

## Introduction

Insecticides have been extensively used since the 1940s to control the mosquito vectors of disease, and have been a vital component in the fight against malaria. However, resistance to some insecticides has developed and is widespread in populations of the major mosquito vector species. As insecticide resistance continues to develop and spread, there is a real danger that these valuable tools will be lost. An understanding of the insecticide modes of action classes is a fundamental step in developing Insecticide Resistance Management (IRM) programmes.

Insecticides contained within WHO prequalified mosquito adulticide products  
For further information on insecticide modes of action (MoA), refer to: [www.irc-online.org](http://www.irc-online.org)

### MoA class 1.

Acetylcholinesterase (AChE) inhibitors: Inhibit AChE, causing hyperexcitation. AChE is the enzyme that terminates the action of the excitatory neurotransmitter acetylcholine at nerve synapses.

1A Carbamates:		
	Bendiocarb	IRS
1B Organophosphates:		
	Malathion	SS
	Pirimiphos-methyl	IRS

### MoA class 3.

Sodium channel modulators: Keep sodium channels open, causing hyperexcitation and, in some cases, nerve block. Sodium channels are involved in the propagation of action potentials along nerve axons.

3A Pyrethroids:		
	Alpha-cypermethrin	IRS, LLIN
	Bifenthrin	IRS
	Deltamethrin	IRS, LLIN
	d, d, trans-cyphenothrin	SS
	Etofenprox	IRS
	Lambda-cyhalothrin	IRS
	Permethrin	LLIN
	Prallethrin	SS
	S-bioallethrin	SS
	Transfluthrin	SS <sup>3</sup>

### MoA class 4.

Nicotinic acetylcholine receptor (nAChR) competitive modulators: Bind to the acetylcholine site on nAChRs, causing a range of symptoms from hyper-excitation to lethargy and paralysis. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.

4A Neonicotinoids:		
	Clothianidin	IRS <sup>1</sup>
	Imidacloprid	SS <sup>2</sup>
4D Butenolides		
	Flupyradifurone	SS <sup>3</sup>

### MoA class 7.

Juvenile hormone mimics: Pre-metamorphic instar - disrupt and prevent metamorphosis  
Adult - reduces fecundity and fertility

7C Pyriproxyfen	IRS <sup>4</sup>
-----------------	------------------

### MoA class 13.

Uncouplers of oxidative phosphorylation via disruption of the proton gradient: Protonophores that short-circuit the mitochondrial proton gradient so that ATP can not be synthesized.

13 Pyrroles:		
	Chlorfenapyr	LLIN <sup>5</sup>

## Insecticide Resistance Management

- Plan: IRM should be considered an integral part of any vector control programme and included during the planning phase
- Monitor: The susceptibility status of the target mosquito populations should be monitored regularly to guide the design of the IRM programme, and choice of intervention
- Rotation: Guided by susceptibility monitoring data, plan to rotate insecticides by MoA class, either temporally or spatially. In the absence of susceptibility data, the rotation of products between IRAC MoA classes will reduce selection pressure for resistance development
- Mixtures: The use of mixtures of insecticides will have the greatest IRM benefit if the insecticides in the mixture are from different MoA classes, and the target mosquito population is fully susceptible to both. Include mosquito larvicides, or other interventions, with alternative MoA in the vector control programme where appropriate



*Aedes aegypti* courtesy of Syngenta



*Anopheles stephensi* courtesy of Syngenta

### Notes:

IRS – Indoor Residual Spraying. LLIN – Long Lasting Insecticide treated Net. SS – Space Spray

1. Prequalified alone and in combination with deltamethrin (IRS)
2. Prequalified in combination with prallethrin (SS)
3. Prequalified combination, transfluthrin and flupyradifurone (SS)
4. Prequalified in combination with alpha-cypermethrin (LLIN)
5. Prequalified in combination with alpha-cypermethrin (LLIN)

Nb. Prequalification relates to products, not individual insecticides or insecticide mode of action classes. Refer to the WHO Prequalification website to identify prequalified Vector Control products  
[www.who.int/pq-vector-control/en/](http://www.who.int/pq-vector-control/en/)

Prequalified MoA classes correct as of January 2021

### Further reading:



Prevention and management of insecticide resistance in vectors and pests of public health importance  
[www.irc-online.org](http://www.irc-online.org)



Global Plan for Insecticide Resistance Management in Malaria Vectors  
[www.who.int/malaria/publications/atoz/gpirm/en/](http://www.who.int/malaria/publications/atoz/gpirm/en/)