Vector control guidelines in Prevention of Reintroduction phase of malaria in Sri Lanka

Anti-Malaria Campaign
Ministry of Health – Sri Lanka

Vector control guidelines in Prevention of Reintroduction phase of malaria in Sri Lanka

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MESSAGE FROM THE DIRECTOR GENERAL OF HEALTH SERVICES

All Provincial Director of Health Services
All Regional Director of Health Services
All Hospital Directors/ Medical Superintendents
All Districts Medical Officers/ MOIC
All Medical Offices of Health

Vector control guidelines in Prevention of Reintroduction phase of malaria in Sri Lanka

Sri Lanka was certified by the WHO as a malaria free country in September 2016. However, Sri Lanka remains at high-risk of re-introduction of malaria due to the presence of malaria vector still in the country and increased travel to and from malaria endemic countries.

Many regions in the country remains receptive with the primary malaria vector *An. Culicifacies* found in most parts of the country. Vector control measures play a vital role in sustaining the malaria free status, by contributing to the elimination of risk of transmission of malaria from within the country based on vulnerability and receptivity.

This guideline could be used for optimum utilization of available resources in a cost-effective manner for focal and localized vector control, specifically targeted for prevention and re-introduction phase of malaria. You are kindly requested to disseminate this guideline among central and regional staff of AMC involved in entomological surveillance and vector control activities. You could use this as a source of information and guidance for any other persons involved and interested in malaria vector control activities in Sri Lanka.

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Contents

Chapter 1

Introduction

1.1. Malaria in the world and in Sri Lanka

Malaria is a life-threatening disease caused by *Plasmodium* parasites that is transmitted to people through the bites of infected female *Anopheles* mosquitoes. There are five *Plasmodium* species that cause malaria in humans, and two of these species, *Plasmodium falciparum* and *Plasmodium vivax* pose the greatest threat. Despite being preventable and treatable malaria continuous to have a devastating impact on human health and livelihood around the world.

Malaria has been a major public health problem in Sri Lanka from ancient times. It has traditionally been known to be endemic in the dry and intermediate zones with climatic conditions conducive to the breeding of the malaria vectors, and epidemic in the wet zone. With establishment of the Anti-Malaria Campaign (AMC) in 1911, actions are taken to record malaria morbidity and mortality routinely. At the peak of Sri Lanka's most devastating outbreak in 1935, over 1.5 million cases of malaria were recorded, resulting in 80 000 deaths. These are astonishing figures, especially since Sri Lanka's population was about 6 million people at the time.

Vector control has been an important aspect in malaria control and prevention activities. With the introduction of DDT, member states endorsed an ambitious proposal for eradication of malaria at the World Health Assembly in 1955. Eradication efforts began and focused on house spraying with residual insecticides, antimalarial drug treatment and surveillance. Some countries had negligible progress while some such as India and Sri Lanka had sharp reductions in the number of cases, followed by increases to substantial levels after efforts ceased. By 1970, the number of malaria cases soared to one million and despite intensified control efforts by the Anti-Malaria Campaign (AMC) it took another five decades to recover the lost ground.

The emergence of drug resistance, widespread resistance to insecticides, conflicts and massive population movements, lack of sustained funding, and lack of community participation made the long-term maintenance of the effort untenable. Eradication campaign was eventually abandoned.

Incidence of malaria in Sri Lanka has markedly declined from year 2000 onwards. The last indigenous malaria case was reported in Sri Lanka in 2012.

1.2. Current Global and Sri Lankan Situation

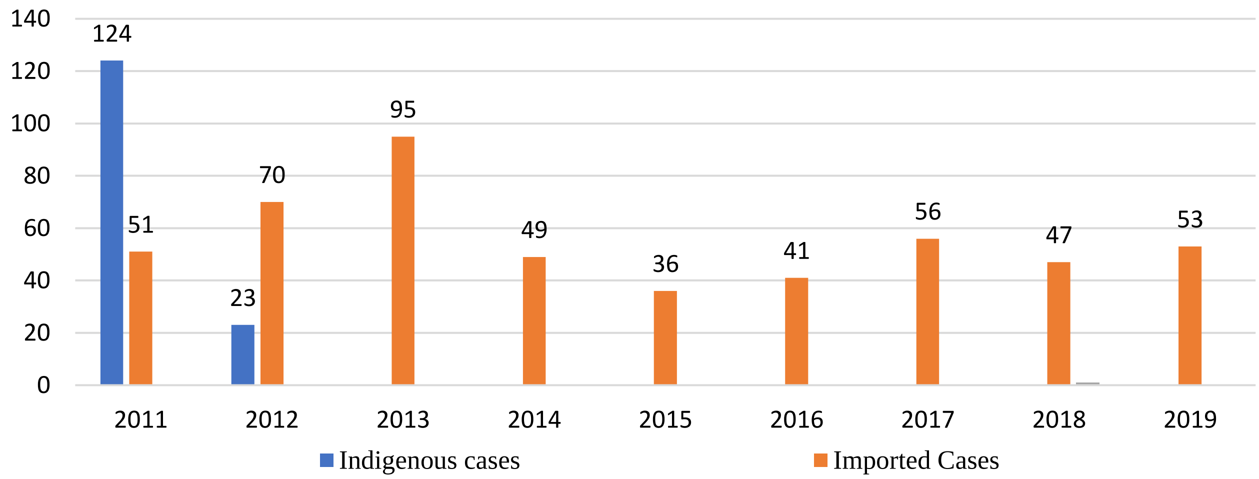
In 2018, an estimated 228 million cases and 405,000 deaths due to malaria had occurred worldwide. Most malaria cases were in the WHO African region (213 million or 93%) followed by WHO Southeast Asia region (3.4%).

In Sri Lanka, a national strategic plan for elimination of malaria (NSP 2008-2012) was prepared with the objective of eliminating *P. falciparum* malaria by 2012 and *P. vivax* malaria by 2014. However, Sri Lanka managed to eliminate malaria in 2012 and after maintaining three years of malaria free status the country was certified as " malaria free" by WHO in 2016.

Since elimination, all reported cases have contracted the disease outside Si Lanka except one introduced case reported in 2018. At present Sri Lanka is burdened approximately with 50 imported cases annually, out of which 70-75% of are Sri Lankans. Nearly 60% of these cases are from African continent; 1/3 had been contracted in India. Predominantly reported parasites are *P. vivax* and *P. falciparum* among these imported cases.

With the elimination of malaria, Sri Lanka is currently in the Prevention of Reintroduction (PoR) phase and great effort has to be made to prevent the reintroduction of malaria in Sri Lanka. However, low disease burden has led to decreased clinical vigilances and skills and lack of community awareness. Delay in diagnosis of imported cases, lack of immunity of the population, population mobility to and from endemic countries to Sri Lanka has also posed major threats for the risk of malaria resurgence in Sri Lanka.

Figure 1 Malaria burden last 10 years (2011-2019)



Note: One introduced malaria case in 2018 in addition to 47 imported cases.

Evolution of vector control in Sri Lanka

In the pre- DDT era, vector control was mainly dependent on larval control. With introduction of DDT using Indoor residual spraying (IRS) method (in 1946), malaria eradication programmes' focus had changed to adult vector control.

Several technical/operational problems, including insecticide resistance, led to introduction of new insecticides namely malathion (in 1976), followed by pyrethroids (in 1994).

WHO introduced global malaria control strategy which was adopted locally in late 80's. Malathion resistance was reported in Sri Lanka in early 80's. In late 80's Insecticide Treated Nets (ITN) with pyrethroids was introduced. Rotational/mosaic use of insecticides and integrated vector control (IVC) methods were initiated to delay development of insecticide resistance.

Though carpet/blanket coverage method was practiced in the past, a new stratification method was developed in1993 using Annual Parasitic Indices (API) of previous years.

Later vector control interventions were implemented in a selective and sustainable manner. In 2003 – 2004, Long lasting Insecticidal Nets (LLINs) were introduced as vector control as well as a personal protection intervention. Up to the end of malaria control phase (2007/2008) vector control relied heavily on targeted IRS and LLINS.

Pre elimination phase commenced in 2008. Local malaria transmission was interrupted through intensified surveillance, early detection and treatment and focal spraying. After malaria was eliminated in 2012, vector control was targeted mainly to prevent onward transmission from imported cases.

1.3. Receptivity and vulnerability patterns in the PoR phase and risk of Malaria resurgence

Although there are no indigenous cases, the receptivity (especially in the previously endemic areas) continues to remain high. In addition, identification of invasive vector *An. stephensi* in 2016 in Northern Province is an added challenge.

Increase in global migration resulted in rise in imported malaria cases. With the development of tourism, increase in construction projects, there is a rise in influx of foreigners to the country in post conflict period. Majority of imported cases are detected from Western province located in the wet zone, whereas in the past prior to elimination, majority of cases were from dry and the intermediate zones.

Due to continued receptivity and vulnerability, Sri Lanka needs to be vigilant to prevent re introduction and establishment of malaria.

Lessons Learnt

In 1963, Sri Lanka lost the golden opportunity to eliminate malaria, when there were only 06 locally acquired (Indigenous) cases reported. However, the opportunity was lost due to multiple reasons.

Identification of presence of invasive malaria vector (*An. stephensi*) among Anopheline population has changed the receptivity pattern in Sri Lanka and is still under evaluation. Potential impact of this invasive malaria vector, in malaria transmission has been reported in Djibouti.

Detection of an Introduced case in 2018 linked to a group of migrant workers from a malaria endemic country highlights the resurgence risk in the current PoR phase.

1.4. Challenges in maintaining zero transmission in PoR

At present, there are several challenges in maintaining zero transmission in the PoR phase in Sri Lanka. The whole world is aiming for elimination of malaria in 2050, and the countries around Sri Lanka are still highly burdened with malaria, mounting a high risk of resurgence.

Retirement of experienced staff, who were actively involved in vector control during the control and elimination phases poses a great challenge. Mobilization of AMC staff for dengue control activities, which is a major public health problem at present in Sri Lanka too pose a challenge.

1.5. Justification

A main objective of AMC in PoR phase, is to maintain zero transmission in the island. Having guidelines on vector control in the PoR phase for Sri Lanka would be useful in planning, logistic management and timely implementation of vector control interventions.

The guide could be used for optimum utilization of available resources in a cost-effective manner by providing guidance for focal and localized vector control in PoR phase.

It would highlight the importance of taking into account the vulnerability and receptivity in planning vector control interventions and the need for generating evidence for decision making through operational research as well.

At present, since receptivity and vulnerability are heterogeneous in Sri Lanka, uniform methods cannot be applied to the whole country. Therefore, the guide would help in providing stratification in a customized manner.

1.5.1 General Objective

To control the malaria vector to sustain zero transmission in PoR phase in Sri Lanka.

1.5.2 Specific Objectives

1. To prevent onward transmission of malaria from all reported malaria cases.
2. To minimize the malaria transmission risk based on vulnerability and receptivity.
3. To actively control/eliminate when invasive potential malaria vector mosquito species are detected.
4. To ensure optimum availability of human resources and logistics for malaria vector control activities at central and regional level.
5. To strengthen and enhance the evidence base of efficacy of vector control intervention in different eco -epidemiological settings.
6. To mitigate the possible development of insecticide resistance among the malaria vectors through rational use of vector control methods.

This guideline is prepared primarily targeting the central and regional staff of AMC involved in entomological surveillance and vector control activities. This could also serve as a source of information and guidance for any other persons involved and interested in malaria vector control activities in Sri Lanka.

Chapter 2

Role of Entomological surveillance in malaria vector control

Entomological surveillance includes systematic collection, analysis and interpretation of entomological data for risk assessment, planning, implementation, monitoring and evaluation and feedback of vector control interventions. Malaria entomology involves study of the biological, behavioral and ecological factors that allow anophelines for transmission of malaria. It also enables systematic investigation of the effectiveness of control measures that are being implemented. Entomology is therefore an essential component in planning, evaluating and improving malaria vector control strategies.

To implement a successful vector control programme, entomological findings can be used as below.

- **Characterize receptivity for risk stratification** to ensure optimum coverage of at-risk population.
- **Monitor the relative density of malaria vector species and their bionomics** to determine the seasonality of vector abundance and the selecting and optimal timing of interventions.
- **Monitor insecticide resistance** as a basis for choosing insecticides in line with insecticide resistance management plans.
- **Monitor efficacy and quality of vector control interventions** to identify gaps and opportunities to ensure optimal implementation and to indicate any corrections required.

2.1 Characterize receptivity for risk stratification

Receptivity is the ability of an ecosystem for transmission of malaria. Receptive eco system comprises of presence of competent vectors, suitable climate and a susceptible population. The receptivity of Regional Malaria Officer (RMO) regions are stratified based on previous entomology data available in the region and is a dynamic process.

Although receptivity is identified, conducting entomological surveillance and vector control interventions are based on linking receptivity with vulnerability. The GN areas need to be fitted into the matrix of risk categorization (Table. 1) enabling the above.

Table 1. Risk categorization based on vulnerability and receptivity

Receptivity / Vulnerability	Low	Moderate	High
Low	Low risk	Low risk	Moderate risk
Moderate	Low risk	Moderate risk	Moderate risk
High	Moderate risk	Moderate risk	High risk

Source: Guidelines for malaria entomological surveillance 2019

2.2 Monitoring of relative density and bionomics of malaria vectors to determine the seasonality of vector abundance and the optimal timing of interventions

Based on data collected by the Anti Malaria Campaign on indoor resting behavior, man biting behavior, seasonality and distribution in major climatic zones of over the past five years and incorporating research findings on malariogenic potential of anophelines, they have been classified as primary, secondary and invasive potential vectors.

Table 2. Classification of primary, secondary and invasive potential malaria vectors in Sri Lanka

Vectoral status	Species
Primary vector	*An. culicifacies*
Secondary vectors	*An. subpictus*
	An. annularis
	An. varuna
	An. vagus
	An. tessellatus
Invasive potential vector	*An. stephensi*

Source: Amendment to the entomological surveillance & vector control activities when a malaria patient is reported: Annex IV of Scope of work to be performed when a malaria patient is reported

Extended sentinel and routine sentinel site monitoring are carried out in selected locations according to the malaria risk analysis (provided in the malaria entomological surveillance guidelines of AMC, 2019). It generates systematic data on bionomics of all the potential malaria vectors. Bionomics of malaria vectors should cover feeding (biting time, place and host preference), breeding and resting behaviours, seasonality, distribution etc. of anophelines. These data collected over a considerable period should be used to assess the receptivity and malariogenic potential of vectors in order to plan and implement vector control interventions.

2.3 Monitoring insecticide resistance

Resistance to commonly used insecticides for malaria control is emerging in vector populations in many countries. Monitoring insecticide resistance for a given concentration of an insecticide is useful in detecting insecticide resistance early to ensure successful vector control interventions.

Insecticide resistance monitoring is carried out by entomology teams as detailed in the malaria entomological surveillance guidelines 2019 and SOPs of AMC (SOP no. 09). The generated data need to be analyzed periodically and based on resistance profile of local vectors, recommendations are provided to prepare plans for procurement of insecticides and for management of insecticide resistance.

2.4 Monitoring efficacy of insecticides used for vector control

Bioassays are carried out to assess the efficacy of vector control interventions. The results are used to recommend appropriate modifications. Bioassay test is performed according to the entomological surveillance guideline 2019 and SOP (No. 12).

2.5 Dissemination of entomological data for decision making

Entomology data collected at central and regional level should be analyzed and utilized for decision making. In addition to utilizing at regional level, the regional data are shared with AMC headquarters for further analysis and decision making. Relevant data bases should be available at regional level and headquarters and the findings need to be disseminated at MOH level.

Entomological data is generated through proactive and reactive spot surveys and extended and routine sentinel surveys. The data generated at GN level should be made available for vector control.

2.6 Use of entomology for vector control in different scenarios

Presence of primary and secondary vectors and their behavior can be understood by using suitable entomological techniques. Receptivity in the relevant area has to be assessed to recommend appropriate vector control interventions to reduce malaria transmission risk.

Following are the possible scenarios of risk of malaria transmission.

Table 3. Use of entomology for vector control in different scenarios

Scenario	Type of Entomological survey	Vector bionomics to be collected	Land area coverage	Frequency of survey
1. When a malaria case is reported	Reactive spots	Occurrence of primary/ secondary vector species (larval & adult). Resting behavior. Human biting behavior (indoor/outdoor). Peak biting time. Sporozoite rate. Parous Rate. Vector breeding habitats. Susceptibility status to the insecticides.	One km radius areas where the patient has stayed at least one night within the previous two weeks since onset of fever/ clinical features and until diagnosed. If vectors or vector breeding places are not detected within the area of 1 km radius in previously malaria endemic areas the survey could be extended more than 1 km.	Initiated within 48 hours from diagnosis of case. Follow up reactive spot survey after 7 days of completion of vector control.
2. Presence of vulnerable populations	Proactive Spots or Routine sentinel survey or Extended routine sentinel survey	Occurrence of primary/ secondary vector species (larval & adult). Resting behavior. Human biting behavior (indoor/outdoor). Peak biting time. Parous Rate. Vector breeding habitats.	Covering an area with 1km radius for proactive spots and 2 km for routine and extended surveys.	Until the vulnerability persist. If vector control is applied, a follow up proactive spot survey after 7 days of completion

		Susceptibility status to the insecticides.		of vector control is conducted.
3. When *An. stephensi* is detected	Proactive Spot survey or Routine sentinel survey or Extended Routine sentinel survey	Density of the new vector (adult/larvae). Resting behavior. Human biting behavior (indoor/outdoor). Peak biting time. Parous Rate. Vector breeding habitats. Susceptibility status to the insecticides.	2 km radius area of the initial place or places where the vector is recorded.	Several pre and post entomological surveys prior and after the vector control activities as long as the vector present in the area.
4. Complex emergencies having malariogenic potential	Proactive Spots or Routine sentinel survey or Extended sentinel survey	Occurrence of primary/ secondary vector species (larval & adult). Resting behavior Human biting behavior (indoor/outdoor) Peak biting time Parous Rate Vector breeding habitats Susceptibility status to the insecticides	Covering an area with 1-2 km radius around the risk group or the area etc.	Initially within a few days and continue periodically.

5. When local transmission (introduced/ indigenous) is established	Extended routine sentinel survey. Reactive spots surveys	Occurrence of primary/ secondary vector species (larval & adult) Resting behavior Human biting behavior (indoor/outdoor) Peak biting time Sporozoite rate Parous Rate Vector breeding habitats Susceptibility status to the insecticides Bio assays for insecticides applied	2 km radius around the local transmission	Initiated within 48 hours from diagnosis of case. Post Reactive spot survey after 7 days of completion of vector control. Monthly surveys until 3 years of after clearing of the foci.
6. When a known vector control tool is applied	spot survey	Occurrence/ density of vector species (adult/larvae)	Around the area where vector control is applied.	Pre survey prior to vector control tool is applied (if relevant). Post survey after vector control tool is applied.

To implement the vector control interventions in different scenarios, vector bionomics are collected by different entomological surveys as given in the table above. These findings are discussed and used for vector control.

When a pilot testing is warranted for a new product or intervention at field level, it should be carried out as given in the table below.

Table 4. Use of entomology when piloting a new vector control tool

	Type of Entomological survey	Vector bionomics to be collected	Expected coverage	Frequency of survey
When piloting a new vector control tool	Proactive spot survey	Occurrence/density and mortality in bio assays of vector species (adult/larvae) as indicated	The area and extent is based on the specifications of the tested tool. Test and control need to be conducted for comparison.	Pre survey prior to vector control tool applied. Post survey after the vector control tool applied.

Chapter 3

Methods of Vector Control

Vector control interventions include tools, technologies and approaches, which are categorized by WHO as below.

Core vector control interventions – These are the methods applicable to whole population at risk of malaria in most eco-epidemiological settings eg. LLIN and IRS.

Supplementary vector control interventions – larval source management, deployment of chemical or biological larvicides. These can be used in addition to core interventions in specific settings and circumstances.

Personal protection methods - Topical repellents, insecticide treated clothing and indoor spatial/ airborne repellents may be beneficial as potential intervention to provide personal protection in specific population groups.

Other vector control measures
Space spraying for exophilic and exophagic vectors

3.1 Core vector control interventions

3.1.1 Indoor residual Spraying (IRS)

IRS is the application of a residual insecticide to potential malaria vector resting surfaces, such as internal walls, eaves and ceilings of houses or structures (including domestic animal shelters), where such vectors might come into contact with the insecticide.

Objectives of IRS:

- To reduce the life span of vector mosquitoes.
- To reduce the density of the vector mosquitoes.
- To reduce human-vector contact through repellent effect thereby reducing the numbers that enter the sprayed rooms.
- To reduce the infected vector mosquito population.

Spraying should be; Total (all the dwellings are sprayed), complete (all sprayable surfaces are covered) and sufficient (ensure uniform application of the required insecticide dose to all sprayable 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 majority of structures are suitable for spraying.

Indoor residual spraying: An operational manual for IRS for malaria transmission, control and elimination. Second edition (June 2015), WHO gives further details of application of IRS including use of appropriate equipment and correct techniques in relation to the below mentioned topics.

1 IRS spray equipment
2 Calibration of spray machine
3 Preparation of spraying solution
4 Personal protection equipment and safely precautions
5 Preparation of households for spraying
6 Spray technique
7 Maintenance of spray equipment

3.1.2 Long lasting Insecticidal Nets (LLIN)

LLINs are nets that are treated at factory level by a process that binds or incorporates insecticide into the fibers. They are designed to maintain their biological efficacy against vector mosquitoes for at least 3 years under recommended conditions of use in the field or 20 WHO standard washes under laboratory conditions. LLINs knock down and kill mosquitoes that land on the net. LLINs provide mechanical and chemical protection for the user. LLINs are mainly effective in reducing of endophilic and endophagic vector mosquitoes.

Selection criteria for the distribution of LLIN

The distribution of LLINs will be governed primarily by receptivity and vulnerability of a particular area based on the trends on incidence of imported malaria cases, receptivity, historical trends and vulnerability in terms of presence of high-risk groups of returnees from malaria endemic countries and regions. Based on the above parameters the Regional Malaria Officer (RMO) has to identify high risk communities for LLIN distribution. Vector control for different settings/ scenarios is given in detail in Table 3.

Procedure for distribution of LLIN

RMOs are expected to select the recipients carefully based on the above-mentioned criteria and under the technical guidance from AMC HQ.

This is to be carried out with the support of persons such as Medical officer of Health (MOH), Grama Niladhari, range PHI and other community leaders when necessary. RMO has to take all possible measures to avoid pilferage, wastage of LLIN and has to ensure that only the selected recipients will obtain the necessary LLIN. Community is emphasized on benefits of LLIN retention and use as a major strategy of PoR of malaria with emphasis to the following;

- Need to use the nets every night irrespective of the season,
- The correct way to hang and use the nets.

Interactive demonstrations are also need to be done before the distribution. The community should be made aware to ensure that the distributed LLIN are used according to given instructions without any deviation. Logistical challenges and miscommunication need to be prevented by the simultaneous community health awareness campaign. The distribution criteria and the LLIN distribution register should be updated.

Storage

Bales of LLINs are well and securely packed; the nets are usually individually wrapped in sealed plastic bags. It is important to ensure that warehouses are clean and dry. Stock management should be based on the "first in, early expiry out" rule. In each RMO Office 500 nets should be kept as a buffer stock.

Follow up

RMO staff need to visit houses and verify whether LLINs are used for intended purposes as well as the adherence to instructions on washing frequency and usage, etc by the community.

Monitoring efficacy of LLIN

Bioassays has to be conducted to assess the potency of an insecticide deposited on LLINs to adult mosquitoes with proven susceptibility after number of washes of insecticide treated net in various time intervals. The LLINs used for testing should be washed at every three-month interval according to the guidelines provided for the usage of particular LLIN type and bioassays should be repeated on regular intervals.

3.2 Supplementary vector control measures

3.2.1 Larval Source Management (LSM)

Larval source management is the management of aquatic habitats (water bodies) that are potential larval habitats for mosquitoes, in order to prevent the completion of development of the immature stages. LSM is undertaken to a supplement the effects of the core vector control interventions (IRS and LLIN). LSM targets the immature, aquatic stages of the mosquito (the larvae and pupae), thereby reducing the abundance of adult vectors. If all potential breeding sites were eliminated or treated it could be expected that LSM would reduce the number of infective bites per person per year, thereby reducing malaria transmission. In well-defined settings where it is feasible, the elimination of larval habitats can be a cost-effective and long-term solution.

Larval control is indicated if a high proportion of the anopheline breeding sites within the vectors' flight range of the community to be protected are few, fixed, findable and manageable. Larval control affects only the vector density and requires a high coverage to be effective. Larval control is useful in the following settings;

- In densely populated areas with relatively few, fixed and findable breeding sites.
- In areas where breeding sites are easy to locate, limited and manageable.
- In new settlement areas.
- In small-scale irrigation schemes and construction sites.
- In instances where the adult vector is resistant to core vector control (IRS, LLIN), the LSM would be the most effective and the viable option.

Types of LSM are as follows;

1. Environmental modification
2. Environmental manipulation
3. Larviciding
4. Biological control

3.2.1.1 Environmental modification:

A permanent alteration to the environment, aimed at eliminating larval habitats including landscaping, surface water drainage, filling and land reclamation

3.2.1.2 Environmental manipulation

Temporary environmental changes to disrupt vector breeding, including water level manipulation eg. flushing, drain clearance to eliminate poolings,

3.2.1.3 Larviciding

Larviciding includes the use of chemical or biological agent or toxins to kill the mosquito larvae or pupae. The residual effects of larvicides varies considerably depending on water quality and type of the breeding sites. The residual effects are relatively short for most larvicides. Identification of mosquito breeding sites and timely application is key to effective larviciding

Indications for larviciding;

- Larvicides are used in breeding sites that cannot be modified and manipulated by environmental methods such as drained, filled etc or where other larval control methods are not rapid enough to contain the situation.
- Larviciding is indicated for vectors which tend to breed in permanent or semi-permanent water bodies.
- In the absence of malaria cases, even high receptive situation chemical larviciding shall not be carried out unless there is an indication of vulnerability in the area and unless in special situations identified by the AMC - HQ.
- If an imported malaria case is reported, a comprehensive larval survey should be carried out within approximately 1km radius and larviciding need to be conducted as required with the technical guidance of AMC HQ.

There are three types of larvicide options as listed below

1. **Synthetic organic chemicals**. e.g. organophosphates such as pirimiphos-methyl and temephos that interfere with the nervous system of immature larval stages,
2. **Insect growth regulators (IGR):** These are chemical compounds which are toxic to mosquito larvae and act by preventing their development into adults.
3. **Microbial Larvicides:** Bacteria, e.g. Bacillus thuringiensis subsp. israelensis (Bti), and Bacillus sphaericus (Bs) that produce insecticidal crystal proteins which, when ingested by larvae, attack the gut lining causing cessation of feeding and subsequent mortality.

3.2.1.4 Biological control

The introduction of natural predators into water bodies such as larvivorous fish and predatory invertebrates.

Of the above discussed LSM options, in addition to Environmental modification and manipulation, the commonly applied LSM currently practiced in Sri Lanka during the PoR phase are the chemical larviciding with temephos and fish introduction as a biological control method. Therefore, these two methods are described in detail below.

Application of Temephos

Temephos, has been used routinely for malaria vector control in Sri Lanka. Temephos acts by contact, affecting the central nervous system through inhibition of cholinesterase, resulting in death. Highly active against the aquatic larvae of vector mosquitoes. Relatively low dosage can kill them before they reach the adult stage.

Commonly used formulations

- Temephos 50% EC (w/v active ingredient, 500g/l)
- 1% Temephos SG (w/w active ingredient, 10g/kg)

Mode of application

- Liquid application is indicated for control when the vectors breed in clean water without or with little emergent/floating vegetation.
- Sand granules are applied in specific situation when there is evidence to suggest the vector breeds in localized water collections.

WHO states that Temephos can be applied to potable water as larvicide treatment at an application rate not exceeding 1mg/litre.

Proper storage and handling

- It has to be stored in original labeled container in a cool, dry well-ventilated place out of direct sunlight.
- Keep in a safe place away from food, seeds or fertilizers. Keep out of the reach of children.
- Wash thoroughly with soap and water after handling the material especially prior to consumption of food or water. EC formulation can be easily absorbed through skin so it is important to have proper PPE when spraying.

- When using larvicides follow the instructions on the product label.
- Do not apply more than recommended dosage or re-apply more often than instructed.
- When used according to product label instructions, larvicides do not harm people, pets, or the environment.

Rate of application

- The amount of formulation applied per unit of area
    - 1% Temephos SG:- ai 1.0 mg/l
    - Temephos 50% EC;- 56–112 ai g/ha

Equipment and materials for application of temephos 50% EC

- Liquid formulations can usually be applied with the same equipment as used for indoor residual spraying, i.e. hand-operated compression sprayers
- Spray mechines should be identified and labeled and need-to be used **exclusively** for larviciding purposes to prevent it being used for IRS and thereby contaminating the machine and the sprayed water source.
- Personal protective equipment needs to be worn during the application.

Ensure a pre and a post larval survey is carried to assess the impact of the intervention.

Larvivorous fish

Larvivorous fish feed mainly on mosquito larvae. Guppy (*Poecilia reticulata*) and "Nalahandaya" (*Aplochilus dayi*) are the most successful species used in malaria vector control in Sri Lanka. It is more appropriate to use Nalahandaya" (*Aplochilus dayi*) whenever possible for fish introduction programmes as it is a local larviverous fish. When introducing 'Guppy (*Poecilia reticulata*)', it is important to introduce to confined habitats such as wells, to ensure that the ecological balance is not disturbed.

The control of breeding places has to be carried out around human settlements in an area with a radius greater than the flight range of the target mosquito species. For successful fish introduction programmes, community participation and intersectoral coordination is vital.

Potential larvivorus fish should have the following characteristics;

- High preference for mosquito larvae
- Surface feeder

- Small in size
- High fecundity
- Tolerant to transportation, stressful environmental conditions, temperature extremes, presence of pollutants and high turbidity.

Effective larval control is most feasible where breeding places are:

- Limited in number
- Easily recognizable
- Easily accessible.
- Confined habitats

Common species of larvivorous fish

Guppy -*Poecilia reticulata*

Top minnow - *Aplocheilus sp.*

Tilapia - *Oreochromis mossambicus* / *Oreochromis niloticus*

Danio - *Danio sp.*

Common Rasbo- *Rasbora daniconius*

3.2.2 Personal protection measures

Personal protection measures include repellents, mosquito coils and protective clothing. The use of repellents and protective clothing are useful for people who are outdoors during peak vector biting periods.

3.2.2.1 Repellents

Most repellents have a very short duration of effect. Repellents can be topical (such as creams, lotions etc), insecticide treated clothing and spatial (such as arerosols and vaporizers). The use of repellents is a measure of individual protection. They complement bed nets and house protection and can be used by people who stay outdoors during part of the night.

3.2.2.2 Protective clothing

Cloths that cover most of the body, i.e. long sleeve jackets and shirts, trousers and socks can provide a certain level of personal protection from mosquito biting.

3.3 Other interventions

3.3.1 Space spraying

Space spraying is effective for exophilic and exophagic mosquitoes. Space spraying immediately kills actively flying mosquito vectors and rapidly reduce populations of flying mosquito vectors. Therefore, it helps in reducing or interrupting the transmission cycle of the disease and can be used for control of disease outbreak.

Types of space spraying

Thermal fogging - insecticide is diluted in a carrier liquid (usually oil-based). Hot gas is used to heat the pesticide spray decreasing the viscosity of the oil carrier and vaporizing it and the high frequency of the pulsating gas break up of insecticide solution to small droplets.
Cold fogging-Droplets are formed by the mechanical breaking up of the spray mixture

Vector control for different settings/ scenarios

Table 5 Vector control for different settings/ scenarios

Scenario	Entomological survey results for response	Vector control options	Remarks
When a case is reported (In an urban area)	Presence of primary vector	One core VC method, taking in to account the feasibility for 500m** radius. Priority to IRS. Focal space spraying within 500m** radius can be considered. Larval control with Temephos and/ or larvivorous fish for appropriate breeding sites	*In situations where LLINs or IRS alone cannot be applied for the entire setting, a combination as per the feasibility can be considered. However, if both core methods use the same insecticide class (eg: pyrethroid) both should not be deployed in the same households or areas. **In the urban setting it is assumed that flying distance is low due to high population density and not able to totally cover by core VC measures.
	Presence of at least one secondary vector or presence of *An. stephensi*	**If conditions for transmission is fulfilled**** Focal space spraying within 500m radius can be considered. Larval control with Temephos and/or lavivorous fish for appropriate breeding sites	**At least two of the following three criteria fulfilled • Presence of gametocytes • Human biting behavior • Previously endemic area
	Primary or secondary vectors not present	No Vector Control is recommended	

When a case is reported (In a rural area)	Primary vector present	One core vector control methods considering the feasibility for 1km radius. Priority to IRS*. Focal space spraying within 500m radius can be considered. Larval control with Temephos and/or laviverous fish for appropriate breeding sites	*In situations where LLINs or IRS alone cannot be applied for the entire settings, a combination as per the feasibility can be considered However, if both core methods use the same insecticide class (eg: pyrethroid) both should not be deployed in the same households or areas
	Presence of at least one secondary vector or presence of *An. stephensi*	**If conditions for transmission is fulfilled**** Focal space spraying within 500m radius can be considered Larval control with Temephos and/or larvivorous fish for appropriate breeding sites	**At least two of the following three criteria fulfilled • Presence of gametocytes • Human biting behavior • Previously endemic area
	Primary or secondary vectors not present	No vector control is recommended	
Vulnerable stationed population	Advisable to do a proactive entomological survey and vector control to be implemented based on the entomological survey findings	If primary vector positive, one of the core vector control method for the risk population can be considered depending on the number and risk*. Priority LLINs. Larval Source Management for breeding sites	*Decision to apply IRS for vulnerable station population has to be taken through discussion between RMO and AMC HQ.

Fluctuating vulnerability (Eg: tourist hotels)	Advisable to do a entomological survey for receptivity	Larval Source Management for breeding sites.	
When an introduced case is reported	Since the local transmission is established, activities mentioned need to be carried out irrespective of the entomological surveillance findings.	**At the site of suspected local Transmission** One of the core VC methods covering minimum radius of 1 km. Priority for IRS. Consider extension of core vector control coverage considering the risk Chemical larvicides for 1 km radius for appropriate breeding sites. Followed by larvivorous fish introduction. Space spraying initially and once in 2 to 3 days for 10 days. Active foci should be followed up for 3 years, the response should be repeated as indicated. If transmission is blocked and the vulnerability persists, the focus should be treated as per management of vulnerable focus.	.
Localized outbreak with indigenous cases	Since the local transmission is established, activities mentioned need to be carried out irrespective of the entomological surveillance findings	**At the site of suspected local Transmission** Demarcate the active focus. One core vector control method covering a minimum radius of 1 km of the perimeter of active focus. Priority for IRS.	

		Consider extension of core vector control method considering the risk Chemical larvicides for 1 km radius for appropriate breeding sites. Followed by larvivorous fish for appropriate breeding sites for 1 km radius Space spraying initially and once in 2 to 3 days for 10 days. Evidence based and coordinated Vector Control response is needed.	
When several foci of transmission occurred	Since the local transmission is established, activities mentioned need to be carried out irrespective of the entomological surveillance findings at the demarcated foci.	Same as for 'Localized outbreak with indigenous cases'. However, need to identify the focus of transmission	

Note: Space spraying is not advocated by AMC as a main vector control method. Where ever it is mentioned in the table, it is mentioned as a possible option and the decision to carry out space spraying and its implementation (eg: extent, timing) need to be decided through discussion between the RMO and the AMC HQ.

Whenever vector control is done it should be based on entomology results. Once IRS or LLIN is implemented, relevant bio assays has to be done to assess the effectiveness of the vector control method.

Chapter 4
Anopheles. stephensi in Sri Lanka

4.1 Monitoring and Control of *An. stephensi* in Sri Lanka

Anopheles stephensi, urban malaria vector of neighboring countries which has the capacity of transmitting malaria was reported from Mannar District of Sri Lanka for the first time in December 2016. Morphology of the *An. stephensi* identified in Mannar is the type form of *An. stephensi* also found in India as the urban vector.

An. stephensi predominantly breeds in man-made container type habitats.

4.1.1 Entomological Surveillance

- Regional entomological surveillance plan for *An. Stephensi* need to be developed by the RMO with inputs and guidance from the AMC HQ.
- Carry out entomological surveys comprising of larval surveys of potential *An. Stephensi* breeding sites covering following areas of the region including;
  - Urban/ town areas with abundance of wells, overhead tanks/ ground tanks and other water storage containers.
  - Transport hubs eg: main bus/railway stations (especially stations where buses/trains are coming from *An.stephensi* positive regions).
  - Areas with coastal entries, fishing harbours and air ports.

4.1.2 Data formats and reporting

- Record the entomological findings in entomology formats provided by AMC HQ.

4.2 Vector Control for *An Stephensi*

Available entomological data in Sri Lanka reveal that *An. stephensi* primarily breeds in wells (used/abandoned). Other breeding sites found with *An. stephensi* breeding in Sri Lanka are overhead tanks, water storage cement tanks (ground level) and water storage containers (eg: barrels, buckets) and ponds. In other countries disposable containers, cisterns, construction sites and gutters are also identified as potential breeding sites.

As *An. stephensi* typically breeds in wells and container type breeding sites such as overhead water tanks and reported resistance against available insecticides for adult mosquito control (based on resistance studies conducted by AMC HQ), Larval Source Management (LSM) is recommended as the main control method for *An. stephensi* in Sri Lanka.

4.2.1 Larval source management (LSM)

The possible methods for Larval Source Management are as follows;

Table 6. Larval source management for different breeding sites of *An.stephensi*

No.	Type of breeding places	Possible control methods
1	Used wells	Apply Temephos as an immediate measure • Apply a cover. • Apply Larvivorous fish (eg: *Poicelia reticulata*) .
2	Abandon wells	• Permenant closure of the well is recomended either by filling with sand or by using concrete slab. • If permenent closure is not possible (Owners/ Authority does not accept permenent closure) applying larvivorous fish should be considered
3	Over Head Tanks (Cement/Plastic)	• The lid of the over head tank should be sealed. • The outlet/ over flow pipe of the over head tank to be covered with mosquito proof net
4	Ground Cement Tanks	• Maintain the cement tank free of mosquito larva by having a sealed lid and outlet/ over flow pipe covered with mosquito proof net. • Covering of the tank • Apply larvivorous fish.
5	Underground Tanks	• Seal the tank
6	Ornamental Ponds	• Apply Larvivorous fish
7	Water Collection Containers eg: Barrel, Plastic Buckets	• Empty and clean the containers weekly. • All the water collection containers should be covered/ sealed with an appropriate lid. • Unnecessary water collections should be discarded
8	Roof Gutters	• Clean the gutter regularly. • Remove if any broken or unserviceable gutter.
9	Other possible breeding places	• Use appropriate Larval control methods

LSM method/s should be selected based on the feasibility, sustainability and effectiveness. Periodic entomological surveillance should be carried out to assess if the LSM has been successful.

4.2.2 Adult Control Approaches

According to the available susceptibility data, adult *Anopheles stephensi* shows some degree of resistance to most of insecticides used in Sri Lanka. It is highly recomended to study adult susceptibility for different classes of insecticides. Entomology surveillance including adult techniques should be carried out in the area in order to find out adults' biology and bionomics specific to the region. Chemical control for adults must be carried out only based on available local susceptiblity data and vector biology and bionomics.

However, if *An. stephensi* is detected in reactive entomological surveillance, adult control measures can be considered with technical guidance of AMC HQ.

Chapter 5

Effectiveness and practical constrains of vector control interventions at field level

Choosing a vector control method can be done based on technical knowledge and the availability of the vector control method. However, effectiveness of the vector control method may differ based on different field settings. Further the different situations may make it less practical and less effective to use expected vector control methods or operational requirements.

It is therefore of great importance to adapt to such circumstances. Identifying such situations and generating evidence through routine practice and applied research of a particular vector control tool will strengthen its evidence base.

5.1 Field level constrains in applying vector control tools and vector control effectiveness

Though the guidelines may suggest ideal application strategies and measures, it may be difficult to implement in certain instances. For example, though IRS is advocated in entire 500m radius when a case is reported, practically conducting it may not be feasible in some urban settings where communities live in close proximity and a large number of houses are situated in the targeted area.

Another instance is the application of Lavivorous fish/ Temephos in wells. It is considered an effective larval control method. However, when applying this control measure there may be less acceptability to introduce it to drinking wells.

Above examples highlight the need to take into consideration the local dynamics when implementing a vector control method.

Vector control method selected may have variable effectiveness based on the field setting. For example, though fish introduction is advocated as a larval control measure in wells, the fish survival may be affected in wells where frequent and high concentration of chlorination is applied.

Therefore, the field setting in which the vector control is applied is very important for its effectiveness.

5.2 Importance of assessing the effectiveness and the practical constrains in applying the vector control activity

During the PoR phase vector control need to be very focused and localized. Therefore, ensuring that it is done in an effective manner through the optimum utilization of resources is of great importance. Understanding the practical constrains and generating evidence of effectiveness of vector control tools would contribute towards achieving this task.

In each instance where vector control tools are applied there may be effectiveness issues and practical constrains. These need to be identified, documented and disseminated to necessary stakeholders for decision making. Further, it may serve as evidence for future reference. In addition to routine evidence, research studies should be conducted especially in view of identifying gaps in information relevant to effectiveness and practical constrains in different field settings.

Importance of local dynamics for effective vector control activities should always be considered and periodically assessed at regional level.

5.3 Decision making based on vector control effectiveness and field level constrains.

In situations where carrying out ideal/expected vector control techniques or specifications is not feasible or in circumstances where the effectiveness is not up to the expected level due to other local level modifications, changes can be made to the vector control activities and the best option can be selected. However, in such situations guidance should be taken from the AMC HQ.

Once such changes are implemented, monitoring the effectiveness of the activity should be periodically assessed and necessary modifications made. Once the activity is completed, the findings should be documented and disseminated to ensure the experience can be utilized for future decision making.

5.4 Assessing the effectiveness of the vector control conducted at district level

Once carried out, any vector control measure decided based on local evidence at district level, they should be assessed by post entomological and other relevant investigations to evaluate their effectiveness for the relevant circumstance. The findings of these vector control methods should be deiminated and shared with the Anti-Malaria Campaign HQ, relevant authorities and stake holders for futures planning, guidance and references.

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