Training Module-3

Alternatives to DDT in Vector Control Management

Developed under GEF Funded Project on

Development and Promotion of Non-POPs Alternatives to DDT
(GEF Project ID: 4612)

Training Programme on
Integrated Vector Pest Management (IVPM)

Executed by
Central Pollution Control Board (CPCB)
Ministry of Environment, Forest and Climate Change (MoEFCC)

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2022

Table of Contents

List of Figures

List of Table

List of Abbreviations

Ae.	*Aedes*
An.	*Anopheles*
Cx.	*Culex*
Bti	*Bacillus thuringiensis* var. *israelensis*
CI	Container Index
cm	Centimetre
CS	Capsule Suspension
CIB & RC	Central insecticides Board and Registration committee
DDT	Dichlorodiphenyltrichloroethane
EC	Emulsifiable Concentration
FAO	Food and Agriculture Organization
ft	Foot
GR	Granule
g	gram
Ha	Hectare
HCH	Hexachlorocyclohexane
HP	Horse Power
IGRs	Insect Growth Regulators
IRS	Indoor Residual Spray
IVM	Integrated Vector Management
IVPM	Integrated Vector and Pest Management
kPa	kilo Pascal
kph	Kilometre per hour
LLINs	Long Lasting Insecticidal Nets
Mph	Miles per hour
Mg	Milligram
m^2	metre square
NGO	Non-Governmental Organization
NVBDCP	National Vector Borne Disease Control Programme
NCVBDC	National Centre for Vector Borne Disease Control

ppm	Parts per million
PPM	Personal Protective Measures
Psi	Pound per Square Inch
SC	Suspension Concentration
Sq. cm	Square centimetre
ULV	Ultra-Low Volume
UNIDO	United Nation Industrial Development Organization
VBD	Vector-Borne Disease
WHO	World Health Organization
WP	Wettable-Powder

- **Alternatives to DDT in Vector Control Management**

Learning Objectives

By the end of the Training programme, the participants should be able to learn about…

- Development of methods and strategies as alternatives to DDT for vector control
- Promotions and development of locally safe, effective, affordable and environmentally sound alternatives to DDT
    - Environmental management methods for vector control
    - Biological control methods
    - Genetic control methods
    - Control of vectors by chemical and non-chemical methods
    - Natural and conventional vector control management strategies

1.1 Introduction

Vector-borne diseases are known to be a major threat to society and their control primarily depends on interrupting transmission through reducing parasite load and vector control. Vector control aims to limit the transmission of pathogens by reducing or eliminating human contact with the vector. A wide range of vector control tools exists, which can be broadly classified into physical, chemical and non-chemical.

The vector control tools target both immature and adult stages of vectors. The measures

used to control the immature stages are usually chemical or biological agents etc. Removing suitable aquatic habitats *viz*. habitat modification or manipulation is used as physical control method. Adult vectors are targeted by reducing the longevity of vector mosquitoes by indoor residual spray (IRS), and space spraying during outbreak containment to reduce the number of infective mosquitoes, LLINs/ITNs are used as other personal protection measures. In addition, repellents, house screening, etc. are also practised by the community. Some novel vector control tools are given below:

2. Conventional Methods

The application of synthetic insecticides is a major tool in mosquito control methods but the continuous application of synthetic insecticides causes the development of resistance in vector species, biological magnification of toxic substances through the food chain and adverse effects on environmental quality and non-target organisms including human health.

Natural vector control methods are the chemical-free vector control methods. They generally come from natural sources like a plant or animal derivatives. Many plants and minerals have insecticidal properties; i.e., they are toxic to insects. Botanical insecticides are naturally occurring chemicals (insect toxins) extracted or derived from plants or minerals.

Most plants contain compounds falling under several categories including repellents, feeding deterrents, toxins and growth regulators, which they use in preventing attacks from phytophagous (plant-eating) insects. These are volatile components and are also effective against mosquitoes and other biting insects. In India, a large number of such plants including their leaves, fruits, seeds, roots, etc. have been exploited since ages. Neem leaves are one of the best examples of natural repellents.

2.1. Smoke

One of the most common and widely used vector control measures is creating smoke from plant extracts/ leaves of different families *i.e.,* lamiaceae, poaceae and pinaceae, which have the potential to be used for the control of mosquitoes. Earlier, it was thoughts to be an ideal eco-friendly approach. Presently burning is banned in metro cities, hence, it should be avoided in those areas. Volatile fumes from the smoke of burning dried leaves are found to be more repelling than those from fresh leaves. Volatiles in the smoke of burning leaves of certain plants have significant repelling properties against many vectors, neem being the most common of them. Plant based mosquito repellents are a

viable source of material for use in protection against mosquitoes and mosquito-transmitted diseases and have some advantages over the currently used synthetic repellents (Aarthi et al., 2010). In this regard, some plants are effective in repelling anopheline mosquitoes e.g., *Otostegia integrifolia*- Indian elm or jungle cork tree (90.1%), *Olea europaea*- European olive or jaitun (79.8%), *Corymbia citriodora*- lemon eucalyptus or safeda (78.7%) and *Ocimum suave*- wild basil or ban tulsi (44.5%). *Ocimum canum* (holy basil or tulsi) can be used as an effective larvicidal and repellent agent against mosquito and water-soaked tulsi seed also act as larvicidal agent (Ramkumar et al., 2015). Plant-based insecticides are now increasing and are believed as a suitable alternative to synthetic chemical insecticides**.**

2.2 Cleanliness

Maintaining cleanliness and elimination of mosquito breeding sites is the most effective measure against a number of vectors. Maintaining good personal hygiene is also very important because sweat not only attracts mosquitoes but also facilitates the parasites to penetrate the host body. At the onset of the rainy season, it is very important to maintain cleanliness and personal hygiene as this season is best suited for mosquito breeding due to congenial conditions. Some species of mosquitoes like *Aedes aegypti* breed primarily in artificial water containers and their life-cycle is closely associated with human activities. Making cleanliness a drive, 'Swachh Bharat Abhiyan' was launched on 2nd October 2014 by Government of India to aware people of cleanliness and its importance. Abhiyan's manifesto recommended activities like involving NGOs and the general public through the vigorous campaign in print and electronic media; repair, maintenance, cleaning and sanitization of public or community toilets; river or pond side waste cleaning; removal of debris and garbage from public places. Some of the basics to control vector-borne diseases that can be undertaken at a small level and personal level are discussed below:

2.2.1 Premises inspection

It is necessary to inspect residential areas/premises and cover or dispose off properly any items that could hold water like tyres, buckets, disposables, cans, bottles, saucers, flower

pots, toys, etc.

2.2.2 Removal of standing water bodies

It is necessary to remove small pools of standing water bodies from the areas near the house. One should do the following activities-.

- Change the water in pet bowls, bird baths, fountains, and pools at least once a week
- Tighten up loose taps that could hold any water
- Tightly cover water storage containers (rain barrels, overhead tanks, etc.) so that mosquitoes cannot lay eggs inside the containers
- Fill water-holding tree holes, with soil or sand to prevent further mosquito breeding

2.2.3 Community awareness and sensitization

To achieve mosquito control successfully, joint efforts of the community and government are essential. Community awareness has shown significant improvement in many habits like avoiding sleeping outside at night, cleaning water containers regularly, covering water tanks, elimination of breeding sites etc (Sreedevi et al., 2016).

Community involvement has become an important component of the vector control strategy too, resulting in the organization of groups to spread messages on VBD prevention and control within the community (Elsinga et al., 2017). This illustrates how available scientific knowledge about vector ecology and disease epidemiology may potentially be harnessed to improve programs of environmental management and community action, as a means for combating the most dreaded VBDs. Participation in educational intervention programmes leads to improved knowledge of vector ecology and disease epidemiology and prevention. Imparting health education to the community directly or through educational institutes is the most effective step to exercise the use of Personal Protection measures (PPMs) and other vector control tools/interventions (Nandha et al., 2012).

3. Environmental Management

Environmental management refers to the change of the environment to prevent and reduce the vector productiveness and human contact with the vector-pathogen by way of the strategies such as destroying, altering, removing or recycling non-essential containers that serve as vector habitats. There are three types of environmental management in controlling mosquito vectors, particularly dengue, which consists of (i) environmental modification, (ii) environmental manipulation and (iii) changes in human habitation or behaviour based on WHO's definition (Figure- 1). Environmental management includes the improvement of water supply and water storage systems, mosquito-proofing of water-storage containers, solid waste management, community clean-up and modification of building structures. Environmental management additionally affects mosquito ecology and population dynamics as well as the epidemiology of mosquito-borne diseases. Notably, environmental management is not supposed to replace other vector-borne diseases control methods but is to impose a co-lateral impact on the reduction of vector population, thereby providing a tool in the development of "Integrated Control" strategies.

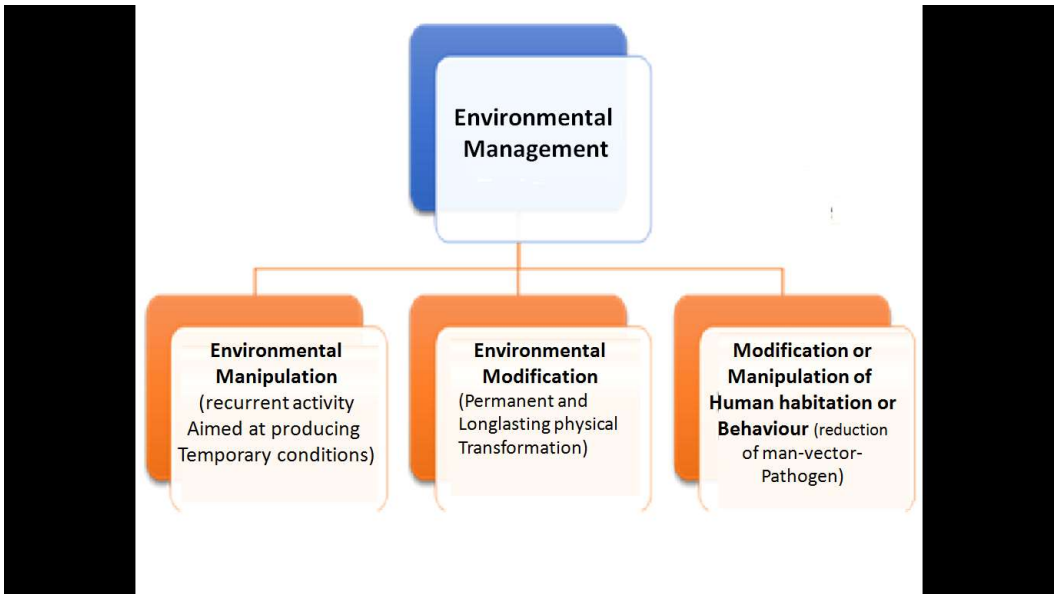


Figure- 1: Components of environmental management (WHO, 1982)

3.1 Environmental manipulation

It is defined as temporary changes to vector habitats unsuited for vector breeding involving the management of “essential” containers, such as frequent emptying and cleaning by scrubbing of water-storage vessels, flower vases and desert room coolers; cleaning of gutters; sheltering stored tyres from rainfall; recycling or proper disposal of discarded containers and tyres; management or removal of plants from the vicinity of homes such as ornamental or wild bromeliads that collect water in the leaf axils. (Figure-2)

Figure- 2: Types of environmental manipulation

3.1.1 The deepening and narrowing of old drains

Old drains can be made narrow and deepened to increase water flowing rate. The technique can be used to create conditions that are not conducive to mosquito breeding.

3.1.2 Synchronized cropping and intermittent irrigation

Use of synchronized cropping method for crops, paddy cultivation, where paddy crop is left dry for two months each year. The periodic wet and dry paddy cultivation has led to a significant reduction of adult mosquito populations in several countries. Alternatively, fields can also be flooded for several days and then left to dry.

3.1.3 Saltwater flooding

Saltwater flooding can be used to create a habitat that is not conducive to mosquito breeding. For example, flood dikes can be constructed to flood lagoons with salt water. Saltwater flooding can also be used in association with drainage systems (e.g., fish ponds and irrigation systems).

3.1.4 Strategies applied to control vegetation

Plants with submerged roots, which allegedly give off chemicals to the water can be

grown to reduce vector population. Floating seeds of almost all woody plants as well as aquatic plants increase the problem, therefore seeds must be dewatered and stranded before germination takes place. In this context shading by the tree near shallow waters proves to be one of the solutions as direct sunlight has a more abundant growth of emergent and microscopic plants, thus providing necessary food and protection for mosquito larvae. Attempts can be made to control such plants by mechanical raking, rolling and crushing may defeat their purpose by producing hundreds of small reproductive fragments. Another method to control vector breeding includes the creation of an unfavourable habitat other than the rooted floating mat aquatic species by deepening and filling techniques.

3.1.5 Strategies applied to man-made lakes

There are different man-made structures called 'Impoundments'. Pre-impoundments are impoundments before the reservoir, and a programme of water level management designed to strand drift and floatage, minimize the invasion and growth of marginal plants, which provide the habitat for anopheline propagation and suppress aquatic plant colonization. On the other hand, water level management shall not be in post-impoundment reservoirs. The main strategy includes (a) filling the reservoir to provide a surcharge (early spring in temperate zones) of 30 cm or more above the normal full pool, followed by a rapid draw to full pool level (b) maintenance of a relatively constant full pool level at the clearing line until the beginning of anopheline mosquito production (c) weekly fluctuations starting when larval populations reach significant numbers. This calls for the lowering of the pool by about 0.3 m and refilling during the week (d) combining seasonal recession and cycle fluctuation followed by field observations and measurements of mosquito density after a few weeks of the third phase.

3.1.6 Stream flushing

A sudden flush of stored water is released into the breeding stream channel, and this is repeated periodically, it will (a) dislodge and expose larvae and eggs, (b) stir up the

bottom sediments, which may bury mosquito larvae; (c) produce a wave-front water fluctuation cycle, which assists in dislodging and perhaps stranding larvae. Flushing shall be done at the beginning of the breeding season with one flush per hour and should end when the stream is drying with only one flush per week or longer.

3.1.7 Coastal flooding and impounding

Generally, some mosquitoes deposit eggs on the moist earth in a depression close to the high point of tides leading to make the area prone to vector production. So, the basic strategy is to restore the tidewater fluctuation to all the isolated pools and depressions. Methods to control breeding include flushing the larvae from protective cover, stranding them, altering vegetation, and destroying larvae by exposing them to predators or circulation of raw cold seawater. Another application of open marsh strategies where the topography is flat is to deepen the marsh by excavating a clean-edged pond to a depth below the low tide level. This will exclude emergent vegetation from the area formerly covered by a series of small grassy pools, which is difficult to drain.

3.2 Environmental Modification

Environmental modification: "A form of environmental management consisting of any physical transformation that is permanent or long-lasting of land, water and vegetation, aimed at preventing, eliminating or reducing the habitats of vectors without causing unduly adverse effects on the quality of the human environment" (Figure- 3).

Figure- 3: Types of environmental modification

3.2.1 Reservoir site clearing

The basin must be cleared of trees, bushes, fences, bridges, houses, sheds, etc., which otherwise would disintegrate and decay, and perhaps float, drift to the shore and accumulate at the head of bights and indentation where floats encourage aquatic plant growth and mosquito production. Permanently and completely submerged trees in deeper regions do not pose any mosquito problems.

Drainage of reservoir margins

Marginal drainage must be provided in the zone between the maximum and minimum water levels of the reservoir. Small water collections, which can dry up in a few days do not need marginal drainage. Areas remained in a permanent body condition due to existence of sub-surface springs that also need drainage.

Deepening and filling

A deepening and filling operation is usually combined with shoreline reshaping by taking soil from land projections to fill indentations or bays. Thus, in addition to eliminating favourable mosquito breeding sites at shallow margins, the operation will result in shorter and straighter shorelines, directly reducing the length of the potential breeding sites (WHO, 1982).

Diking and dewatering

Where deepening and filling would involve major land-moving operations, it may be necessary to consider the possibility of building dikes or levees to isolate large shallow bays for reclamation by dewatering. Such areas, if remain inundated, could provide numerous mosquito breeding places, which would be extremely difficult to control.

3.2.2 Irrigation

Many of the health hazards connected with irrigation can be prevented or at least reduced by measures taken in the planning, design, construction and operation of irrigation systems (Figure- 4). There are different water conveyance structures for irrigation *i.e.,* open canals and pipe conduits. Mosquito problems are to be expected in the whole canal complex, but the greatest risk is in the minor distribution channels, which are more suitable for mosquito breeding. Where water flow is slow, where canal banks are eroded or choked with vegetation, or where channel sections are irregular, mosquito breeding is a real or potential danger. Good and bad features are often found in irrigation systems as

shown in Figure- 5.

Design of irrigation systems

For mosquito control, there are certain special aspects, which need to be considered in the design of an irrigation scheme. Major methods to prevent and control these situations (which need to be given serious consideration by the engineer), include:

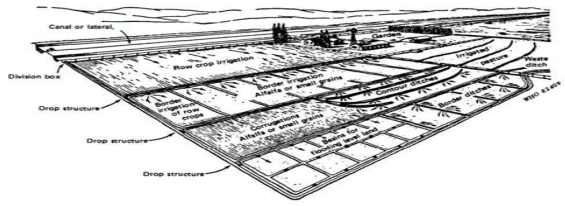


Figure- 4: Different methods for applying water to the field (WHO, 1982)

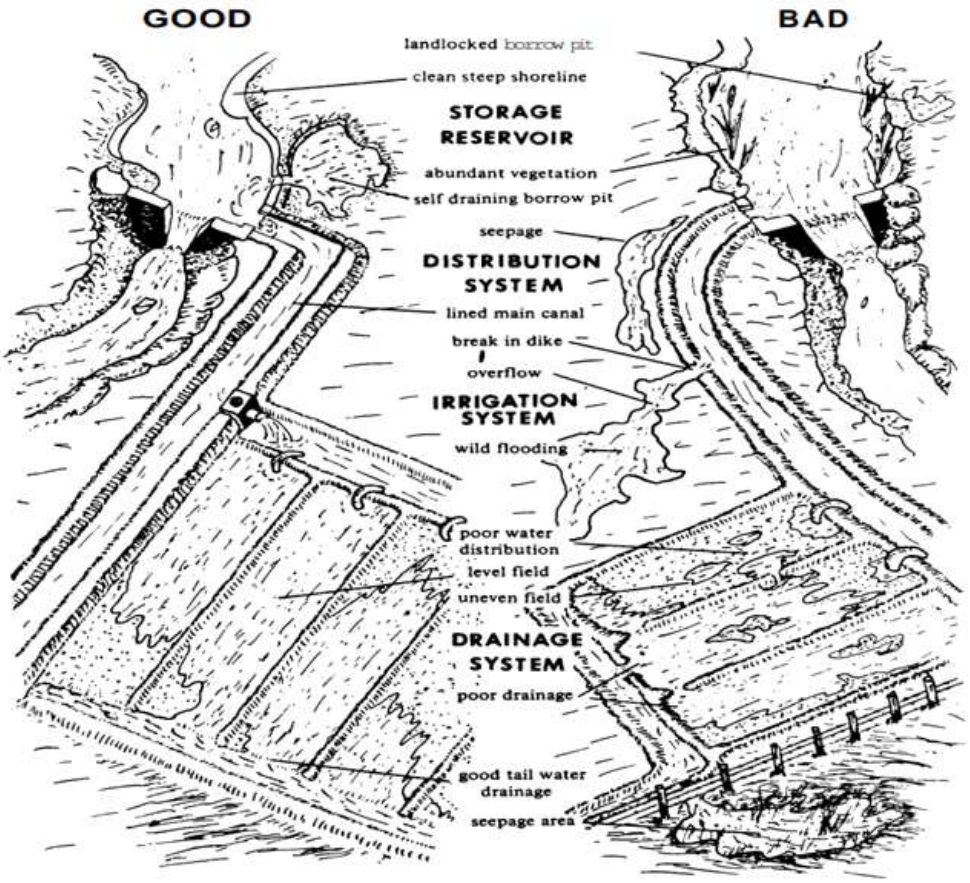


Figure- 5: Good and bad features often found in irrigation system (Mulhern, 1980)

a) Use of a safer irrigation method, such as mechanized or localized sprinkler irrigation, if technically feasible and economically justified
b) Use of closed conduits instead of open canals for water conveyance
c) Lining of canals
d) Good alignment of canals and avoidance of sharp curves
e) Effective canal maintenance to ensure that the canals are in good shape and generally free from vegetation and silting at all times
f) Intermittent irrigation and periodical drying of canals and fields
g) Canal flushing
h) Proper forming and grading of the land to be irrigated
i) Good irrigation practices with suitable control to avoid over-irrigation and water accumulation on irrigated land

Reinforcement of the bank

To eliminate backwater pools and marginal pockets, the eroded or fallen stream banks will have to be rebuilt in alignment with the unaltered banks (Figure- 6). This work may require the construction of levees, which will also give flood protection and prevent the formation of swamps by water overflowing into low-lying areas.

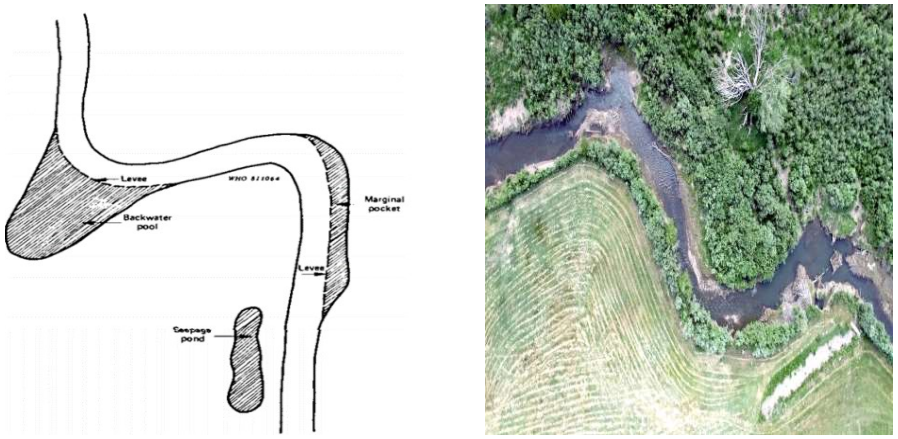


Figure- 6: Mosquito breeding in rivers and other natural streams (WHO, 1982)

Where stones are abundant, the levees can be advantageously replaced with barriers made of loose rocks, cobbles, etc., encased within wire mesh. These casings, known as gabions (Figure- 7), are made by setting on the site a long and relatively narrow strip of wire mesh. They are generally laid against the natural banks of the river but they can also be designed as a gravity structure to stand free in those sections where the banks are completely destroyed.

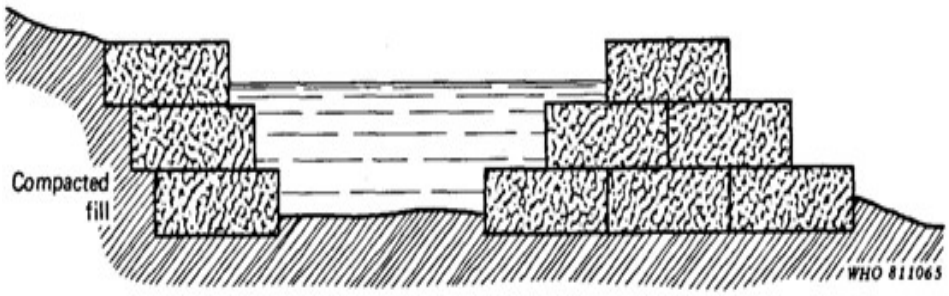


Figure- 7: Gabions placed to replace a demolished embankment (WHO, 1982)

Deepening of a central channel

The hydraulic characteristics of the channel can be improved by correcting the gradient where the silt deposit on the stream bed is irregular. The line of maximum channel depth does not coincide with the centre line but moves from one side to the other. The realignment of the maximum depth line and the straightening of the gradient can be carried out by dredging the bed material using mechanical dredgers, power shovels, dragline bucket excavators, or hydraulic dredgers of the sand-pump type (Figure- 8).

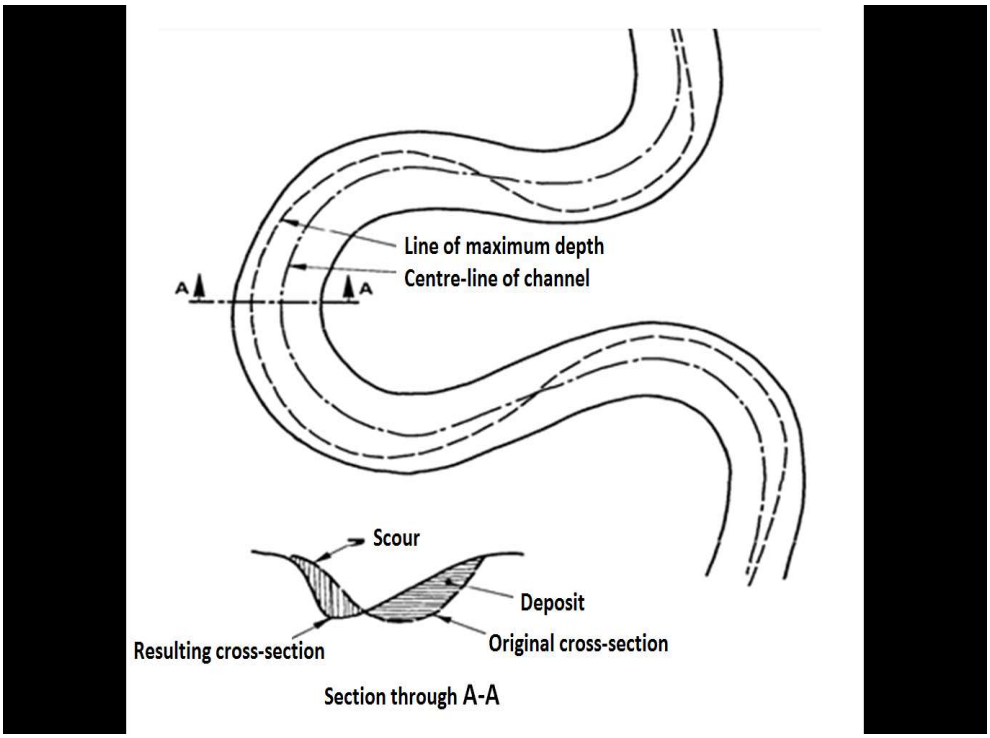


Figure- 8: Distortion of the channel bed of a meandering stream caused by torrential flows (WHO 1982)

Diversion of peak flow through 'floodways'

The risk of mosquito production in the floodway channel arises during the dry season when it is out of service but may intercept natural tributary drainage throughout its course. The total flow of these tributaries may not be enough to flush out small depressions in the channel. In this situation, the lining of the floodway bed with concrete inverts is indicated.

Drainage for agriculture and land reclamation

In humid areas, drainage is mainly required for the removal of excess rainwater that either saturate the topsoil and collects in flat low-lying areas and land depressions or runs into streams and rivers to overflow and inundate the adjacent lands. In areas frequently exposed to flooding, the capacity of the drainage system must be sufficient to accommodate not only the surplus of irrigation water and the runoff produced by normal rain storms but also the flood waters.

Mosquito production is generally associated with the absence of drainage systems or their inadequacy to cope with high-intensity rainfall or with excess water resulting from over-irrigation, marsh expansion or inundations. Measures to stop mosquito breeding include:

a) Use of buried drains instead of open ditches as far as possible

b) Lining of the ditches or lining of the invert, if open ditches have to be used

c) Good alignment of ditches and avoidance of sharp curves

d) Ditch flushing

e) Effective maintenance of the scheme

Landfilling and Grading

Filling of small holes, borrow pits, ponds, abandoned ditches, unused wells, other similar water pockets in and around villages is a simple effective means of mosquito source reduction, which has been used in malaria control programmes with good results (Figure-9). An overall survey of the land is needed before preparing a land-forming plan for the entire area. The final grades of land should be uniform, without depressions or low areas, to facilitate irrigation.

Following are different methods for filling and grading:

- Sanitary landfill sites where wastes are disposed off can form medium-sized depressions where water may be collected and remain stagnant. These sites can be managed efficiently by daily placing soil cover on the refuse to avoid the breeding of vectors and to protect against odour and unsightliness.

- Land shaping can be done where insufficient filling material is available for proper grading. The main purpose is to smooth out roughness in the topography without any major alteration except for what is needed to improve surface drainage.

- Natural fills can be used in areas with intense and frequent rainfall and heavy concentration of sediments are found in ditches and streams. By appropriate planning, this sediment can be trapped, allowed to settle, and used as a filling material to eliminate in due course a swamp or intermittently flooded area.

- Large hydraulic fills include disposing of the dredged material by using it for filling. It is suitable for the filling of very large areas, particularly those adjacent to a river course, navigation channel or sea coast, at a very low additional cost.

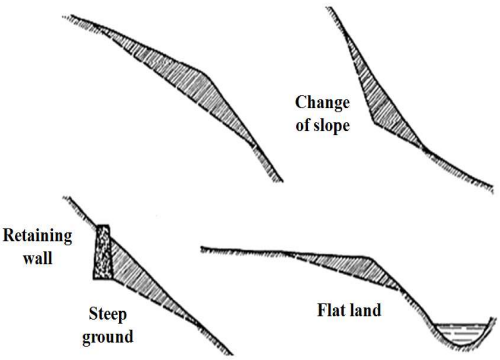


Figure- 9: Different situations of filling material to control vector breeding (WHO, 1982)

3.3 Modification or manipulation of human habitation or behaviour

3.3.1 Resettlement of population

In any resettlement or settlement project, site selection is the primary consideration. Settlements should be located as far away from mosquito sources as possible. Sanitary facilities of a standard that ensures protection against disease transmission should be provided. The provision of drainage ditches to get rid of rainwater and proper drainage for each water point (hand pump, stand post, etc.) to remove spilt and wastewater is an important measure for reducing mosquito sources. Apart from this, instant protection should be taken, which may include a medical screening of new arrivals, treatment of detected cases and chemoprophylaxis, spraying of houses with residual insecticides, mosquito proofing of houses, etc.

4. Biological Control

Environment friendly alternatives have been explored to reduce the selection pressure for insecticide resistance. These various bio-control strategies target different stages of the mosquito life-cycle with the aim of being safe for the environment and sustainable. These diverse bio-control strategies include natural organisms that kill mosquitoes, exploiting mosquito behaviour to improve mosquito mortality, and releasing mosquitoes that are either sterile or unable to transmit the disease.

Biological methods of mosquito control consist of the utilization of natural enemies of the mosquitoes and of biological toxoids to achieve effective control. For many years, it has been observed that certain plants, invertebrate predators (such as immature stages of Odonata, a few Beetles, Bugs, *Toxorhynchites* etc.), and vertebrate animals (such as frogs and fish) feed on mosquito eggs and larvae. Larvivorous fish and larvicidal bacteria have been used on an operational scale in vector-borne disease control programmes and it is only recently that comprehensive studies have been undertaken on their potential as effective biological agents for mosquito control (Fock, et al., 1985). Different biological agents used in vector control are described below:

4.1 Copepods

Copepods are small aquatic crustaceans, most of them are omnivorous and prey on immature mosquitoes, especially first-instar larvae but rarely on later stages. Copepods can be easily transported, either actively or passively, often as resistant dry stages, making them a keen biological control agent (Figure- 10). Several species of copepods (small crustaceans) have been found to control mosquito larvae in Australia, Brazil, and Vietnam. *Mesocyclops longisetus*, *M. mendocinus*, *Tropocyclops prasinus, Eucyclops serrulatus, E. solitarius* and *E. ensifer* are potential biological control agents for anopheline vectors. Species of copepods, including *M. aspericornis*, *M. thermocyclopoides, M. guangxiensis, Macrocyclops albidus, M. darwini, M. leuckuarti,*

M. formosanus and *M. longisetus* have been reported as potential biological control agents in several countries like India, Sri Lanka, Taiwan etc (Veronesi et al., 2015 and Dhanker et al., 2013)

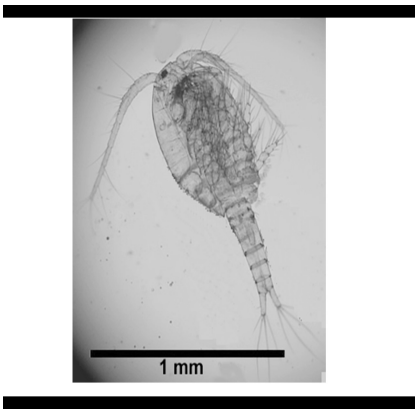


Figure- 10: Copepod

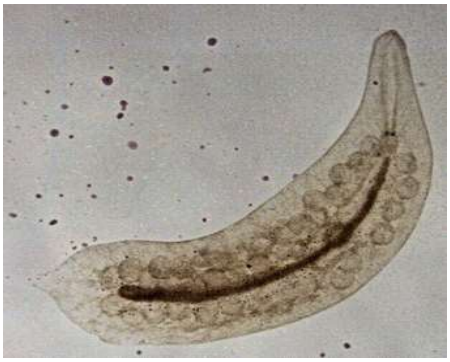
4.2 Nematodes

Romanomermis iyengari and *R. culicivorax* have been found to be effective parasites of aquatic stages of mosquitoes in paddy fields. With more research on production and storage, this genus of nematode may provide a reasonable natural control agent. An additional species, *Octomyomermis muspratti* is difficult to mass produce because of its asynchronous egg hatching, tolerance for salinity, pollution and desiccation. It has the potential for dispersal by infected adult mosquitoes (Petersen, 1977).

4.3 Flatworms

Certain species of *Turbellaria* flatworms attack mosquito larvae in nature. The species of *Planarian* flatworms have long been known to be predators of immature mosquitoes for example *planarian* species *Dugesia tigrina, D. dorotocephala* (Woodworth), *Girardia anceps*, *Mesostoma ehrenbergii* (Figure- 11), however there is no commercial potential

for their use at present.



Mesostoma ehrenbergii

Dugesia tigrina

Figure- 11: Planarian flatworms

4.4 Fungi

The fungus *Erynia aquatica* is a species known to infect the immature aquatic stages of mosquitoes. The fungus is capable of causing epizootics. It has been found in both freshwater and brackish water mosquitoes and has a resting spore stage that may survive well in storage making it an attractive microbial agent (Becker et al., 1997).

Coelomomyces indicus (Blastocladiomycota: Blastocladiales) is an obligatory parasitic fungus with complex alternating life cycles - involving microcrustacean heteroecious hosts and restricted to aquatic Diptera including Culicidae, which is found to be naturally present in paddy fields; typically, the infected ovaries of adult females are sterile. Experimental infection of mosquito larvae by this fungus showed that a crustacean, *M. leuckarti*, acts as an intermediate host.

4.5 Invertebrate predators

Invertebrate predators play an important role in the natural regulation of mosquito populations. Most of them, however, have biological characteristics preventing their mass production for biological control purposes. One outstanding exception is represented by mosquitoes of the genus *Toxorhynchites*, whose several species can be mass-produced. *Toxorhynchites* females do not bite at all, and the larvae have predatory habits.

Toxorhynchites are promising enough for the control of *Aedes* mosquitoes breeding in plant axils, tree holes, cut bamboo, abandoned containers and similar sites. Most species of *Toxorhynchites* live in forests. *T. splendens* (Figure- 12) consume mosquito larvae in tree crevices (particularly those belonging to the genus *Aedes*).

Figure- 12: *Toxorhynchites splendens* mosquito

4.6 Anuran predators

Anurans (particularly frogs and toads) are also being used (Figure- 13) for mosquito control. Tadpoles, with various life-history characteristics, actively prey upon the eggs of *Ae. aegypti* (Bowatte et al., 2013). It has been shown that this mosquito species has a preference to lay eggs in tadpole water, tadpoles of *Polypedates cruciger*, *Bufo, Ramanella, Hoplobatrachus* and *Euphlyctis* genera feed on these eggs.

Polypedates cruciger

Bufo melanostictus

Figure- 13: Tadpoles as predators

4.7 Bacteria

Some spore-forming bacteria, and in particular certain strains of *Bacillus thuringiensis* and *B. sphaericus* produce bacterial toxins, which are lethal to mosquito larvae but are innocuous to most non-target aquatic organisms and vertebrates. They, therefore, constitute environmentally safe bio-larvicides. *Bti* is a gram-positive, spore-forming bacterium that releases insecticidal toxins and virulence factors that selectively target the larval stages of insects. Bio-larvicide formulations derived from the serotype H-14 of *B. thuringiensis* are on the verge of industrial production. Several other promising strains have recently been isolated (Lacey, 2007).

4.8 Biolarvicide - protozoan parasite

Chilodonella uncinata (Ehrenberg), 1838 (Subphylum: Ciliophora: Cryptophorida: Chilodonellidae), a natural biological control agent was discovered in mosquito vectors (*Culex tritaeniorhynchus* and *Cx. pseudovishnui*) of Japanese encephalitis (Das, 2003). *Chilodonella uncinata* has a unique mode of behaviour. In presence of susceptible mosquito larvae, it changes itself and becomes parasitic in habit. They attack one single larva at different points (head, thorax, abdomen, siphon, anal fin, antennae, etc.) and enter body cavity of the host larva by drilling through the host cuticle (Figure- 14 A & B). Thereafter, it multiplies inside the host body at the expense of the internal viscera of the host larva and releases numerous minute motile spores, ultimately killing the larva and

finally escaping the cadaver of larva (recycle in the environment) to attack fresh larvae to continue the cycle. The organism is so virulent that even a few of them can cause chronic infection leading to death in susceptible host larvae (Das, 2004). A lower dose of this protozoan formulation can be used as a potential biolarvicide to control mosquito larvae of *Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus* and JE vector as an alternative to chemical insecticides under integrated vector management (Das, 2016).

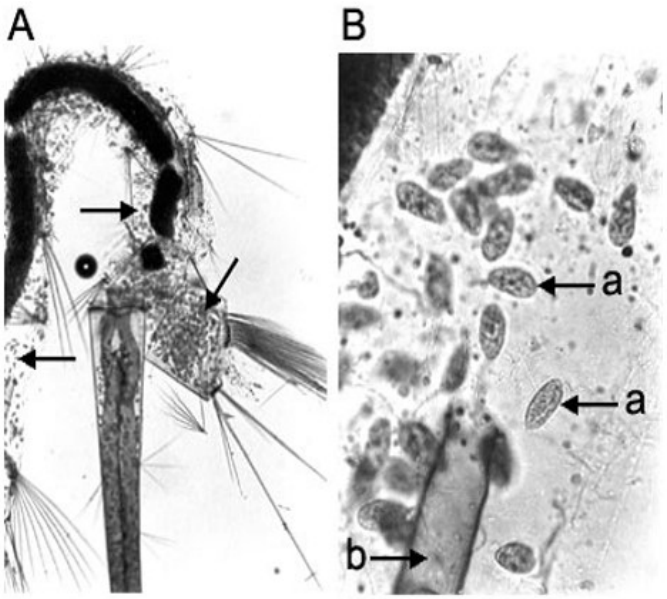


Figure- 14: Protozoan parasite- A, *Cx tritaeniorhynchus* larva: Arrow showing, endoparasites (microbe). B, a, endoparasites. b, disintegrated alimentary canal (Das, 2003)

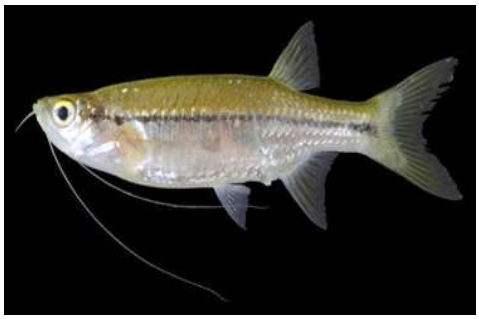
4.9 Larvivorous fishes

Fish have been widely used in public health, since 1903. One of the most successful and widely used biological control agents against mosquito larvae is the top water minnow or *Gambusia affinis* fish. Fish other than *Gambusia* as early as the most attention as a

mosquito control agent is *Poecilia reticulata*. Studies revealed that there are several indigenous fishes like *Esomus danricus, Badis badis, Chanda nama, Puntius ticto, Rasbora daniconius, Amblypharyngodon mola, Colisa fasciata* etc., which have proved very good mosquito larvivorous and are commonly found in Indian fresh waters, some of which are shown in Figure- 15 (MRC, 1993). Other fishes like *Aplocheilus, Oryzias* and *Aphanius* are also mosquito larvivorous.

Amblypharyngodon mola

Rasbora daniconius ***Puntius ticto***



Esomus danricus

Badis badis

Figure- 15: Larvivorous fishes

These fishes were found to have significant larvivorous potential in various conditions. However, they either cannot be mass-produced or are not hard enough to withstand transportation, variation in water quality, turbidity and temperature. Also, these fishes produce smaller broods than exotic fish (Chandra et al., 2008).

I. *Gambusia affinis*

Gambusia affinis has been in use in India since 1928. It is an exotic species and has been distributed throughout the warmer and some temperate parts of the world**.** This species is the most widely used against mosquito larvae. Their mouths are adapted to feeding from the surface (Figure- 16). It originates from Central America but because of its success in controlling mosquitoes, has been introduced in many parts of the world. This fish can withstand large fluctuations in temperature. They are most productive in the relatively clean water of moderate temperature.

Habitat

It is a very hardy fish and can adapt to a wide range of temperatures as well as the chemical and organic content of the water. The optimum temperature for reproduction ranges from 24˚C to 34˚C but the fish can survive at freezing temperatures too. It can survive in water with pH ranging from 6.5 to 9.9. It lives and multiplies in ponds stocked with larger fish provided the pond is shallow and has protective vegetation for refuge.

Size and longevity

The maximum size attained by a male is 4.5 cm. and by a female 5.2 cm to 6.8 cm. Their life span is approximately 4 (±1) years.

Breeding habit

The female matures in about 3 to 6 months. Each ovary contains approximately 120 eggs. Young ones are released in broods of 25-30 at a time. A single female may produce between 900 and 1200 offsprings during its lifespan.

Breeding season

Gambusia breeds throughout the year after maturity, especially in tropical conditions. In a relatively colder climate such as in the north and north-west India, the breeding period lasts from May to September and in the warmer climate of southern India from April to November.

Figure- 16: *Gambusia affinis* fish

Larvivorous efficiency

The larvivorous efficiency of *Gambusia* is due to the following characteristics:

- A single full-grown fish eats about 100 to 300 mosquito larvae per day.
- Being a surface feeder, it is suitable for feeding on both Anophelines and Culicines larvae.
- It is small and inedible.
- It can withstand transportation and does not require any specialized equipment or containers.
- It survives in new places (water bodies) and multiplies easily. After release when it becomes well established in a water body, the fish can survive and does not require constant care.

II. *Poecilia reticulata* (Guppy)

Like *Gambusia*, Guppy (Figure- 17) is also an exotic fish introduced in India in 1910. It is easy to care for, and it reproduces quickly and prolifically. It is now widely distributed in India and is an important larvivorous fish.

Habitat

It is a very hardy fish and survives in all types of water bodies. Once well established, it can be found in the habitat even after many years. It tolerates high degree of pollution with organic matter. The temperature range suitable for breeding is from 24˚C to 34˚C. However, it cannot survive in cold water (often below 10˚C) and stock may need replenishment if the temperature falls below 10˚C. It can survive in water with pH ranging from 6.5 to 9.0.

Size and longevity

The male is 3 cm long, whereas the female is 6 to 9 cm in length. It lives for 4 ± 1 year.

Breeding habitat

Guppy takes about 90 days to mature. Each ovary contains 100 to 160 eggs. The female gives birth to young ones in broods of 5 to 7 at a time. About 50 to 200 young ones are released by the female every four weeks.

Breeding season

Breeding season depends on climatic conditions. In warmer climate it may breed from April to November.

Figure- 17: *Poecilia reticulata* fish

Larvivorous efficiency

The larvivorous efficiency of *Poecilia* is due to the following characteristics:

- A single fish eats about 80 to 100 mosquito larvae per day. Therefore, it is comparatively less efficient than *Gambusia affinis.*
- It is a surface feeder.
- It can tolerate handling and transportation very well.
- Does not require specialized transportation equipment.
- Survives and reproduces when introduced into new water bodies.

III. *Oreochromis mossambicus* (Mozambique tilapia)

This is cichlid (freshwater) fish (Figure- 18). It has been reared successfully in irrigated paddy fields and use for both, to control mosquitoes and as a source of food. With an optimal temperature of 22°C, it reproduces very rapidly. The species can live and reproduce in fresh and brackish water (WHO, 2013).

Figure- 18: ***Oreochromis mossambicus***

Habitat

Mozambique tilapia generally prefers slow-moving water bodies such as lagoons, rivers and impoundments, but can also colonise faster-flowing creeks and streams. In addition to fresh waters, it can also live in habitats influenced by tides, such as the upper reaches of estuaries and coastal lagoons.

Size and Longevity

Mozambique tilapia can reach a length of over 40 cm under optimal conditions, with males typically growing larger than females and living up to ten years.

IV. *Danio rerio*

This belongs to carp's family. It is a local fish and many other subfamilies of *Danio* are distributed almost all over India. It is a strong swimmer and it can live-in slow-moving streams (Figure- 19).

Figure- 19: *Danio rerio*

Habitat

This fish is found both in stagnant and flowing water. As a powerful swimmer, it can

negotiate against the water current. It survives in all types of water collections but is sensitive to pH and temperature changes. Optimum water temperature is between 22˚C and 28˚ C. It is most abundant in South India (Sharma, 1996).

Size and Longevity

4.5 cm to 5 cm male and female of equal length live for about 3 ± 1 years.

Breeding habit

Although no firm evidence is available, it spawns at least twice a year and young ones hatch within 24 to 48 hours.

Breeding season

Not much is known but probably breeds during March/September or November depending on the suitable climate.

Larvivorous efficiency

It is carnivorous fish and mostly feeds on insects on water surface.

Different fish species and their application in different mosquito breeding sites for example mine pits, swamps etc. are shown in the Table-1.

Table- 1: Suitable fish species used in different mosquito breeding habitats (Source: NIMR)

Aquatic habitats	Main vector mosquito	Fish species	Number of fish to be released
Ponds/rain water pools	*An. culicifacies*	*Gambusia* and Guppy	10–20 fish/m^2
Water storage tanks, ornamental tanks, fountains, swimming pools and cisterns	*An. stephensi, Aedes spp.*	*Gambusia* and Guppy	5–10 fish/m^2
Mine pits	*An. culicifacies*	*Gambusia* and Guppy	2500/acre (For immediate control
Wells	*An. stephensi*	*Gambusia* and Guppy	50–250 (For rapid control)

Swamps	*Cx. quinquefasciatus*	Guppy, *Aplocheilus* and *Colisa*	10,000/acre
Farm ponds and check dams	*An. culicifacies*	*Gambusia, Aphanius* and *Aplocheilus*	25–50/m^2
Drains	*Cx. quinquefasciatus*	Guppy and *Colisa*	
Paddy fields	*An. culicifacies*	*Gambusia, Danio, Aplocheilus, Oryzias* and *Aphanius*	5000/acre

5. Chemical Control

Chemicals have been used to control vector-borne diseases by targeting both, larvae as well as adults of the vector species. The present strategy of vector control is to integrate various control techniques and to limit the use of chemical insecticides to control epidemiologically important areas of the vector population. This approach might prevent or delay the development of resistance. Some of the chemicals used in chemical vector control methods are discussed below:

5.1 Plant products

Plant based repellents have been used for generations in traditional practice as a personal protection measure against flies, ants and mosquitoes. Knowledge on traditional plant repellents obtained through ethno-botanical studies is a valuable resource for the development of newer natural products. Most plants contain compounds that prevent attack from phytophagous (plant-eating) insects. These chemicals fall into several categories including repellents, feeding deterrents, toxins, and growth regulators (Anoop et al., 2017). Most can be grouped into five major chemical categories: Nitrogen compounds (primarily alkaloids), Terpenoids, Phenolics, Proteinase inhibitors and Growth regulators.

5.1.1 Pyrethrum

Pyrethrins are a mixture of six chemicals that are toxic to insects and are commonly used to control mosquitoes, fleas, flies, moths, ants and many other pests. Natural Pyrethrum is extracted from crushed flowers of *Chrysanthemum cineraraefolium*. Pyrethrum 2% extract has been registered with Central Insecticides Board and Registration Committee (CIB & RC) for use in vector control. They have been used as models to produce long lasting chemicals called pyrethroids, which are man-made.

It is the oldest effective insecticide that has been used in several countries. Its safety for use is unparallel and has been used as anti-helminthic and also introduced in urban water

supply without toxic hazards to the consumer. Pyrethrum is a contact poison and may be formulated as a solution, emulsion, dust or granules. Pyrethrum extract is the extract of pyrethrum flowers (*Chrysanthemum cineraraefolium* L) in a mineral oil with or without a minute quantity of added anti-oxidant but without a synergist. It is a clear transparent liquid free from sediments, suspended matter or other extraneous impurities, greenish and possesses the characteristic odour of pyrethrum flowers. Pyrethrum excites the nervous system of insects that touch or eat it, which quickly leads to paralysis and ultimately death.

5.1.2 Neem-derived products

The neem plant (*Azadirachta indica)* and its derived products have shown a variety of insecticidal properties on a broad range of insect species. It has been argued that the pesticidal efficacy, environmental safety, and public acceptability of neem and its products for control of crop pests would ensure its adoption into mosquito control programmes (Okumu et al., 2007). Presently, however, none of the commercially available neem formulations, which include emulsifiable concentrates (ECs), wettable powder (WPs), suspension concentrates, ultra-low volume (ULV) and granular formulations are used for this purpose.

5.2 Synthetic chemicals

Synthetic chemicals are defined as chemicals, which are man-made. Synthetic contact insecticides are now the primary agents of insect control. In general, they penetrate insects readily and are toxic to a wide range of species. Chemical-based control measures have dominated as compared to other strategies over the years. Synthetic chemicals are used in major vector control strategies. It is a central, critical component of all malaria control strategies; it relies primarily on two interventions: LLINs and IRS. In India ITNs and IRS have been the cornerstones of vector control. The use of chemical insecticides remains the predominant means of controlling insect vectors (WHO, 2015). However, the emergence of insect-resistant species suggests an alternative replacement to these chemicals, Pyrethroids are the only class of insecticides approved for treating bed nets or

curtains because of their high effectiveness and strong excito-repellent effect on mosquitoes, yet, low mammalian toxicity, pyrethroids are synthetic chemicals whose structures mimic the natural insecticide pyrethrum.

5.2.1 Paris green

Paris green is an inorganic arsenic compound that was used extensively from 1921 until the 1940s to control anopheline larvae (Jan, 1997). This green powder is practically insoluble in water. The particles float on the surface where they poison the surface-feeding anopheline larvae. Its advantages were low cost, high effectiveness, portability and ease of distribution. No ill effects were recorded in animals, fishes and insects, and treated water remained suitable for domestic use. It was an important tool for malaria control programmes but its use was banned due to extremely high toxicity in non-targeted organisms.

5.3 Organic chemicals

5.3.1 Organochlorines

Organochlorines (OC) are second generation insecticides and widely used all over the world. They belong to the group of chlorinated hydrocarbon derivatives, which have vast application in vector and pest control. These compounds are known for their high toxicity, slow degradation and bioaccumulation. Even though many of the compounds, which belong to OC were banned in developed countries, the use of these agents has been rising. This concerns particularly abuse of these chemicals, which is in practice across the continents. Though insecticides have been developed with the concept of target organism toxicity, often non-target species are also affected badly by their application.

Organochlorine insecticides are classified into three subgroups:

- Dichlorodiphenyltrichloroethane (DDT)
- Chlorinated cyclodienes

- Hexachlorocyclohexanes (BHC, chlordane, lindane, mirex, and toxaphene)

In general, organochlorine insecticides are neurotoxic. Organochlorine, especially DDT is used for residual sprayings for the control of vectors of malaria (mosquito) and leishmaniasis (sand-fly).

5.3.1.1 Effects on human health and vectors

DDT and chlorinated benzene types of insecticides exert paraesthesia of the tongue, lips, and face; apprehension; tremors; and clonic-tonic convulsions (Jayaraj et al., 2016). Stimulation of the Central Nervous System (CNS) is the most prominent effect. The acute signs produced by cycloidienes include dizziness, nausea, vomiting, myoclonic jerking, motor hyperexcitability, convulsive seizures, and generalized convulsions. Organochlorines, in general, are considered to be endocrine-disrupting compounds, and some of them (methoxychlor; o, p′-isomers of DDT; dichlorodiphenyldichloroethylene (DDE); dichlorodiphenyldichloroethane (DDD); dieldrin; toxaphene and endosulfan) have been associated with estrogen like effects in the reproductive system of laboratory animals. Organochlorines are also identified as potential carcinogens.

5.3.2 Organophosphates

Organophosphates (OPs) are third-generation insecticides. OPs are chemical substances originally produced by the reaction of alcohols and phosphoric acid. OPs have two distinctive features: they are generally more toxic to vertebrates than other classes of insecticides and most of them are chemically unstable or non-persistent. It is this latter characteristic that brought them into agricultural use as substitutes for the persistent organochorines. OPs are also the main components of nerve gas. OPs such as malathion (25%WP), fenitrothion, pirimiphos-methyl, temephos and chlorpyrifos are used in vector control. Malathion and pirimiphos-methyl are used for space spray or fogging, whereas, fenthion and temephos are used as larvicides.

5.3.2.1 Effects on human health and vectors

Organophosphates, upon entering the body through ingestion, inhalation, or contact with skin inhibit cholinesterase, an enzyme in the human nervous system that breaks down acetylcholine, a neurotransmitter that carries signals between nerves and muscles. The enzyme is said to be phosphorylated when it becomes attached to the phosphorous moiety of the insecticide, an irreversible binding. This inhibition results in the accumulation of acetylcholine (ACh) at the neuron and muscle (neuromuscular) junctions or synapses, causing rapid twitching of voluntary muscles and finally paralysis.

5.3.3 Carbamates

Carbamate pesticides are N-methyl carbamates derived from carbamic acid (NH_2COOH). The functional group present in carbamate insecticides are carbamate esters. They are structurally and mechanistically similar to organophosphate insecticides. Carbamates cause carbonylation of acetylcholinesterase at neuronal synapses and neuromuscular junctions (Silberman et al., 2002). Their mechanism of action is by reversible inactivation of the enzyme acetylcholinesterase.

Carbamates break down in the environment within weeks or months (Goel & Aggarwal, 2007). In general, Carbamates show very low mammalian oral and dermal toxicity and an exceptionally broad spectrum of insect control. Carbamates along with other chemicals are used for the control of vectors of different diseases like malaria, dengue, leishmaniasis and Chagas disease.

5.3.4 Synthetic pyrethroids

Synthetic Pyrethroids (SP) are chemically similar to naturally occurring pyrethrin, extracted from pyrethrum of dried flowers of *Chrysanthemum*. SPs are considered as third-generation insecticides. Though they are analogs of pyrethrins, their production has involved extensive chemical modifications, which make them highly toxic and less degradable in the environment (Coats et al., 1990). The pyrethroids are grouped into two classes namely Type I and Type II, based on their toxicological and physical properties. Type I pyrethroids are derivatives of pyrethrin that do not have a cyano group and elicit

tumours and Type II pyrethroids have cyano group and cause choreoathetosis and salivation.

SPs are claimed to be selectively toxic to insects, however, they are extremely toxic to aquatic organisms, including fish in concentrations similar to those used for controlling mosquito, black fly and tsetse fly larvae, which are the actual targets. Pyrethroids are broad spectrum insecticides, effective against a wide range of insect pests. Prior to harvest, they are sprayed over edible products to control pests and are also used as household insecticides and grain protectants. They are employed in animal houses, fields, green houses and are extensively used in veterinary medicine. SPs are mainly used in Insecticide Treated Nets (ITNs) and space spray for the control of various vectors.

The modes of action of SPs resemble that of DDT, and work by keeping open the sodium channels in neuronal membranes. Pyrethroids affect both the peripheral and central nervous systems of the insect. They initially stimulate nerve cells to produce repetitive discharges and eventually cause paralysis.

Long-Lasting Insecticidal Nets

Long-Lasting Insecticidal Nets (LLINs) are used practically to prevent mosquito bites as a method of control of malaria and kala-azar vectors. LLINs are a highly effective means for preventing malaria infection and reducing associated morbidity and mortality particularly in endemic areas. In these nets, insecticide treatment is done at the industry itself during the process of manufacturing. The net fibres are treated with insecticide following two techniques:

- The insecticide is incorporated directly into the fibres and the insecticide diffuses to the surface with temperature and
- The insecticide impregnated with the net is protected by a chemical (resin) coating thereby withstanding repeated washes, and thus these nets are called Long-Lasting Insecticidal Nets.

The bio-availability of the insecticide on the surface of the net will be sufficient to be lethal to vector mosquitoes for extended periods (3 years). There are also collateral benefits to the users including personal protection from other haematophagous insects. Presently, NCVBDC distributes LLINs, to different malaria-endemic regions through states.

5.3.4.1 Effects on human health and vectors

Pyrethroids work by disrupting an insect's nervous system causing a weakened state followed by death. Pyrethroids affect the sodium channels and lead to paralysis of the organism. Pyrethroids have a comparatively slight level of mammalian toxicity and have a fast biodegradation quality (Thatheyus et al., 2013). Exposure to very high levels of the compounds in air, food or water may cause giddiness, headache, vomiting, muscle twitching, low energy, convulsions and loss of consciousness (Goel & Aggarwal, 2007).

Acute and sub-acute studies have shown the main effects of pyrethroids as neurotoxicity at high doses and liver hypertrophy, which are reversible if death does not occur. Many pyrethroids are mild to severe irritating to the skin and eyes and some cause facial skin sensitization. Suppression of the immune system and damage to the nervous system depends on the types of pyrethroids. The mutagenicity of pyrethroids is considered to be very low and only permethrin has been reported as a potential or weak carcinogen by the U.S. Environmental Protection Agency (EPA, 1979).

6. Genetic Control

Insecticides are preferred to control mosquito populations but the main disadvantages of using insecticides are (a) development of resistance (b) environmental pollution (Knipling et al., 1968). Several genetic modifications have been proposed, which are derived from mating based mechanisms known as “vertical transmission”. The mechanism is classified as:

- Self-sustaining genetic systems, which are intended to persist or spread invasively in the wild population
- Self-limiting, which means that it disappears rapidly unless it is being maintained in the environment
- Population suppression aims to reduce the number of vector mosquitoes in the target areas
- Population replacement is the strategy to reduce the ability of affected mosquitoes to transmit specified pathogens.

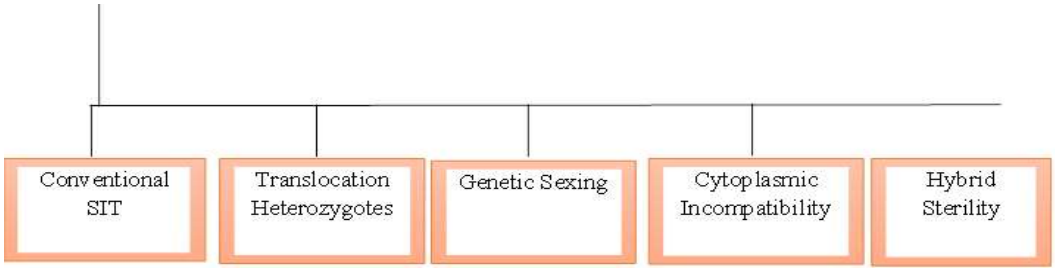


Figure- 20: Different types of genetic control methods

6.1 Sterile Insect Technique

The Sterile Insect Technique (SIT) depends on dominant lethal mutations transmitted by the released males into the eggs laid by their wild mates. The SIT is an eco-friendly insect pest control method involving mass-rearing and sterilization of target mosquitoes using radiation followed by the systematic area-wide release of the sterile males in defined areas, where they mate with wild females resulting in no offspring and a declining pest population.

It is one of the few available vector control tools with a proven record of vector elimination over large areas, including up to continental scales. Elimination of an obligate vector will interrupt transmission (Figure- 20).

- Conventional SIT
- Translocation heterozygotes
- Genetic sexing
- Cytoplasmic incompatibility
- Hybrid sterility

All of these types of induced sterility are potentially useful for insect control. The use of sterility based on sperminactivation has not been extensively explored but is nevertheless potentially useful. SIT is actively developed against vectors of zika, chikungunya, dengue and also against vectors of malaria**.**

6.1.1 Conventional SIT

Mosquitoes are mass-reared, pupae or adults less than 24 hours are sterilized by radiation or chemosterilants and released into the natural population (Baxter, 2016). The released sterile males compete with the wild males for mating. When the females mate with the

sterile males they do not produce any progeny thus, reduces the mosquito population. The field studies conducted using this method have limitations for field application due to compitation, fitness and fertility.

6.1.2 Translocation heterozygotes

It is the breakage of two non-homologous chromosomes and the reattachment of broken parts to inappropriate parts. The translocated heterozygotes are mass-reared and released into the field. The fertility of translocation heterozygotes reduces to 50% hence it is also known as semi-sterility. The advantage of this method is progeny surviving, such crosses also inherit the same translocation and in turn passes to their next generation.

6.1.3 Genetic sexing

Genetic sexing is the genetics-based separation of males from females of the same species. The classical Genetic Sexing Strains (GSS's) have been developed for various insects including anophelines and they rely on the linkage of a dominant selectable marker to the male determining chromosome. Linkage is accomplished by radiation-induced translocations followed by crossing and screening of the offspring. Resistance genes e.g., temperature-sensitive lethal genes and insecticide-resistance genes have been used as selectable markers. This strain was created by linking an insecticide (propoxur) resistance gene to the male chromosome and an inversion was induced to suppress further recombination and thus stabilize the strain. Females were removed from the population by treatment of the eggs with a discriminating dose of insecticide (Helinski et al., 2006).

6.1.4 Cytoplasmic incompatibility

Cytoplasmic incompatibility (CI) is the most widespread and perhaps, the most prominent feature that *Wolbachia* endosymbionts impose on their hosts. Cytoplasmic incompatibility results in embryonic mortality (EM) in mating between insects of the same species with different *Wolbachia* infection statuses. It can be either unidirectional or bidirectional. Unidirectional CI is typically expressed when an infected male mates with an uninfected female. Bidirectional CI usually occurs in mating between infected individuals

harbouring different strains of *Wolbachia* (Zabalou et al., 2004). Thus, reciprocal mating is fully compatible, as mating takes place between infected individuals. For example, crosses between some populations produce no offspring at all; while in other cases females of one population may cross with males of another population and offspring are produced, hence this reciprocal cross is completely sterile. Control can be achieved by mass rearing and release of males into an area populated by incompatible crossing types. A comparative cytoplasmic incompatibility exists in *Aedes* and can be used for genetic control in future.

6.1.5 Hybrid sterility

In some species of insects, there are a number of crossing-types or races, which produce fertile females but sterile males among their progeny. These sterile hybrids are outstanding material for use in insect control because though the males are sterile, they are probably to be competitive or even much more energetic than sterile males produced after radiation or chemosterilants treatment.

6.2 Refractoriness to disease transmission

It means the production of mosquitoes that are refractory to the development of the parasite and thus incapable of transmitting disease. Gene coding for the antibody against *Plasmodium* gamete is introduced (Benelli et al., 2005). When a mosquito gets infected, the gametes will be killed as soon as they are formed and interrupt the disease transmission. It is under trial and the current focus is on this technique. However, the use of genetic control for mosquitoes has achieved little success. The limitations are:

- Lack of mating competitiveness in released males
- Immigration of fertile females from regions close to the release sites
- Non-acceptability by the people

6.3 Population replacement using *Wolbachia*

Trans-infection comprises of transferring specific bacteria from their natural host to a new host. *Wolbachia endosymbiont* can result in stable novel infections causing two properties, which can be exploited in vector control as cytoplasmic incompatibility and pathogen interference (Figure- 21).

The Pathogen Interference (PI) strategy has been used successfully to modify local *Ae. aegypti* populations in pilot trials in Australia, even additional studies will be necessary to demonstrate the epidemiological impact of this modification, particularly on dengue transmission ((McGraw & O'Neill, 2013).

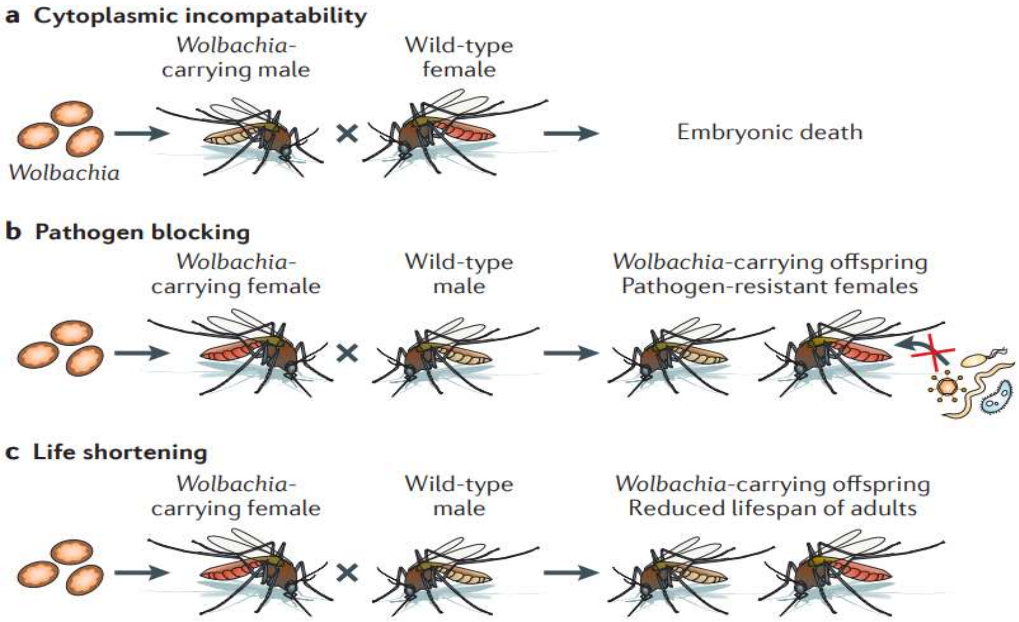


Figure- 21: Population replacement using *Wolbachia* (McGraw & O'Neill, 2013)

6.4 Release of Insects carrying a Dominant Lethal (RIDL) gene

RIDL comprises releasing mosquito males that have been genetically engineered to carry a dominant lethal gene (Gabrieli et al., 2014). The constraint of the lethal gene with the use of tetracycline as a dietary supplement has been the subject of analysis. Transgenic *Ae. aegypti* larvae are rescued from lethality by a diet supplemented with this antibiotic, but even in its absence, up to 3-4% of transgenic larvae survive to adulthood. A small description for the same is shown in Figure- 22.

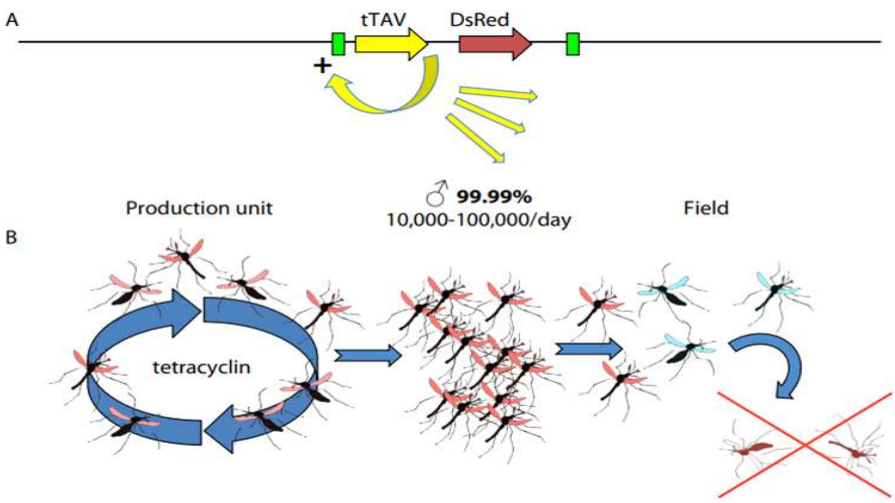


Figure- 22: Release of Insects carrying a Dominant Lethal gene (RIDL)

- Scheme of the transgene. The tetracycline activator variant (tTAV) protein binds to its promoter, activates its transcription and perturbs overall gene expression in the cells, resulting in mosquito death, unless tetracycline that binds and inactivates tTAV is provided.

- During mass rearing in the production unit, mosquitoes develop normally in the presence of tetracycline. For an intervention, males are sorted at the pupal stage (based on the smaller size of male pupae). Once released, they mate with wild females whose progeny will die due to unrestricted tTAV activity (Bouyer and Marois, 2018).

6.5 Gene silencing using RNA interference

Silencing precise gene expression through RNA interference in larvae proved to be

proficient in the lab to kill *Ae. aegypti* females with the aid of targeting the female-unique isoform of a sex determination gene (doublesex), concomitantly with testis-expressed genes, which produced a populace of mosquitoes that were both notably male-biased and sterile.

The potential of this mechanism is inherent in its mode-of-action viz. the subsequent degradation of complementary target mRNA upon entry of specific dsRNA into the cell (Agrawal et. al., 2003). Therefore, by delivering dsRNA targeting any endogenous gene transcript to the intended pest organism, the expression of this gene can be knocked down at the post-transcriptional level.

6.6 Other genetic approaches

Several types of population control involve the release of insects in the natural environment, which are not sterile, however, which could introduce factors into the natural population that could eventually lead to the decline of that population. There are serious restrictions on the release of non-sterile insects into the environment as there are many instances where this approach can be envisaged. For many vectors, the release of harmless males into a population at its low seasonal density could conceivably have beneficial results. Some examples of these genetic factors are:

a) Sex-ratio distorters

b) Detrimental genes incorporated into chromosomes, which have the meiotic drive

c) Males heterozygous for chromosome translocations

d) Insects bearing conditional lethal genes, which allow the parents to survive in the laboratory but which would be lethal to their descendants under field conditions

All of these genetic factors are known to exist in vector species but the search for these factors desired to be intensified. Furthermore, their role in population suppression ought to be assessed.

7. Insecticides used under NCVBDC

Under the National Centre for Vector-Borne Disease Control (NCVBD), insecticides are used based on certain epidemiological and entomological criteria. NCVBDC recommends the use of insecticides for Indoor Residual Spray, indoor/outdoor space spray, treatment of mosquito nets, larvicides for dengue, urban malaria, filaria and other vector control methods. Following (Figure- 23) are the different insecticides recommended for larval and adult control:

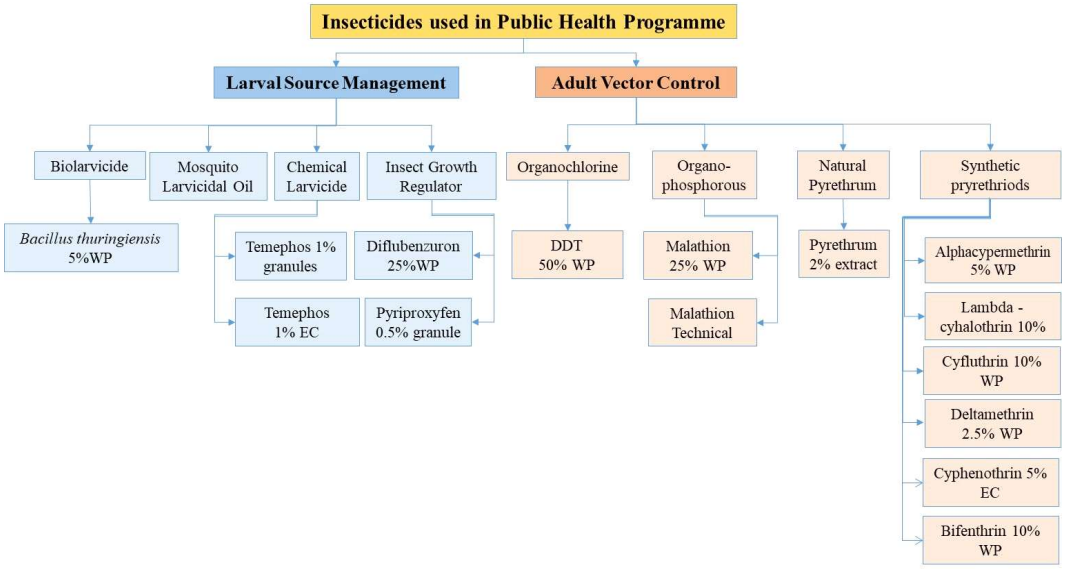


Figure- 23: Insecticides used in India for larval and adult vector control

7.1 Larval Source Management

Larval Source Management (LSM) 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 (WHO 2013). There are four types of LSM:

- **Habitat manipulation**: a recurrent activity, e.g., flushing of streams
- **Chemical control**: the regular application of biological or chemical insecticides to water bodies
- **Biological control**: control by using other organisms (Fish, bacteria)

Larviciding has to be done on weekly or fortnightly intervals to avoid the emergence of adults. Chemical larvicides are best used in situations where the disease and vector surveillance indicate the existence of certain periods of high risk and in localities where outbreaks might occur.

7.1.1 Mosquito Larvicidal Oil (MLO)

This oil was and continues to remain the classic larvicide. The oil not only suffocates but also poisons the mosquito larvae. Its action on larvae is due to causing suffocation by producing a surface film, which cuts off their supply of air, blocking respiratory tubes with particles of oil, and reduction of surface tension, making it difficult for larvae to remain at the surface and thus causing them to be drowned. The oiled breeding sources

tend to deter the adults from depositing their eggs. It kills all aquatic stages of mosquitoes.

7.1.2 Temephos 50% EC

The chemical name is O, O, O′, O′-Tetramethyl O, O′- Disulfanediylbis (1,4-phenylene) di-phosphonothioate. Temephos is an organophosphorus compound with very low mammalian toxicity. It is used as 50% emulsion concentrate in the programme (with a dose of 1 ppm). The product acts as a contact poison and has a prolonged residual effect.

7.1.3 Temephos 1% GR

One per cent Temephos sand granules are applied to containers using a calibrated plastic spoon to administer a dosage of 1 ppm. This is recommended for use in stored water like coolers etc. for control of vectors of dengue and chikungunya.

7.1.4 Insect Growth Regulators

Insect Growth Regulators (IGRs) interfere with the development of the immature stages of the mosquito by the interference with chitin synthesis during the moulting process in larvae or disrupting of pupal and adult transformation processes. Most IGRs have low mammalian toxicity. Two such compounds recommended by NCVBDC are Pyriproxyfen and Diflubenzuron.

7.1.4.1 Pyriproxyfen 0.5% GR

Pyriproxyfen (4-phenoxyphenyl (RS)-2-(2-pyridyloxy) propyl ether) is a broad-spectrum insect growth regulator with activity against a variety of insects. It mimics natural insect hormones that stop young insects from maturing into adults. This product Pyriproxyfen 0.5% GR is recommended for larval control.

7.1.4.2 Diflubenzuron 25% WP

Diflubenzuron is a benzoylurea-type insecticide of the benzamide class. Diflubenzuron is

a chitin synthesis inhibitor, which is another type of insect growth regulator. Unlike juvenile mimic hormones, the chitin synthesis inhibitors interfere with the normal synthesis of insect exoskeletons during moulting or at the hatching of eggs.

7.2 Adult Vector Control

Adult mosquitoes can spread diseases. When surveillance activities show that adult mosquito populations are increasing or they are spreading diseases, adulticides are used to kill adult mosquitoes to minimize the risk of disease transmission. There are different adult vector control methods, out of which insecticidal residual spray is one of the most cost-effective control measures for malaria and Kala-azar in India. The objective of IRS is to interrupt transmission by reducing the numbers of infective vectors. This can be achieved by ensuring the safe and correct application of the insecticide to indoor surfaces of houses and animal shelters. For malaria, only human dwellings are covered, whereas, both human dwellings and animal shelters are covered for kala-azar. The success of IRS operations depends on planning and implementation. IRS planning should be made, based on the capacity for achieving complete and uniform coverage. When there are resource constraints, it is preferable to limit the size of the operation and achieve quality coverage. Other methods like LLINs, Indoor space spray, Outdoor fogging are also recommended.

Presently different formulations of synthetic chemical insecticides are in the use for vector control. For Indoor Residual Spraying, the following insecticides are in use - DDT 50% WP (under phased-out process with little use), Malathion 25% WP and Synthetic Pyrethroid (SP), which includes deltamethrin 2.5% WP, cyfluthrin 10% WP, lambda-cyhalothrin 10% WP, alphacypermethrin 5% WP, etofenprox 10% WP and bifenthrin 10% WP.

7.2.1 Malathion 25% WP

Malathion is an organophosphate insecticide. The chemical name is (Diethyl [di-methoxyphosphino -thio] butanoate). In tropical areas such as India and Brazil, it is used in malaria control efforts as a residual insecticide that is applied to interior walls and

roofs (Singh et al., 2011a). Malathion is also one of the commonly used agricultural pesticides.

7.2.2 Synthetic pyrethroids

Commercial pyrethroid products commonly use petroleum distillates as carriers. Some commercial products also contain OP or carbamate insecticides because of the rapid paralytic effect of pyrethrins on insects. There are some new insecticides introduced for the control of vector-borne diseases in India. The cost of these insecticides is much higher than the cost of DDT and malathion. Pyrethroids are formulated as emulsifiable concentrates, wettable powders, granules, and concentrates for ULV application. Currently, following insecticides are being under the programme.

- **Deltamethrin 2.5% WP**

Deltamethrin is a pyrethroid composed of a single stereoisomer, of possibly 8 stereoisomers, selectively prepared by the esterification of (1R,3R)- or cis-2,2-dimethyl-3-(2, 2- dibromo vinyl) cyclopropane carboxylic acid with (alpha S)- or (+)-alpha-cyano-3-phenoxy benzyl alcohol or by selective recrystallization of the racemic esters obtained by esterification of the (1R,3R)- or cis-acid with the racemic or (alpha R, alpha-S, or alpha-R/S)- or + or – alcohol. The chemical name is [(S)-Cyano- (3-phenoxyphenyl)-methyl] (1R,3R)-3-(2,2-dibromoethenyl)-2,2-dimethylcyclopropane-1-carboxylate.

- **Cyfluthrin 10% WP**

Cyfluthrin is a pyrethroid insecticide and a common household pesticide. It is a complex organic compound and the commercial product is sold as a mixture of isomers. The chemical name is [(R)-cyano- [4- fluoro-3-(phenoxy) phenyl] methyl] (1R,3R)-3-(2,2-Dichloroethane)-2,2- dimethylcyclopropane-1-carboxylate.

- **Lambda-cyhalothrin 10% WP**

Lambda-cyhalothrin is a mixture of isomers of cyhalothrin. Lambda-cyhalothrin is available as 10% wettable powder in pre\weighed sachets. The chemical name of lambda-cyhalothrin is (RS)-alpha-cyano-3-phenoxybenzyl3-(2-chloro-3,3,3-trifluoropropenyl)-2, 2, - dimethyl cyclopropane carboxylate.

- **Alphacypermethrin 5% WP**

Alphacypermethrin is a synthetic pyrethroid. Alphacypermethrin is the common name accepted by the International Organization for Standardization (ISO) for racemate comprising of two isomers R and S of Cyano-(3-phenoxyphenyl) methyl (1R)-cis-3-(2-2 di-chlorovinyl)- 2- 2-dimethyl-cyclopropane carboxylate.

- **Bifenthrin 10% WP**

Bifenthrin is a pyrethroid insecticide with the chemical name- 2-Methyl-3-phenylphenyl) methyl (1S, 3S)-3-[(Z)-2-chloro-3, 3, 3- trifluoroprop-1-enyl]- 2,2-dimethylcyclopropane-1-carboxylate. Bifenthrin 10% WP is also approved for public health use in India under IRS.

7.2.2.1 Space Spray

- **Pyrethrum extract 2%**

It is the oldest effective insecticide that has been used in several countries. Its safety for use is unparallel and has been used as anthelmintic and also introduced in urban water supply with non-toxic hazards to the consumer. Pyrethrum is a contact poison. The active ingredients are pyrethrins. It may be formulated as a solution, emulsion, dust or granules. Pyrethrum extract is the extract of commercial pyrethrum flowers (*Chrysanthemum cinerariifolium* L.) in a mineral oil with or without a minute quantity of added anti-oxidant but without a synergist. It is a clear transparent liquid free from sediment, suspended matter or other extraneous impurities, greenish and possesses the characteristic odour of pyrethrum flowers. Used for indoor space spray (WHO, 2003).

- **Cyphenothrin 5% EC**

Cyphenothrin[cyano-(3-phenoxyphenyl) methyl]2,2-dimethyl-3-(2-methylprop-1-enyl) cyclopropane-1-carboxylate is a synthetic pyrethroid insecticide and has been registered for use to control cockroaches, houseflies and mosquitoes in houses. This is used for indoor and outdoor fogging.

- **Malathion Technical**

Five parts of Technical Malathion (95%) is mixed with 95 parts of Diesel (1:19 Tech. Malathion & Diesel v/v i.e. 5% solution) is used in vehicle-mounted or portable thermal fogging machine with 6 (5-8) km/hour (http://nvbdcp.gov.in/) speed of the vehicle/operator for outdoor fogging. Outdoor fogging is recommended only for epidemic control and not as routine practice.

7.2.3 Long-Lasting Insecticidal Nets (LLINs)

LLINs are nets that are treated by a process that binds or incorporates insecticide into the fibres. They are designed to maintain their biological efficacy against vector mosquitoes for at least 3 years under recommended conditions of use in the field, obviating the need for regular insecticide re-treatment. The use of long-lasting insecticidal nets (LLINs) is a widely implemented and cost-effective public health intervention tool for malaria control and prevention in most malaria-endemic countries. Long Lasting Insecticidal Nets (LLINs) are being promoted by WHO and roll-back malaria partners as a cost-effective and sustainable method for protection against malaria, these are nets treated in the factory with an insecticide incorporated into the net fabric, which makes the insecticide last at least for 20 washes in standard laboratory testing and three years of recommended use under field conditions. With LLINs therefore, the time-consuming method of retreating old nets is no longer necessary (WHO, 2001). Though LLINs have limited utility in dengue control due to day biter vectors. However, it can be effectively utilized to protect those who are infected or sleep during the day like infants, pregnant women, old members of house, who stay at home during the day and night shift workers, who sleep during the day.

Distribution of LLINs

The type of bed nets that can be provided depends on the brands registered in India and the supply situation. NCVBDC will inform the states about the expected effective life of the types of nets provided each year and any specific requirements. It is assumed that an average household has 5 members (2 adults and 3 children). It is then possible for one LLIN to cover on average 1.8 persons (2 adults or 3 children or 1 adult plus 1-2 children). Thus, for a given village the number of LLINs to be provided is usually equal to the number of households multiplied by 2 or the total population divided by 1.8.

This will normally ensure a sufficient quantity for the following schedule from NCVBDC guidelines.

1-2 persons: 1 LLIN

3-5 persons: 2 LLINs

6-7 persons: 3 LLINs

8-10 persons: 4 LLINs

7.2.4 Indoor Residual Spray (IRS)

IRS is the application of long-acting chemical insecticides on the walls and roofs of all houses and domestic animal shelters in a given area, in order to kill the adult vector mosquitoes that land and rest on these surfaces. The effectiveness of IRS as a malaria control intervention arises from the fact that many disease transmitting vectors are considered “endophilic”; that is, the mosquito vectors rest inside houses after taking a blood meal. These mosquitoes are particularly susceptible to control through Indoor Residual Spray (IRS). It is a core vector control intervention that can rapidly reduce disease transmission. It involves the application of a long-lasting residual insecticide to internal walls and ceilings of housing structures and animal shelters where potential disease vectors may come into contact with the insecticide while resting. For several months, the insecticide will kill mosquitoes and other insects that come in contact with these surfaces (NVBDCP, 2007 & 2012).

IRS does not directly prevent people from being bitten by mosquitoes. Rather, it usually kills or reduces the life span of mosquitoes, which come to rest on the sprayed surface after feeding. IRS thus prevents transmission of infection to other persons. When a vector comes into contact with a sprayed surface, it absorbs a lethal dose of insecticide, thereby reducing its lifespan. This results in a progressive decline in vector density and longevity, especially among older female mosquitoes, and a reduction in overall vectoral capacity, thereby contributing to a reduction in disease transmission. IRS is most effective against indoor feeding (endophagic) and indoor resting (endophilic) vectors**.** The objectives of IRS are to reduce and ultimately interrupt, disease transmission by reducing vector

survivorship, density, and human-vector contact, in a manner that is safe for human health and the environment. Specific objectives are as below:

- To reduce the vector's lifespan to less than the time it takes for the sporozoites to develop. In this way, the vector can no longer transmit parasites from one person to another.
- To reduce vector density by immediate killing. In some situations, particularly with *Anopheles* (in the case of malaria), IRS can lead to the local elimination of important malaria vectors.
- To reduce human-vector contact through a repellent effect, thereby reducing the number of mosquitoes that enter sprayed rooms.

7.2.5 Indoor space spray

Space spray is recommended for control only in emergency situations to suppress an ongoing epidemic or to prevent an incipient one. The objective of space spray is the massive, rapid destruction of the adult vector population. Any control method that reduces the number of infective adult mosquitoes, even for a short time should reduce parasite/pathogen transmission during that time, but it remains unclear whether the transient impact of space treatment is epidemiologically significant in the long run. Effective space spray is dependent upon the following specific principles:

- Target insects are usually flying through the spray cloud (or are sometimes impacted while resting on exposed surfaces). The efficiency of contact between the spray droplets and target mosquitoes is therefore crucial. This is achieved by ensuring that spray droplets remain airborne for the optimum time period and that contain the right dose of insecticide. These two issues are largely addressed by optimizing the droplet size.

- If droplets are too big, they drop to the ground too quickly and don't penetrate vegetation or other obstacles encountered during application (limiting the effective area of application). If one of these big droplets impacts an individual mosquito

then it also ‘overkills’ since a high dose will be delivered per individual mosquito.

- If droplets are too small then they may either not deposit on a target insect (no impact) due to aerodynamics or they can be carried upwards into the atmosphere by convection currents.

- The optimum sizes of droplets for space-spray application are droplets with a Volume Median Diameter (VMD) of 5–15 microns.

7.2.6 Outdoor fogging

An outdoor spray, technically a fog is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 0.5-15 μm in diameter. These droplets are intended to be distributed through a volume of air over a given period. Space spraying is the outdoor spray of insecticides to kill adult mosquitoes. These droplets deliver a lethal dose of insecticide to target mosquitoes upon impact. It is only effective when the droplets remain airborne. Space sprays are applied mainly as thermal fogs or cold fogs. The traditional methods for generating a space spray include thermal fogging (whereby a dense cloud of insecticide droplets is produced, giving the appearance of a thick fog) and Ultra Low Volume (ULV), whereby droplets are produced by a cold, mechanical, aerosol-generating machine.

Since large areas cannot be treated at any given time, this method is a very effective way to rapidly reduce the population of flying mosquitoes in a specific area. As there is no residual activity from the application. This method can be particularly effective in epidemic situations, where a rapid reduction in mosquito numbers is required. The insecticide is dispersed using a hand-held or vehicle-mounted equipment to produce the fog.

- **Thermal fog**

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. Most of the droplets are smaller than 20 μm. The droplet size is affected by the interaction between the formulation, the flow rate and the temperature of the nozzle (usually > 500°C). The volume of spray mixture applied in vector control is usually 5-10 litres per hectare, with an absolute maximum of 50 litres per hectare (WHO, 2013). The hot emission gas is obtained from engine exhaust, friction plate/engine exhaust or a pulse jet engine.

Advantages

- Easily visible fog so dispersal and penetration can be readily observed and monitored
- Low concentration of an active ingredient in the spray mixture and reduced operator exposure
- The visual effect for Community satisfaction as people can see the fog

Disadvantages

- Large volumes of organic solvents are used as diluents, which may have a bad odour and can result in staining
- High cost of diluents and spray application
- Householders may object and obstruct the penetration of fog into houses by closing windows and doors
- Fire risk from machinery operating at very high temperatures with flammable solvents
- Can cause traffic hazards in urban areas
- **Cold fog**

In cold fogging, 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 are fitted with high-speed rotary nozzles and the spray droplets are generated without any external heat. With cold fogs, the volume of spray is kept to a minimum. Ultra-Low-Volume insecticide formulations are commonly used for such applications.

Advantages

- Amount of diluent is kept to a minimum resulting in lower application costs and increased acceptability
- Some formulations are ready to use, thereby reducing operator exposure
- Water-based and water-diluted formulations can be used, which pose a low fire hazard and are comparatively safe
- Application is more efficient due to the application of a lower volume of liquid.

Disadvantages

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

8. Equipment for Larviciding and Adulticiding

Under NCVBDC various insecticide mechanical application tools are being practised for IRS, Larviciding and Space Spray.

8.1 Knapsack sprayer

This type of sprayer is suitable for applying chemicals to several field crops but it can also be used to spray breeding sites with larvicides. Knapsack sprayer is flat or bean-shaped, which consists of a pump and air chamber permanently installed in a 9 to 22.5 litre tank (Figure- 24). A frame or shield prevents contact between the tank and the back. The person maintains pressure in the tank by pumping air with a lever with one hand and directing the spray lance with the other. The handle of the pump extending over the shoulder or under the arm of the operator makes it possible to pump with one hand and spray with the other. The pressure developed in these sprayers depends on the pump and varies from 3 to 12 kg/cm^2. The application rate is 500 lit/ha. The coverage is 0.5-1.0 ha/day.

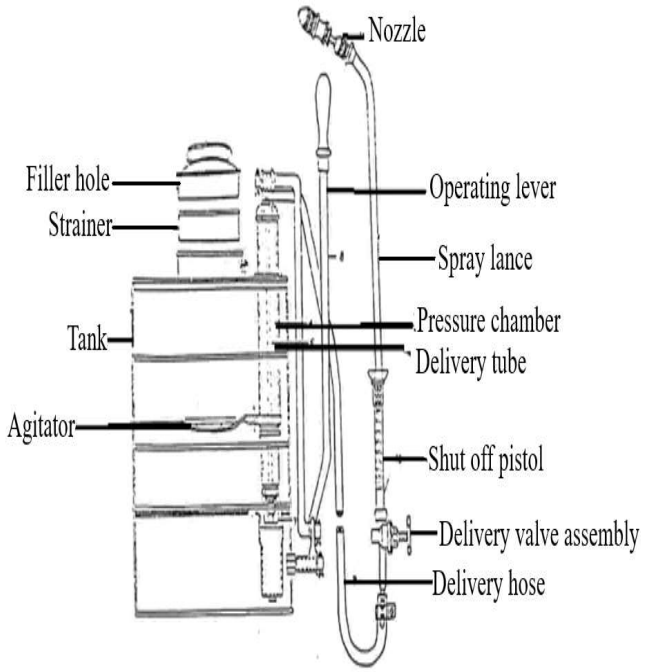


Figure- 24: Knapsack sprayer (Source: WHO)

8.2 Stirrup pump

The pump is mounted on a footrest or stirrup and is inserted in the spray liquid in a bucket (Figure- 25). A hose attached to the pump leads to the spray lance. Two persons are needed, one to pump and one to direct the spray.

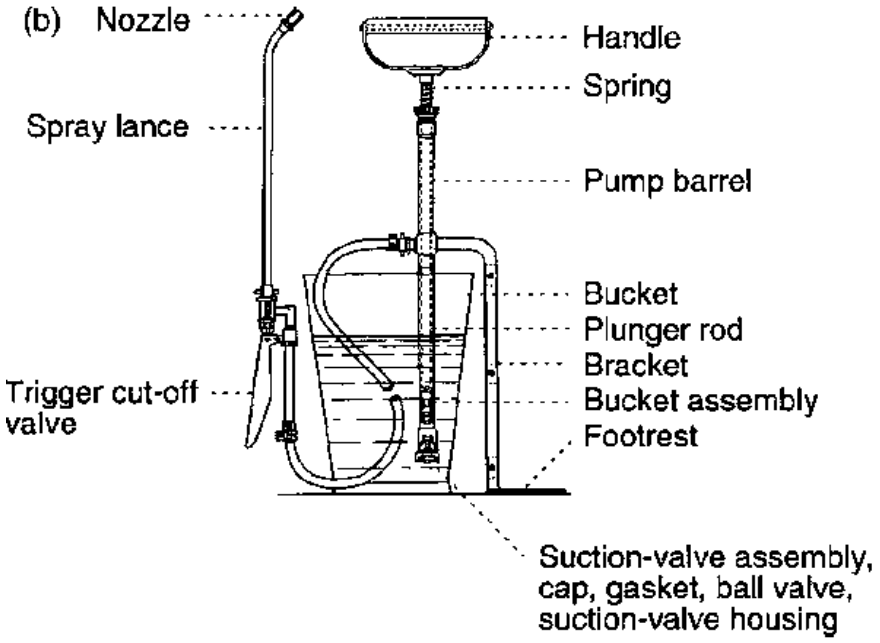


Figure- 25: Stirrup pump (Source: WHO)

The pressure varies with the speed of pumping, and so it is difficult to make uniform spray applications. Because of their inaccuracy and because of the risk of spilling insecticide from the open bucket inside houses, stirrup pumps are not recommended. They should not be used with hazardous pesticides**.** These pumps are being used in vector control and are traditional equipment. The sprayer is provided with 5-metre delivery pipe. The field capacity of the sprayer is 0.3 ha/day.

8.3 Hand compression pump

These sprays (Figure- 26) are usually considered the standard equipment for residual spray. The best-adapted type of sprayer that is recommended by the WHO, consists of a

cylindrical tank with a capacity of 10 litres, in which the insecticide solution is compressed by an air pump and projected evenly through a lance, on the end of which is a slit nozzle. A pressure gauge on the tank indicates whether the correct pressure (from 25 to 55 psi) is being used during spraying. If there is no pressure gauge, the number of strokes of the pump needed to produce a correct initial flow will have to be determined and monitored during the spraying. Tank pressure drops during spraying, resulting in a decrease in flow, a wider angle of spray, and an increase in the size of the droplets. When this happens, the tank needs to be pumped again, which is the disadvantage of this sprayer. Now a days lance is fitted with a control flow valve (CFV) to maintain uniform discharge (Rozendaal, 1997).

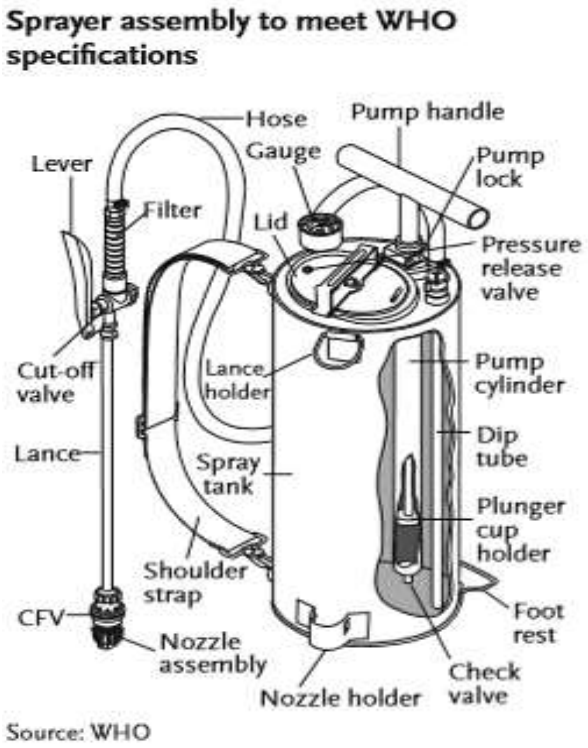


Figure- 26: Hand compression sprayer (Source: WHO)

For operation, the tank is filled up to 3/4th of its capacity and pressurized by a hand plunger pump, which remains inside the tank or from a compressor. The pressure inside the tank is usually maintained at 3-4 kg/cm^2. The operator mounts the sprayer on his back securing it by shoulder straps and operates the trigger valve, which enables the spray liquid to flow through the lance and nozzle.

8.3.1 Nozzle

The solid or Jetstream nozzle is used to treat cracks and crevices to control bedbugs, soft ticks, cockroaches and ants.

- Flat-spray nozzle delivers a fan-shaped spray and is preferred for residual wall-spraying
- Hollow-cone nozzle is used to spray mosquito breeding sites and ticks and mites habitats in vegetation
- Solid-cone nozzle is used to spray mosquito breeding sites (Figure- 27).

The flat-spray nozzle steel or ceramic is commonly used for wall-spraying (WHO recommends nozzle 8002E) and produces a spray with an angle of 80° emits 550 ml per minute at a standard 150 Kpa (1.5 bar) pressure through CFV or 650 ml/min at a 200Kpa (2 bar) pressure (WHO, 2015). The nozzle tip is designed with flat surfaces on either side of the orifice so that it can be removed easily.

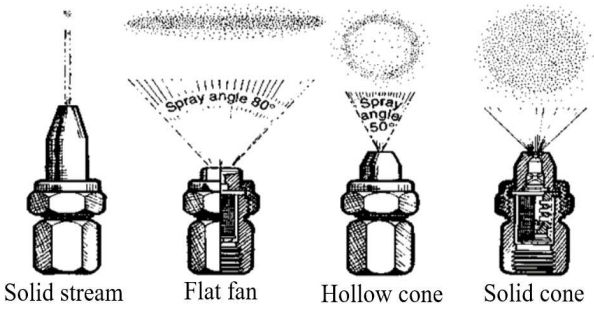


Figure- 27: Types of nozzles (Source: WHO)

8.4 Fogging machine

In such devices, insecticide is dissolved in an oil of reasonably high flashpoint, which is vaporized into a high-velocity stream of hot gas. At the point of discharge into the atmosphere, the mixture containing insecticide condenses in the form of fog. When droplets smaller than 15 μm fill a volume of air to such an extent that visibility is reduced, the air is termed as fog. Usually, thermal fogging machines are used to create fog in which pesticide dissolved in oil of suitable flash point is injected in the hot gases produced by burning the fuel. The fogging machine consists of a fuel tank/reservoir, formulation tank, pump, fogging nozzle, fogging coil, water pump and other controls (Figure- 28).

There are two basic methods, which are employed for the production of fog. In one sort, the mixture is injected into the exhaust gas of a pulse-jet (Thermal fogger portable) internal combustion engine at a point it will be completely vaporized and then right away discharged. This is utilized generally for hand operating machines. In other vehicle mounted method, petrol is burnt and constantly supplied with a large volume of heated air at low pressure making a dense fog.

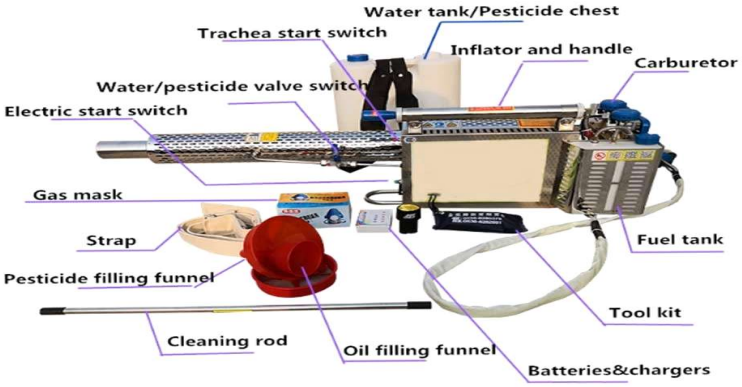


Figure- 28: Fogging machine

8.4.1 Portable thermal fogging machine

A portable thermal fogging machine has a thermal energy nozzle into which the insecticide liquid (both oil and water miscible formulations) is metered (Figure- 29). The main components shall be mounted on a robust frame. If required, the machine shall be provided with a battery starting mechanism consisting of batteries, ignition coil, a spark system and a small manually or battery-operated air pump to pressurize the fuel line when starting the machine. All hot surfaces must be adequately guarded to avoid burn injury to the operator. There should shall be no sharp edges that might injure workers during normal operation. All parts that are regulated while operating the equipment should be permanently and identifiably marked. The sprayer shall have clearly visible safety instructions on the machine to warn operators not to leave a fogging machine unattended while in operation.

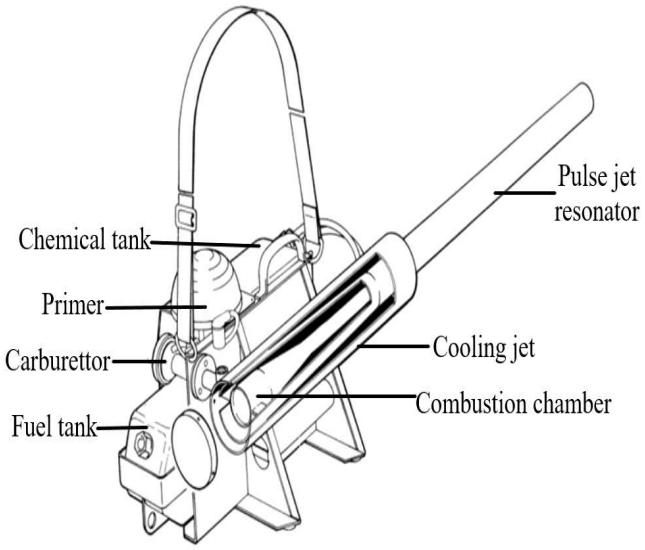


Figure- 29: Portable fogging machine

8.4.2 Ultra-Low Volume (ULV)

ULV involves the application of a small quantity of concentrated liquid insecticides. The use of less than 4.6 litres/ha of an insecticide concentrate is usually considered as an ULV application. ULV is directly related to the application volume and not to the droplet size. Nevertheless, droplet size is important and the equipment used should be capable of producing droplets in the 10 to 15-micron range, although the effectiveness changes little

when the droplet size range is extended to 5-25 microns. Aerosols, mists and fogs may be applied by portable machines, vehicle-mounted generators or aircraft equipments (Figure-30).

Figure- 30: ULV fogging machine

8.5 Vehicle mounted generators

Vehicle-mounted aerosol generators can be used in urban or suburban areas with a good road system (Figure- 31). One machine can cover up to 1500-2000 houses (or approximately 80 ha) per day. It is necessary to calibrate the equipment, vehicle speed, and swath width (60-90m) to determine the coverage obtained by a single pass. A good map of the area showing all roads is of great help in undertaking the application. An educational effort may be required to persuade the residents to cooperate by opening doors and windows. The speed of the vehicle and the time of day of application are important factors to consider when insecticides are applied by ground vehicles. The speed of the operator/vehicle should be 6 (5-8) kms/hour When the wind speed is greater than 16 km/h or when the ambient air temperature is greater than 28˚C, the insecticide should not be applied. The best time for application is the early morning (approximately 06.00-08.30 hrs) or evening (approximately 17.00-19.30 hrs) (NVBDCP, 2015).

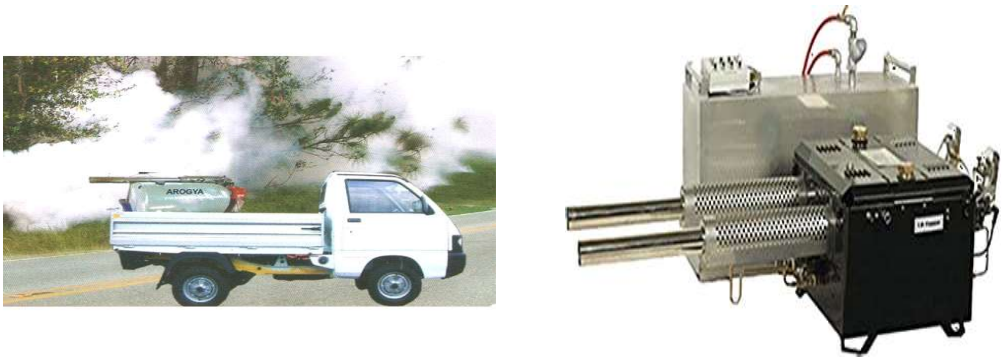


Figure- 31: Vehicle mounted fogging machine

8.5.1 Vehicle-mounted thermal fogging machine

Large thermal fog generators use an air-cooled motor to run an air blower, fuel pump and insecticide pump. Air from the "roots type air blower" is delivered into the combustion chamber. There it is mixed with gasoline vapour and ignited, so that temperatures reach 426–648°C. The diluted insecticide liquid is pumped via a simple flow delivery valve and injected into a cup in the fog head or directly into the nozzle. The insecticide liquid is vaporized by the hot gases.

Despite this high temperature, trials with some insecticides recovered at the jet tip show very little degradation of active ingredient. This is because the time spent at that temperature is only for a fraction of second, which is not long enough to cause serious degradation. The hot gases then pass out of the machine. As the hot oil vapour is discharged through a relatively large nozzle into the cooler outside air, it condenses to form very small droplets of thick white fog. Delivery rates of up to 10 litres per minute can be achieved with larger machines.

8.5.2 Vehicle-mounted cold fogging machine

A 5–20 hp 4-stroke gasoline engine is used to drive a high-volume air blower, forcing air at a rate of approximately 6 m^3 per minute at low pressure (50kPa) to one or more nozzles (WHO, 2013). The angle of projection of the cold fog from these nozzles can be adjusted.

The pesticide container may be pressurized to force the formulation to the nozzle, or positive-displacement pumps may be used.

Positive-displacement pumps are used, which can be linked electrically to the vehicle in order to vary output as a function of vehicle speed. In particular, spraying ceases when the vehicle stops. Alternatively, a high-pressure, low-volume air source is used with an air compressor, rather than a blower. On these machines, nozzles ranging from the standard industry "paint gun nozzle" to proprietary nozzles that atomize well up to a flow rate of 0.5 litre per minute are available. Another design uses a rotary nozzle coupled with an electric motor, which operates at a very high speed (Figure- 32).

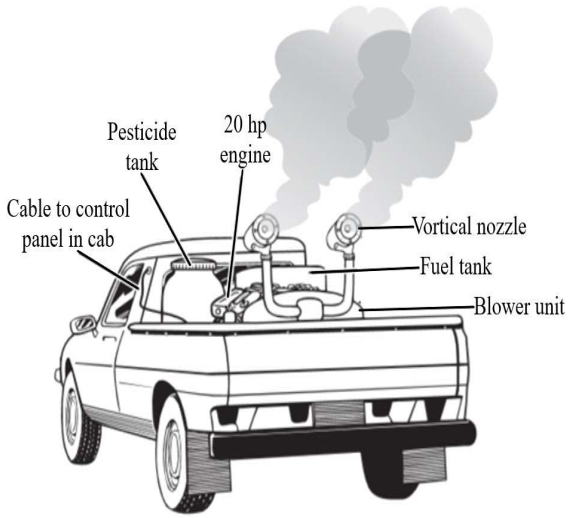


Figure- 32: Vehicle-mounted cold fogging machine (WHO, 2003)

9. Alternatives to DDT Developed by UNIDO for Vector Control

Botanicals have widespread insecticidal properties and will obviously work as a new weapon in the arsenal of synthetic insecticides and in future may act as suitable alternative product to fight against vector-borne diseases. Importance was given on the application of alternative strategies in mosquito control under the Integrated Mosquito Management (IMM). Development of resistance in vector species has been observed due to continuous application of synthetic insecticides. Toxic substances through the food chain and its adverse effects on environmental quality and non target organisms including human health has also been recorded. Application of active toxic agents from plant extracts as an alternative for mosquito management was available from ancient times. Insecticidal effects of plant extracts vary not only according to plant species, vector species, geographical varieties and parts used, but also upon extraction methodology adopted and the polarity of the solvents used during extraction. A wide selection of plants from herbs, shrubs and large trees is used for extraction of toxins. Phytochemicals are extracted either from the whole body of little herbs, large plants and trees or from various parts like fruits, leaves, stems, bark, roots etc.

9.1 Neem based products

The neem plant (*Azadirachta indica*) and its derived products have shown a variety of insecticidal properties on a broad range of insect species. Neem products exhibited a wide range of effects that are potentially useful for malaria control and include antifeedant, ovicidal activity, fecundity suppression, insect growth regulation and repellency. These effects are frequently attributed to the azadirachtin active ingredient of the products (Ghosh et al., 2012).

Larval control using neem seed powder offers a sustainable additional tool for malaria vector control. The most effective way to use is to apply seed extract/neem oil to breeding sites when larval population are comparatively lower, during the dry season, in order to eradicate as many immature mosquitoes as possible and reduce the population available

for breeding when conditions become more favourable. Once the rainy season commences, regular applications of seed extract/neem oil should continue to prevent immature mosquitoes from emerging as adults. Considering the wide distribution and availability of neem and its products along the country, this may prove as a readily available and cheap alternative as conventional larvicides (Gianotti R. L. et al., 2008).

Global Environmental Fund (GEF) initiated the project with the objective "To introduce bio-and botanical pesticides and other locally appropriate cost-effective and sustainable alternatives to DDT as first step for reduction and eventual elimination of dependency on DDT, ensuring food safety, enhancing livelihood and protecting human health and the environment" and assigned to UNIDO (United Nation Industrial Development Organisation) under project component "Alternatives to vector control" for expected component 'Gradually decreased use of DDT on the basis of availability of locally appropriate cost-effective and sustainable alternatives to DDT ready for enhancement to large scale production'. With UNIDO support five formulations of neem have been developed viz. Suspension Concentrate (SC), Spreading Oil (SO) formulation, tablet formulation, neem mosquito coil and neem cream (Personal protection).

9.1.1 Neem based spray/IRS

Indoor Residual Spraying with adulticide is one of the effective vector control tools. In India, it is extensively used for the control of malaria and Kala-azar. Indoor resting (endophilic) mosquitoes effortlessly pick up the lethal dosage of insecticide through their tarsal contact and such lethal contact reduces the longevity of the infected vectors resulting in the interruption of disease transmission.

At present, UNIDO has developed neem Suspension Concentrate (SC), which may be used for indoor spray to repel mosquitoes but neem-based adulticide product or its formulation for IRS is under progress for commercial production.

9.1. 2 Neem based larvicides

Larvicides are used for vector control under disease control programmes. It includes

chemical larvicides, bio-larvicides and IGRs. These compounds are generally nerve poisons and inflict mortality of mosquitoes at immature stages.

Larval control using neem-derived products offers a sustainable additional tool for malaria vector control. The efficacy of neem seed extracts has shown to degrade under exposure to sunlight within seven days and thus the toxicity is non-persistent in the environment. This not only provides environmental benefits but also means that regular applications of neem seed extracts would be required to maintain efficacy. Neem oil has good larvicidal properties for anophelines and suppresses successful adult emergence at very low concentrations.

Formulations such as Emulsifiable Concentrate (EC), Suspension Concentrate (SC) liquids etc. shall be applied to the habitats using a knapsack sprayer/ hand compression sprayer for which a prototype can be developed using NCVBDC guidelines to handle and to use insecticides. Other formulations such as granules, pellets, tablets and briquettes can be manually broadcasted or thrown into the water.

The impact of the larvicidal treatment is responsible to lower the density of adult mosquitoes resting indoors (human dwellings/ animal sheds), which can be measured by using hand catch method. This process provides information on the trend in the reduction of adult population of target mosquito species due to the effect of the larvicidal application.

Neem based larvicidal formulations developed by UNIDO such as Suspension Concentrate, spreading oil and tablet formulation have been developed and scaled up. Suspension Concentrate formulation at 2.5% concentration and spreading oil formulation at 0.16% concentration resulted in optimum larvicidal effect. The doses will be further optimized during bio-efficacy data generation for registration.

Effect on non-target organisms

The immediate predator of mosquito larvae is *Poecilia* fish (*Poecilia reticulata*) and the neem oil did not have any detrimental effect on longevity and survival of *Poecilia* fish.

According to the several studies as referenced below, neem is found safe towards this fish and other non-target organisms including tadpoles and *Gambusia affinis*.

9.1.3 Neem based repellents (coils, liquid & cream)

Neem based repellents can be used for personal protection against mosquitoes and other hematophagous insects. Neem based products viz. Neem mosquito coil and neem cream are good repellents. They can be used for personal protection against mosquitoes and other hematophagous insects.

Neem Repellent Cream: The cream applied on human hand skin @ 0.5 g/ 150 sq. cm gave optimum repellency lasting for 4-4.5 hours.

The neem-based coil developed by UNIDO, which has been tested in Peet-Grady chamber produced repellency with burning duration of 5.5-6 hrs.

- Protection time against the natural population of mosquito vectors and pest species-
- Cream: 4- 4.5 hrs; Coil: 5-6 hrs
- Effective dose-
- Cream: 0.5 g/ 150 sq. cm of skin, Coil: 1 coil/ room of up to approx. 10x10 ft. size
- Human safety (Safe for human use).

9.2 Long-Lasting Insecticidal Nets

UNIDO developed LLINs, manufactured and scale-up by HIL (India) Limited formerly known as Hindustan Insecticides Limited (HIL), a Govt. of India Enterprise. LLINs are a ready to use bed net, made from 100% Polyethylene (HDPE + LDPE), Alphacypermethrin (a.i.) 0.667% w/w insecticide is incorporated and CIB granted registration under section 9 (3b). They are strong, durable and will hold up well to everyday use and are wash resistant.

9.3 Bt based products

UNIDO developed Bt-based bio-larvicides, manufactured and scaled-up by HIL (India)

Limited. Three formulations viz. Suspension Concentrate (SC), Wettable Powder (WP) and spreading oil have been developed at pilot plant leve. Of these, technology for two formulations namely Aqueous Suspension (AS) and Wettable powder (WP) have been developed by ICMR-Vector Control Research Center (VCRC) under the project for commercial level scale up.

10. Glossary

Acetylcholinesterase

Acetylcholinesterase is a type-B carboxylesterase enzyme located primarily in the synaptic cleft with a smaller concentration in the extra junctional area.

Active ingredients

An active ingredient is the element or substance in an insecticide that gives repelling or killing power or biologically active.

Adulticides

Type of insecticides used to kill adult insects or pests.

Alkaloids

Cyclic organic compound containing nitrogen in a negative oxidation state, which is of limited distribution among living organisms.

Adult susceptibility test

Adult susceptibility bioassay is a direct response-to-exposure test; it measures mosquito mortality to a known standard dose of a given insecticide (*i.e.,* the diagnostic or discriminating concentration).

Advocacy

Advocacy is a process by an individual or group, which aims to influence public policy and resource allocation decisions within political, economic, and social systems and institutions. Advocacy can include many activities that a person or organization undertakes including media campaigns, public speaking etc.

Aerosol

An aerosol is a suspension of small particles in air or another gas.

A*f*I

Annual *falciparum* Incidence is calculated as total positive *Plasmodium falciparum* in a year x 1000 divided by total population.

Antibody

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

Antibiotic

Antibiotics are molecules that kill or stop the growth of, microorganisms, including both bacteria and fungi.

Anganwadi

It is a rural child care center in India, providing care for mothers and young children in a rural area.

API

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

Arbovirus

A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

ASHA

Accredited Social Health Activist (ASHA) is one of the key components of the national health mission (earlier national rural health Mission), which provides every village in the country with a trained female community health activist.

Aldrin

A brown, water-insoluble, toxic solid consisting of more than 95 percent of the chlorinated hydrocarbon C12H8Cl6: is used as an insecticide.

Alpha-cypermethrin

Alpha-cypermethrin is a pyrethroid insecticide consisting essentially of two of the four cis isomers comprising cypermethrin. Alphacypermethrin is a highly active broad-spectrum insecticide, effective by contact and ingestion against target pests.

Amastigotes

The nonmotile, parasitic form in the life cycle of some protozoans and especially

Leishmania that usually develops in the cells of vertebrate hosts and occurs as a minute, ovoid or spherical body with a prominent, rod-shaped kinetoplast and a rudimentary, internal flagellum arising from a basal body.

Amplifying hosts

It is a host in which infectious agents multiply rapidly to high levels, providing an important source of infection for vectors in vector-borne diseases.

Anthropogenic factors

Anthropogenic factors of the environmental changes influence the organic world and are introduced into nature by human activity. In reworking nature and adapting it to their own needs, people influence the lives of animals and plants by altering their habitats. The influence may be indirect or direct.

Anthropophilic

Anthropophilic is associated with humans or attracted to humans, especially for food sources.

Antibodies

Antibodies are substances, which are formed in the serum and tissue fluids in response to an antigen and react with that antigen specifically and in some observable manner.

Antigens

An antigen is a substance that, when introduced into a body evokes an immune response to produce a specific antibody with which it reacts in an observable manner.

API

The Annual Parasite Incidence (API) is a malariometric index to express malaria cases per thousand population. API refers to high and moderate malaria transmission risk areas.

Arbovirus

Arbovirus is an arthropod-borne virus. A virus that multiplies in a blood-sucking arthropod and is principally transmitted by the bite of arthropods to vertebrate hosts.

Arthropods

An animal of the phylum Arthropoda, characterized by the presence of a segmented body, an exoskeleton, jointed appendages, a dorsal blood vessel, a haemocoel and a ventral nerve cord.

Aspirator

It is a device to collect small insects and other invertebrates. The aspirator is having one tube through which they are sucked into the bottle, and another, protected by muslin or gauze, which sucks insects.

Autochthonous

Originating or formed in the place where found; indigenous.

Bacillus thuringiensis

Bacillus thuringiensis (Bt) is an aerobic, spore-forming, gram-positive, rod-shaped bacterium distributed widely in the natural environment. It's used to control mosquito larvae as known as larvicide or bacterial larvicide.

Bacteria

Bacteria are prokaryote single-celled micro-organisms with a simple nucleus intermediate in size between protozoa and rickettsia.

Bacterial larvicides

The bacteria like *Bacillus thuringiensis* var. *israelensis* and *Bacillus sphaericus* have been used extensively for mosquito control and be effective and safe for non-target organisms cohabiting with mosquito larvae.

Bait

Bait is the active placement or manipulation of edible or inedible items, to attract or distract potential prey, facilitating prey capture.

Bancroftian filariasis

Bancroftian filariasis is a disease caused by a nematode of the genus *Wuchereria*, that is transmitted in larval form by mosquitoes.

Behaviour Change Communication

The changes that the intended audiences are expected to make in their behaviour and the expected changes in the factors that influence behaviour such as knowledge, attitudes and perceptions.

BG-sentinel trap

The BG-Sentinel mosquito trap is essentially a collapsible, fabric container with a white lid with holes covering its opening. In the middle of the gauze cover, the air is sucked into

the trap through a black catch pipe by an electrical fan, drawing approaching mosquitoes into a catch bag.

Bioassay

Bioassays are methods that utilize living materials to detect substances or determine the potential toxicity of chemicals or contaminated matrices. They are widely used to screen for potentially hazardous chemicals in contaminated soils, potable and wastewater, foods, and other materials.

Biological control

Deliberate introduction of biological agents such as pathogens, parasites and predators (especially fish) to control arthropod population.

Bioaccumulation

Bioaccumulation is defined as the accumulation of chemicals in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, and pore water in the sediment

Biodegradation

Biodegradation means that the decaying of all organic materials is carried out by a huge assortment of life forms comprising mainly bacteria and fungi, and other organisms.

Botanical larvicides

The plant products used to kill or control mosquito larvae are called botanical larvicides.

Botanical pesticides

The plant products used to kill or control the pest are called botanical pesticides.

Bristles

A large seta or short stiff coarse hair or filament.

Brugia malayi

Brugia malayi is a nematode, filarial worm, one of the causative agents of Brugian filariasis in humans.

Canals

Canals are artificial (manmade) channels, generally regular in shape, which are constructed to convey water to the farm fields from a river or reservoir.

Capitulum

Anterior body of mites and ticks including the mouthparts (also commonly known as the gnathosoma).

Capsule suspension

Capsule suspensions are water-based slow-release formulations containing active ingredients encapsulated inside polymer microcapsules. The CS formulations are very useful to provide a prolonged effect for controlling target pests.

Carbamates

Synthetic insecticides are derivatives of carbamic acid, e.g., carbaryl and propoxur.

Carcinogens

The term "carcinogen" denotes a chemical substance or a mixture of chemical substances, which induce cancer or increase its incidence.

Chelicera

The paired piercing appendages present as mouthparts of mites and ticks.

Chemical control

The use of chemicals to disrupt the life cycle of vectors at different stages of their life cycle is known as chemical control.

Chemosterilant

Chemicals used to induce sterility, but not usually death, in arthropods to control them, e.g., *apholate* and *tepa*. Chemo Sterilized insects are sometimes used in the genetic control of insect vectors.

Chemoprophylaxis

Chemoprophylaxis is the administration of drugs to prevent the development of a disease.

Claws

A hooked structure curved at the end of the leg of an insect, which is usually paired.

Climate

Climate is the average weather condition of the earth's surface over a long period of time,

taking into account temperature, precipitation, humidity, wind, barometric pressure, and other phenomena.

Clypeus

Clypeus is the area of the facial wall of an insect's head between the labrum and the frons, usually separated from the latter by a groove.

Cocoon

Cocoon is the protective formation of the pupae of many insects. The cocoon is usually woven of silk thread secreted by the larva before pupation.

Cold fogs

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.

Collaboration

It is a process in which entities share information, resources, and responsibilities to jointly plan, implement and evaluate a program of activities to achieve a common goal.

Community

Community is a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings.

Communicable diseases

Communicable diseases spread from one person to another or from an animal to a person through any medium. The spread often happens via airborne viruses or bacteria, but also through blood or other bodily fluid.

Congenital malaria

Congenital malaria, occurring as a result of vertical transmission of parasites from mother to child during pregnancy or prenatally is a rare clinical condition. It occurs as a consequence of clinical attacks of malaria during pregnancy but also may be detected rarely in infants of asymptomatic women, where the diagnosis may be missed.

Concentration

The amount of solute dissolved in a unit amount of solvent.

Conventional SIT

Mass rearing of mosquitoes followed by manual sex separation to assure that exclusively males are to be sterilized by ionizing radiation and further released to mate with wild females resulting in no progeny.

Conjunctivitis

Conjunctivitis refers to any inflammatory condition of the Conjunctiva. It is the most common cause of "red eye". Virus and bacterial conjunctivitis is the most common cause of infectious conjunctivitis.

Crystal protein

Crystal proteins made by the bacterium *Bacillus thuringiensis* (*Bt*) are pore-forming toxins that specifically target invertebrates (insects and nematodes) and are generally innocuous to mammals.

Cytoplasmic Incompatibility

Cytoplasmic incompatibility occurs when factors in the cytoplasm of the two gametes are not compatible, resulting in the death of the zygote.

Death rate

Death rate or mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Definitive host

Host in which parasites reach to maturity. This rarely occurs in arthropod vectors, but the noted exception is the development of malarial parasites, involving sexual reproduction, in mosquitoes. See Intermediate host.

Degeneration

A morbid change consisting in a disintegration of tissue/in substitution of a lower form for a higher form of structure

Deltamethrin

Deltamethrin is an insecticide belonging to the pyrethroid family. Pyrethroids are man-made versions of pyrethrins, natural insecticides from chrysanthemum flowers.

Demography

Demography is the study of human populations with respect to their size, structure and

dynamics.

Dengue Virus (DENV)

The dengue virus (comprises four distinct serotypes- DEN-1, DEN-2, DEN-3 and DEN-4), which belonging to the Genus Flavivirus, family Flaviviridae.

Deutonymph

It is the second nymph stage of a mite.

Dieldrin

Dieldrin is an organochlorine compound resulting from the epoxidation (carbon-carbon double bond into oxiranes) of the double bond of aldrin. It is the active metabolite of the pro insecticide aldrin. It has a role as a xenobiotic and a carcinogenic agent. It is an organochlorine insecticide, an organochlorine compound and an epoxide. It derives from aldrin.

Diflubenzuron

Diflubenzuron is a direct-acting insecticide normally applied directly to plants or water against mosquito and noxious fly larvae.

Disability

A physical or mental condition that limits a person's movements, senses or activities.

Disease morbidity

Morbidity is the state of being symptomatic or unhealthy for a disease or condition. It is usually represented or estimated using prevalence or incidence.

Distribution

In epidemiology, distribution means the frequency and pattern of health-related characteristics and events in a population.

Dominant lethal

A dominant lethal mutation occurs in a germ cell and results in the death of the fertilized egg or developing embryo.

Dose

Dose is a quantity of an insecticide, medicine or drug taken or recommended to be taken or used at a particular time.

Ecological interrelationships

Ecological interrelationships describe the interactions between and among the organisms within their environment.

Ecology

Ecology is the study of the interaction between living organisms, including humans, and their physical environment.

Ecosystem

The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem.

Ecosystem integrity

Ecosystem integrity is defined as the system's capacity to maintain structure and ecosystem functions using processes and elements characteristic of its eco region.

Electric vaporizer

Electric vaporizers enable harmful flies and mosquitoes to be removed from indoor spaces owing to the vaporization of the natural and herbal volatile oils in liquid form by means of electricity.

Emulsifiable Concentrate

Emulsifiable concentrates are typically optically transparent oily liquid formulations that are prepared by dissolving a certain amount of pesticide in organic solvents (such as benzene, toluene, xylene and solvent oil), which may also contain surfactants and other additives. These systems are then diluted with water before application, which leads to the spontaneous formation of an oil-in-water emulsion that contains pesticides inside the oil droplets.

Emulsifiable concentration

Emulsifiable concentrates are typically optically transparent oily liquid formulations that are prepared by dissolving a certain amount of pesticide in organic solvents (such as benzene, toluene, xylene, and solvent oil), which may also contain surfactants and other additives.

Endemic

Endemic refers to the constant presence or usual prevalence of a disease or infectious agent in a population within a geographic area.

Endocrine disruption

An endocrine disruptor is an exogenous substance or mixture that alters the function (s) of the endocrine system and consequently causes adverse health effects in an intact organism, its progeny, or population.

Endophagic

An insect that feeds indoors..

Endophilic

Insects, such as some mosquitoes, tend to inhabit or rest indoors before or after blood-feeding.

Endosymbiont

Endosymbionts are organisms that form a symbiotic relationship with another cell or organism.

Endrin

Endrin is a white crystalline, odourless solid dissolved in a liquid carrier. It is water emulsifiable. Endrin is used as a pesticide to control insects, rodents, and birds.

Entomological surveillance

Periodic collection of data related to knowledge of local vector species and their susceptibility to insecticides, as well as on vector and human behaviors that may allow mosquitoes to avoid contact with interventions and thereby maintain residual transmission, which is essential to inform vector control strategies and track their impact on disease.

Entomology

Entomology is the science dealing with the scientific study of insects.

Environment

Environment is a complex of many variables, which surrounds man as well as living organisms. The environment includes water, air and land and the interrelationships, which exist among and between water, air and land and human beings and other living creatures such as plants, animals and microorganisms.

Environmental management

Environmental management consists of actual decisions and action concerning policy and practice regarding how resources and the environment is appraised, protected, allocated, developed, used, rehabilitated, remediated and restored.

Environmental Modification

A form of environmental management consisting in any physical transformation that is permanent or long-lasting of land, water and vegetation aimed at preventing, eliminating or reducing the habitat of vectors without causing an unduly adverse effect on the quality of the human environment.

Environmental protection act

The act relates to the protection and improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property. The Act is an “umbrella” legislation designed to provide a framework for central government coordination of the activities of various central and state authorities established under previous laws, such as the Water Act and the air Act.

Enzootic cycle

The sylvatic cycle is the fraction of the pathogen population's lifespan spent cycling between wild animals and vectors. Pathogens that contain a sylvatic cycle include trichinosis, dengue viruses, *Yersinia pestis*.

Enzyme

Enzymes are biological catalysts (also known as biocatalysts) that speed up biochemical reactions in living organisms, and which can be extracted from cells and then used to catalyze a wide range of commercially important processes.

Epidemic

The occurrence of more cases of disease than expected in a given area or population

during a particular period.

Epidemiology

Epidemiology is the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to the control of health problems.

Epithelium

Epithelium represents an interface between the internal and the external environment.

Epizootic

Disease events in an animal population are analogous to an epidemic in humans. An epizootic may be restricted to a specific locale (an "outbreak"), general (an "epizootic"), or widespread ("panzootic").

Epizootics

An epidemic outbreak of the disease in an animal population, often with the implication that it may extend to humans.

Eradication

It is the permanent reduction to zero of the worldwide incidences of infection caused by a specific agent as a result of deliberate efforts.

Esterification

Esterification is the general name for a chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product.

Evaluation

Evaluation is a systematic determination of a subject's merit, worth and significance, using criteria governed by a set of standards. It can assist an organization, programme, design, project or any other intervention or initiative to assess any aim, realizable concept/proposal, or any alternative, to help in decision-making.

Evaporation

Evaporation can be defined as the process where a liquid is transformed into its gaseous state.

Excavation

Excavation means loosening and takeout materials leaving space above or below ground.

Exophagic

Insects, such as some mosquitoes, feed outdoors.

Exophilic

Insects, such as some mosquitoes, tend to inhabit or rest outdoors.

Exotic fish

A number of fish species have been imported from foreign countries and introduced for culture. Since these fishes are not the natives, they are called exotic fishes.

Exotic species

Exotic species often referred to as alien, non-native, non-indigenous, or introduced species, are those that occur in areas outside of their natural geographic range.

Extraction

Extraction is a process in which one or more components are separated selectively from a liquid or solid mixture.

Extrinsic incubation period

The interval between the acquisition of an infectious agent by a vector and the vector's ability to transmit the agent to other susceptible vertebrate hosts. E.g., in malaria - the extrinsic incubation period is 10-20 days.

Fauna

The aggregate of animal species inhabiting a particular region. The fauna of a region evolves historically from various animal groups known as faunistic complexes.

Fecundity

Fecundity is the physiological maximum potential reproductive output of an individual (usually female) over its lifetime and represents one of the major cornerstones of theoretical and applied population biology.

Fertility

Fertility is the natural capability to produce offspring. As a measure, the fertility rate is

the number of offspring born per mating pair, individually or population-wise.

Fertilizer

A chemical or natural substance is added to soil or land to increase its fertility.

Flooding irrigation

Surface or flood irrigation is the application of water by gravity flow directly onto the soil. Flood irrigation is the oldest irrigation method, and in its uncontrolled form is a natural phenomenon on which many areas still base their crop cycle.

Fogging

Fogging is defined as space spraying of insecticide against mosquitoes to prevent an outbreak of mosquito-borne infection.

Food chain

The sequence of transfers of matter and energy in the form of food from organism to organism.

Forest ecosystems

A forest ecosystem is a community formed by plants and animals of that particular area that interact with the chemical and physical features of the environment in which they live.

Formulation

Putting together the components in appropriate relationships or structures according to a specific given formula. It is often used in a way that includes dosage in dispersible form.

Gametocytes

A gametocyte is a eukaryotic germ cell that divides by mitosis into other gametocytes or by meiosis into gametes during gametogenesis. The sexual stage of the malarial parasite in the blood may produce gametes when taken into the mosquito host; it may be male (microgametocyte) or female (macrogametocyte).

Gastrointestinal

Related to the stomach and intestine.

Genal comb

The genal comb is a row below the head, which is horizontally placed and is present in the back of the pronotum of a flea.

Gene coding

A mapping between tri-nucleotide sequences called codons and amino acids; every triplet of nucleotides in a nucleic acid sequence specifies a single amino acid.

Gene expression

Gene expression is the process by which the genetic code, the nucleotide sequence, of a gene is used to direct protein synthesis and produce the structures of the cell.

Genes

A gene is the basic physical and functional unit of heredity.

Genetic modifications

Genetically Modified Organisms (GMOs) can be defined as organisms in which the genetic material (DNA) has been altered in a way that it does not occur naturally by mating or natural recombination.

Genitalia

It's one of the reproductive organs of both sexes of insects.

Genome

A genome is an organism's complete set of DNA, including all of its genes. Each genome contains all of the information needed to build and maintain that organism.

Genotypes

Genotype is the complete gene set of the organism.

GIS

A Geographic Information System (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

Globalization

The term broadly refers to the expansion of global linkages, the organization of social life on a global scale. Globalization is a multifaceted phenomenon, which encompasses

economic, social, political, technological and cultural dimensions.

Granules

Granules are agglomerates of powdered materials prepared into larger, free-flowing particles. They typically fall within the range of 850 μm to 4.75 mm in size. The shape of granules is generally irregular.

Gravity

Any two objects that have mass attraction towards each other with a force, we call gravity.

Habitat

Usually means the physical environment in which an animal lives, e.g., the skin in the case of scabies mites, streams for simuliidae larvae and animal nests for many ixodid ticks.

Hazardous pesticides

Hazardous Pesticides means pesticides that are acknowledged to consist particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions.

HBI

The Human Blood Index (HBI) represents the proportion of blood meals derived from humans by mosquito vectors. It may be used to estimate the human biting habit, an important component of vectorial capacity, as a proxy measure of malaria transmission.

Health hazard chemicals

Health hazard chemicals means chemicals for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees.

Homeostasis

Homeostasis is the body's automatic tendency to maintain a relatively constant internal environment in terms of temperature, cardiac output, ion concentrations, blood pH, hydration, dissolved CO_2 concentration in blood, blood glucose concentration, concentrations of wastes, etc.

Homologous chromosome

Homologous chromosomes are made up of chromosome pairs of approximately the same length, centromere position, and staining pattern, for genes with the same corresponding loci. One homologous chromosome is inherited from the organism's mother; the other is inherited from the organism's father.

Host

An organism infected with or is fed upon by a parasitic or pathogenic organism (e.g., nematodes, fungi, viruses etc.). It is also described as an animal or plant that nourishes or supports a parasite.

Hotspot

It refers to areas of elevated disease burden or high transmission efficiency. Hotspot can also refer to an area with a high risk for infectious disease emergence or reemergence.

Humidity

The amount of moisture or water vapor present in the air. The absolute humidity changes as air temperature or pressure changes, if the volume is not fixed. The term “humidity” is a general term to quantify the amount of water vapor in the gas.

Hybrid sterility

Hybrid sterility is defined as the inhibition and suppression of the reproductive capacity of F1 or later-generation hybrids between genetically different strains or populations usually belonging to different species.

Hydraulic

It is denoting or relates to a liquid moving in a confined space under pressure.

Hypnozoites

Hypnozoites are dormant forms in the life cycles of certain parasitic protozoa that belong to the phylum Apicomplexa and are best known for their probable association with latency and relapse in human malarial infections caused by *Plasmodium ovale* and *P. vivax.*

Hypostome

The central unpaired holdfast organ of the tick capitulum; the hypostome is covered with recurved spines that enable it to serve as an anchoring device while the tick feeds.

Immigration

It is the number of individuals of the same species that have come into the habitat from

elsewhere during the period under consideration.

Immunity

The term 'immunity' is defined as resistance exhibited by the host against any foreign antigen including microorganisms. This resistance plays a major role in the prevention of infectious diseases. Immunity may be innate or acquired.

Immuno-suppressed

Immuno-suppression involves an act that reduces the activation or efficacy of the immune system. Some portions of the immune system itself have immuno-suppressive effects on other parts of the immune system, and immune-suppression may occur as an adverse reaction to the treatment of other conditions.

Impoundments

Impoundments are a common characteristic of human-dominated rivers and offer a means by which water travel time could be managed to promote denitrification.

Incidence

It is defined as the number of new cases occurring in a defined population during a specified period of time.

Incubation period

The time interval between invasion by an infectious agent and appearance of the first signs or symptoms of the disease.

Indicators

A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention.

Indoor Residual Spray

IRS involves coating the walls and other surfaces of a house with a residual insecticide. For several months, the insecticide kills mosquitoes and other insects that come in contact with these surfaces.

Infection

It means the entry and development or multiplication of a pathogenic agent in the body of humans or animals.

Infectivity rate

It is typically used to measure the frequency at which disease spreads within a defined population during a specified time frame.

Infestation

It means the external invasion or colonization of animals or their immediate surroundings by arthropods, which may cause clinical signs or are potential vectors of pathogenic agents.

Ingredients

An ingredient is a substance that forms part of a mixture.

Insect Growth Regulators (IGRs)

Sometimes known as insect development inhibitors. IGRs are a group of chemicals that either prevent the development of larvae into pupae or pupae into an adult.

Insecticide

Insecticides are toxic substance that is used to kill insects. Such substances are used primarily to control pests that infest cultivated plants or to eliminate disease-carrying insects in specific areas.

Insecticide resistance

The ability of arthropods to tolerate doses of insecticides which would prove lethal to the majority of normal (susceptible) individuals of the same species.

Insecticide-Treated Nets

Insecticide-Treated Nets (ITNs) are a form of personal protection, which are simple mosquito nets that have been treated with an insecticide. These nets require ‘re-dipping' to restore the insecticide element every 6-12 months.

Integrated Pest Management

Integrated Pest Management **(**IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties.

Integrated Vector Management

Integrate Vector Management (IVM) is a rational decision-making process for the optimal use of resources for vector control. The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control. The ultimate goal is to prevent the transmission of vector-borne diseases such as malaria, dengue, Japanese encephalitis etc.

Intensity

Intensity refers to the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise.

Intermediate host

Ordinarily, a necessary host and one in which only the immature stages occur in the host, for example- The human body is an intermediate host for Plasmodium parasite.

Invertebrates

Invertebrates belong to the animal kingdom. They lack a backbone and have soft bodies because they don't have an internal skeleton (endoskeleton) for support although, some of them possess an exoskeleton that encompasses the entire body. Invertebrates do not possess lungs since they respire through their skin and are heterotrophic.

Irrigation

The process of supplying water to land by artificial means. Its basic objective is to supplement the natural supply of water, for raising crops with an economic and efficient system. Controlling and harnessing various natural resources. To achieve it, irrigation systems are required.

Isomers

If two or more different compounds have the same molecular formula, they are known as isomers.

Labium

A lower mouthpart of an insect that is formed by the second pair of maxillae united in the middle line formed by a fusion in embryonic life of separate right and left maxilla.

Labrum

An upper or anterior mouthpart of an arthropod consists of a single median piece, which forms the floor of the mouth in mandibulate insects with many sensory structures.

Landfills

The landfill is defined as a "facility in which solid waste from municipal and/or industrial sources is disposed of in the land.

Larval density

Larval density is the number of larvae collected to the number of dips made.

Larval habitat

These are the places where eggs are laid, larvae hatch, instars moult, pupate, and adults emerge. They may be natural or man-made, permanent or temporary, large or small.

Larvicide

A larvicide is an insecticide that specifically targets the larval life stage of an insect. Larvicides may be contact poisons, stomach poisons, growth regulators, or (increasingly) biological control agents and are most commonly used against mosquitoes.

Lethal mutation

A type of mutation in which the effect(s) can result in death or reduce significantly the expected longevity of an organism carrying the mutation.

Light trap

Light trapping is the most common and regular sampling technique. Nocturnal arthropods particularly insects are attracted by artificial light sources therefore light traps have been widely used to collect nocturnal insects.

LLINs

LLIN is a mosquito net impregnated with insecticide. The insecticide is cleverly bounded within the fibres that make up the netting and is 'slow released' over a 4-5 years period.

Longevity

How long an organism lives, is often expressed as the mean expectancy of life. Vector longevity is one of the most important factors in disease transmission dynamics and vector control.

Lymph node

The lymph nodes are organized lymphoid organs that contain lymphocytes within a fine reticular stroma.

Lymphatic system

The lymphatic system is part of the vascular system and an important part of the immune system, comprising a large network of lymphatic vessels that carry a clear fluid called lymph directionally towards the heart.

Mammalian toxicology

Mammalian Toxicology surveys chemical agents and examines how such chemicals impact Mammalian health, emphasizing the importance of minimizing environmental exposure to chemical and physical hazards through media like contaminated water, soil and air.

Mammals

Mammals are various warm-blooded vertebrate animals of the class mammalian, including humans, characterized by a covering of hair on the skin and, the presence of milk-producing mammary glands in females for nourishing the young.

Man Hour Density

Man Hour Density (MHD) is an important index to determine relative densities of mosquitoes to compare the prevalence of vectors in the same areas of seasons, months or years or to compare different places also.

Management

Management is the organizational process that includes strategic planning, setting objectives, managing resources, deploying the human and financial assets needed to achieve objectives, and measuring results.

Mandible

The jaws present in biting and chewing insects. Mandibles can be needlelike piercing organs, present in mosquitoes, or tooth-like present in chewing lice.

Maxilla

The second pair of jaws in chewing insects is persistent when the mouth is modified.

MDA

Mass Drug Administration (MDA) is the administration of anti-malarial treatment to every member of a defined population or every person living in a defined geographical area at approximately the same time and often at repeated intervals.

Mechanical control method

Mechanical control methods involve the complete or partial removal of plants by mechanical means, including harvesting, shredding, mowing, rototilling, rotovating and chaining.

Meral rod

A vertical thickening of the body wall (mesopleuron part) of the thorax of fleas.

Merozoite

Daughter cell resulting from schizogony (merogony).

Metamorphosis

The relatively abrupt change in body form between the immature and sexually mature adult stages.

Microcephaly

Microcephaly is a birth defect where a baby's head is smaller than expected when compared to babies of the same sex and age.

Microfilaria

First-stage juvenile filaria nematodes are usually found in the blood or tissue fluids of the definitive host.

Mists

Mists are dispersions of liquids in gases. They are formed during the nebulization of liquids, during condensation from the vapour phase and during chemical processes (for example oil mist, and hydrogen chloride in damp air).

Monocytes

Monocytes are a type of white blood cell that fights off pathogens. Monocytes are the biggest type of white blood cell in the immune system. Firstly, they are formed in the bone marrow, which is released into our blood and tissues. When certain germs enter the body, they quickly rush to the site for attack.

Morphology

Morphology is the study of the shapes and arrangement of parts of organisms, in order to

determine their function, their development, and how they may have been shaped by evolution.

Mortality

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Mortality rate

A mortality rate is a measure of the frequency of occurrence of death in a defined population during a specified interval.

Moulting

Moulting is the process of producing a new cuticle and the subsequent shedding of the old cuticle.

Mutagenesis

Mutagenesis refers to those changes in the genetic material in cells brought about spontaneously either by chemical or physical means whereby successive generations differ in a permanent and heritable way from their predecessors.

Mutation

A mutation is a heritable change in the genetic material that is not due to genetic recombination. The mutation alters the structure or number of genes or entire chromosomes.

Neglected tropical disease

The diverse group of communicable diseases that prevail in tropical and subtropical regions countries e.g., malaria, chikungunya, dengue, lymphatic filariasis.

Nematodes

A member of phylum Nematoda comprising elongated cylindrical worms, parasitic in animals or plants or free-living in soil or water.

Neurotoxicity

Neurotoxicity refers to the direct or indirect effect of chemicals that disrupt the nervous system of humans or animals. Numerous chemicals can produce neurotoxic diseases in humans, and many more are used as experimental tools to disturb or damage the nervous system of animals.

N-methyl Carbamates

Methyl carbamate (also called methylurethane, or urethylane) is an organic compound and the simplest ester of carbamic acid (CH_3NO_2).

Nocturnal

Some organisms are active during the night therefore they are called as nocturnal. e.g., microfilariae of Wuchereria bancrofti nocturnally periodic.

Non-target biota

Non-target organisms/ species are not the direct targets for their control or management.

Nozzles

A nozzle is a simple device used to break apart a fluid flow into a spray pattern. It atomizes liquid into droplets, disperses the droplets in a specific pattern, metres liquid at a certain flow rate and provides hydraulic momentum.

Nymph

Nymphs are the immature form of an insect, such as an apterygote arthropod, which does not pass through a pupal stage during metamorphosis. Nymphs resemble adults' stages but are smaller and lack fully developed wings and genitalia.

Oil in water emulsion

Oil-in-water emulsions are conventionally defined as thermodynamically unstable systems, which include two immiscible liquids (generally water and oil), in which oil is distributed into the water.

Omnivorous

Omnivores consume materials from different trophic levels of the food web. Many, if not most, aquatic animals eat more than one type of food during their lifespan, both from the plant as well as animal origin.

Organization

A social unit of people, systematically structured and managed to meet a need or to pursue collective goals continuingly.

Outbreak

Outbreak is an occurrence of significantly more cases of disease than expected in a given area among a specific group of people over a particular period of time.

Palmate hair

Palmate hair is the hair of seta with flattened, movable, usually horizontal branches radiating from a common point on a short stem.

Parasite

A parasite is a microorganism, which lives on a living host and derives nutrition from the host, without any benefit to the host.

Parasitemia

The presence of parasites in the blood.

Passive Surveillance

Regular reporting of disease data by all institutions that see patients (or test specimens) and are part of a reporting network is called passive surveillance.

Pathogens

A pathogen is defined as an organism causing the disease to its host. Pathogens are taxonomically widely diverse and comprise viruses and bacteria as well as unicellular and multicellular eukaryotes.

Pathogenesis

The parasite or pathogen can interfere with one or more of the essential functions of the plant or animal.

Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bioaccumulation in ecosystems, as well as their significant negative effects on human health and the environment.

Pesticide

Pesticides are chemical compounds that are used to kill pests e.g., DDT, Malathion, Pyrethrum etc.

Pests

Pest is an insect (or organism) that causes harm to humans, their livestock, crops or possessions. Pest includes nematodes, weeds, bacteria, insects, fungi, molluscs, phytoplasma, viruses and viroids.

Pesticides

Pesticides are chemical compounds that are used to kill pests.

Phagocytes

A cell that can engulf particles, such as bacteria and other microorganisms or foreign matter. Principal phagocytes include neutrophils and monocytes, both of which are types of white blood cells.

Phytochemicals

Phytochemicals are defined as bioactive nutrient plant chemicals in fruits, vegetables, grains, and other plant foods that may provide desirable health benefits beyond basic nutrition to reduce the risk of major chronic diseases.

Pleural rod

Pleural rod is a vertical ridge that divides the mesosternum (thoracic plate above the coxa of the 2ndpair of legs).

Pneumonia

Pneumonia is "a severe form of an acute lower respiratory infection that specifically affects the lungs" and is typically caused by bacteria.

Pneumonic plague

Infection of the lungs by Yersina pestis, the bacterial agent that causes plague (a human disease).

Polarity

In chemistry, polarity refers to the way in which atoms bond with each other.

Population density

Population density is defined as the number of persons per square kilometre. It is an important index of population, which shows the concentration of the population in a particular area.

Predator

An animal that feeds upon other animals (prey) that are either smaller or weaker than itself.

Prevalence

Prevalence measures the amount of disease in a population at a given time and can be expressed as a percentage. The point prevalence is a single assessment at a fixed point in time, whereas the period prevalence is the percentage of a population who has the disease at any time within a stated period.

Proboscis

In invertebrates, the term usually refers to tubular mouthparts used for feeding and sucking. The proboscis is used to describe an elongated nose or snout.

Progeny

The product of reproduction or replication, also known as offspring.

Proliferation

To proliferate normally means to increase rapidly in number or quantity, or to grow or reproduce by rapid production of new parts (biological).

Promastigotes

A stage in the unicellular life-cycle, typically trypanosomes, where the flagellum is anterior to the nucleus and free from the cell body.

Pronotal comb

The pronotal comb is a row behind the head, at the back of the pronotum.

Prothorax

The first thoracic segment bears the anterior legs but no wings.

Protonymph

It is the first instar of the growth and developmental stage in mites.

Protozoa

Protozoa are single-celled, animal-like organisms.

Protozoan

Single-celled animals with at least one well-defined nucleus, some of which are pathogenic.

Public health

Public health is the science of protecting and improving the health of people and communities.

Public health entomology

Public health entomology focuses on the population biology of vector-borne infections, seeking to understand how such pathogens perpetuate over time and attempting to devise methods for reducing the burden that they impose on human health.

Pulvilli

The expanded terminal structure of the pretarsus of some genera of mites, which may be membranous bell- or sucker-like discs.

Radiation

Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio, and microwaves.

Recrystallization

The process of recrystallization involves the dissolution of the solid in an appropriate solvent at an elevated temperature and the subsequent re-formation of the crystals upon cooling so that any impurities remain in the solution.

Remote sensing

Remote sensing is science of obtaining information about an object or feature without physically coming in contact with that object or feature. The process infers surface parameters from measurements of electromagnetic radiation (EMR) from the earth's surface. This EMR can either be reflected or emitted from the Earth's surface. It is a useful tool for vectorborne diseases.

Repellents

Substances applied to skin, clothing, or other surfaces, which discourages insects

(particularly mosquitoes) to sit, climb or bite. Repellents are used to repel mosquitoes, ticks, flies, and other biting insects.

Reservoir

Reservoirs are those water bodies formed or modified by human activity for specific purposes, in order to provide a reliable and controllable resource.

Resistance

A genetic change in an organism in response to selection by drugs/pesticides, which may impair control in the field.

Sanitation

Sanitation refers to the provision of facilities and services for the safe management of human excreta from the toilet to containment and storage and treatment onsite or conveyance, treatment and eventual safe end use or disposal.

Schizonts

Mature malaria parasite in host liver cells (hepatic schizont) or red blood cells (erythrocytic schizont) that is undergoing nuclear division by a process called schizogony.

Scutum

The sclerotized plate on the dorsal surface of Ixodidae hard ticks, also known as the dorsal shield.

Serotype

A group within a single species of microorganisms such as bacteria or viruses share distinctive surface structures.

Slide *falciparum* Rate (S*f*R)

Percentage of slides found positive for P. falciparum parasite from examined slides.

Slide Positivity Rate (SPR)

Percentage of slides found positive for malaria parasite from examined slides.

Social mobilization

Social mobilization is the process of bringing together all societal and personal influences to raise awareness of and demand for health care, assist in the delivery of resources and services, and cultivate sustainable individual and community involvement.

Space spraying

A space spray – technically a fog (sometimes referred to as an aerosol) – is a liquid insecticide dispersed into the air in the form of hundreds of millions of tiny droplets less than 50 μm in diameter. It is only effective while the droplets remain airborne.

Species

A group of individuals in natural populations that can inter-breed by mating within the group and producing fertile progeny; individuals are usually similar in appearance and behavior.

Spermatheca

The spermatheca is a single pouch-like structure connected by the median oviduct through spermathecal duct, which receives spermatophore during copulation. In higher diptera, there is three spermatheca present.

Spinosad

Spinosad is a naturally derived fermentation product, which has demonstrated insect control activity against a large number of pests. The product is isolated from actinomycetes *Saccharopolyspora spinosa*.

Spiracles

A breathing pore is an external aperture and is sometimes guarded by the valves from which the oxygen is inhaled and carbon dioxide is exhaled into the environment. The number of spiracles may vary from species to species and in generalized insects 2 thoracic and 8 abdominal spiracles are present.

Spiracular bristles

It is a stiff hair-like structure of any of several tracheal openings in the exoskeleton of an insect, spider, or another terrestrial arthropod.

Sporogony

The sexual stage in the life cycle of a sporozoan parasite, with the development of the zygote into one or several haploid spores, each containing a distinctive number of sporozoites.

Sporozoite rate

Sporozoite rate is the number of mosquitoes infected with sporozoites divided by the total number of mosquitoes examined using each respective method of mosquito collection,

expressed as a percentage.

Sporozoites

It refers to the minute, motile, an infective form of certain protozoa, which infects the host cells. For example, sporozoites of *plasmodium* are the infective protozoans, injected by the mosquito.

Sterilization

Sterilization describes a process that destroys or eliminates all forms of microbial life and is carried out in healthcare facilities by physical or chemical methods.

Stylostome

The feeding tube produces around the mouth parts of trombiculid mites in the skin of the host.

Surveillance

Systematic ongoing collection, collation, and analysis of data and the timely dissemination of information to those who need to know so that action can be taken.

Susceptibility

Susceptibility means “the state of being susceptible” or “easily affected.”

Tarsi

It is the jointed appendages attached at the apex of the tibia and bears the claws and pulvilli.

Temephos

Temephos is a non-systemic organophosphorus insecticide, mainly used as a larvicide to control mosquitoes.

Thermal fogging

Thermal fogging is the generation of ultra-fine droplets in a range of 1-50 µm using thermo- pneumatic energy. The fluid to be fogged is first vaporized by an increase in temperature and the vapour is then condensed upon introduction to the cooler atmospheric air.

Thorax

The thorax or chest is a part of the anatomy of various animals located between the neck and the abdomen. The thorax includes the thoracic cavity and the thoracic wall.

Toxicity

Toxicity can be defined as the relative ability of a substance to cause adverse effects in living organisms.

Transgenic strain

Organisms into which genetic material from another organism has been experimentally transferred.

Transmission intensity

The frequency with which people living in an area are bitten by anopheline mosquitoes carrying human malaria sporozoites

Transovarial transmission

The transmission of an infectious agent from parent to offspring via infection of the developing egg, which subsequently results in infectious adult arthropods is an important transmission mechanism among viruses in the order Bunyavirales.

Transstadial transmission

It occurs when a pathogen remains with the vector from one life stage to the next.

Trophozoites

It is the general term for the active, feeding, and multiplying stages of most protozoa. In parasitic species, this is the stage usually associated with pathogenesis.

Tropical countries

Tropical countries are those that lie within the region that lies between the tropic of cancer and the tropic of Capricorn. India is therefore a tropical country.

Urbanization

Urbanization is an index of transformation from traditional rural economies to modern industrial ones. It is a progressive concentration of the population in urban units.

Vaccine

Vaccines are biological agents that elicit an immune response to a specific antigen derived from an infectious disease-causing pathogen, that enhance immunity against disease and either prevents (prophylactic vaccines) or, in some cases, treats disease (therapeutic vaccines).

Vector

Vector is described as an arthropod or any living carrier that transports an infectious agent to a susceptible individual. Transmission by a vector may be mechanical or biological e.g., mosquito, bed bugs, ticks, mites, fleas etc.

Vector-Borne Diseases (VBDs)

Infectious diseases of animals and humans caused by pathogenic agents such as bacteria, helminths, protozoa and viruses transmitted by hematophagous arthropod vectors, which include bedbugs, biting midges, black flies, fleas, kissing bugs, lice, mites, mosquitoes, sand flies and ticks, among others.

Vector density

The prevalence of vectors in a particular area is termed as vector density.

Vector incrimination

The vector capable to transmit the pathogen to an uninfected host is called vector incrimination.

Vectorial capacity

It is a measurement of the efficiency of vector-borne disease transmission.

Vegetation

Vegetation can be defined as an assemblage of plants of one-to-many species growing in areas of different sizes.

Vegetation manipulation

Vegetation manipulation refers to any human interference with the normal processes in the plant's life in order to stimulate or retard growth, to change its shape or growth model, or to stimulate or retard flowering and fruit set by applying physical or chemical procedures.

Vertebrates

Vertebrates are members of the larger phylum chordata. The distinct feature is presence of the vertebral column, or backbone, which surrounds and protects the main nerve cord.

Other major chordate features at some point in their life cycles includes notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail.

Vertebrate Animals

An animal with a skull, which surrounds the brain and a skeleton of bone or cartilage, including the spine of vertebral bones surrounding a spinal cord of nerves; includes mammals, aves, fishes, reptiles and amphibians.

Vertical transmission

Transmission of an infection from a mother to her offspring during the perinatal period (the period immediately before and after birth). Transmission might occur across the placenta, in the breast milk, or through direct contact during or after birth. eg., HIV, hepatitis B and hepatitis C.

Veterinary

Relating to the diseases, injuries, and treatment of farm and domestic animals.

Vicinity

The area or region near or about a place; surrounding district; neighbourhood.

Virology

Virology is the study of viruses, complexes of nucleic acids and proteins that have the capacity for replication in animal, plant and bacterial cells.

Virulence factors

It determines the degree to which the pathogen causes damage, invasion, and infectivity.

Volume Median Diameter (VMD)

The volume median diameter is the diameter half the volume of the aerosol particles contained in particles with larger diameters and half is contained in particles with a smaller diameter.

Waterholes

Wildlife water holes are an important habitat component for a variety of wildlife. They provide drinking water for many wild animal species including bats, wild boars, elephants

turkeys and deers and these also serve as breeding habitat for many amphibians.

Wetlands

Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.

Wettable powder

Water dispersible powder technical grade insecticide diluted with an inert carrier (dust) and to which a wetting agent or surfactant has been added. The resultant wettable powder is then mixed with water for spraying onto the surface.

Zoonotic disease

A disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans. There are multitudes of zoonotic diseases.

Zoophagic

Zoophagic is defined as feeding on animals or animal matter; specifically (of a mosquito) feeding on animals other than humans.

Zoophilic

Zoophilic mosquitoes are mosquitoes that prefer animals for blood.

Zygote

Cell that forms by the union of a male and female gametes.

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