Substantial field experience has shown that accurate quantification for such campaigns is generally not feasible and the cost of accounting for existing nets outweighs the benefits.

### Loss rates of nets

Countries are encouraged to prospectively monitor the durability of LLINs using methodology outlined in the WHO guidelines for monitoring the durability of long-lasting insecticidal mosquito nets under operational conditions. Countries that have specific data on the viability or durability of nets in their country can use this to estimate number of viable nets and remaining life. Rates of loss can also be calculated as:

- 8% for year 1 (0–12 months) since distribution,
- 20% for year 2 (13–24 months) since distribution,
- 50% for year 3 (25–36 months) since distribution.

These rates of loss are based on data available and may change over time as more data become available. The examples below show how these numbers would be used to calculate LLIN losses since the time of distribution.

#### Example: calculation of existing LLINs for 2020

Year nets distributed	2018 (3 <sup>rd</sup> year)	2019 (2 <sup>nd</sup> year)	2020 (1 <sup>st</sup> year)
Quantity distributed	50 000	100 000	10 000
Quantity lost	$50\,000 \times 0.5 = 25,000$	$100\,000 \times 0.2 = 20\,000$	$10\,000 \times 0.08 = 800$
Proportion available	$1 - 0.5 = 0.5$	$1 - 0.2 = 0.8$	$1 - 0.08 = 0.92$
Nets existing from each year	25 000	80 000	9 200
Total existing nets 2020			114 200



## Storage

Bales of LLINs are well and securely packed; the nets are essentially non-perishable and are usually individually wrapped in sealed plastic bags. It is important to ensure that warehouses are clean and dry. As pesticide products, LLINs have limited shelf-life and prolonged storage should be avoided as far as possible.

The tightly packed and tied bales can be stacked several layers high (up to a height of 5 m) without any damage to the bottom layers. In theory, 5.8 bales of polyester LLINs occupy a volume of 1 m<sup>3</sup>; in practice, 4 bales/m<sup>3</sup> is a reasonable working figure. Thus, if a warehouse space is 10 m x 20 m with a storage height of 3 m, available volume is 600 m<sup>3</sup>, which would accommodate 600 x 4 = 2400 bales or a total of 240 000 polyester LLINs.

Monofilament polyethylene LLINs can be stored at 6 bales/m<sup>3</sup>, so that the same warehouse volume of 600 m<sup>3</sup> would accommodate 3600 bales or 144 000 LLINs of this type.

## Management of old LLINs

Old LLINs should only be collected where there is assurance that:

- i. communities are not left uncovered, i.e. new LLINs are distributed to replace old ones,
- ii. there is a suitable and sustainable plan in place for safe disposal of the collected materials.

If LLINs and their packaging (bags and baling materials) are collected, the best option for disposal is high-temperature incineration. They should not be burned in the open air. In the absence of appropriate facilities, they should be buried away from water sources and preferably in nonpermeable soil.

### Good practices

- Recipients of LLINs should be advised to continue using their nets beyond the three-year anticipated lifespan of the net, irrespective of the condition of the net, until a replacement net is available.
- Recipients of LLINs should be advised to continue using their net even if it is damaged or contains holes, irrespective of the age of the net, until a replacement net is available.

### 5.1.3 Global indicators for monitoring LLIN

Currently the three basic survey indicators, as developed by the RBM Monitoring and Evaluation Reference Group (MERG) and adapted by WHO for the World Malaria Report are:

- proportion of households with at least one LLIN,
- proportion of population with access to an LLIN within their household,
- proportion of population reporting having slept last night under an LLIN by age (<5 years; 5–14 years; 15+ years), gender and access to LLIN.

## 5.2 INDOOR RESIDUAL SPRAYING

Indoor residual spraying (IRS) is the application of insecticides on the inner surfaces in dwelling houses and domestic animal shelters to kill the target insects when they enter and rests on the treated surfaces. Certain compounds may cause excito-repellent and deterrent effects on insects.

Indoor residual spraying remains one of the most applicable and effective methods to reduce the transmission of certain vector-borne diseases such as malaria and leishmaniasis. A rapid and large-scale impact on the endophilic vector populations is achieved when  $\geq 80\%$  of the targeted dwellings in at risk areas are sprayed with an appropriate insecticide. The method relies on the fact that most part of the targeted vector population will at some point come into contact with the sprayed surfaces, either before feeding or during post-feeding resting. If the wall, roof and other potential indoor resting sites are treated with an effective residual insecticide, the vector will pick up a lethal dose as they rest.

IRS with a WHO PQ product (Annex 9) is a core intervention for deployment in malaria-endemic locations. WHO recommended insecticides are listed in Table 5.1. DDT, which has not been prequalified, may be used for IRS if no equally effective and efficient alternative is available, and if it is used in line with the Stockholm Convention on Persistent Organic Pollutants. The use of any pesticide/insecticide in Nepal for public health or agricultural purpose is guided by the *Pesticide Management Act 2019*. The list of banned pesticides in Nepal as of 2020 is listed in the Annex 12.

The IRS products are prequalified based on their safety, quality and entomological efficacy, which includes evaluation of their mortality effect on mosquitoes when applied to a range of interior surfaces of dwellings found in malaria-endemic areas. Residual efficacy needs to continue for at least three months after the application of the insecticide to the substrate, usually cement, mud or wood. Insecticides are available in various formulations to increase their longevity on different surfaces.

IRS is considered an appropriate intervention where:

- the majority of the vector population feeds and rests inside houses,
- the vectors are susceptible to the insecticide that is being deployed,
- people mainly sleep indoors at night,
- the malaria transmission pattern is such that the population can be protected by one or two rounds of IRS per year,
- the majority of structures are suitable for spraying and
- structures are not scattered over a wide area, resulting in high transportation and other logistical costs.

**Table 5.1: WHO recommended insecticides for indoor residual spraying against malaria vectors**

Insecticide compounds and formulations	Class group	Dosage (g a.i./m <sup>2</sup> )	Mode of action	Duration of effective action (months)
DDT WP	OC	1-2	contact	>6
Malathion WP	OP	2	contact	2-3
Fenitrothion WP	OP	2	contact & airborne	3-6
Pirimiphos-methyl WP, EC	OP	1-2	contact & airborne	2-3
Pirimiphos-methyl CS	OP	1	contact & airborne	4-6
Bendiocarb WP, WP-SB	C	0.1-0.4	contact & airborne	2-6
Propoxur WP	C	1-2	contact & airborne	3-6
Alpha-cypermethrin WP, SC	PY	0.02-0.03	contact	4-6
Alpha-cypermethrin WG-SB	PY	0.02-0.03	contact	up to 4
Bifenthrin WP	PY	0.025-0.05	contact	3-6
Cyfluthrin WP	PY	0.02-0.05	contact	3-6
Deltamethrin SC-PE	PY	0.02-0.025	contact	6
Deltamethrin WP, WG, WG-SB	PY	0.02-0.025	contact	3-6
Etofenprox WP	PY	0.1-0.3	contact	3-6
Lambda-cyhalothrin WP, CS	PY	0.02-0.03	contact	3-6
Clothianidin WG	NN	0.3	contact	3-8
Clothianidin + deltamethrin WP-SB	NN	0.225	contact	6-8

(List updated January, 2019)

Note: WHO recommendations on the use of pesticides in public health are valid ONLY if linked to WHO specifications for their quality control. Updated list of WHO prequalified IRS products are available at Annex 9 and website at: <https://www.who.int/pq-vector-control/prequalified-lists/en/>

### 5.2.1 When to use IRS

The timing of IRS application or 'rounds' is a critical factor for a successful programme. Best practice is to schedule the completion of spray application to coincide with the build-up of vector population just before the onset of the peak transmission season. This ensures fresh deposits of insecticide during periods of peak mosquito density.

Insecticides from the synthetic pyrethroid class have been used in Nepal for IRS for more than a decade. A different product from the same group is changed every three years. Currently, Lambda-cyhalothrin (10% WP) is used in Nepal.

Since onset of summer season is marked with a higher intensity of mosquitoes and sandflies followed by the outbreaks of Malaria and Kala-azar, two rounds of IRS are to be scheduled in March/April and August/September.

### 5.2.2 Surfaces to be sprayed

While conducting insecticide spraying for malaria, all interior surfaces of the walls, ceilings, inner roof, inside of the patio, veranda and even the inside of the eaves should duly be covered. For Kala-azar, only walls up to 2 meter from the floor need to be sprayed. However, in areas where Kala-azar and malaria vectors co-exist, IRS can be done as required for malaria vector.

## 5.3 SPACE SPRAYING

A space spray – technically a fog – is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 30µm in diameter. The objective of space spraying is the massive, rapid destruction of the adult vector population. Space spraying is recommended for control only in emergency situations to suppress an ongoing epidemic or to prevent an incipient one.

If space spraying is used early in an epidemic and on a sufficiently large scale, the intensity of transmission may be reduced, which would give time for the application of other vector control measures that provide longer-term control, including larviciding and community-based source reduction. However, the minimum treatment frequency and geographic area requiring treatment remain unknown. And it remains unclear whether the transient impact of space treatments is epidemiologically significant in the long run for malaria control.

Continuous entomological and epidemiological surveillance should be conducted to determine the appropriate application schedule and the effectiveness of the control strategy.

- Space spraying efficiency is dependent on:
  - Method of release (aircraft, vehicle, hand-held equipment),
  - Fog types (cold or thermal),
  - Droplet size, application rate, climatic conditions,
  - Building structures, configuration and penetration of space sprays,
  - Target area size,
  - Terrain and accessibility,
  - Peak flight times.
- Space spraying can be applied as (i) Thermal fogging or (ii) Cold fogging

Space-spraying formulations have traditionally been oil-based. The oil carrier inhibits evaporation of small fog droplets. Diesel is used as a carrier for thermal fogging, but creates a thick smoke and oily deposits, which may lead to public rejection. For environmental reasons, water-based formulations have been made available in recent years.

Formulations such as wettable powders (WP), suspension concentrates (SC) and water-dispersible granules (WG) are unsuitable for space spraying. An appropriate formulation must be chosen and the label instructions carefully followed for all applications. WHO prequalified insecticide for space spray is listed in Annex 11 and Table 5.2. Updated list available at: <https://www.who.int/pq-vector-control/prequalified-lists/en/>

Formulations for space spraying are:

- Hot fogging concentrate (HN). A formulation suitable for application by thermal fogging equipment, either directly or after dilution.
- Ultra-low-volume liquid (UL). A homogenous liquid ready for use through ULV equipment which is specially formulated for low volatility.
- Emulsion, oil in water (EW). A heterogenous fluid formulation consisting of a solution of insecticide in an organic liquid dispersed as fine globules in a continuous water phase.
- Emulsifiable concentrate (EC). A homogenous liquid formulation to be applied as an emulsion after dilution in water or oil.

**Table 5.2: WHO recommended insecticides for space spraying against mosquitoes**

Compound and formulation	Indoor		Outdoor	
	(g AI/ 1000 m <sup>3</sup> )		(g AI/ha)	
	Cold fog	Thermal fog	Cold fog	Thermal fog
Deltamethrin UL	0.5	0.05	0.5 – 1.0	0.5 – 1.0
Deltamethrin EW	-	0.05	1	-
Lambda-cyhalothrin EC	-	-	1 - 2	2
Malathion EW and UL	-	-	112-600	112-600
Permethrin (25 cis:75 trans; 10.35% w/w) + s-bioallethrin (0.14 w/w) + piperonyl butoxide (9.85% w/w) EW	0.55 permethrin	0.73 permethrin	-	-
d-d, trans-cyphenothrin EC	0.1 - 0.2	0.2	3.5 - 4.00	3.5 - 4.0

(List updated 2016)

## 5.4 LARVAL SOURCE MANAGEMENT

Larval Source Management (LSM) is the management of aquatic habitats that are potential larval habitats for mosquitoes in order to prevent the completion of development of the immature stages.

There are four types of LSM:

1. Habitat modification: a permanent alteration to the environment, including landscaping, surface water drainage, filling and land reclamation, coverage of water storage containers with mosquito-proof lids or permanent slabs and coverage of the water surface with impenetrable to vectors,
2. Habitat manipulation: a recurrent activity including water level manipulation, eg. flushing streams, drains,
3. Larviciding: the regular application of biological or chemical insecticides to water bodies,
4. Biological control: the introduction of natural predators into water bodies.

Larviciding should be implemented during the population bottleneck of the target vector. For example, when malaria transmission is at its lowest, to reduce the density of adult mosquitoes before the rainy season begins. The number of water bodies requiring treatment during winter is reduced as such larviciding become more manageable and therefore likely to be cost effective. This application is line with the WHO interim recommendation that larviciding should be considered for vector control, to supplement IRS or LLINs, in areas where the breeding sites are few, fixed and findable.

The list of WHO recommended compounds and formulations for control of mosquito larvae are listed in Table 5.3.

**Table 5.3: WHO recommended compounds and formulations for control of mosquito larvae**

Insecticide compounds and formulation(s)	Class group	Dosage (active ingredient)		
		General (open water bodies)		Container-breeding
<i>Bacillus thuringiensis israelensis</i> , strain AM65-52 (3000 ITU/mg), WG	BL	125–750 g/ha	12.5–75 mg/m <sup>2</sup>	1–5 mg/L
<i>Bacillus thuringiensis israelensis</i> , strain AM65-52 (200 ITU/mg), GR	BL	5,000–20,000 g/ha	500–2000 mg/m <sup>2</sup>	-
<i>Bacillus thuringiensis israelensis</i> , (strain AM65-52 + <i>B. sphaericus</i> strain ABTS-1743; 50 BspH ITU/mg), GR	BL	5,000–20,000 g/ha	500–2000 mg/m <sup>2</sup>	60–80 mg/L
Chlorpyrifos EC	OP	11–25 g/ha	1.1–2.5 mg/m <sup>2</sup>	-
Diflubenzuron DT, GR, WP	BU	25–100 g/ha	2.5–10 mg/m <sup>2</sup>	0.02–0.25 mg/L
Novaluron EC	BU	10–100 g/ha	1–10 mg/m <sup>2</sup>	0.01–0.05 mg/L
Pyriproxyfen GR	JH	10–50 g/ha	1–5 mg/m <sup>2</sup>	0.01 mg/L
Pyriproxyfen 2 MR	JH	-	-	1 disc (40 mg Al)/40L
Fenthion EC	OP	22–112 g/ha	2.2–11.2 mg/m <sup>2</sup>	-
Pirimiphos-methyl EC	OP	50–500 g/ha	5–50 mg/m <sup>2</sup>	1 mg/L
Temephos EC, GR	OP	56–112 g/ha	5.6–11.2 mg/m <sup>2</sup>	1 mg/L
Polydimethylsiloxane (Aquatain) AMF 89% w/v		-	1 L/1000m <sup>2</sup>	1 mL/m <sup>2</sup>
Spinosad DT, EC, GR, SC	SP	20–500 g/ha	2–50 mg/m <sup>2</sup>	0.1–0.5 mg/L
Spinosad 83.3 monolayer DT	SP	250–500 g/ha	25–50 mg/m <sup>2</sup>	-
Spinosad 25 extended release GR <i>Open bodies of water</i>	SP	250–400 g/ha	25–40 mg/m <sup>2</sup>	-
<i>Control of Culex quinquefasciatus in open bodies of water with high organic matter</i>	SP	1000–1500 g/ha	100–150 mg/m <sup>2</sup>	-

\* DT = tablet for direct application; EC = emulsifiable concentrate; GR = granule; MR = matrix release formulation; SC = suspension concentrate; WG = water-dispersible granule; WP = wettable powder;

BL = Bacterial larvicide; BU = Benzoylureas; JH = Juvenile hormone mimics; OP = Organophosphates; SP = Spinosyns.

- For the BL Class group, the dosage are of the formulated product and not of all active ingredient.

There are five main groups of larvicides: oils and surface agents; synthetic organic chemicals; bacterial larvicides; spinosyns; and insect growth regulators.

### 1. Oils and surface films

These agents include petroleum distillates and monomolecular surface films (MMF) such as isostearyl alcohol made from renewable plant oils. They act by suffocating larvae or disrupting surface tension, inhibiting the ability of larvae to rest and breathe at the surface of the water causing them to drown and interfering with adult emergence. They are considered effective in control of larval stage but may be impacted by wind or absorbed by vegetation. These agents will affect any aquatic invertebrate requiring use of the air-water interface for breathing, resting or egg-laying. Re-treatment is needed weekly.

### 2. Synthetic organic chemicals

Organophosphates are synthetic organic chemicals that can kill mosquito larvae by interfering with the enzyme acetylcholinesterase, which is required to regulate nerve transmission in all organisms. The organophosphate temephos has been used extensively as a larvicide against blackfly larvae in the West Africa Onchocerciasis Control Programme, against copepods in the guinea-worm eradication programme, and against *Aedes* larvae in domestic water storage containers in dengue control programmes. Pyrethroids are toxic to fish and may select for resistance, and therefore must not be used for control of mosquito larvae.

### 3. Bacterial larvicides

Bacterial larvicides (BL) include products based on the insecticidal crystal proteins produced by *Bacillus thuringiensis* var. *israelensis* (Bti), and *Bacillus sphaericus* (Bs). Upon ingestion by mosquito larvae, these proteins are modified by enzymes in the larval midgut and then bind with specific receptors on the midgut epithelium, resulting in pore formation and interruption of feeding and homeostasis. Frequency of re-treatment with bacterial larvicides can range from 1 to 4 weeks depending on formulation, habitat, temperature, and species.

### 4. Spinosyns

Spinosyns are metabolites extracted from fermentation using the bacterium *Saccharopolyspora spinosa*. Spinosyns acts as a nicotinic acetylcholine receptor (nAChR) allosteric activator. It is available as an emulsifiable concentrate, dispersible tablets, granules and suspension concentrate, and has very low acute toxicity to mammals.



## 5. Insect growth regulators

Insect growth regulators (IGRs) belong to two groups:

- Juvenile hormone mimics such as methoprene and pyriproxyfen, which prevent the development of larvae and pupae into adults,
- Chitin synthesis inhibitors such as diflubenzuron and triflumeron, which kill larvae when they moult.

## 5.5 PERSONAL PROTECTION

Personal protection methods can be interventions from the use of repellents to application of window screens. Topical repellents, insecticide-treated clothing and spatial/airborne repellents have all been proposed as potential methods for malaria prevention in areas where the mosquito vectors bite or rest outdoors, or bite in the early evening or early morning when people are not within housing structures. They have also been proposed for specific population groups, such as those who live or work away from permanent housing structures (e.g. migrants, refugees, internally displaced persons, military personnel) or those who work outdoors at night. In these situations, the effectiveness of the core interventions (ITNs or IRS) may be reduced.

Repellents have also been proposed for use in high-risk groups, such as pregnant mothers. Despite the potential to provide individual protection against bites from malaria vectors, the deployment of the above personal protective methods in large-scale public health campaigns has been limited, at least partially due to the scarcity of evidence of their public health value. Daily compliance and appropriate use of the repellents seem to be major obstacles to achieving such potential impact.

The main personal protection measures are described below:

- Repellents: Repellents are a common means of personal protection against mosquitoes and other biting insects. The formulations (lotions or sprays) based on the following active ingredients are recommended by WHO:
  - DEET (*N,N*-diethyl-3-toluamide)
  - IR3535
  - Icaridin (KBR3023 or Picaridin)
  - Dimethyl phthalate, benzyl benzoate, dimethyl carbamate and ethyl hexanediol

There are number of natural repellent products not evaluated by WHO, including essential oils such as citronella oil, lemongrass oil.

- Treated clothing: Treated clothing have not been evaluated by WHO. They aim to reduce the risk of mosquito biting. School children should adhere to these practices whenever possible. Impregnating clothing with chemicals such as permethrin can be especially effective in preventing mosquito bites.
- Untreated clothing: Wearing long sleeves and trousers with stockings may protect the arms and legs, the preferred sites for mosquito bites.
- Mats, coils and aerosols: Household insecticidal products, namely mosquito coils, pyrethrum space spray and aerosols have been used extensively for personal protection against mosquitoes. Electric vaporizer mats and liquid vaporizers are more recent additions which are marketed in practically all urban areas.

## 6. SELECTION OF VECTOR CONTROL METHODS

Most of the vector control methods can be used to control several different diseases so that their application is useful when several diseases coexist in the same environment.

In areas where diseases are co-endemic, vector control interventions that are effective against multiple diseases should be used. For example, when malaria and Kala-azar are co-endemic in a few districts, control measures such as IRS can be effective against both diseases if spraying of the whole wall is performed (rather than only to 2 m height, the norm for Kala-azar only IRS) and both vectors are susceptible to the chosen insecticide. For example, insecticide-treated nets protect against Japanese encephalitis, filariasis and malaria in areas where these diseases occur together. LLINs, insecticide-treated curtains or screening are also likely to be effective against both vectors if vectors are susceptible and the mesh size of the material will not permit sand flies to pass through.

When several vector-borne diseases occur together in the same area, decision-making should include an additional step, opportunities to use synergistic effects must be identified. Decisions must be made not only on the vector control methods to be used for each disease but also on the relative importance of each disease. Thus, vector control could target more than one disease, including low-priority diseases, which, on their own, would not justify the control effort.

Each vector control method has its advantages and disadvantages, and an appraisal of methods guides selection of the most appropriate one for the local context. The appraisal covers the aspects of effectiveness, human and environmental safety, risk for development of resistance, affordability, community participation, policy and logistic support.

Some methods, such as source reduction to prevent vector breeding, may be moderately effective but affordable with the active participation of communities. Other methods, such as indoor residual spraying, may be effective against malaria and have strong logistic and policy support at national level but may carry risks, such as the development of resistance.

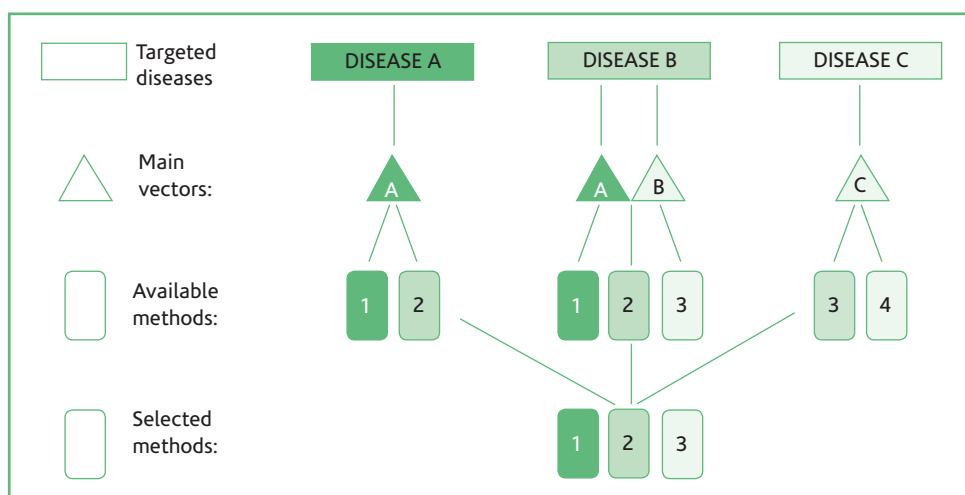
Evidence on local vectors (i.e. species, ability to transmit disease, breeding habitat, behaviour and susceptibility to insecticides) should be used to select the most effective interventions.

## 6.1 VECTOR CONTROL ACROSS MULTIPLE DISEASES

A simple hypothetical situation in which there are three local diseases with three main vectors is shown in Fig 6.1. The available four vector control methods are available of which three are selected to provide the best use of resources. In the final selection, an optimal combination of methods is chosen to cover the entire complex of vector species.

In addition to integrating multiple vector control methods to target a single disease, simultaneously targeting multiple diseases using the same vector control programme infrastructure and possibly the same interventions have the potential for economies of scale and scope, and even greater increases in cost-effectiveness. No large-scale vector control programmes have trialled multi-disease vector control, but several examples of ‘accidental’ control of vector-borne diseases suggest the potential of this approach.

Campaigns to reduce the incidence of malaria in India in the 1950s by indoor residual spraying of insecticides are credited with drastically reducing the burden from visceral leishmaniasis by killing its sand fly vectors as they rested inside homes.



**Fig 6.1:** Selecting of VC methods against multiple disease and their vectors.

Each vector control tool selected for use in a particular setting should be implemented to a high standard, at optimal timing and coverage to all population at risk. High coverage of evidence-based and cost-effective tools offers the greatest immediate opportunity to reduce the ability of malaria vectors to transmit disease. Where high coverage has not been achieved, this should be prioritized.

Community engagement and mobilization are also a critical component of uptake of many vector control interventions for malaria. Source reduction to prevent vector breeding, may be moderately effective but affordable with the active participation of communities. One tool can have multiple effects against several vectors and diseases, for example, use of LLINs where there is both malaria and Kala-azar may be effective for both diseases. In some settings, multiple vector control tools can have greater impact in reducing a VBD transmission or disease burden than a single tool. The Table 6.1 illustrates the use of various vector control methods across multiple disease.

**Table 6.1: Vector control tools for multiple diseases**

Intervention category	Intervention tools	Disease targeted					
		Malaria	Dengue/ Chikungunya/ Zika	Japanese encephalitis	Kala-azar	Lymphatic filariasis	Scrub typhus
Chemical	LLIN	+++	*	*	++	++	
	IRS	+++		+	+++	++	
	Space Spray		E	E			+
	Larviciding	++	++			++	
	Repellents	+	*	*			++
Biological control	Bti/Bs	++	++			++	
	Larvivorous fish	+	++				
Environmental management	Source reduction	++	+++			++	++

- +++ Core intervention
- ++ Supplementary intervention
- + Best practice tool for which evidence may be required
- E In epidemic periods
- \* Personal protection tool

## 6.2 DISEASE SPECIFIC RECOMMENDATION ON VECTOR CONTROL TOOLS

### 1. Malaria

IRS and LLIN are the core vector control interventions recommended for malaria elimination. The regular application of biological or chemical insecticides to water bodies (larviciding) is recommended for malaria prevention and control as a supplementary intervention in areas where high coverage with a core intervention has been achieved, where aquatic habitats are few, fixed and findable, and where its application is both feasible and cost-effective. The following settings are potentially the most suitable for larviciding as a supplementary measure implemented alongside the core interventions:

- urban areas: where breeding sites are relatively few, fixed and findable in relation to houses (which are targeted for ITNs or IRS).
- arid regions: where larval habitats may be few and fixed throughout much of the year.

**Environmental management** (habitat modification and manipulation) should, where feasible, be the primary strategy to reduce the availability of larval habitats. However, no systematic reviews have so far been conducted to inform the development of WHO guidance in this area.

**Larvivoracious fish:** No recommendation can be made on deployment of larvivoracious fish as malaria prevention and control intervention because evidence on the effectiveness (or harms) of larvivoracious fish was not identified.

**Topical repellents** for malaria prevention is not recommended as an intervention with public health value; however, topical repellents may be beneficial as an intervention to provide personal protection against malaria.

**Insecticide-treated clothing** for malaria prevention is not recommended as an intervention with public health value; however, insecticide-treated clothing may be beneficial as an intervention to provide personal protection against malaria in specific population groups.

**Spatial airborne repellent** is not recommended for prevention and control of malaria.

**Space spraying** should not be undertaken for malaria control, and IRS or ITNs should be prioritized instead.

**Housing Improvements:** Available evidence indicates poor-quality housing and neglected peri-domestic environments are risk factors for the transmission of malaria, arboviral diseases (e.g. dengue, yellow fever, chikungunya, zika virus disease), chagas disease and leishmaniasis. Closing open eaves, screening doors and windows with fly screens or mosquito netting, and filling holes and cracks in walls and roofs reduce the mosquitoes' entry points into houses and together with metal roofs, ceilings, and finished interior walls, these modifications may reduce transmission of malaria and other vector-borne diseases.

**Special Condition:** In the acute phase of a humanitarian emergency, the first priorities for malaria control are prompt and effective diagnosis and treatment. Vector control also has the potential to play an important role in reducing transmission. However, the evidence base on the effectiveness of vector control interventions deployed in these settings is weak.

During the acute phase, decisions on vector control and prevention will depend on:

- malaria infection risk,
- behaviour of the human population (e.g. mobility, where they are sleeping or being exposed to vector mosquitoes),
- behaviour of the local vector population (e.g. indoor resting, indoor biting, early evening or night biting),
- the type of shelter available (e.g. ad-hoc refuse materials, plastic sheeting, tents, more permanent housing).

## Scale back of vector control after malaria transmission has been reduced

As a result of sustained vector control, there has been a general decline in malaria transmission in most settings. Now the general expectation is that the discontinuation of vector-control implementation in such settings would be associated with a minimal risk of resurgence, and that such scale-back would be an appropriate way to reduce expenditure on malaria programmes.

After comprehensive review of historical evidence and mathematical simulation modelling using a range of epidemiological and intervention scenarios were undertaken, following conclusion and recommendations are made from WHO:

### Recommendation

- In areas<sup>1</sup> with ongoing local malaria transmission (irrespective of both the pre-intervention and the current level of transmission), the scale-back of vector control is not recommended. Universal coverage with effective malaria vector control (including the use of new vector control tools when they become available) of all persons in such areas, should be pursued and maintained.
- In areas<sup>1</sup> where transmission has been interrupted, the scale-back of vector control should be based on a detailed analysis that includes assessment of the receptivity<sup>2</sup> and vulnerability<sup>3</sup>, active disease surveillance system, and capacity for case management and vector control response. Precise measures of malaria receptivity and vulnerability, and the levels of these parameters at which scale-back of vector control carries minimal risk of resurgence, remain to be comprehensively defined. Similarly, it is difficult to predict whether zero local transmission can be maintained in areas with moderate to high receptivity and vulnerability in the absence of vector control. Moreover, where there has been minimal change in receptivity, the stability of the malaria parasite–vector relationship following interruption of malaria transmission is not well understood.
- Disease and entomological surveillance should be strengthened to identify areas for geographical scale-back as well as timely detection and appropriate response to resurgence.

<sup>1</sup> the minimum size of an area is determined by availability of reliable disaggregated disease surveillance data and feasibility for decisions on vector control implementation. The area is not necessarily based on administrative boundaries.

<sup>2</sup> the ability of an ecosystem to allow transmission of malaria.

<sup>3</sup> the frequency of influx of infected individuals or groups and/or infective anophelines.

## 2. Dengue, zika and chikungunya

*Aedes aegypti* and *Aedes albopictus* are the main vectors of zika, chikungunya and dengue. Larval source reduction using environmental management/manipulation is the only core vector interventions for dengue/zika or chikungunya vector. Chemical larvicides should be complimentary and be restricted to containers that cannot be eliminated or managed.



## Methods for larvicide treatments

Productive larval habitats should be treated with chemicals only if environmental management methods or other non-chemical methods cannot be easily applied or are too costly. Larvicides may be impractical to apply in hard-to-reach natural sites such as leaf axils and tree holes, which are common habitats of *Ae. albopictus*, or in deep wells. The difficulty of accessing indoor larval habitats of *Ae. aegypti* (e.g. water-storage containers, plant vases, saucers) to apply larvicides is a major limitation in many urban contexts.

Perifocal treatment involves the use of hand-held or power-operated equipment to spray, for example, wettable powder or emulsifiable-concentrate formulations of insecticide on larval habitats and peripheral surfaces. This will destroy existing and subsequent larval infestations in containers of non-potable water and will kill the adult mosquitoes that frequent these sites. Perifocal treatment can be used to treat containers, irrespective of whether they hold water or are dry at the time of application.

The internal and external walls of containers are sprayed until they are covered by a film of insecticide, and spraying is also extended to cover any wall within 60 cm of the container. Perifocal treatment thus has both larviciding and residual adulticiding characteristics. This method is suitable only for collections of non-potable water (such as in large piles of tyres or discarded food and beverage containers). Care must be taken not to treat containers used to store potable water.

Larvicides in water-storage containers should have low toxicity to other species and should not significantly change the taste, odor or color of the water. WHO's guidelines for drinking-water quality provide guidance on the use of pesticides in drinking-water. Formulations of pesticides used for vector control in drinking-water should strictly follow the label recommendations and should only be those approved for such a use by national authorities. Placing chemicals in domestic water, particularly drinking-water, is often viewed with suspicion and may be unacceptable in some communities.

A systematic review of database (1980-2013) evaluated the evidence of the effectiveness of dengue vector control interventions in (a) reducing vector indices and (b) preventing dengue transmission. The main findings were:

- House screening can reduce vector abundance and emerging evidence that it reduces dengue transmission.
- Community-based campaigns can impact vector abundance, with emerging evidence for impact on transmission.
- No evidence on impact of fogging on transmission.
- Indoor residual spraying (IRS) did not impact significantly on infection risk.
- Skin repellents, insecticide-treated bed nets or traps had no effect, whereas insecticide aerosols and mosquito coils were associated with higher dengue risk.

**Space spraying** is recommended for control only in emergency situations to suppress an ongoing epidemic or to prevent an incipient one. The objective of space spraying is the massive, rapid destruction of the adult vector population. However, there has been considerable controversy about the efficacy of aerosol insecticide applications during epidemics of dengue and yellow fever. Any control method that reduces the number of infective adult mosquitoes, even for a short time, should reduce virus transmission during that time, but it remains unclear whether the transient impact of space treatments is epidemiologically significant in the long run. There is no well-documented example of the effectiveness of this approach in interrupting an epidemic. Nevertheless, if space spraying is used early in an epidemic and on a sufficiently large scale, the intensity of transmission may be reduced which would give time for the application of other vector control measures that provide longer-term control, including larviciding and community-based source reduction.

Not only insecticide susceptibility but also droplet size, application rate and indoor penetration of the insecticide are all crucial to the efficacy of this method for controlling *Aedes aegypti*. Indoor penetration of an insecticide depends on the structure of the building, whether doors and windows are left open during spraying and, when applied from vehicle-mounted equipment, residential block configuration, the route of the spray vehicle and meteorological conditions. Where indoor penetration of droplets is likely to be poor, indoor application with portable equipment will be more effective against *Aedes aegypti*. However, rates of coverage are much lower and accessibility may be difficult, particularly in large cities.

### 3. Japanese encephalitis

The information on vector control at public health are limited. Regular use of mosquito avoiding practices can be another low cost JE prevention method. Use of larvicides or space spray during outbreak can be considered.

### 4. Kala-azar

The methods of choice are indoor residual spraying for endophilic sandflies, use of WHO recommended insecticide-treated or long-lasting insecticidal nets, environmental management including local sanitation and improved housing.

### 5. Lymphatic filariasis

The primary intervention against lymphatic filariasis is preventive chemotherapy (MDA). However, vector control can play an important role in lymphatic filariasis elimination. Vector control for the elimination of lymphatic filariasis should focus on complementing, or replacing in some situations, mass drug administration.

The major vector of LF in Nepal is *Culex quinquefasciatus*. It has developed high levels of resistance to the pyrethroid insecticides used in LLINs in many countries. LLINs and IRS are less effective against culicine vectors of LF.

Environmental management (source reduction) and larvicide use are also effective when *Culex* are principle vector. Use of expanded polystyrene beads is suitable in areas where *Culex* species that breed in pit latrines and soakage pits are the primary vector for lymphatic filariasis. Integrated use of mass drug administration and expanded polystyrene beads in Zanzibar and India was shown to reduce transmission.

## 6. Scrub typhus

Biting can be prevented by avoiding infested terrain and applying repellents to skin and clothing. Benzyl benzoate, dimethyl phthalate, deet, dimethyl carbamate and ethyl hexanediol are effective repellents. Under conditions of frequent exposure the best protection is given by impregnated clothing and by tucking trousers inside socks during outdoor work.

The control of mites by killing them in their habitats is very difficult because of the patchy distribution of their populations. If it is possible to identify the patches of vegetation that harbour large numbers of larval mites (mite islands), it may be advantageous to remove them by burning or cutting and then to scrape or plough the top-soil. Mowing grass or weeds in these areas also helps. Such measures are recommended in the vicinity of camp sites and buildings.

Where the removal of vegetation is not possible, mite islands can be sprayed with residual insecticide. The spraying of vegetation up to a height of 20 cm around houses, hospitals and camp sites was effective against grass mites in Europe. The insecticides can also be applied as fogs with ultra-low-volume spray equipment.



# 7. ENTOMOLOGICAL SURVEILLANCE

Entomological surveillance can be defined as the regular, systematic collection, analysis and interpretation of entomological data for risk assessment, planning, implementation, monitoring and evaluation of vector control interventions. All surveillance activities must be clearly linked to programme decisions to ensure optimal vector control.

The general objectives of the entomological surveillance in major vector control program includes:

1. Characterize receptivity to guide stratification and selection of interventions. The entomological parameters considered in risk characterization include the vector species present and the characteristics that influence transmission. Important traits such as biting (time, place and host preference), dispersion and resting behaviour should be known for all the principal vectors, as these traits determine receptivity and thus guide the selection of interventions,
2. Track the relative density of vector species and their bionomics to determine the seasonality of transmission,
3. Track insecticidal resistance,
4. Identify threats related to effectiveness of vector control due to composition and behavior of vector population,
5. Monitor vector control intervention coverage and quality to identify gaps and opportunities.

## 7.1 TECHNIQUES FOR MONITORING ADULT VECTORS

### 7.1.1 Mosquito

Adult surveys should be conducted over a representative period during the transmission season in order to understand the population dynamics. A well-designed survey for adult *Anopheles* will include traps as well as methods of capturing the resting adults. The resting behavior of *Anopheles* after blood feeding provides a very good opportunity for effective survey and identification of the key

problem vectors, because it will enable the collector to find blood-fed adults and to determine which hosts have been fed upon. Collection of adults during host seeking is also useful but requires considerable evening work and involves a risk of receiving bites. Several methods of mosquito collection, mentioned below, are available which are undertaken alone or in combination with others depending on objectives of the survey.

**Suction tube (aspirator):** This is the most widely used and convenient method for mosquito collection. Aspirator tube is generally having a length of 30-45 cm and is made up of glass or plastic tubing. A piece of mosquito netting fixed over a short piece of smaller diameter rubber tubing, which is inserted into the end of larger tubing. A 50-cm long rubber tubing is slipped over the end of glass tubing provided with mosquito netting. The resting mosquito are sucked gently and the other end of tube is closed with a finger or cotton plug before transferring to a cage/ test tube. Not more than 10 mosquitoes should be collected at a time to avoid injury to the mosquitoes.

**Light traps:** The CDC light trap (Fig 7.1) and traps of similar design have proven to be effective tools for monitoring *Anopheles* populations and generally attract different species of mosquitoes than human landing catch. These devices are hung in a room with a person sleeping under an untreated net and the light attracts mosquitoes. This simulates the number of bites received per person per night. Mosquitoes are sucked into a net bag by an electric fan. Light traps are useful for obtaining an overall picture of the population and to monitor population changes over time. Since attraction to light is primarily a host-seeking behavior, the traps tend to catch many mosquitoes prior to taking a blood meal.



**Fig 7.1: CDC light trap**

(Source: S. Lindsay)

**Pyrethrum spray catch (PSC):** This method (Fig 7.2) takes advantage of the tendency of malaria vectors to rest inside houses. Plastic or cloth sheeting is laid down in a house, and pyrethrum insecticide is then applied as an aerosol. The mosquitoes killed and knocked down by the spray are collected. Since the mosquito will rest on the ceilings and walls of houses after taking a blood meal, this method tends to catch more blood-fed individuals.

**Human landing catch (HLC):** During a human landing catch (Fig 7.3), an aspirator is used to collect mosquitoes approaching or landing on humans for a blood meal. The method provides a very clear picture of which species are blood feeding on humans in the specific location. These surveys require staff to work in the evening



**Fig 7.2: Pyrethrum spray catches**

Source: S. Lindsay (left), Gates Malaria Partnership Vector Biology Course (right)

and are time consuming. In some countries, particularly where there are circulating arbo-viruses such as Rift Valley Virus, National Research Ethics committees have discouraged the use of Human Landing collections. In other countries, collectors are provided with malaria prophylaxis and close follow-up. Programmes should check with national research ethics committees if and how human landing collections can be implemented.



**Fig 7.3 (a): Human landing catches**



**Fig 7.3 (b): Animal bait catches**

Different methods of adult mosquito collection only work under specific conditions. For example, pyrethrum spray catch is less fruitful in areas with low vector densities and high volumes of insecticide-treated material inside houses. Therefore, if a method is not collecting many specimens, alternative tools should be considered.

## Entomological investigations in a malaria outbreak

Launching an outbreak investigation requires planning and strategy. Field entomologists use a series of steps to answer three key questions, “What is the problem? What is the cause? And what can we do about it?”

**Mosquito field Sampling:** Entomological investigation in the field is guided by epidemiological investigation results. Mosquitoes are sampled using classic human landing collections or light traps. Larval searches are conducted in water bodies in the immediate vicinity. Larvae and pupae are sampled using a standard dipping method in water collections.

**Anopheles identification:** Adult mosquitoes collected, or neonate mosquitoes are sorted by genera, and *Anopheles* specimens are morphologically identified based on keys in use in the Guiana Shield. Morphological identifications are also conducted sometime using established protocols.

The purpose of entomological assessment is to incriminate malaria vectors responsible for above-normal increase in disease prevalence and incidence. The detailed assessment includes:

- Measurements for applications of mosquito age grading and salivary gland dissection.
- Identify the entomological indicators of malaria transmission.
- Calculate the entomological indicators associated with resting and feeding habits, human-vector contact, and entomological inoculation rates for malaria.
- Measure the components of the vectoral capacity model and understand its value for malaria transmission and control.
- Interpret the entomological measurements and their implications for malaria vector control.

### 7.1.2 Sand flies

- i. **Hand collection:** This is the most common method wherein sand fly sitting on a surface are caught with the help of an aspirator or test tube and a torch light. This method is particularly useful for longitudinal monitoring of man-hour densities. In sand fly collection, the ordinary mosquito barrier netting between glass tube and rubber tubing of the aspirator must be replaced by a muslin cloth as the smaller size of sand flies enable them to escape through ordinary mosquito net.
- ii. **Trap collection:**
  - **Sticky trap:** This is the most extensively used trapping device wherein sand flies are trapped in a layer of castor oil.
  - **Illuminated Sticky trap:** Box shaped batteries are hung on the walls facing sticky traps to make them illuminated. These traps provide higher catch, compared to ordinary traps.
  - **Light traps:** CDC miniature light traps are often used for sand fly collections. However, nylon mesh cage suspended in a rigid frame are



better than the collapsible cages provided with the traps. Further, for sand flies they are modified to give UV light or white light.

- **Funnel traps:** These are particularly useful in collecting flies from rodent burrows. Traps are placed just at the mouth of the burrow to catch the flies emerging out of burrows. The inner side is provided with sticky paper or foil.
- iii. **Bait collections:** Both human and animal baits can be used. However, the fact that sand flies are well known for their patchy distribution must be kept in mind while designing bait sampling. Due to clustering habit of sand flies, bait sampling must be extended to cover all parts of a village.

## 7.2 TECHNIQUES FOR LARVAL COLLECTIONS

### 7.2.1 Mosquito larval collection

Larvae are collected with the objectives to establish the breeding habits of different species, its geographical distribution, study the development of aquatic stages and to evaluate the impact of anti-larval measures on the larval density. This also helps in rearing adults for taxonomic studies or biological observation (bioassay/susceptibility tests.). Personnel will need basic training in recognition of mosquito genera in the larval stage. Most important is the ability to distinguish between *Anopheles*, *Culex* and *Aedes* mosquitoes

- i. **Dipping:** The dipping method is the most frequently used for the collection of mosquito larvae (Fig 7.4). Mosquito dippers of various shapes and sizes may be employed. A 'standard dipper' consists of a white plastic, metal or porcelain cup attached to the end of a stick (Fig 7.5). The cup usually has a capacity of 350 to 400 ml and has a drain spout for transferring the sample to collection vessels for return to the laboratory.



Fig 7.4: Larval collections



**Fig 7.5:** Dippers for larval surveys.

Potential larval habitats should be approached slowly and carefully and facing the sun, to avoid heavy footsteps or casting a shadow over or disturbing the water, which may cause larvae to dive to the bottom. Larvae are generally found at the surface, close to vegetation or floating debris and at the edges of larger and deeper water bodies. Dipping should be conducted close to floating debris and vegetation, on the windward side of the habitat where larvae and pupae will be concentrated, and not on rainfall. Water bodies often constitute a variety of microhabitats (e.g. open water, under floating vegetation) containing different mosquito species. These should all be sampled to obtain an accurate picture of the species composition of the area.



**Fig 7.6:** Using a net to sample larvae.

*Source: Vincent Robert, Malaria Journal 2002*

*Anopheles* larvae are generally best collected using the 'shallow skim' approach. The dipper is tilted by 45 degrees and its leading edge submerged two centimetres below the water surface. The dipper is moved quickly but gently in a straight line until the dipper is full but not overflowing. There should be an interval of 2-3 minutes between each dip to allow stage 3<sup>rd</sup>, 4<sup>th</sup> larvae and pupae to come to the surface again. The larval density is assessed in terms of average larval density per dip.

- ii. **Netting:** Nets are also useful for collecting *Anopheles* larvae and have been shown to be more efficient especially for collecting pupae (Fig 7.6). However, for durability in routine operational use, dippers are generally preferred.

Larvae may be collected from large stretches of water along the edge of streams, ponds, wells, and other large water bodies. A larval net consists of a ring of iron frame of 25 cm in diameter with nylon/muslin cloth net measuring about 10 cm long. A long wooden handle is attached to the ring. For collecting larvae, the net is held at an angle of 30 degree and skimmed rapidly through the surface water near emerging or floating vegetation. The net is inverted and washed out in a bowl of water to collect and count larvae. The density is measured in terms of density per larval net.

- iii. **Pipetting:** Small pipettes or small spoons may be used for collecting larvae from the shallow breeding sites like hoof prints, etc. The larvae can be collected from the small, narrow tree holes or from the axils of leaves using a wide pipette or a siphon. The water can be siphoned off with a piece of rubber tubing and the holes may be washed two or three times with extra water to retrieve left over larvae.

### 7.2.2 Sand fly larvae collection

Sand flies breed in cracks, crevices and other places with soils rich in organic content. The resemblance in soil and larval coloration makes it difficult to detect larvae visually in their habitat. For this reason, control measures directed against immature stages are not considered as an option in leishmaniasis control programmes.

The soil is collected, kept in a Petri dish and then examined under microscope (40 x magnification). For screening larger soil samples, soil and leaf litter samples from potential breeding sites are mixed with water and the supernatant (containing material such as dead leaves and exuviae of insects) is poured off. The remaining material is mixed with a saturated sugar solution (3 parts sugar + 5 parts water) and sand fly larvae float to the surface, from which they are collected and placed in plaster-lined pots containing some suitable larval diet. This method has the advantage of preserving the larvae alive so that they can be reared to adults. This being of crucial importance in areas where more than one sand fly species occurs, because specific identification of immature stages is generally impossible.

### 7.3 MOLECULAR XENOMONITORING

Molecular xenomonitoring (MX) is a process of screening mosquitoes—not humans—for parasites to estimate whether they are circulating in human populations. This is a promising tool for LF surveillance. MX is especially useful during and following MDA, when new case detection becomes difficult. Direct assessment of LF worms in vector mosquitoes with polymerase chain reaction (PCR) techniques is increasingly used to detect recurrence of new infections during post-MDA surveillance. However, this is difficult to conduct as large numbers of mosquitoes need be collected and processed for testing with this method.

This method is also being used extensively for surveillance of zika, dengue and chikungunya virus infection in field caught mosquitos.

### 7.4 INDICATORS FOR ENTOMOLOGICAL SURVEILLANCE

The major methods for *Anopheles* surveillance are human landing catches, resting collections using aspirator, pyrethrum spray catches (whenever mosquito densities are low or more mosquitoes are required), animal baited traps (depending on species host preference) and larval sampling. Aspirator collections should be performed in all index villages, while whole night human landing catches on indoor and outdoor human baits should be performed in one of the index villages in a district during the transmission season and every quarter thereafter. Animal bait collections should be done in the same village twice a year (once during transmission and once during non-transmission season).

Insecticide resistance testing on both adult anophelines should be performed at least yearly in all districts, with priority given to those districts where no information has been collected during the preceding 5 years. Larval susceptibility tests should be performed once a year in every district where larvicides/biocides are in use, but particularly in urban areas where organophosphorus compounds such as temphos and fenthion are being used as larvicides. Contact bioassay should be conducted during spray season at 2-weekly intervals to determine the residual efficacy of IRS.

The main entomological indicators for malaria vectors can be categorized into five groups (Table 7.1):

- adult vector composition (species occurrence and density),
- adult vector behaviour (human blood index, human biting rate, biting time, biting location, resting location),

- immature vector aquatic habitats (habitat availability and occupancy, larval density),
- proxies for transmission (sporozoite rate, entomological inoculation rate, receptivity),
- adult vector resistance to insecticides (resistance frequency, status, intensity and mechanisms).

**Table 7.1: Entomological surveillance indicators for malaria vectors**

INDICATOR	OUTCOMES	CALCULATIONS
<b>Adult vector composition</b>		
Occurrence	Adult female vectors present or absent.	Presence of <i>Anopheles</i> species known to support the development of <i>Plasmodium</i> sporozoites. Requires correct identification of species.
Density	Number of adult female vectors collected, usually per sampling method and unit time.	Collection numbers are reported by individual sampling method or summed for all sampling methods. <sup>a</sup> Vector seasonality refers to changes in species abundance by season. Vector composition is the relative abundance of each species as a proportion of the total number of vectors collected.
<b>Adult vector behavior</b>		
Human biting rate	Number of adult female vectors that attempt to feed or are freshly blood-fed, per person per unit time.	Number of female <i>Anopheles</i> vectors collected that were freshly blood-fed or attempted to feed per total number of units of collection. The units of collection depend on the sampling method; yields from human landing catches are reported per human per collection hour, and yields from CDC light traps, pyrethrum spray catches and window exit traps are reported per trap per night per number of human occupants in houses used for collection.
Human blood index (host preference)	Proportion of blood-fed adult female vectors that feed on humans.	Number of female <i>Anopheles</i> vectors that feed on human blood / total number of <i>Anopheles</i> vectors from which the blood meal was identified.
Biting time	Number of adult female vectors that attempt to feed or are freshly blood-fed, per person per unit time, usually expressed per 2-hr increment.	Number of adult female vectors that attempt to feed or are freshly blood-fed, per person per unit time, usually expressed per 2-hr increment.

Biting location	Proportion of attempted bites or successful blood-feeds by adult female vectors indoors and outdoors, per unit time.	Simultaneous use of the same sampling method(s) indoors and outdoors for an indication of endophagy and exophagy. Endophagy index = number of <i>Anopheles</i> vectors biting indoors / [number biting indoors + number biting outdoors] <sup>b</sup>
Resting location (indoor resting density)	Proportion of adult female vectors collected resting indoors (and outdoors in structures sampled), usually per human-hour.	Simultaneous use of similar sampling method(s) indoors (including in houses and cattle sheds) and outdoors for an indication of endophily and exophily. Endophily index = number of <i>Anopheles</i> vectors collected resting indoors (indoor resting density) / [number resting indoors + number resting outdoors]. <sup>b</sup>
<b>Immature vector aquatic habitats<sup>e</sup></b>		
Habitat availability	Number of aquatic habitats present and absent, by area and habitat type.	Number of potential habitats for <i>Anopheles</i> vector egg-laying and immature stage development identified in an area.
Habitat occupancy	Larvae and pupae present and absent, by area and habitat type.	Number of aquatic habitats found to harbour <i>Anopheles</i> vector larvae or pupae / number of potential habitats for <i>Anopheles</i> vector egg-laying and immature stage development in an area, by category of habitat.
Larval density	Number of immature vectors collected, by individual habitat.	Number of immature <i>Anopheles</i> vectors collected per dip, per person per unit time. Usually recorded by stage (I–IV instars and pupae) and by habitat and reported by stage category (early instar, late instar, pupae) for an area.
<b>Proxies for transmission</b>		
Sporozoite rate	Proportion of adult female vectors with sporozoites in their salivary glands.	Number of female <i>Anopheles</i> vectors identified as sporozoite positive / total number females <i>Anopheles</i> analysed. Indicates proportion of <i>Anopheles</i> vectors present and biting that are considered infectious.
Entomological inoculation rate (EIR)	Number of infectious bites by adult female vectors per person per unit time, usually per year.	Calculated as: human biting rate x sporozoite rate from human landing catches or vector density x human biting rate x sporozoite rate based on CDC light trap collection. Reported per year, season, month or night. Yearly or seasonal EIR are best calculated by adding monthly EIRs in order to account for strong seasonality in transmission. Indicates intensity of malaria parasite transmission, but there are no standard protocols.



Receptivity <sup>f</sup>	Classification of areas according to transmission risk.	Receptivity is a function of the presence of competent <i>Anopheles</i> vectors, a suitable climate and a susceptible human population, and is generally based on a combination of the indicators listed above.
<b>Adult vector insecticide resistance <sup>c</sup></b>		
Resistance frequency	Proportion of adult female vectors alive after exposure to insecticide.	100% – (number of dead or incapacitated <sup>d</sup> <i>Anopheles malaria</i> vectors / total number exposed to a discriminating concentration of insecticide in standard bioassays.
Resistance status	Classification of adult female vector populations as confirmed resistant, possibly resistant or susceptible.	Classification based on proportion of mosquitoes dead or incapacitated <sup>d</sup> after exposure to a discriminating concentration of insecticide in a standard bioassay, whereby: < 90% = confirmed resistance; 90–97% = possible resistance; ≥ 98% = susceptibility.
Resistance intensity	Classification of adult female vector populations as having high, moderate or low resistance.	Classification based on proportion of mosquitoes dead or incapacitated <sup>d</sup> after exposure to 5 x and 10 x intensity concentrations of an insecticide in a standard bioassay, whereby: <ul style="list-style-type: none"> <li>• High-intensity resistance: &lt; 98% after 10 x exposure</li> <li>• Moderate intensity resistance: ≥ 98% after 10 x exposure but &lt; 98% after 5 x exposure</li> <li>• Low intensity resistance: ≥ 98% after 10 x and 5 x exposure but &lt; 98% after 1 x exposure</li> </ul>
Resistance mechanism(s)	Mechanisms detected or not detected in adult female vectors.	Based on detection of the mechanism by molecular or biochemical tests for molecular markers (e.g. kdr, Ace-1R) or enzyme profiles (e.g. mono- oxygenases, esterases, glutathione S-transferase). Outcomes and interpretation depend on the test used.

a The behavioural characteristics of vector species can bias the numbers collected by different sampling methods. Combination of the results obtained with a variety of sampling methods and comparison by relative abundance can mitigate some of the inherent bias.

b Exophagy or exophily index : 1 – endophagy or endophily index.

c Other indicators of resistance have been defined for adults and larvae that are not commonly used in routine surveillance, such as resistance level (i.e. concentration required to kill 50% or 95% of test mosquitoes, LD50 and LD95) and resistance ratio (i.e. LD50 for test population / LD50 for susceptible strain).

d The criteria depend on the testing procedure used (e.g. WHO susceptibility test or CDC bottle bioassay).

e Relevant for areas in which LSM is being considered or applied as a supplementary intervention (i.e. where there are few, fixed and easily accessible larval habitats).

f Additional assessments are required to refine the classifications of receptivity.

The entomological indicators for the dengue, chikungunya and kala-azar vectors are listed in Table 7.2 and 7.3.

**Table 7.2: Entomological surveillance indicators for dengue and chikungunya vectors**

Surveillance method	Index	Calculation
<b>IMMATURES</b>		
Dipping for larvae or pupae	House index (HI)	Number of houses infested / Number of houses inspected X 100
	Container index (CI)	Number of positive containers / Number of containers inspected X 100
	Breteau index (BI)	Number of positive containers / Number of houses inspected X 100
	Pupal index	Number of pupae / Number of houses inspected X 100
<b>ADULTS</b>		
Resting collections (aspirator or handheld net)	Man-hour density	Number of <i>Aedes</i> mosquitoes caught x Number of minutes collected /60
Oviposition traps or tyre section larvitrap	Density trap	Number of <i>Aedes</i> mosquitoes caught / Number of traps

**Table 7.3: Entomological surveillance indicators for Kala-azar**

Surveillance method	Index	Calculation
<b>ADULTS</b>		
CDC light trap: collection for moving sandflies between 1800h-0600h	Sand fly density	Number of sand fly per light trap per night
Aspiration: (indicator: MHD i.e man hour density) from resting surface for morning collection.	-	Man hour density
Sticky trap: Applied for moving sandflies. The surface is A4 size plastic sheet, it is not so effective	-	Per trap per night

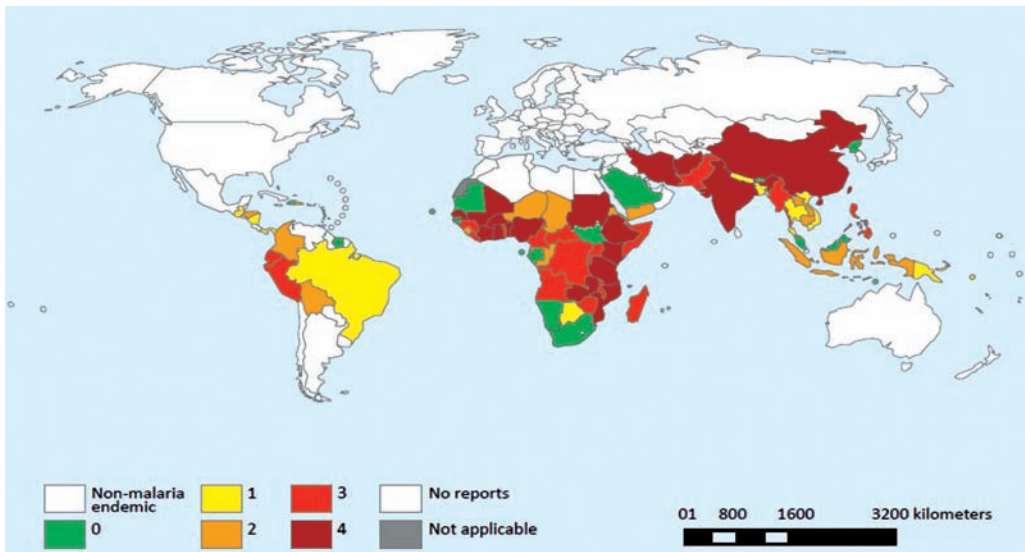


# 8. INSECTICIDE RESISTANCE

## 8.1 RESISTANCE IN MALARIA VECTORS

The WHO Global report on insecticide resistance in malaria vectors (2010–2016) showed that resistance to the 4 commonly used insecticide classes – pyrethroids, organochlorines, carbamates and organophosphates – is widespread in all major malaria vectors across the WHO regions. Between 2010-2016, a total of 61 countries have reported resistance to at least one class of insecticide, with 50 of those countries reporting resistance to 2 or more classes (Fig 8.1).

In Nepal, the use of DDT in malaria control was discontinued from 1990 onwards, but malathion was used for indoor spraying until 1997. Since 2000 onwards, only pyrethroids have been used in Nepal for vector control purposes.



**Fig 8.1:** Map showing number of insecticide classes to which resistance in malaria vectors was reported for the period 2010–2016

Recent study (2018) on insecticide resistance showed the malaria vectors (*Anopheles fluviatilis*, *Anopheles annularis* and *Anopheles pseudowillmori*) were susceptible to the pyrethroids insecticides being used in Nepal.

Resistance to the four insecticide classes commonly used in these interventions has emerged in malaria vector populations throughout the world. Of particular concern is pyrethroid resistance, because this insecticide class is used in all WHO-recommended LLINs and is also used for IRS in many countries. Although it is still unclear to what extent insecticide resistance impacts on the effectiveness of current malaria vector control tools, the emergence and spread of resistance is clearly a major threat to the significant gains made against malaria in recent years.

### Resistance in NTD vectors

1. **Dengue vectors:** Significant use of insecticides (including larvicides, repellents, space sprays, treated materials and coils) in the home and the private sector results in unquantifiable, unregulated use of insecticides for control of *Aedes* sp. in many dengue-endemic countries.

Resistance to pyrethroids and, to a lesser degree, organophosphates in the primary dengue vector, *Aedes aegypti*, is widespread. While fewer studies have been done on *Aedes albopictus*, the available data suggest that resistance is less prevalent in this species than in *Aedes aegypti*.

2. **Kala-azar vectors:** Susceptibility of sand flies in South Asia showed that the major vector, *Phlebotomus argentipes*, has developed resistance to DDT in areas where it is used regularly, such as Bihar, parts of West Bengal, Jharkhand and Maharashtra. (In Bihar, 43% of the vectors were reported to be resistant to DDT in 2012.) In recently endemic areas of eastern Uttar Pradesh and some areas of West Bengal, *P. argentipes* is still susceptible.

In Gadchiroli district, where pyrethroids have been used for more than a decade, *P. argentipes* showed some tolerance to this insecticide class.

In Nepal, *P. argentipes* has been found to be susceptible to all other insecticides such as malathion, bendiocarb, deltamethrin, and lambda-cyhalothrin.

### 8.1.1 Insecticide resistance mechanism

Insecticide resistance mechanisms are the means by which insects overcome exposure to an insecticide. These mechanisms reduce susceptibility of the insect to the lethal effects of the chemical, and thereby allow their survival. Various types of resistance have been observed to date, and can be broadly categorized as metabolic, target-site, cuticular (reduced penetration) and behavioral resistance.

### Metabolic resistance

Metabolic resistance is a common mechanism type that confers resistance in malaria vectors. It occurs when internal enzymes in mosquitoes break down or sequester insecticide molecules before they can have a toxic effect. Insect strains that have developed higher amounts or more efficient forms of these enzymes that can metabolize insecticides may exhibit phenotypic resistance. Three families of metabolic enzymes are strongly associated with resistance in malaria vectors: monooxygenases (P450s), esterases and glutathione-S-transferases (GSTs). For instance, increased expression of multiple monooxygenases has been associated with pyrethroid resistance, esterase-mediated resistance has been shown to reduce susceptibility of malaria vectors to both organophosphates and pyrethroids and increased expression of GSTs has been associated with dichlorodiphenyltrichloroethane (DDT) resistance. These enzyme systems may also have a broad spectrum of activity and be capable of detoxifying a range of insecticides.

Metabolic mechanisms are commonly detected using biochemical and molecular assays with dead mosquitoes, or bioassays with live mosquitoes. In bioassays, mosquitoes from a resistant population are exposed to an insecticide only or to a synergist and then an insecticide using an adaptation of the WHO susceptibility or CDC bottle bioassay method. If a higher mortality is observed for mosquitoes exposed to the synergist and insecticide than for those exposed to the insecticide alone, this is considered a proxy for the involvement in resistance of the metabolic enzymes targeted by the specific synergist. For example, piperonyl butoxide (PBO) affects monooxygenase activity; therefore, if mosquito mortality is higher with pre-exposure to PBO than without exposure, this serves as a proxy indication of the involvement of monooxygenases in resistance. However, there may be additional effects with other forms of resistance (e.g. knockdown resistance, *kdr*); hence, this should not be considered a definitive indicator of metabolic mechanisms only.

### Target-site resistance

Target-site resistance occurs when a genetic mutation has modified the protein receptor within the mosquito that an insecticide is supposed to attack, which effectively blocks or reduces the toxic effect of the insecticide. For example, the main target sites for pyrethroids and organochlorines are voltage-gated sodium channels of nerve cell membranes. A *kdr* mutation reduces sensitivity of the channels to the binding of these insecticide classes. Similarly, mutations in the gene for acetylcholinesterase (called *Ace-1R* - insensitive acetylcholinesterase) confer resistance to organophosphates and carbamates. Molecular assays are generally used to measure the frequency of *kdr* mutations, and molecular or biochemical assays are used to measure the frequency of *Ace-1R* mutations or to measure the activity of acetylcholinesterase.

### Cuticular resistance

Cuticular resistance (or reduced penetration) occurs when the absorption of insecticide into a mosquito is reduced because of changes in the insect's outer cuticle, the hard outer covering layer composed of epidermis. This type of resistance can reduce the efficacy of various insecticides, and often occurs in the presence of other resistance mechanisms. Presence of this mechanism is identified by examination of physical aspects of individual mosquitoes (e.g. cuticular thickness in relation to susceptible mosquitoes); however, standard methods and reporting have not yet been established.

### Behavioral resistance

Behavioral resistance is defined by a change in mosquito activity, such as avoidance of insecticide treated surfaces or changes in feeding or resting patterns in response to the presence of insecticide. Relatively little is known about the extent and impact of this type of resistance because no standard methods to detect and report such changes have been established, and it can be difficult to measure because longitudinal observations are required.

### Cross-resistance

The resistance mechanisms can confer resistance to one or more classes of insecticides and can develop cross resistance between different classes of insecticides that share the same mode of action. Thus, vectors that are resistant to DDT because they possess the *kdr* resistance-associated gene will probably also be resistant to certain pyrethroid insecticides. Likewise, the *Ace-1* mutation can confer target-site resistance to both carbamate and organophosphate insecticides.

Cross-resistance occur when insecticides of two or more classes of insecticides are metabolized by the same enzyme. Furthermore, the prevalence of multiple insecticide resistance mechanisms that co-occur in single populations and even in individual mosquitoes is increasing in malaria affected countries. The existence of cross resistance and multiple resistance restricts the choice of alternative insecticides in situations where resistance has been detected.

General patterns of cross-resistance have been established for the four insecticide classes in common use and for five resistance mechanism types (Fig 8.2).

**Fig 8.2: Cross-resistance patterns of different classes of insecticide**

BIOCHEMICAL MECHANISM OF RESISTANCE					
	Metabolic			Target-site	
	Esterases	Mono-oxygenases	GSH S-transferases	kdr	Altered AChE
Pyrethroids	●	●●		●●	
DDT		●	●●	●●	
Carbamates	●	●●			●●
Organophosphates	●●	●			●●

Size of dot indicates anticipated relative importance of the mechanism type in conferring resistance to the specified insecticide class.

AChE, acetylcholinesterase; DDT, dichlorodiphenyltrichloroethane; GSH, glutathione; kdr, knockdown resistance

Source: GPIRM (WHO, 2012)

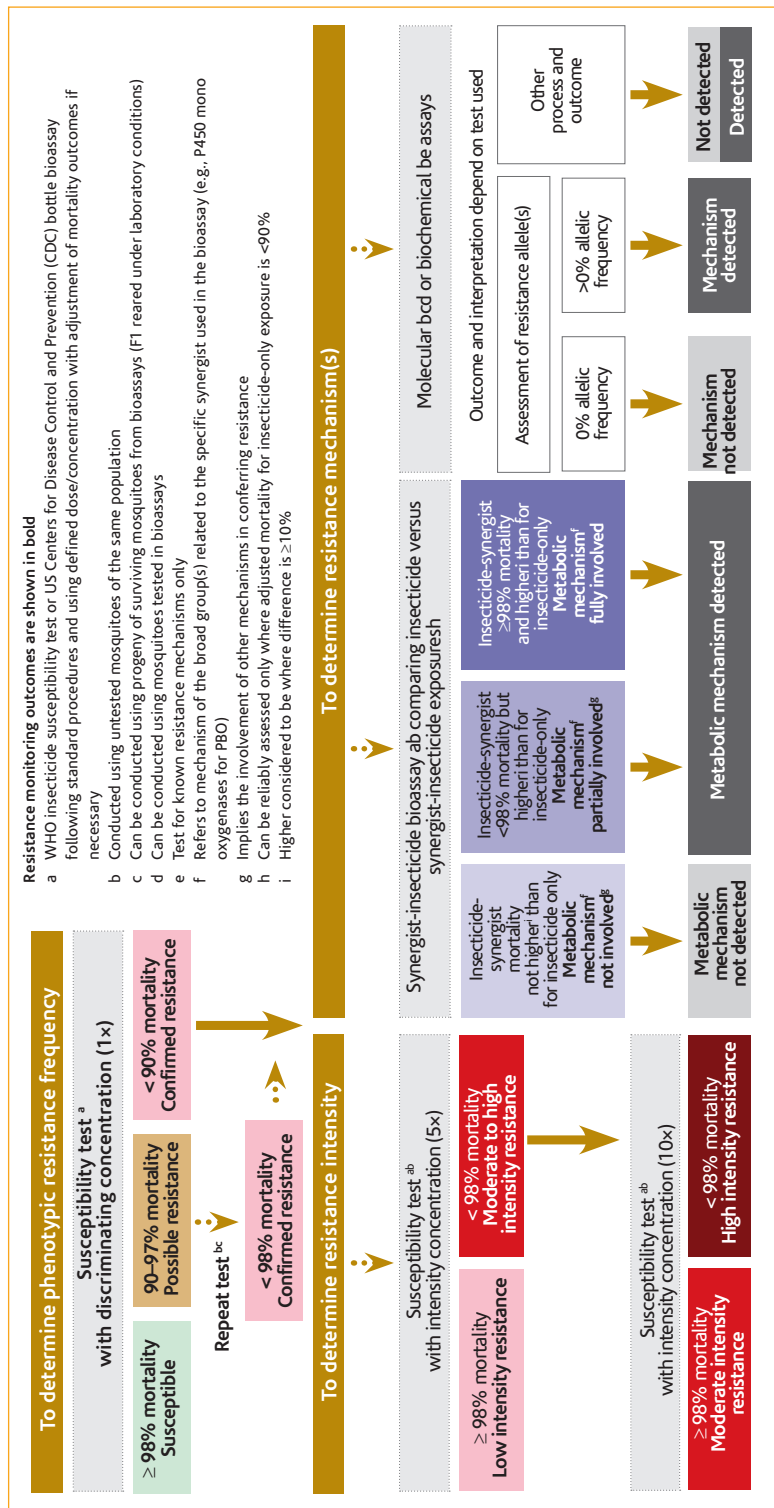
### 8.1.2. Insecticide susceptibility tests

Two main test protocols are currently available for assessing mosquito susceptibility to insecticides: the WHO susceptibility (“tube”) test and the CDC bottle bioassay. Both test measure intensity of resistance, which may be useful for detecting changes in resistance over time and for detecting metabolic mechanisms through the use of synergists.

The WHO susceptibility bioassay is a direct response-to-exposure test. It measures mosquito mortality to a known standard concentration of a given insecticide, either with a discriminating concentration or with intensity concentration. The test algorithm procedure itself is summarized in Fig 8.3.

Any resistance phenotypes detected using the discriminating insecticide concentrations can be assessed for their potential operational significance by exposing subsequent or additional mosquito samples to the applicable 5x and 10x higher concentrations of those insecticides. Exposures at the higher concentrations will yield information on the intensity of resistance, which can be defined as the “strength” of a resistance phenotype. Confirmed levels of resistance at 5x and especially at 10x the discriminating concentration may indicate or predict operational control failure, and highlight a particularly urgent need to develop and implement an appropriate resistance management strategy.

**Fig 8.3: Overview of the process and outcomes for insecticide resistance monitoring in malaria vector mosquitoes. Includes measures of: 1) phenotypic frequency via discriminating concentration bioassays 2). Resistance intensity via intensity concentration bioassays, and 3) resistance intensity via synergist-insecticide bioassays, molecular and biochemical assays.**



Source: Guidelines for malaria vector control. Geneva: World Health Organization; 2019

### Biochemical and molecular test are used to detect the resistance mechanism

- i. Changes in the target site that reduces insecticide binding (target-site resistance): Often done using DNA-based diagnostics. These tests detect the actual mutation responsible for resistance (*kdr* allele). A negative result does not indicate that the specimen is not resistant to an insecticide, only that it does not contain the resistance mechanism being assayed.
- ii. Increase in the rate at which the insecticide is metabolized (metabolic resistance): Enzymes responsible for insecticidal mechanism are carboxylesterases, cytochrome-p-450s and glutathione-S-transferases. Biochemical assays detect the level of activity of these enzymes.

#### CDC bottle bioassay

The CDC bottle bioassay provides a complementary method for detecting insecticide resistance in malaria vector populations. WHO bioassay measures mortality rates in mosquitoes exposed to a discriminating concentration of insecticide for a fixed period, the CDC bottle bioassay measures a discriminating length of time required to incapacitate susceptible mosquitoes using a predetermined concentration of insecticide.

Both the WHO and the CDC method can reliably identify insecticide resistance where it occurs. However, the results are not directly comparable because the CDC method focuses on the proportion of mosquitoes incapacitated, whereas the WHO bioassay is concerned with mortality.

## 8.2. INSECTICIDE RESISTANCE MANAGEMENT IN MALARIA VECTORS

IRM strategies are intended to maintain the effectiveness of vector control, despite the threat of resistance. IRM strategies have been used in agriculture and to address some public health situations over the past century. Integrated vector management, by reducing reliance on chemical control, can also be considered a means of IRM.

### 8.2.1 Resistance management approaches

To minimize and mitigate the risk of insecticide resistance affecting malaria prevention and control efforts, a pragmatic approach must be taken that leverages appropriate tools on the basis of available evidence. Up-to-date monitoring information is therefore required to feed into the decision-making processes and adjust plans as required. Research and development is also needed to develop new interventions, such as those that use new insecticide classes or reduce reliance on insecticides.

Historically, the most common way insecticides have been deployed to control malaria vectors has been through 'sequential use'. A single insecticide class is used continuously or repeatedly until resistance makes it less effective or ineffective, after which a switch is made to an insecticide with a different mode of action to which there is no (or less) resistance. Theoretically, this may decrease the resistance due to non use of the insecticide. However, practical examples of such reversion are rare and tend to be short-lived when they do occur. This practice of sequential use is not considered good practice for malaria vector control as it counters the proactive resistance management approach.

Resistance management approaches have been developed largely based on experience with agricultural pest management. These approaches aim to limit or delay the emergence of resistance by removing selection pressure or by killing resistant mosquitoes, such as by exposing them to multiple insecticides. These form an important part of IRM, and include use of mixtures of insecticides, mosaic spraying, rotations of insecticides and deployment of multiple interventions in combination.

The possibility of cross-resistance needs to be considered when managing insecticide resistance through the approaches discussed below. Use of insecticides to which there is cross-resistance in local malaria vectors – whether in a mixture, mosaic, rotation or combination – is likely to lead to poorer public health outcomes and increased resistance frequencies.

#### ■ Mixtures

Mixtures are formulations that combine two or more insecticides with different modes of action. The theory is that the presence of resistance in a population should be rare, such that any individual that survives exposure to one insecticide is highly likely to be killed by the other insecticide or insecticides. Recent modelling work suggests that mixtures will be beneficial to resistance management only if at least one of the insecticides is highly effective at killing susceptible genotypes. Ideally, all insecticides in a mixture should have a similar residual life and remain bioavailable over time; however, in practice this can be difficult to achieve.

#### ■ Mosaics

Mosaics involve the use of insecticides of different classes in neighbouring geographical areas. The optimal spatial scale (size of areas) for mosaics has yet to be determined. However, mosaics can be operationally challenging to implement.

#### ■ Rotations

Five insecticide classes with three modes of action are now available for use in IRS against adult malaria vectors. Rotations involve switching between insecticides with different modes of action at pre-set time intervals, irrespective of resistance



frequencies. The theory is that resistance frequencies will decline (or at least will not increase) during the period of non-use of insecticides of a specific mode of action. This approach has had some success in slowing the evolution of resistance in agriculture. However, although this approach is currently considered best practice for resistance management where IRS is used, there is only weak evidence of its impact on resistance.

### ■ Combinations

Combinations expose the vector population to two classes of insecticides with differing modes of action through the co-deployment of different interventions in the same place; for example, pyrethroid LLINs combined with a non-pyrethroid IRS.







There are limited options for IRM with LLINs. However, they may retain an effect despite increased resistance to pyrethroids. Firstly, nets provide a physical barrier against biting by mosquitoes as long as they are intact. Secondly, in most vector species, resistance to pyrethroids does not completely reduce the effect of the insecticide. It has also been observed that the irritancy of pyrethroids ('hyperexcitatory response') may reduce mosquito blood-feeding or encourage diversion to other hosts by certain vector species that do not feed exclusively on human hosts. This effect can vary, however, by species and geographical location.

## 8.3. RESPONDING TO INSECTICIDAL RESISTANCE

Resistance monitoring should ideally be conducted at sufficient sites that are representative of the eco-epidemiological setting(s) throughout the area for which intervention(s) are to be deployed. Resistance monitoring data should be collected for all principal malaria vectors at least annually. Resistance to each insecticide class being deployed or intended to be deployed should be tested so as to adequately guide selection of interventions and establish a baseline of information for new classes. However, implementation of resistance management or mitigation approaches need not wait until comprehensive data are available from resistance monitoring across the entire target area.

Fig 8.4 and Fig 8.5 indicates whether the different product classes of insecticides are considered optimal, acceptable or not recommended based on the resistance status (frequency), intensity and mechanisms of local vectors.

**Fig 8.4: Selection of IRS product class based on outcomes from insecticide resistance monitoring in principal malaria vector(s), for areas in which IRS is the core malaria vector control intervention**

INTERVENTION	PRODUCT CLASS	INSECTICIDE RESISTANCE TO THE CLASS OF INSECTICIDE IN THE IRS PRODUCT					
		PRIMARY MEASURES		SECONDARY MEASURES			
		Resistance status		Resistance intensity		Resistance mechanism(s)	
		No confirmed resistance to insecticide class <sup>1</sup>	Confirmed resistance to insecticide class <sup>2</sup>	Moderate or low intensity resistance <sup>3</sup>	High intensity resistance <sup>2</sup>	Mechanisms known to confer resistance to class not detected	Mechanisms known to confer resistance to class detected
Resistance outcomes (See Figure 8.3)							
IRS <sup>7</sup>	Organophosphate, organochlorine <sup>6</sup> , carbamate or pyrethroid formulations	++	-	- <sup>4</sup>	-	++	- <sup>5</sup>
	Fast-acting insecticide formulations (with comparable entomological effectiveness to the above product class, i.e. neonicotinoids)	++	-	- <sup>4</sup>	-	++	- <sup>5</sup>

Options are indicated as: optimal (++), acceptable (+), or deployment not supported by data (-).

- <sup>1</sup> for all major vector species to all insecticides tested of the insecticide class(es) used in the IRS product.
- <sup>2</sup> for at least one major vector species to at least one insecticide of the insecticide class used in the IRS product.
- <sup>3</sup> including moderate to high intensity where 10x intensity concentration has not been tested.
- <sup>4</sup> may be considered acceptable if there is also confirmed resistance to all other insecticide classes in available IRS products.
- <sup>5</sup> may be considered acceptable if mechanisms are detected that are known to confer resistance to all other insecticide classes in available IRS products.
- <sup>6</sup> note that while DDT may have some utility for malaria vector control, as of 18 September 2018, there were no DDT IRS formulations prequalified by WHO.
- <sup>7</sup> to be applied in rotation and/or mosaics with insecticide formulations of a different mode of action.

**Fig 8.5: Selection of ITN/LLINs product class based on outcomes from insecticide resistance monitoring in principal malaria vector(s), for areas in which ITNs are the core malaria vector control intervention**

INTERVENTION	PRODUCT CLASS	PYRETHROID INSECTICIDE(S) RESISTANCE					
		PRIMARY MEASURES		SECONDARY MEASURES			
		Resistance status		Resistance intensity		Resistance mechanism(s)	
		No confirmed resistance <sup>1</sup>	Confirmed resistance <sup>2</sup>	Moderate or low intensity <sup>3</sup>	High intensity <sup>2</sup>	P450s not detected and/or shown to not be involved	P450s detected and/or shown to be fully or partially involved
Resistance outcomes (See Figure 8.3)							
ITN	Pyrethroid-only nets	++	+	+	+	+	+
	Pyrethroid plus synergist nets i.e. PBO nets	- <sup>4</sup>	++ <sup>5</sup>	+	+	- <sup>4</sup>	++

Dark grey shading indicates that criteria specified for both resistance status and resistance mechanisms should be fulfilled for this to be considered optimal.

Options are indicated as:

optimal (++), acceptable (+), or deployment not supported by data (-).

<sup>1</sup> for all major vector species to all pyrethroid insecticides tested.

<sup>2</sup> for at least one major vector species to at least one pyrethroid insecticide.

<sup>3</sup> including moderate to high intensity where 10x intensity concentration has not been tested.

<sup>4</sup> may be considered acceptable instead of pyrethroid-only nets if this will not compromise coverage (e.g. total cost of the delivered PBO net is equal to or less than that of a pyrethroid-only net).

<sup>5</sup> where % mosquito mortality in standard bioassays with the insecticide used on the ITN is 10–80%.

### 8.3.1 Selection of alternative insecticides:

When choosing alternative insecticides, it is important to consider factors related to cross resistance, efficacy and costs. These factors should be taken into account in the following situation:

- when introducing alternative insecticides in an IRS rotation (which may or may not include the current insecticide, depending on the resistance status),
- when introducing non-pyrethroid based IRS in areas with high coverage with LLINs,
- when changing from an insecticide to which resistance has developed.

Firstly, the possibility of cross-resistance to other insecticides should be considered. Information about which insecticides may confer cross-resistance can be obtained either by identifying the resistance mechanisms and examining the known cross-resistance patterns or by conducting susceptibility tests for each of the other insecticides.

Secondly, testing should be conducted to determine the insecticides to which there is currently resistance and avoid using these insecticides in IRM if necessary. In the event of resistance to all four classes of insecticide, vector control programmes should rotate annually through as many classes as possible and should start rotations with the insecticides to which there is the lowest frequency of resistance. In an area in which LLINs are also used, pyrethroids should be avoided.

Vector control interventions are seldom selected on the basis of resistance data alone. Other influential factors specific to local contexts, such as appropriateness of the intervention for housing structure, population acceptance or compliance, and available capacity for deployment. Cost and availability of products can also be major factors affecting resistance management. Implementation of IRM should not come at the expense of reductions in vector control coverage for populations at risk of malaria.

# 9. IMPLEMENTATION OF VECTOR CONTROL INTERVENTIONS

## 9.1 IRS

Successful IRS requires a high level of policy commitment, dedicated program and health system capacity to deliver high quality and coverage of IRS in a timely manner. Good planning, management, and timing are key prerequisites for successful delivery of an IRS campaign. Inputs such as adequate human resource, logistic, transport and financial resources, as well as adequate organizational and planning capacity, must be availed. It is also critical that adequate information on the vector, socio-economic situation and cultural practices are well known and documented.

Baseline data collection will precede implementation of IRS to document the above and other information required to make informed decisions and needed for monitoring and evaluation of the IRS program.

The IRS management cycle is an effective framework that outlines activities at different stages of the planning and delivery of the spray campaign (Fig 9.1). It also provides guidance for programme managers in the timely management of IRS operations. An effective IRS programme is based on a well-defined management cycle of operations which is linked to:

- the seasonality of disease transmission,
- the annual health planning and financial budgeting cycles.

**The four phases of an IRS campaign are as follows:**

### 1. Phase-I: Baseline appraisal (new programmes/post-season review)

- baseline or annual epidemiological, entomological, demographical and operational situational analysis, including review and surveys of disease burden and trends, vector ecology, population at risk, and coverage of IRS where available.
- annual update of geographic reconnaissance of target districts, including population at risk, and target household structures or units to be sprayed.
- operational assessment of insecticides, sprayers, transport, including review of arrangements for stock control, storage and repairs.

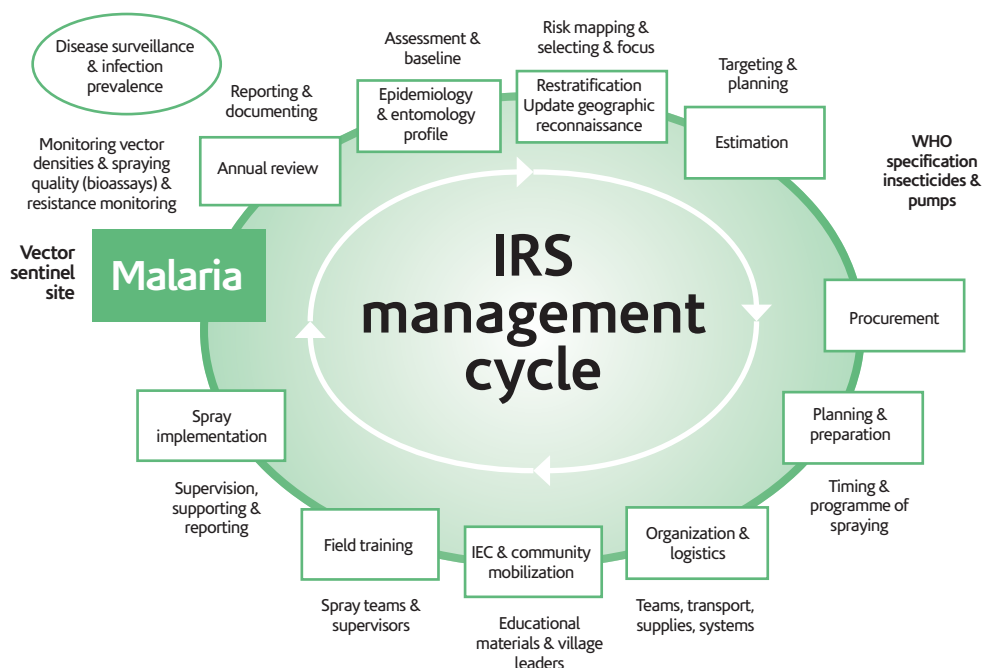


Fig 9.1: IRS management cycle

**2. Phase-II: Pre-season planning, procurement and preparation**

- inventory and estimate of annual needs for insecticides, equipment, spray teams, transport, fuel and funds.
- procurement of necessary equipment and insecticides.
- planning and preparation for schedule of spraying.
- organization and logistics for the spray teams, transport, commodities and delivery.
- environmental impact assessment and pesticide management plans.
- plan IRS publicity, IEC and community mobilization.
- begin recruitment and cascade training of coordinators, supervisors and spray teams.

**3. Phase-III: Season implementation of IRS spraying**

- distribution of insecticides, sprayers, personal protective equipment and supplies.
- collection of baseline entomological data from both IRS targeted and comparable control sites.

- IRS implementation including supervision and reporting.
- conduct quality control of spraying using either WHO cone bioassay test or colorimetric assay within 1 week of the start of the campaign.

**4. Phase-IV: End of season recording, reporting and evaluation**

- annual review of entomological monitoring and epidemiological surveillance.
- annual review of IRS performance, documentation and reporting.

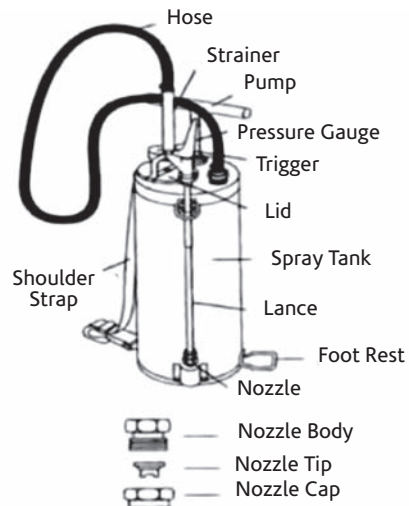
**9.1.1 Standard operating protocol for conducting indoor residual spray**

The purpose of the SOP is to provide instructions on how to manage a functioning sprayer pump, their correct use, cleaning, trouble shooting and repairs. The SOP also provides instruction on preparation of the insecticide suspension, spraying techniques, planning for the spray rounds of IRS including human resources and insecticide requirements. The SOP will be mainly for the use of the programme officer at the district/higher level offices responsible for the control of VBDs.

**1. Equipment for IRS - hand operated compression sprayer**

Indoor residual spraying of insecticides is normally done using portable compression sprayers. Before starting a spray operation, the equipment must be checked. Faulty sprayers may result in poor control or over-treatment. Examine the sprayer visually to ensure that all parts are present, assembled correctly and in good working order (Fig 9.2).

- a. Sprayer tank
- b. Shoulder strap
- c. Lid
- d. Pump (handle)
- e. Pressure gauge
- f. Lance
- g. Strainer
- h. Hose
- i. Nozzle
- j. Trigger on/off valve.
- k. Foot rest



**Fig 9.2: A compression sprayer**

The WHO guidelines are available for hand-operated compression sprayers for IRS application. The sprayer, with fittings assembled, must have no sharp edges or projections that might injure workers during normal operation.

Function, components and design: A hand-compression sprayer basically consists of a tank for holding a liquid insecticide formulation, which can be pressurized by means of a hand pump attached to it. The compressed air forces the liquid out of the tank via a hose with a cut-off valve, a lance and a nozzle. Specifications for tanks are available through WHO publication: *Equipment for vector control specification guidelines*.

The sprayer should be fitted with a control flow valve (CFV). The recommended valve operates at 1.5 bar and gives a constant output at the nozzle until the tank pressure is below the stated pressure of the CFV. Spraying will then stop, indicating that the operator must re-pressurize the tank. Some sprayers come a CFV fitted in the factory while in others a CFV can be fitted by the users.

Correct type of nozzle should be fitted and is not damaged or worn out. Flat fan nozzle with provide 80° swathe and output of 550 ml/min at 1.5 bar or 650 ml/min at 2-bar pressure. The nozzle tip should be of hardened stainless steel, ceramic or equivalent material to withstand erosion of the nozzle where water contains sand particles.

**To check that the sprayer works properly, follow the steps below:**

- Pour clean water into the tank (never fill the tank more than 3/4 full).
- Fit the lid and lock it in position by turning the handle.
- Operate the pump using both hands and with foot on the foot rest. Pump until the tank pressure is 4 bar [58 pounds per square inch (psi)]. Every full stroke usually gives about 1 psi. (Note. 1 bar = 100 millibar = 14.5 psi = 100 kpa).
- Check for any leakage (hissing sound will come in case of leakage of air).
- Measure the discharge rate per minute: Open the trigger on/off valve for one minute, collect the discharge and measure the amount in a measuring jug. Repeat this for 2 more times and average the measurements. With the above procedure if the nozzle is fitted with a CFV at 1.5 bar, the output of the same nozzle will be 550 ml/min  $\pm$ 10 ml/min. If the discharge rate is incorrect, check the nozzle and the screen filters to ensure they are not clogged. If necessary, replace the nozzle. Repeat the calibration. The addition of a CFV set on the lance will ensure that the flow rate does not decrease as the pressure in the tank falls.
- Clogged Nozzle: The opening in a nozzle is very small and must not be damaged. Clogged nozzles should be put in a container and immersed in water for several hours before the blockage is removed with a very soft toothbrush. NEVER clean a nozzle with a hard pin or piece of wire and NEVER put a nozzle to your mouth to blow through it.



## 2. Preparation of the insecticide suspension formulation

Prepare the insecticide spray according to the manufacturer's instructions. The insecticide may be mixed separately in a bucket and poured into the sprayer.

Water-soluble sachets, tablets and insecticide granules are added directly to the water-filled tank. These formulations mix readily with water and reduce the hazards associated with handling and mixing in a separate container.

The amount of formulated insecticide required for the preparation of an insecticide spray is based on the average discharge rate of the sprayer and the speed of application. When the compression sprayer is fitted with a CFV, the output of the nozzle remains the same although the pressure inside the tank decreases as it empties.

	Application rate (ml/m <sup>2</sup> )	The surface area suspension can be sprayed on to (m <sup>2</sup> )
CFV at 1.5 bar	30	250 (filled with 7.5 L)
No CFV	40	200 (filled with 8L)

### Example 1: Using a CFV with 1.5-bar pressure

A target application of 2 g of active ingredient of insecticide/m<sup>2</sup>, applying at the rate of 30 ml/m<sup>2</sup> to treat 250 m<sup>2</sup>, requires 500 g of active ingredient in 7.5 liters of water (calculation: 2 g/m<sup>2</sup> x 250 m<sup>2</sup>). Therefore, for a formulated insecticide of 50% wettable powder, 1000g of the formulated product should be mixed with water to give 7.5 litres of suspension (calculation: 500 g / 0.50 = 1068 g).

### Preparing sprayers fitted with a CFV

- Take 7.5 L filtered water into a bucket or cover the lid of the tank with a muslin cloth to filter water.
- Pour 2-3 L water into the tank.
- Put correct amount of insecticide or a sachet into the tank.
- Close the lid and pressure up to 2 bar(29 Psi) to prevent accidental opening of the lid while shaking. Shake the tank horizontally 2-3 times.
- Release air, open the lid, and add the remaining of the 7.5 L water.
- Close the lid and prime up to 58 Psi usually by giving 58 pump strokes or more.

### Example 2: If sprayer does not have a CFV

An average application rate of 40 ml/m<sup>2</sup> is assumed, noting that the pressure drops while spraying. A target application of 400 mg (= 0.400 g) of active ingredient of insecticide/m<sup>2</sup>, applying at the rate of 40 ml/m<sup>2</sup> to treat 200 m<sup>2</sup>, requires 80 g of active ingredient in 8 liters of water (calculation: 0.400 g/m<sup>2</sup> x 200 m<sup>2</sup>). Therefore,

for a formulated insecticide of 80% wettable powder, 100 g of the formulated product should be mixed with water to give 8 litres of suspension (calculation:  $80 \text{ g} / 0.80 = 93.5 \text{ g}$ ).

**Preparing sprayers not fitted with a CFV:** Take 8 L water in the tank with a muslin cloth to filter water.

**Note 1:** The amount of active ingredient (a.i.) in liquid formulations (e.g. SC) may be expressed as weight/weight (w/w) or weight/volume (w/v). In the latter case, the calculations proceed as in the previous examples. However, in the case of w/w, consult the label carefully, it will also give the amount of active ingredient per litre. Convert this to a percentage before proceeding with the calculations, as stated above. For example, if the label indicates that the formulation is 8% w/w, but also indicates that it contains 100 g a.i./L: convert 100 g/L to a percentage (Calculation:  $100 \text{ g} / 1000 \text{ ml} = 10\%$ ).

**Note 2:** In some countries, compression sprayers of 10-litre liquid capacity are used. With such tank capacity, the spray suspension covers a larger area. The surface area to be treated should be calculated based on the application rate and the remaining calculations carried out as detailed above.

### 3. Spraying techniques

Apply spray in vertical swathes 75 cm wide, with an overlap of 5 cm. Spray from roof to floor, using a downward motion, to complete one swathe. Step sideways and spray upwards from floor to roof.

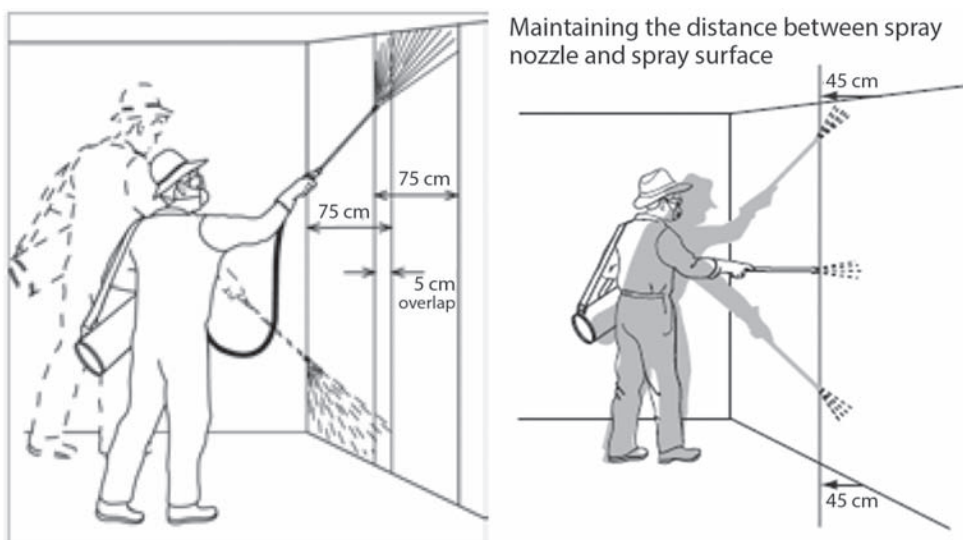
To ensure the correct swathe width, keep the spray tip about 45 cm from the wall (Fig 9.3). Lean forwards as you spray from top of the wall and move back as you bring the nozzle downwards. Continue the procedure, moving in a clockwise direction until spraying of the room is completed.

Time your spray speed to cover one meter every 2.2 seconds, i.e. 4.5 seconds for a 2 m high wall. Timing may be aided by mentally counting “one thousand and one – one thousand and two – one thousand and three – ...”.

If spraying stops because of a blockage in the nozzle, unscrew the nozzle cap, remove the blocked nozzle and replace with a new one. The blocked nozzle should be cleaned as explained above. Do not let spray drip onto the floor.

When the CFV stops the spraying, re-pressurize the tank to 58 Psi (4 bars).

After spraying has been completed for the day, the spray operator returns to the central location where spray operations are organized, and where tanks are emptied and cleaned.







**Fig 9.3:** Application of IRS

#### 4. Procedures after spraying

- Advise the occupants to stay outside the house until the spray is dry.
- Instruct the householder to sweep or mop the floor before children or pets are allowed to re-enter.
- Instruct the householder not to clean the sprayed surfaces.
- Disposal of remains of insecticides and empty packaging
- At the end of the day's work, the inside of the sprayer should be washed, and any residual insecticide flushed from the lance and nozzle. The rinsate should be collected and carefully contained in clearly marked drums with a tightly fitting lid. This rinsate should be used to dilute the next day's tank loads or disposed properly by the supervisor.
- Never pour the remaining insecticide into rivers, pools or drinking-water sources.
- Decontaminate containers where possible. For glass, plastic or metal containers this can be achieved by triple-rinsing, i.e. part-filling the empty container with water three times and emptying into a sprayer for the next application. Then the containers can be disposed as usual wastes.
- All empty packaging should be returned to the supervisor/designated collection center for safe disposal.

### 5. Stencil marking

After accomplishment of spraying, stencil symbols are marked on the most conspicuous section of the front house wall with saffron paint considering the first house as house No. 1.

Symbols	Meaning
	Whole house sprayed
	Half of the house sprayed
	One third area of the house sprayed
	Not sprayed

Following specifications should be on the right side of the symbol:

- Spray cycle:
- Group number:
- Team number:
- Spray man ID No:
- Spray date:

### 6. Maintenance of equipment

After completing the day's work, de-pressurize the tank and empty any remaining insecticide into the bucket. Clean the tank as explained below.

1. De-pressurize the tank.
2. Fill the tank half-full with clean water.
3. Replace the lid.
4. Pressurize the tank slightly and then shake the tank to ensure all inside surfaces are washed.
5. Pump up to 2.5 bar (=36 psi) pressure.
6. Spray water through nozzle into a bucket or a container.
7. De-pressurize the tank and pour out any remaining liquid in a bucket.
8. Unscrew the trigger on/off valve handle and check and clean the strainer.
9. Reassemble the trigger on/off valve.

10. Remove the nozzle tip and wash.
11. Refit the nozzle.
12. Clean the outside of the tank.
13. With the lid open, turn the tank upside down, open the on/off valve and let all the water drain out of the hose and lance.
14. Ensure the lance is parked to protect the nozzle when not in use.
15. When storing the sprayer for long period, hang it upside down with the lid open to allow air circulation. Allow lance to hang from the D-ring on the tank with the trigger valve kept open.

## 7. Estimating the number, size and composition of spray teams

The number and size of spray teams for IRS operations depend on the sprayable surfaces, application rates and spray round required. These instructions are essential for calculating the amount of insecticide needed for the operation, and for spray operator training and supervision.

### ■ Types of sprayable surfaces

The persistence of an insecticide sprayed on a surface varies with the type of insecticide, its formulation and the type of surface. Most insecticides last longer on wood and thatch than on mud. Mud surfaces, cement blocks, concrete and brick absorb the insecticide, and certain types of mud may also break it down chemically. The residual efficacy of insecticides on absorbent surfaces is 10–20% less than on non-absorbent surfaces. Therefore, it is important to ensure the right concentration of the recommended dosage is sprayed on non-absorbent surfaces.

### ■ Application rates

The application rate is the amount of insecticide active ingredient (a.i.) applied to a unit of surface area and is expressed in grams per square metre (g/m<sup>2</sup>) of the surface. The correct application is one of the most important issues in IRS programmes.

### ■ Number of spray rounds

The implementation of spray operations of all sprayable houses in an area over a period of time is called a spray round. The repetition of spray rounds at regular intervals is the “spraying cycle”. The frequency of the spraying cycle will depend on the malaria transmission patterns of the area and the residual effect of the insecticide formulation chosen. Spray rounds should ideally be completed in less than 2 months and just before the transmission season begins. In endemic areas with perennial transmission, two rounds of spraying in 6-month cycles may be recommended to ensure that there is adequate year-round coverage with residual insecticides. If the transmission pattern exhibits bimodal peaks, spraying

rounds should target the peaks. In areas with one seasonal transmission, one spray round, in yearly cycles before the period of transmission, should be enough to have an impact on malaria transmission.

### 8. Estimating insecticide requirements for IRS

Population Level: To estimate the amount of insecticide required for an IRS spray round, the following is needed:

- N: number of houses to be sprayed- obtained by counting or from census/ local data
- S: Average sprayable surface per house in m<sup>2</sup> (modern and traditional structures)
- C: Concentration of the active ingredient in the formulation (% a.i): Included in the manufacturer’s packaging
- Y: Insecticide application dose (g/m<sup>2</sup>): application rate of insecticide to be used on each type of structure according to WHO recommendation.
- Q: the total quantity of insecticide needed (kg) is calculated as shown below:

$$Q = \frac{S \times Y \times N \times 100}{C} = \dots\dots\dots \text{grams}$$

*Note: When the full quantity of insecticide needed is calculated, a 10% is added as a buffer.*

### CALCULATIONS

Example 1: Determine the amount of insecticide formulation required to treat 11, 607 formal structures with an average sprayable surface area of 300 m<sup>2</sup>. The insecticide formulation selected is lambda-cyhalothrin 10% WP. The dose to be applied (application rate) is 0.025 g of a.i. per m<sup>2</sup>.

Q = (300 x 0.025 x 100) /10 x 11 607 = 870 525 g  
 870.5 kg of insecticide formulation are required to spray 11, 607 structures/houses;  
 + 10% buffer stock = 87 kg  
 The total amount of lambda-cyhalothrin required: 957.5 kg

Example 2: Determine the amount of insecticide formulation required to treat 6250 traditional structures with an average sprayable surface area of 125 m<sup>2</sup>. The insecticide formulation selected is DDT 75% WP. The dose to be applied (application rate) is 2.0 g of a.i. per m<sup>2</sup>.

Q = (125 x 2.0 x 100)/75 x 6250 = 2 083 333 g  
 2083.3 kg of insecticide formulation are required to spray 6250 structures/  
 houses; + 10% buffer stock = 208 kg  
 Total amount of DDT required: 2291.3 kg

### 9.1.2 IRS operational indicators

IRS is a vector prevention and control intervention that has a quick and significant impact when implemented correctly and at high coverage level of the target population. Unlike LLINs, IRS may not be deployed for personal protection. Consequently, it is crucial to monitor operation achievements of IRS to ensure effective and timely delivery of the services. The following are major operational indicators that need to be monitored:

- Proportion of structure/ households sprayed in the target area (80% or more).
- Proportion of population protected with IRS in the target areas (80% or more).
- Period and length of spraying in relation to the peak transmission season.
- Quality of spraying (through the WHO cone bioassay tests).
- Susceptibility of the vectors to the sprayed insecticide(s), through efficacy assessment.

## 9.2 SPACE SPRAY

A space spray – technically a fog– is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 30 µm in diameter. It is only effective while the droplets remain airborne. Space sprays are applied mainly as thermal fogs or cold fogs (Fig 9.4).

Space spraying is designed for:

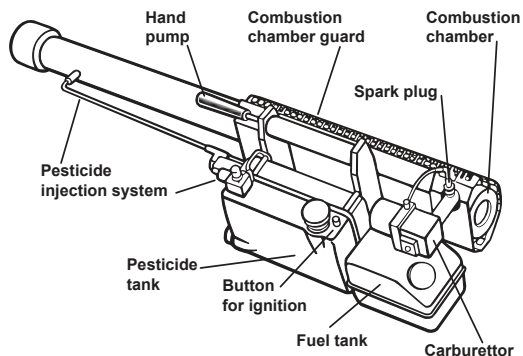
- rapid knock-down,
- rapid mortality, and
- rapid method of control in epidemic and emergency situation.

### 9.2.1 Thermal fogging

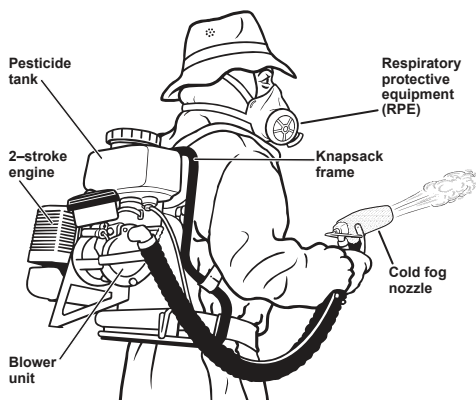
The insecticide used in thermal fogs is diluted in a carrier liquid, which is usually oil-based. Hot gas is used to heat the pesticide spray, decreasing the viscosity of the oil carrier, and vaporizing it. When it leaves the nozzle the vapour hits colder air and condenses to form a dense white cloud of fog. The hot emission gas is obtained from engine exhaust, friction plate/engine exhaust or from a pulse jet engine.

#### Advantages of thermal fogging (versus cold fogging)

- Easily visible fog can be observed and monitored.
- Good public relations as people can see something being done about the problem.
- Low concentration of pesticides in the spray mixture and limited operator exposure.



**Fig 9.4 (a): A hand carried thermal fogger**



**Fig 9.4 (b): A knapsack cold fogger**

**Disadvantages of thermal fogging (versus cold fogging)**

- Large volumes of organic solvents are used as diluents, which may have a bad odour and result in staining.
- High cost of diluent and spray application.
- Requires special and expensive equipment.
- Householders may object and obstruct penetration of fog into houses by closing windows and doors.
- Efficacy often depends on the meteorological conditions at the time of application, including wind direction, rain, and temperature.
- Fire risk from machinery operating at very high temperatures with flammable solvents.
- Can cause traffic hazards in urban areas due to reduced visibility.



### 9.2.2 Cold fogging

With cold fogs the droplets are formed by the mechanical breaking up of the spray mixture, either by passing it through high-pressure nozzles or by passing a slow stream of the mixture through a high-velocity vortex of air. Some equipment is fitted with high-speed rotary nozzle(s). The spray droplets are generated without any external heat.

#### Advantages of cold fogging (versus thermal fogging)

- The amount of diluent is kept to a minimum, resulting in lower application cost and increased acceptability.
- Some formulations are ready to use, thereby reducing operator exposure.
- May use water-based and water-diluted formulations, which pose a lower hazard and are relatively environmentally friendly.
- Because a lower volume of liquid is applied, application is more efficient.
- No traffic hazard as the spray cloud is almost invisible.

#### Disadvantages of cold fogging (versus thermal fogging)

- Dispersal of the spray cloud is difficult to observe.
- Higher technical skills and regular calibration are required for efficient operation of the equipment.

### 9.2.3 Pre-spray activities

Before embarking on any space spray treatment, it is essential to clearly define the problem, the pest species involved and its behavior, and to characterize the area for treatment. This will allow for appropriate planning and will ensure that all the equipment and resources required are available for timely and efficient operations.

#### 1.Planning and needs assessment

When planning a space spray operation, it is necessary to identify the location and magnitude of the pest or vector-borne disease problem and the epidemiological situation. The area for space treatment must be well defined and characterized, including the density of the human population, type of dwellings/buildings, road layout, vegetation and accessibility. These factors will assist in determining the most appropriate space spray application method(s) and choice of equipment. Vehicle-mounted equipment is suitable only if there is a good network of roads. Portable equipment is more versatile and can complement vehicle-mounted equipment for spraying areas that are otherwise inaccessible and for treating the insides of buildings, but coverage is slower.

Maps are needed to facilitate advance planning of spray routes. If suitable maps of the area are unavailable it may be necessary to prepare them. The total area in hectares should be calculated and then the options for spray routes must be established. The route distances and vehicle or walking speeds should be calculated so that the correct dosage can be applied for the flow rate of the machine.

The number and type of machines (e.g. portable or vehicle-mounted), and the number of machine operators and ancillary personnel will be determined by the size and characteristics of the area to be treated, the time needed to complete each application cycle and its frequency. Consider the following example:

1000 hectares per day must be sprayed by vehicle-mounted equipment. Assuming that one machine can cover 60 hectares per hour (180 hectares in 3 hours of operation), six machines will be needed to complete this task in one evening. Alternatively, three machines can treat the area in two evenings.

Two persons are normally needed for each vehicle-mounted fogger, one to drive and the other to be responsible for the equipment. Operators must be well trained in the safe use and maintenance of the equipment as well as in the safe handling and application of insecticides. Operations must be adequately supervised.

(1 hectares = 10,000 square meters)

All personnel involved in space treatments must be provided with protective equipment including overalls and respiratory and ear protection equipment.

The public should be well informed in advance about the purpose and schedule of operations and how they can cooperate. To allay public concerns, information should also be provided about the safety of the treatments and may include specific advice, for example, to beekeepers and pet owners. A “hotline” may be established so that members of the public can obtain further information. In urban areas, the police and fire departments should be informed of the schedule of operations.

## 2. Calibration of the equipment

Each insecticide has particular physical and chemical properties and biological effectiveness. Insecticide manufacturers recommend different dosage rates for specific control situations and target species. Each machine must therefore be calibrated to ensure that the correct amount of insecticide is delivered.

The output rate of the machine (delivered volume per unit of time) will depend on the speed of the vehicle (or walking speed or time per house/room with portable equipment), effective swathe width (metres) and quantity of the chemical preparation as per manufacturer's recommendation (litres per hectare, including any carrier substances).

### 9.2.4 Outdoor applications

- Advanced route planning should precede outdoor ground fogging operations and may require a combination of vehicle-mounted and hand-carried or knapsack equipment in areas with difficult or limited vehicle access. Consideration must also be given to the following:
- Spraying should not be undertaken when it is raining, when winds exceed 15 km/hour, or in the heat of the day.
- Doors and windows of houses and other buildings should be open to allow penetration of the spray cloud for improved efficacy.
- In areas where the roads are narrow and the houses are close to the roadside, the spray should be directed backwards from the vehicle. In areas where the roads are wide, with buildings far from the roadside, the vehicle should be driven close to the roadside and the spray should be directed at an angle (downwind) to the road rather than directly behind the vehicle.
- The nozzle of vehicle-mounted cold fog machines may be directed upwards at an angle when there are barriers that impede airflow, e.g. boundary walls and fences; for vehicle-mounted thermal foggers, the nozzle should be directed horizontally.
- The distance between successive passes through a built-up area will be largely dependent on the layout of roads. A track spacing of 50 metres is generally recommended, with the vehicle moving upwind so that the fog drifts downwind away from it and the operators.
- Spray application route relative to wind direction in an urban setting. Coverage is from downwind to upwind. In this example, the first swathe targets flying adults in the proximity of the breeding site.
- As far as possible, the predetermined speed of the vehicle should be maintained and the spray must be turned off when the vehicle is stationary.
- The downwind side of the spray area should be treated first, working systematically from downwind to upwind.
- To avoid driving into the spray cloud, dead-end roads must be sprayed only on the way out.
- Try to avoid directly spraying shrubbery and expensive floral areas unless using a water-based/water-diluted product.

To calculate the output rate of vehicle-mounted equipment, the vehicle speed and width of the track spacing are needed. Thus a 50-metre track spacing and a vehicle speed of 12 km/hour, 50 x 12 000 m/hour, will permit the treatment of 600 000 m<sup>2</sup> per hour, equivalent to 10 000 m<sup>2</sup> (1 hectare) per minute. In this example, if the insecticide label recommends an application rate of 0.5 litre of UL formulation per hectare, the flow rate must be adjusted to deliver 0.5 litre per minute.

Most ULV machines can be easily adjusted to achieve the required flow rate but thermal foggers may require a change of restrictor.

When using portable equipment, at a walking speed of 60 metres per minute and with track spacing of 10 metres, 600 m<sup>2</sup> can be sprayed in one minute (0.06 hectares per minute). For an application rate of 0.5 litre per hectare, the flow rate must therefore be 30 ml/minute (500 ml x 0.06).

### 9.2.5 Indoor applications

Personnel conducting this work require training on the safety measures to be followed. Several rules apply for the inhabitants and the spray operators:

- Shut off all electricity at the master switch.
- Turn off all heating and cooking equipment.
- The risk of fire is less with water-diluted products.
- Protect all water containers and foodstuffs.
- Remove fish or cover fish tanks.
- Ensure all occupants and animals remain outside the house during spraying and stay outside for 30 minutes after spraying. Ensure that the building is ventilated before reoccupation.
- Close all doors and windows before spraying and keep them closed for 30 minutes after spraying to ensure maximum efficacy.
- Spray operators should work backwards and away from the fog to minimize exposure.
- For small single-storey houses, the spray can be delivered from the front door or through an open window without having to enter every room of the house, provided that adequate dispersal of the insecticide droplets can be achieved.
- For large single-storey buildings, it may be necessary to apply the spray room by room, beginning at the back of the building and working towards the front.
- For multi-storey buildings, spraying is carried out from top floor to the ground floor and from the back of the building to the front. This ensures that the operator has good visibility at all times.

Equipment calibration for indoor applications is usually based on dosage per house or room. Thus it is necessary to calculate the time required to spray a house or room. With a flow rate of 20 ml/minute, and the area of a house being 0.04 hectare (400 m<sup>2</sup>), the target application rate of 0.5 litre per hectare (500 x 0.04) is delivered in one minute. Similar calculations are needed when treating other situations, such as refuse areas for fly control.

Calibration of a machine should be done periodically, usually after 25 hours of operation, or at any time when major maintenance is performed. Similarly, if a change of insecticides is made, recalibration is needed. For any change of insecticide or major operating conditions, a sample of droplets should be measured to verify acceptable droplet size.

(1 hectares = 10,000 square meters)

### 9.2.6 Timing of application

- In the early morning and late evening hours, the temperature is usually cool. Cool weather is more comfortable for workers wearing protective clothing. Also, adult *Aedes* mosquitoes are most active at these hours.
- In the middle of the day, when the temperature is high, convection currents from the ground will prevent concentration of the spray close to the ground where adult mosquitoes are flying or resting, thus rendering the spray ineffective.
- An optimum wind speed of 6 km/hr enables the spray to move slowly and steadily over the ground, allowing for maximum exposure of mosquitoes to the spray. Air movements of less than 3 km/hr may result in vertical mixing, while winds greater than 13 km/hr disperse the spray too quickly.
- In heavy rain, the spray generated loses its consistency and effectiveness. When the rain is heavy, spraying should stop and the spray head of the ULV machine should be turned down to prevent water from entering the blower.
- Spraying is permissible during light showers. Also, mosquito activity increases when the relative humidity reaches 90%, especially during light showers.

### 9.2.7 Frequency of application

In order to decide on the number of treatments and the interval between treatments, the purpose of the operation must be well-defined, i.e. abatement of nuisance species or interruption of transmission of a vector-borne disease. For the latter, the interval will be less than the incubation period of the pathogen in the vector. For containment of outbreak of *Aedes*-borne diseases (e.g. dengue, chikungunya) and during emergencies, space spraying should ideally be carried out every 2–3 days for 10 days for rapid reduction in vector density. Further applications should then be made once or twice a week to sustain suppression of the adult vector population. Continuous entomological and epidemiological surveillance should be conducted to determine the appropriate application schedule and the effectiveness of the control strategy.

### 9.2.8 Monitoring and evaluation of spraying operations

An operational log (daily report form) must be kept, showing pertinent data including the area treated, the date and time of application, meteorological conditions, type and amount of insecticide delivered and any operational difficulties encountered. The log must be regularly checked by the supervisor, who should record remarks on the performance of the equipment, malfunctions and hazards encountered.

Evaluation of the efficacy of spray operations is carried out using techniques that are largely specific to the target insect. Space sprays are transient and only insects flying at the time of the application are affected. Therefore, adult populations can increase as a result of immigration from outside the treated area or emergence from a pupal population. Entomological impact can be assessed either by comparing pre- and post- spray densities of the target insect or the mortality of caged insects, or by a combination of both methods.

## 9.3 LARVICIDING

Larviciding is complementary to environmental management. When selecting larvicides and specific formulations, those involving the least hazard to humans and the environment are preferable. Other considerations are total programme costs, transportation requirements, availability of suitable equipment and most importantly, storage requirements and shelf life. Costs should be calculated 'per person protected per day or per year', not simply on purchase price per kilogram.

Unless larval habitats are very extensive (e.g. river flood plains), most larvicides can be applied by ground applicators utilizing either ground equipment (boat, vehicle mounted dry product spreader/liquid sprayer, handheld or backpack dry product spreader/liquid sprayer) or by hand for specific circumstances. Liquids can be applied in dilute or concentrated form. Dilute mixtures are usually used for application of large volumes using large droplets. Low volume (LV) and ultralow volume (ULV) application (of fine sprays, mists or aerosols) can be used for more concentrated mixtures. This technique applies the minimum amount of liquid (<5 L/ha) and if conducted correctly, results in substantial savings through its speed of application, lower handling costs and smaller staff requirements. In addition, coverage of large surface areas can be achieved by taking advantage of wind drift under appropriate atmospheric conditions.

### 9.3.1 Equipment

Hand application of granules may be sufficient for many applications, such as routine treatment of small urban sources, many LSM operations will require the use of some equipment. Especially when liquid sprays are employed and for application of granules in large areas.

The choice of equipment, equipment calibration, and applicator training are critical for the success of LSM operations. The choice of equipment will depend on a variety of factors:

- Choice of larvicide formulation (liquid or granular).
- Nature and size of targeted larval habitats.
- Availability of fuel, oil and maintenance services for power equipment.
- Local capacity to securely store equipment that may be useful for agriculture or other pursuits.

### 9.3.2 Application of liquid sprays

Liquid larvicide sprays are used in a number of applications due to their efficiency and potential cost savings. Extensive, dense, emergent vegetation in larval habitats can limit the effectiveness of liquid sprays. Manual application of high volume sprays is an appropriate choice for small to medium sized habitats that have a low density of emergent vegetation. For high volume, hand application of liquid insecticides to larval habitats, compression or backpack sprayers (Fig. 9.5) fitted with a solid stream nozzle should be employed using the swathing spray or spot spray methods.

#### ■ Swathing spray method

This method (Fig. 9.6) allows treatment swaths of up to 10m wide (with 180° sweep) with this equipment and is generally used for larval sources >10 m<sup>2</sup> in size or areas containing multiple small sources (puddles, residual streambed pools, and hoofprints) in close proximity to each other.

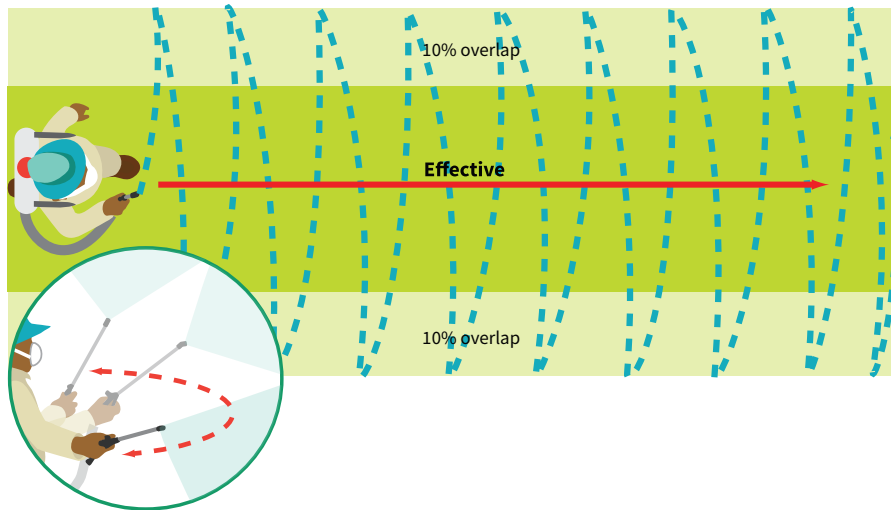
#### ■ Spot spray method

The spot spray method (Fig 9.7) is used to treat individual small sources rapidly. Oscillation of the spray wand achieves even coverage of the source but is more directed to cover specific small sources and avoids waste of larvicide.

Both methods will be needed to be employed during the course of daily treatments. In this case, spray concentration should be selected based on calibration for swathing spray, and applicators should be trained to mentally 'time' their spot treatments so as to deliver sufficient material in spot treatments. For example, if a sprayer has been calibrated to deliver 20 L of total spray volume per ha with walking speed of 60 m/min and a 10 m swath, then the applicator is treating 600 m<sup>2</sup>/min (10m<sup>2</sup> per second). In this case, the applicator should be trained to spray for <0.1 sec/m<sup>2</sup>.



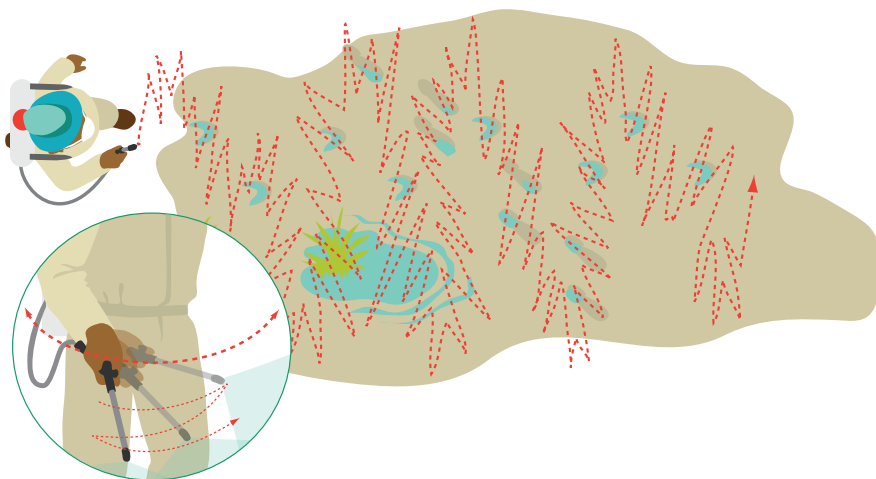
**Fig 9.5:** Example of suitable spray equipment for high volume, hand application of liquid larvicides.



**Fig 9.6:** Schematic of swathing spray method.



Swing spray wand back and forth to create an arc while walking through the source. Always make a full semi-circle (180°) and keep the wand pointed high. Spray mix rate will depend on effective swath, walking speed and sprayer flow rate.



**Fig 9.7:** Schematic of spot spray method for individual larval sources less than 10 m<sup>2</sup> in size note that the spray wand is oscillated to cover the surface evenly with drops from a solid stream.

### 9.3.3 Low volume (LV) and ultra-low volume (ULV) spray methods

For low volume sprays of mosquito larvicides, power backpack (Fig 9.8) and vehicle-mounted mist blowers or ULV sprayers can be utilized to disperse fine (small drop) sprays to target cryptic habitats and cover large areas.

Truck-mounted ULV and backpack LV spraying of Bti AM65-52 WG was successfully used in a malaria elimination project on Tekong Island, Singapore. These methods have also been successfully used for control of *Aedes* species.



**Fig 9.8:** Low volume spraying of Bti AM65-52 WG for malaria vector control on Teking Island

### 9.3.4 Application of granules and pellets

Solid formulations including granules and pellets are often required for penetration of emergent vegetation in larval sources. They are applied undiluted and can be applied by hand without equipment. Equipment including manual rotary disk spreaders, power backpack blowers, vehicle-mounted rotary disk spreaders and blowers are useful to improve swath coverage, application efficiency and homogeneity of coverage.

# 10. MANAGEMENT OF INSECTICIDES

Good management of IRS operations begins with the procurement of the insecticides. Insecticide procurement is a highly specialized and complex subject. Expertise is required to ensure that appropriate high-quality pesticide products are procured rapidly, efficiently, economically and in a fair and transparent manner. It also requires the existence of national policies and guidelines, with clear and transparent procedures supported by appropriate legal provisions and controls. In selecting a pesticide and an appropriate formulation, consideration should be given to:

- the biological effectiveness of the pesticide (including residual activity where appropriate) against the target pest or vector,
- the susceptibility of the target species to the insecticide and its role in the prevention and management of resistance to pesticides,
- the method(s) of application,
- risks to human health and the environment,
- national registration status of the product,
- WHO recommendations for the intended use,
- existence of adequate capacity for safe handling, application and life-cycle management (e.g. distribution, storage and disposal),
- obligations under international conventions, e.g. the Stockholm Convention with regard to DDT.

Estimating the correct quantity of pesticides to be procured is an important step in procurement. The steps comprise quantification and forecasting and should be guided by information from a logistics management and information system. This would include records of existing stocks and their location, accurate estimates of the population to be covered, disease incidence, past consumption figures, a sound distribution plan and documented experience in managing the vector(s).

Procurement of a high-quality pesticide begins with a definition of the correct specifications for the intended purpose. Many problems associated with pesticide use arise from incomplete or inappropriate specification in tenders and procurement documents.

In general, the specifications of pesticides to be procured should include:

- the common name of the active ingredient(s), or, in the absence of a common name, the chemical name; use of trade names should be avoided,
- the content of active ingredient and the acceptable limits in the product, expressed in g/kg for solids and g/l for liquids,
- the formulation of the product (e.g. wettable powder, emusifiable concentrate, suspension concentrate),
- relevant chemical and physical properties and their acceptable limits,
- maximum permissible levels of relevant impurities,
- storage stability requirements at low or elevated temperature, as appropriate,
- whether the product comply with WHO specifications for pesticides and its specification number,
- whether the product has been recommended by WHO for the intended purpose.

The responsibilities of successful suppliers go beyond the supply of pesticides. It should also include product stewardship and support, with provision of information and other materials, training and disposal of empty containers.

Subject to mutual agreement with the supplier:

- The supplier will collect all empty pesticide containers for proper disposal, according to national regulations,
- The supplier will take back products that remain unused after a specified time,
- The supplier will provide protective gear, material safety data sheets, antidotes and cholinesterase test kits for monitoring exposure of applicators to the procured pesticides, when required,
- The supplier will provide training in proper handling and use of the pesticides supplied.

### **Quality control of pesticides:**

Quality control of pesticides is essential to minimize risks associated with their handling and use and also to guarantee their efficacy and stability during storage. Poor-quality pesticides can result in inadequate application of the product, increase the risk for users and the environment and lead to ineffective control and potential development of resistance.

WHO specifications for pesticides provide an international point of reference against which products can be judged, either for regulatory purposes or in

commercial dealings, and thus prevent the trade of substandard products. All public health pesticides offered for sale should meet the WHO specifications, when they exist.

Quality control involves choosing an independent certified or accredited laboratory, random sampling of appropriate samples, shipment of samples to the selected laboratory, quality control and reporting by the selected laboratory. To guarantee the transparency of procurement, the sampling agent and the laboratory must be independent of the supplier.

Pre-shipment analysis ensures that the product offered meets the relevant specifications before shipment, thereby avoiding subsequent problems if the product delivered is of poor quality. Quality control on arrival or after shipment may be required if the traceability of the product cannot be guaranteed, if the product appears to have been tampered with or if it is known to have been exposed to unacceptable shipping and storage conditions.

The WHO Collaborating Centre for Quality Control of Pesticides can be requested by procurement entities to perform the quality control of pesticides that they procure.

### Effective use of insecticides

Once the decision to use insecticides a means of vector control is determined, the next step is to plan for implementation. (Refer to chapter 9 for IRS management cycle)

## 10.1 SAFETY OF USERS, OPERATORS AND THE ENVIRONMENT

The different types of insecticide applications used be for vector control pose different risks and these should be clearly assessed at four different levels as follow:

1. **The safety of the population concerned:** The risk to the population will depend on the potential for contact with treated or contaminated materials. This may vary from the application of a larvicide to water which could be used for drinking to the potential contact with a sprayed wall or contaminated floor (in indoor residual spraying). There is also the possibility of an accidental overdose. All necessary information, education and communication measures should be taken to ensure that the population is capable of taking the necessary precautions to avoid dangerous contamination.
2. **The safety of the applicators and handlers of the insecticide used:** The applicators and handlers of the insecticide may be exposed to a continuous and higher risk than the inhabitants of the treated area. For each type of

application and for each insecticide formulation used, the protective clothing and other devices required should be specified. In the selection of a particular application, it is necessary to consider whether it is suitable for the climate of the area concerned. The applicators must be trained in use of the necessary protective devices and supervised to ensure that they are actually used in the field.

3. **Safety in storage and transport:** Safety in storage and transport includes not only the safety of those handling the insecticide containers but also the prevention of accidents which may result in the contamination of people, food or the environment. This requires not only safe packing and the training of handlers, but also regulations to prevent the transport of insecticide containers in vehicles which may also be used to transport livestock or foodstuffs.
4. **Safety of the environment:** The risks to the environment, including the impact on non-target organisms and the persistence, vary considerably with the type of application and the insecticide used. Risks are also associated with the disposal of unused insecticide residues and the cleaning of equipment in the field. Insecticides may also do serious damage to painted surfaces.

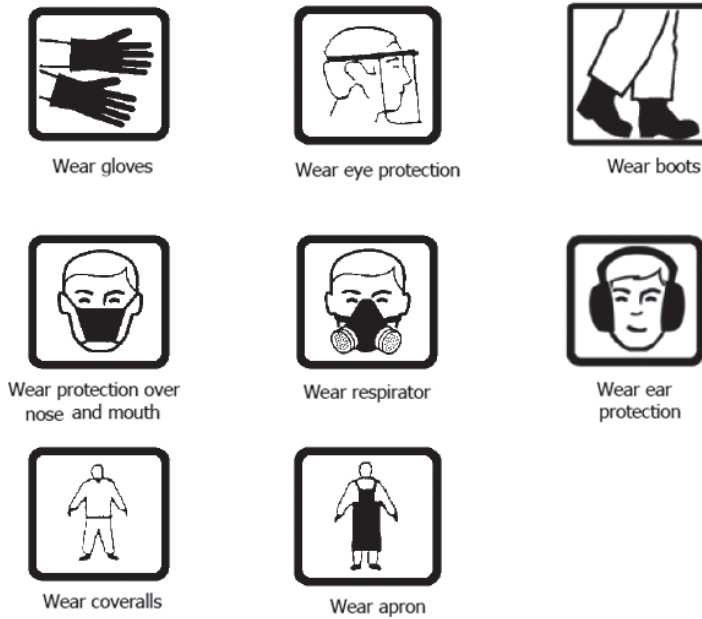
Exposures to insecticide may occur while handling the insecticide during opening, mixing and preparation, when spraying the insecticide, when disposing the insecticide solution and containers. Good practices include:

- The operator must always wear hat and face shield or goggles.
- Do not eat, drink or smoke while working (golden rule).
- Wash hands, face and any other contaminated part with soap and water after spraying and before eating, smoking, etc.
- Bath at the end of every day's work and change into different clean clothing.
- Soak the protective clothing end of every working day.
- Keep used PPE away from the family.
- Change clothes immediately if they become contaminated.
- Inform the supervisor immediately if one feels unwell.

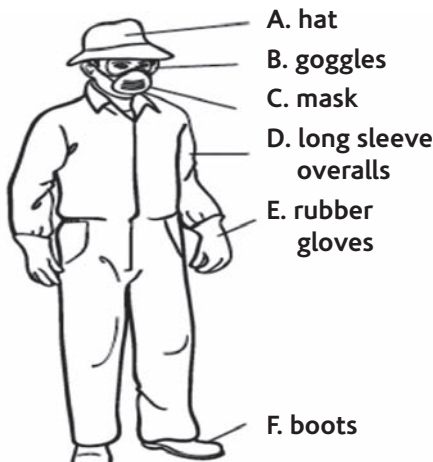
### 10.1.1 Personal protective equipment (PPE)

A pesticide may enter the body through the skin (dermal exposure), mouth (oral exposure), nose and lungs (inhalation exposure) and eyes (ocular exposure). Most occupational exposure to pesticides occurs through the dermal and inhalation routes, during mixing and loading, application from splashes and spray, including spray drift or by contact to the contaminated surfaces, equipment and materials.

The pesticide label is the primary means of communicating information to the pesticide user. It includes precautionary statements to reduce risk, such as pictograms, “signal” words and associated directions on PPE and safety. Fig 10.1 (a) provides some examples of common PPE pictograms for pesticide use. Protective clothing and equipment is shown in Fig 10.1 (b) and must be worn in accordance with the safety instructions on the product label.



**Fig 10.1 (a):** Common PPE pictograms for pesticides use



**Fig 10.1 (b):** Spray operator protective equipment

As a minimum precaution and to reflect real-life situations in LMIC, users should wear lightweight work clothing that covers most of the body, such as a long-sleeved shirt, long trousers, a hat, chemical-resistant gloves and boots that do not absorb spray. In this context work clothing is defined as clothing that can be obtained readily and worn by operators during working hours.

Respiratory protective equipment (RPE) is used to protect against inhalation and absorption through the nose or mouth. RPE varies from simple disposable masks to respirators. Most liquid pesticides are not volatile and form fine droplets or liquid particles in the air. Particles, solid or liquid, but not vapors, are removed by particulate air filters. Respirators protect against vapors (such as during soil fumigation) and very fine aerosols.

For respiratory protection, particulate air filters masks (such as N95 and FFP) are recommended for operations involving application of pesticides in the form of granule formulations or of water-diluted pesticides that do not form fine aerosols  $< 0.3 \mu\text{m}$ .

Respirators are recommended to protect pesticide operations during activity such as fogging in which there is a high concentration of airborne liquid droplets vapours, gases and very fine aerosols ( $< 0.3 \mu\text{m}$ ).

Nuisance dust masks and surgical mask provide protection only from large dust particles and large spray droplets. This type of mask will not protect the wearer from hazardous dust particles, liquid in air emulsion small particles or vapours of pesticides. Thus, these masks are not considered protective devices and are not recommended for IRS operations.

Avoiding exposure by using PPE and by paying attention to personal hygiene by washing exposed parts of the body after work and before eating, smoking and toileting will minimize risk. There may have difficulties in hot and humid conditions because of discomfort caused by wearing protective apparel with low heat dissipation. Therefore, pesticides should preferably be applied early or late in the day.

### 10.1.2 Storage of insecticides

Storage of insecticides differ by duration and quantity of stored pesticides. Country usually have multiple levels of storage facilities: large-volume central/regional facilities where pesticide are first delivered and then re-stored at end-of-campaign; district or operational base facilities where pesticides are received and distributed.



The following guidelines apply to any pesticide storage facilities, regardless of size:

- Storage facilities should be locked and be guarded at all times.
- Roofs should be well maintained (e.g. no leakage).
- A notice should be prominently displayed on the outside of the store in the local language(s) with a skull and crossbones sign saying “Danger, Keep Out, Pesticide Storage” to convey that entry is prohibited to unauthorized persons.

### **Location of storage**

- Away from schools, animal feed depots, water courses and residential homes (generally 100 meters away).
- Minimum of 50 meters away from health clinics, and generally away from pedestrian routes to the clinic.
- Out of potential flood zones, water zones, wells and other supplies of water for domestic or stock animal use.
- Storehouses should be secure and well ventilated.
- Away from areas where ground water is close to the surface.
- Easily accessible by transport and easy exit in case of an emergency.
- Should be located on high ground and fenced, with access only for authorized persons.
- There should be easy access for insecticide delivery vehicles and, ideally access on at least three sides of the building for fire fighting vehicles and equipment in case of emergency.

### **Design and structure of storage building**

- Ventilated so that pesticide vapors as well as temperatures don't reach dangerously high daytime temperatures (window access usually provide proper ventilation).
- Floors should be impermeable (e.g. concrete surface) to minimize absorption in case of spills and facilitate clean up.
- Large enough to allow for proper accommodation of pesticides as well as storing empty containers and pesticide waste.
- Stock and issue registers should be kept up to date. Access to the insecticides should be limited to authorized personnel only.
- The store room should have a prominently displayed mark of caution used for poisonous substances.
- Containers should be arranged to minimize handling and thus avoid mechanical damage which could give rise to leaks.

### Pesticide shelving/stacking

Insecticides must not be kept where they would be exposed to sunlight, water, or moisture which could affect their stability. Containers, bags or boxes should be well stacked to avoid possibility of spillage. Pesticides should always be shelved on wooden pallets and not directly on the floor to prevent them from getting wet. Liquid materials should not be stacked above dry materials. Pesticide stacking should not be unreasonably high, a general rule is to not exceed a height of 2 m (Fig 10.2 and Fig 10.3).

Containers should be arranged to minimize handling and thus avoid mechanical damage giving rise to leaks. Floor spaces should be uncluttered to permit easy inspection and allow free airflow. This also enables immediate clean up in the event of any leakage or spills.

### Transportation of insecticides

- Insecticides should be transported in well sealed and labeled containers, boxes or bags.
- Insecticides should be transported separately. It should not be transported in the same vehicle as items such as agricultural produce, food, clothing, drugs, toys, and cosmetics that could become hazardous if contaminated.
- Pesticide containers should be loaded in such a way that they will not be damaged during transport, their labels will not be rubbed off and they will not shift and fall off the transport vehicle onto rough road surfaces.
- Vehicles transporting pesticides should carry prominently displayed warning notices.
- The pesticide load should be checked at intervals during transportation, and any leaks, spills, or other contamination should be cleaned up immediately using accepted standard procedures. In the event of leakage while the transport vehicle is moving, the vehicle should be brought to a halt immediately so that the leak can be stopped, and the leaked product cleaned up. There should be official reports to the national level and follow-up inquiries in the event of fires, spills, poisonings, and other hazardous events.



**Fig 10.2:** Well stacked pesticide boxes on pallets. **Fig 10.3:** Wet floor in the storage facility.

## 10.2 DISPOSAL OF REMAINS OF INSECTICIDES AND EMPTY PACKAGING

Contaminated solid waste is generated during the implementation of IRS activities in the form of empty pesticide sachets, damaged PPE equipment, used cleaning equipment, materials such as sawdust used to clean up spills, and contaminated soil from accidental spills. These substances create pesticide residue and pose health and environmental hazards if not disposed in an environmentally sound manner.

At the end of the day's work during IRS activities, the inside of the spray pump should be washed, and any residual insecticide should be triple rinsed and flushed from the lance and nozzle. The rinsing water should be collected and carefully contained in clearly marked drums. With a tightly fitted lid. This should be used to dilute the next day's tank loads or disposed properly by the supervisor at disposal sites like pits or dugs. If there are no IRS operations next day, the rinsed liquid can be sprayed on the walls of the building outside.

Never pour the remaining insecticide into rivers, pools or drinking-water sources. Soak pits are often constructed in well funded IRS programs but generally it is not operationally possible to create a soak pit and use for the disposal of insecticides.

All empty packaging should be returned to the supervisor for safe disposal according to national guidelines. The used packages shall not be left outside to prevent their re-use.

### 10.2.1 Soak pit

This method is more effective when resources are available. A soak pit is a specially-designed hole in the ground for disposing of biodegradable waste (e.g., waste from pyrethroids, carbamates, and organophosphates). A properly constructed and sited soak pit protects the environment from contamination while allowing pesticides to degrade and become harmless.

A soak pit measuring 2m by 1m by 1m is usually sufficient to absorb the effluent produced from 20-30 spray operators during the duration of the spraying operations. The bottom of the pit is lined with 1.0 to 1.5 bags of sawdust (where feasible), followed by to 2 bags of charcoal (Fig 10.4a, 10.4b). A layer of stone aggregate is then placed on top, followed by a layer of coarse gravel, and then a layer of small gravel to create a filter one meter in depth (see illustration). As the effluent percolates through these materials, the pesticides filter out and degrade before reaching the surrounding soils. A concrete curb should be built around the soak pit to contain effluent and divert runoff from the surrounding area.

Location: Soak pits should be adjacent to or co-located with both the progressive rinse area and the wash area. This is to avoid potential spills when transporting effluent to the pit. Note: Due to access limitations and distances of some spray sites, a scaled down version of the soak pit located near the site, may be more appropriate.

Decommissioning: Soak pits will not require extraction of the gravel, stones, charcoal or saw dust filter; instead the pit area will require restoration to previous conditions by filling in, leveling and planting with appropriate local vegetation.

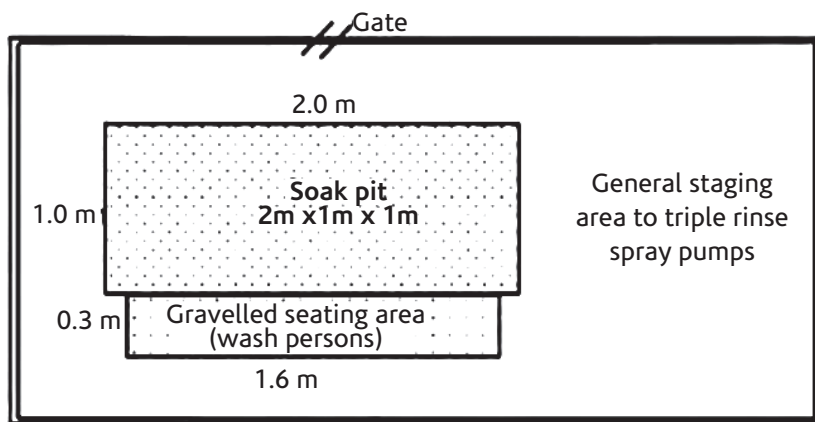


Fig 10.4 (a): Soak pit: top view

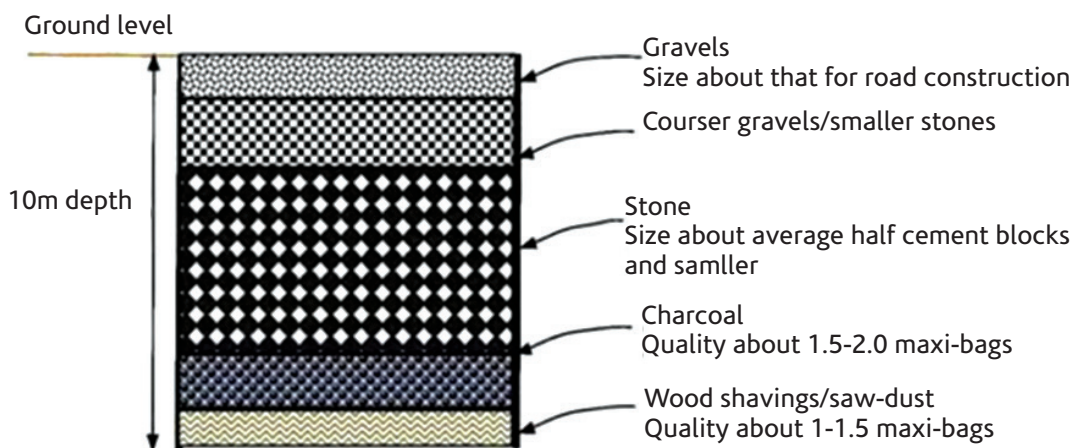


Fig 10.4(b): Soak pit: cross section showing filling material

## 10.3 INSECTICIDE DISPOSAL

Each year thousands of public health insecticides containers are emptied and become waste items that require disposal. FAO/WHO recommends that the practice of disposal of insecticide packaging at the place of use by burying or burning be prohibited. Label instructions provide warning information about container and rinse water disposal, and caution against the contamination of foods, feeds and water supplies. Disposal inconsistent with label instructions is a violation.

This section details the standard requirements for the following:

- Solid waste storage and management.
- Disposal of pesticide containers.
- Disposal of unwanted pesticides.

### 10.3.1 Solid waste storage and management

All the IRS solid waste must be collected at the end of the spray round and stored in centralized warehouses while waiting disposal. Certain IRS wastes like empty sachets and respirators are collected on a daily basis while other waste types (e.g. gloves, and covering sheets) are collected periodically.

#### Safe and secure storage

The storage facility must be lockable, with a roof in good condition, adequate ventilation, accessible and away from flood prone areas (Fig 10.5).



**Fig 10.5:** Storage facility with lock, fire extinguisher and warning sign

### 10.3.2 Solid waste disposal

#### 1. Pesticide containers

##### Disposal of uncontaminated waste

Materials that have not been in contact with pesticides (secondary wastes: boxes and paper) can be disposed of as municipal waste.

##### Disposal of contaminated waste

Insecticide containers are hazardous to both mankind and the environment. There is a danger that empty containers could be reused for storing food and water, which could result in poisonings. Containers abandoned in the environment can lead to pollution in soil and groundwater. Empty containers awaiting disposal should be stored in a special, secure area in the pesticide store area to ensure that they are not stolen and used for other purposes. A container management plan should be in place and ensure that:

- the containers are decontaminated directly following the use of their contents,
- inappropriate use of the empty containers is prevented, and
- it is easy for users to return their empty containers to the storage.

Empty sachets should always be cleaned out, as far as is practicable, before disposal to minimize both hazard and waste of residual pesticide. Sachets that have contained emulsifiable concentrate, or wettable powder (wp) formulations should be triple rinsed with water and the rinsings added to the spray pump before the tank is filled to the required volume. Contaminated PPE should be triple rinsed, shredded or punctured and sent to central disposal centers.

FAO/WHO recommend that the practice of disposal of pesticide packaging at the place of use by burying or burning be prohibited. Highly contaminated cardboard, paper and jute materials should be collected along with other contaminated wastes and sent to the central disposal centers along with other contaminated waste (Fig 10.6).

Both the bags for individual nets and the packaging used to wrap bales of nets are made of various materials. Having been in direct contact with the pesticides present in the enclosed LLIN, an individual net bag is an “empty pesticide container” as defined by the FAO/WHO guidelines on management options for empty pesticide containers and should be handled in a manner consistent with that guidance.

##### Practices to be strictly avoided:

- Re-use of LLIN bags for any purpose,
- Burning LLIN bags and baling material in open air as there is a risk of emission of harmful substances that mainly pollute local air, surface water, soil and food,



- Disposing of LLIN bags and contaminated baling material as ordinary waste or in improper sanitary landfills.

When the LLINs are delivered at the household level with individual plastic packaging, the packaging should be triple-rinsed with plain water. The rinsate is then disposed off in a pit of low permeable soil, away from the residence, at least 100 m away from a water source. The packaging can then be disposed off as a plastic waste or possibly buried in a pit as described.

## 2. Unwanted pesticides

Good procurement practices should be followed to prevent expiration of the insecticides due to poor operation or excessive procurement. Whenever possible, only one year's supply of pesticides should be ordered (pesticides mostly have a two year shelf life).

Often, it will be necessary to dispose of expired pesticides. Where very large quantities are to be disposed of, professional and technical advice must be sought from higher authority. The disposal of any obsolete pesticides should follow the requirements of the Stockholm and Basel Conventions. Information available at: <https://unitar.org/sustainable-development-goals/planet/our-portfolio/basel-rotterdam-stockholm-conventions>.

In most cases, the only option for dealing with unused and obsolete pesticides stocks is to destroy them. But destroying pesticide waste is neither cheap nor technically simple. Destruction processes vary depending on the type of contaminant. But in general, high temperature incineration is the most widely used method. However, the incineration of hazardous waste is not without its problems. It can create toxic emissions, leaves ash that is hazardous and the filters that remove the toxic emissions become toxic.



**Fig 10.6:** Cardboard boxes with empty sachets stored and labeled properly.

The technology to deal with hazardous chemical waste safely does not currently exist in most developing countries including Nepal. Providing temporary solutions such as repackaging and storage in the hope that a better solution will emerge in the foreseeable future is unacceptable, since long terms security and integrity of the pesticides and their containers cannot be guaranteed. The search for environmentally benign destruction technologies has also so far been unsuccessful. Therefore, at present, the only available technology for the destruction of most obsolete pesticides is dedicated high temperature incineration at a highly regulated facility. Currently, only Europe allows the import of pesticide waste for incineration.

The pesticides disposal plan should use the international standards to deal with the waste treatment and disposal. Further information on the international laws regarding the obsolete pesticide management is available at: <http://www.fao.org/agriculture/crops/obsolete-pesticides/how-deal/codes-and-conventions/en/>

**To use expired pesticide?** Not recommended routinely. However in special conditions, the expire pesticides can be tested for its efficacy. Samples from each batch of obsolete pesticide stocks should be sent to either the original manufacturer or a GLP lab qualified to do chemical analysis and issuance of a Certificate of Analysis (CoA). If the product complies with all parameters according to manufacturer's specifications, it can be used for vector control at the soonest, preferably within the next 6 months.



# Annexes





## Annex 2: Daily/weekly reporting form for spray team leaders

Province/ District ..... Village/Municipality .....

Ward ..... Date .....

Name and ID No. of Spray Operator .....

DAY/ WEEK	SPRAY OPERATOR (INITIALS)	TOTAL NO. OF HOUSEHOLDS SPRAYED	NO. OF PEOPLE IN SPRAYED HOUSEHOLD	NO. OF ROOMS/ STRUCTURES/ UNITS IN HOUSEHOLD	NO. OF ROOMS/ STRUCTURES/ UNITS IN HOUSEHOLD SPRAYED	PROPORTION OF HOUSEHOLDS NOT SPRAYED (%)	NO. OF MOSQUITO NETS HANGING	TOTAL NO. OF INSECTICIDE USED	TOTAL NO. OF EMPTY SACHETS/ BOTTLES RETURNED

Spray team leader’s remarks on operational problems and suggested solutions

---



---



---



---



---

Signature of spray team leader \_\_\_\_\_

### Annex 3: Summary monthly reporting form for district IRS coordinators

Province/ District ..... Village/Municipality .....

Ward ..... Date .....

Responsible Officer IRS Coordinator .....

WEEK	SPRAY TEAM	TOTAL NO. OF HOUSE-HOLDS TARGETED TO BE SPRAYED FOR CYCLE	TOTAL NO. OF HOUSE-HOLDS SPRAYED	PROPORTION OF HOUSE-HOLDS SPRAYED (%)	TOTAL NO. OF PEOPLE IN SPRAYED HOUSE- HOLD	TOTAL NO. OF ROOMS/ STRUCTURES/ UNITS IN HOUSEHOLD	TOTAL NO. OF ROOMS/ STRUCTURES/ UNITS IN HOUSEHOLD SPRAYED	PROPORTION OF HOUSE-HOLDS NOT SPRAYED (%)	NO. OF MOSQUITO NETS HANGING	TOTAL NO. OF INSECTICIDE SACHETS/ BOTTLES USED	TOTAL NO. OF EMPTY SACHETS/ BOTTLES RETURNED

Responsible Officer remarks on operational problems and suggested solutions

---



---



---



---

Signature of Responsible Officer: \_\_\_\_\_

### Annex 4: Spray team leader and IRS supervisor’s checklist

Province/ District ..... Village/Municipality .....

Ward ..... Date .....

Village Team leader \_\_\_\_\_

Number of spray operators \_\_\_\_\_

Name of village being sprayed \_\_\_\_\_

Estimate of number of target structures \_\_\_\_\_

Name of team leader \_\_\_\_\_

What was the spray operator doing on your arrival? \_\_\_\_\_  
 \_\_\_\_\_

**Observe the use of protective clothing:**

Overalls \_\_\_\_\_ Boots \_\_\_\_\_ Hat \_\_\_\_\_

Gloves \_\_\_\_\_ Mouth/nose mask/face shield \_\_\_\_\_

**Procedure before starting to spray:**

Are the residents informed? Yes No

Are food items, water containers; cooking utensils covered/ taken outside? Yes No

Are the residents outside during spraying and until 60 minutes after? Yes No

Are domestic animals outside during spraying and until 60 minutes after? Yes No

**Spraying technique:**

Is the sprayer filled correctly? Yes No

Is the sprayer pressurized correctly? Yes No

Is the sprayer pressure gauge checked frequently and pressure maintained between 245–380 kPa (35–55 psi) or 2.5–3.8 bar for sprayers without a 1.5 bar CFV?	Yes	No
Is the sprayer pressure gauge checked and pressure maintained above 200 kPa (29 psi) or 2.0 bar for sprayers with 1.5 bar CFV?	Yes	No
Is the sprayer handled and carried correctly?	Yes	No
Is the sprayer shaken periodically before and during spraying?	Yes	No
Is the nozzle held at a constant distance from the target (45 cm)?	Yes	No
Is the nozzle moved at a constant speed over all surfaces?	Yes	No
Is footwork performed so that adjacent swaths overlap for uniform spray coverage?	Yes	No
Is distribution of insecticide on wall uniform/adequate?	Yes	No
Is distribution of insecticide on roof/ceiling uniform/adequate?	Yes	No
Does spray operator spray behind and under furniture?	Yes	No
Does spray operator spray under the eaves?	Yes	No
Does spray operator spray behind the doors?	Yes	No
Does spray operator eat, drink or smoke without first washing?	Yes	No
Has the spray operator completed daily record form?	Yes	No

Any comments from household members \_\_\_\_\_

\_\_\_\_\_

Any comments from village or community leaders \_\_\_\_\_

\_\_\_\_\_

Areas requiring attention and action \_\_\_\_\_

\_\_\_\_\_

Proposed solutions and recommendations \_\_\_\_\_

\_\_\_\_\_

Supervisor name and signature \_\_\_\_\_

**Annex 5: Estimating insecticide products for indoor residual spraying**

Insecticide Product	Concentration of active ingredient (%)	Application dose of active ingredient (g/m <sup>2</sup> )	Number of applications required in 1 year	Total amount of formulation required per m <sup>2</sup> per year
	a	b	c	$E = (b \cdot c) 100/a$



### Annex 6: Calculation for amount of insecticide required for each tank load

Insecticide name, concentration in % and formulation type: *			
Insecticide application dose:			
Volume to be used in the sprayer tank (7.5 with CFV or 8L without CFV):			
Rows	Calculations parameters	Measurement unit	Values
A	Dose of the insecticide active ingredient to be applied on walls (in gram per square meter)	g/m <sup>2</sup>	
B	Percentage of the insecticide formulation being used (%)*	%	
C	Amount of water in the sprayer tank in milliliter (mL)	mL	
D	Amount of liquid suspension applied per m <sup>2</sup> of wall using a CFV (in mL/ m <sup>2</sup> ) **	mL/ m <sup>2</sup>	
E	Surface to be treated with one tank load = C÷D in m <sup>2</sup>	m <sup>2</sup>	
F	Quantity of active ingredient needed to cover the area given in row 'E'= A × E***	Gram or mL	
G	Quantity of formulation needed per selected tank load to cover the area given. G = F × 100/B	Gram or mL	
*For example, Alpha-cypermethrin 5% WP			
**30 mL with CFV, and 40 mL without CFV			
*** Gram for solid formulations and mL for liquid formulations			

## Annex 7: LLIN monitoring and supervision checklist form

Province/ District ..... Village/Municipality .....

Ward ..... Date .....

Name of Health Facility: .....

**Malaria Risk Stratification: High / Moderate / Low**

ANC:       Mass distribution:       Outbreak Response:

### 1. Service Data

1.1 Check and record previous month's total ANC attendance: \_\_\_\_\_

1.2 Check and record the previous month's LLIN distribution: \_\_\_\_\_

### 2. Logistics Management:

2.1 Is there a tally card/bin card/ inventory control card available for tracking LLINs?

YES                       NO

2.2. What is the physical count of LLINs in stock at this facility/distribution site as of today?

\_\_\_\_\_

2.3. What is the quantity on hand of LLINs recorded in the tally card/bin card/ inventory control card as of today? \_\_\_\_\_

2.4. From where will this facility receive its next supply LLINs?

Facility Store       District Store                       Regional Store

Other (specify)       Please list: \_\_\_\_\_

2.5. Does LLINs issued to beneficiaries correspond with available records on target beneficiary?

YES                       NO

**Annex 8: List of WHO prequalified vector control products: LLIN**

	Product name	Applicant	Active ingredient	AI concentration
1	OLYSET Net	Sumitomo Chemical Co., Ltd	Permethrin	2% (1000mg/m2)
2	OLYSET PLUS	Sumitomo Chemical Co., Ltd	Permethrin; PBO	2% (1000mg/m2) permethrin; 1%PBO
3	Interceptor	BASF SE	Alpha-cypermethrin	200 mg/m2
4	Interceptor G2	BASF SE	Alpha-cypermethrin; chlorfenapyr	100 mg/m2 alphacypermethrin; 200 mg/m2 chlorfenaypr
5	Royal Sentry	Disease Control technologies LLC	Alpha-cypermethrin	5.8 g/kg (261 mg/m2)
6	Royal Sentry 2.0	Disease Control technologies LLC	Alpha-cypermethrin	5.8 g/kg (203 mg/m2)
7	Royal Guard	Disease Control technologies LLC	Alpha-cypermethrin; Pyriproxyfen	5.5 g/kg; 5.5 g/kg (120D) and 5.0 g/kg; 5.0 g/kg (150D)
8	PermaNet 2.0	Vestergaard S.A.	Deltamethrin	55 mg/m2 (1.8 g/kg for netting in 75D; 1.4 g/kg for netting in 100D)
9	PermaNet 2.0	Vestergaard S.A.	Deltamethrin, PBO	Roof: 4 g/kg Deltamethrin, 25 g/kg PBO Sides (deltamethrin only): 2.8 g/kg for 75D, 2.1 g/kg for 100D
10	Duranet LLIN	Shobikaa Impex Private Limited	Alpha -cypermethrin	5.8 g/kg (261 mg/m2)
11	MiraNet	A to Z Textile Mills Limited	Alpha -cypermethrin	0.45% (4.5 g/kg) - 180 mg/m2
12	MAGNet	V.K.A Polymers Pvt Ltd	Alpha -cypermethrin	5.8 g/kg (261 mg AI/kg)
13	VEERALIN	V.K.A Polymers Pvt Ltd	Alpha -cypermethrin; PBO	6.0 g/kg (216 mg/m2) : Alpha-cypermethrin 2.2 g/kg (79 mg/m2) : Piperonyl butoxide
14	Yahe LN	Fujian Yamei Industry & Trade Co., Ltd	Deltamethrin	1.85 g/kg 75D; 1.4 g/kg 100D
15	SafeNet	Mainpol GmbH	Deltametrin	5.0 g /kg (200 mg/m2)
16	Yorkool LN	Tianjin Yorkool Int'l Trading Co., Ltd	Deltamethrin	55 mg/m2 (1.8 g/kg for 75D; 1.4 g/kg for 100D)
17	Panda Net 2.0	LIFE IDEAS Biological Technology Co. Ltd	Deltamethrin	1.8 g AI/kg (76 mg AI/m2)
18	Tsara Boost	NRS Moon Netting FZE	Deltamethrin, PBO	Deltamethrin: All panels – 12% (120mg/m2) Piperonyl butoxide: All panels – 44% (440mg/m2)
19	Tsara Soft	NRS Moon Netting FZE	Deltamethrin	80 mg/m2
20	Tsara Plus	NRS Moon Netting FZE	Deltamethrin, PBO	Deltamethrin: Roof - 3 g/kg (120mg/m2); Sides - 2.5 g/kg (100mg/m2) Pyperoni butoxide: Roof - 11g/kg (440mg/m2)

### Annex 9: List of WHO prequalified vector control products: IRS

Product name	Applicant	Active ingredient	AI concentration
1 SumiShield 50WG	Sumitomo Chemical Co., Ltd.	Clothianidin	50%
2 Fendona 5 WP	BASF SE	Alpha-cypermethrin	5%
3 RUBI 50 WP	Tagros Chemicals India Pvt Ltd	Alpha-cypermethrin	5%
4 RUBI 100 WP	Tagros Chemicals India Pvt Ltd	Alpha-cypermethrin	10%
5 RUBI 50 SC	Tagros Chemicals India Pvt Ltd	Alpha-cypermethrin	5%
6 RUBI 100 SC	Tagros Chemicals India Pvt Ltd	Alpha-cypermethrin	10%
7 RUBI 250 WG-SB	Tagros Chemicals India Pvt Ltd	Alpha-cypermethrin	25%
8 PALI 250 WG	Tagros Chemicals India Pvt Ltd	Deltamethrin	25%
9 REVIVAL 100 WP	Tagros Chemicals India Pvt Ltd	Lambda-Cyhalothrin	10.0%
10 REVIVAL 100 CS	Tagros Chemicals India Pvt Ltd	Lambda-Cyhalothrin	10.0%
11 K-Othrine WG250	Bayer S.A.S.	Deltamethrin	25% (250 g/kg)
12 K-Othrine Polyzone	Bayer S.A.S.	Deltamethrin	6.25% (62.5 g/L)
13 Ficam	Bayer S.A.S.	Bendiocarb	80% (800 g/kg)
14 Fludora Fusion	Bayer S.A.S.	Clothianidin, Deltamethrin	Clothianidin: 50%, Deltamethrin: 6.25%
15 Actellic 300CS	Syngenta Crop Protection AG	Pirimiphos-methyl	300g/L
16 ICON 10 CS - IRS	Syngenta Crop Protection AG	ambda-Cyhalothrin	100g/L
17 Icon WP	Syngenta Crop Protection AG	ambda-Cyhalothrin	100g/L
18 Bistar 10WP	FMC Corporation	Bifenthrin	10%
19 Vectron 20WP	Mitsui Chemicals Agro, Inc.	Etofenprox	200 g/kg (20%)
20 Fendona 10 SC	BASF SE	Alpha-cypermethrin	9.6%
21 Fendona 6 SC	BASF SE	Alpha-cypermethrin	5.8%
22 Pendulum 6 SC	Gharda Chemicals Limited	Alpha-cypermethrin	6.0%
23 Pendulum 10 SC	Gharda Chemicals Limited	Alpha-cypermethrin	10.0%
24 Actellic EC	Syngenta Crop Protection AG	Pirimiphos-methyl	500g/L
25 ICON CS - ITN Kit	Syngenta Crop Protection AG	Lambda-Cyhalothrin	25g/L
26 Vectron 10EW	Mitsui Chemicals Agro, Inc.	Etofenprox	100 g/kg (10%)

## Annex 10: List of WHO prequalified vector control products: Larvicide

Update 11/4/2019

	Product name	Applicant	Active ingredient	AI concentration
1	Sumilarv 0.5G	Sumitomo Chemical Co., Ltd.	Pyriproxyfen	0.50%
2	Sumilarv ZMR	Sumitomo Chemical Co., Ltd.	Pyriproxyfen	2%
3	Abate 500 EC	BASF SE	Temephos	500g/L
4	Abate 1 SG	BASF SE	Temephos	1%
5	LIMITOR 5 GR	Tagros Chemicals India Pvt Ltd	Pyriproxyfen	0.5%
6	Temeguard	Charada Chemicals Limited	Temephos	50.0%
7	VectoBac GR	Valent BioSciences LLC	Bacillus thuringiensis subsp. Israelensis, strain AM65-52	2.8% - 200 ITU/mg
8	VectoBac WG	Valent BioSciences LLC	Bacillus thuringiensis subsp. Israelensis, strain AM65-52	37.4% - 3000 ITU/mg
9	VectoMax FG	Valent BioSciences LLC	Bacillus thuringiensis subsp. israelensis, strain AM65-52 + Bacillus sphaericus, strain ABTS-1743	4.5% (45g/kg) Bti 2.7% (27g/kg) Bsph 50 ITU/mg
10	Mosquiron 100EC	ADAMA Makhteshim Ltd.	Novaluron	100g/L
11	Spinosad 7.48% DT	Clarke Mosquito Control Products, Inc.	Spinosad	7.48%
12	Spinosad 20.6% EC	Clarke Mosquito Control Products, Inc.	Spinosad	240 g/L (20.62 % w.w)
13	SPINOSAD 25 EXTENDED RELEASE GR	Clarke Mosquito Control Products, Inc.	Spinosad	2.50%
14	Spinosad 0.5% GR	Clarke Mosquito Control Products, Inc.	Spinosad	0.50%
15	Spinosad Monolayer DT	Clarke Mosquito Control Products, Inc.	Spinosad	8.33%
16	MOZKILL 120 SC	Dow AgroSciences LLC	Spinosad	120 g/L
17	Du-Dim 2 DT	Arysta LifeScience	Diflubenzuron	20 g/kg
18	Device 25WP	Arysta LifeScience	Diflubenzuron	250 g/kg
19	Dimilin GR	Arysta LifeScience	Diflubenzuron	20 g/kg
20	Aquatain AMF	Aquatrain Products Pty Ltd	PDMS (Polydimethylsiloxane)	78-89%

Update 11/4/2019

**Annex 11: List of WHO prequalified vector control products: Space spray**

Product name	Applicant	Active ingredient	AI concentration
1 Gokilaht-S 5EC	Sumitomo Chemical Co., Ltd.	d, d, trans-Cyphenothrin	5%
2 REVIVAL 25 EC	Tagros Chemicals India Pvt Ltd	Lambda-Cyhalothrin	2.5%
3 SENTRIN 20 EW	Tagros Chemicals India Pvt Ltd	Deltamethrin	2.0%
4 Aqua K-Othrine	Bayer S.A.S.	Deltamethrin	2% (20g/L)
5 Aqua Reslin Super	Bayer S.A.S.	S-Bioallethrin (esdepallethrine), Permethrin and Piperonyl Butoxide	1.42 g/L S-Bioallethrin 102.7 g/L Permethrin 98.4 g/L Piperonyl butoxide
6 Icon 2.5 EC	Syngenta Crop Protection AG	Lambda-Cyhalothrin	25g/L
7 Icon 5 EC	Syngenta Crop Protection AG	Lambda-Cyhalothrin	50g/L
8 Fyfanon EW Insecticide	FMC Corporation	Malathion	40.9%
9 Fyfanon ULV Mosquito Insecticide	FMC Corporation	Malathion	96.5%
10 Cielo ULV	Clarke Mosquito Control Products, Inc.	Prallethrin; Imidacloprid	Prallethrin 0.75% Imidacloprid 3%

## Annex 12: List of banned pesticide in Nepal

नेपालमा प्रतिबन्धित भएका विषादीहरू	
1. अल्ड्रिन (Aldrin)	13. मोनोक्रोटोफस (Monocrotophos)
2. बीएचसी (BHC)	14. मिथाइन पाराथियन (Methyl Parathion)
3. क्लोरोडेन (Chlordane)	15. इन्डोसल्फान (Endosulfan)
4. डाइअल्ड्रिन (Dieldrin)	16. फोरेट (Phorate)
5. डी.डी.टी (DDT)	17. बेनोमाइल (Benomyl) to be sold/used until 2077/9/16
6. इन्ड्रिन (Endrin)	18. कार्बोफुरन (Carbofuran) to be sold/used until 2077/9/16
7. लिन्डेन (Lindrin)	19. ट्रिओजोफस (Triozophos) to be sold/used until 2077/9/16
8. हेप्टाक्लोर (Heptachlor)	20. डाइक्लोभरस (Dichlorovus) to be sold/used until 2077/9/16
9. अर्गानो मर्करी फंगीसाइड (Organo Mercury Fungicide)	21. कार्बारिल (Carbaryl) to be sold/used until 2077/9/16
10. फोस्फमिन्डोन (Phosphamidon)	22. कार्बोसल्फान (Carbosulfan) to be sold/used until 2078/4/19
11. मिरेक्स (Mirex)	23. डाइकोफल (Dicofol) to be sold/used until 2078/4/19
12. टोक्सोफेन (Toxofen)	24. एलुमिनियम फोस्फाइड (Aluminium Phosphide 56% 3 gram tablet) to be sold/used until 2078/4/19

Source: Plant Quarantine and Pesticide Management Centre (2020)

## REFERENCES

1. A toolkit for integrated vector management in sub-Saharan Africa. Geneva: World Health Organization, 2016.
2. Best management practices for indoor residual spraying in vector control activities, PMI BMP manual, USAID, 2010.
3. Bowman, Leigh R et al. "Is dengue vector control deficient in effectiveness or evidence?: systematic review and meta-analysis." PLoS neglected tropical diseases vol. 10, 17 Mar. 2016.
4. Development of an urban molecular xenomonitoring system for lymphatic filariasis in the Recife Metropolitan Region, Brazil .Ramesh A, et al., 2018.
5. Environmental management tool kit for obsolete pesticides. FAO pesticide disposal series, 2011.
6. Global report on insecticide resistance in malaria vectors: 2010–2016. WHO
7. Global strategic framework for integrated vector management. Geneva: World Health Organization; 2004.
8. Guidelines for drinking-water quality: Fourth edition incorporating the first addendum. WHO, 2017.
9. Guidelines for procuring public health pesticides. WHO, 2012.
10. Guidelines for malaria vector control. WHO, 2019.
11. Guidelines for personal protection when handling and applying pesticide – International code of conduct on pesticide management. FAO and WHO, 2020.
12. Global vector control response 2017–2030. World Health Organization, 2017.
13. Information note. Risks associated with scale-back of vector control after malaria transmission has been reduced. WHO.GMP. November 2015.
14. International code of conduct on the distribution and use of pesticides: guidelines on management options for empty pesticide containers. FAO/WHO, 2008.
15. Lymphatic filariasis. In geographical distribution of arthropod-borne diseases and their principal vectors. WHO,1989.
16. Malaria entomology and vector control, guide for participants. WHO, 2013.
17. Malaria surveillance, monitoring and evaluation: a reference manual. Geneva: World Health Organization;2018.
18. Manual on integrated vector management India, 2015.
19. Management of insecticide resistance among vectors of public health importance: report of the ninth meeting of the Global collaboration for development of pesticides for Public Health (GCDPP), 9–10 September 2014.
20. Public health image library, centers for disease control and prevention, 2020. website <https://phil.cdc.gov/>



21. Recommendations on the sound management of packaging for long lasting insecticidal nets (LLINs), WHO, 2011.
22. Space spray application of insecticides for vector and public health pest control: A practitioner's guide, WHO, 2003.
23. Species composition, seasonal occurrence, habitat preference and altitudinal distribution of malaria and other disease vectors in eastern Nepal. Dhimal, Meghnath & Ahrens, Bodo & Kuch, Ulrich, 2014.
24. Test procedures for insecticide resistance monitoring in malaria vector mosquitoes – 2nd ed., WHO 2018.
25. Vector control : methods for use by individuals and communities / prepared by Jan A. Rozendaal, WHO, 1997.
26. WHO global plan for insecticide resistance management: malaria surveillance, monitoring & evaluation: a reference manual, 2012.
27. WHO position statement on integrated vector management; Geneva: World Health Organization; 2008.

NOTE





**World Health  
Organization**

---

**Nepal**