EMERGENCY VECTOR CONTROL USING CHEMICALS

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Christophe Lacarin and Bob Reed

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The authors would like to hear from anyone who uses the guidelines in the field with comments on their usefulness and areas which require adaptation or improvement. Please forward comments or suggestions to Bob Reed at WEDC.

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Contents

Glossary

Active ingredient	The chemical which constitutes the insecticide in its pure form.
Arbovirus	Arthropod borne virus. Any group of pathogenic viruses borne and transmitted by mosquitoes, ticks, etc.
Arthropod	An invertebrate animal with a segmented body, jointed limbs and an external skeleton. These include, among others, insects, centipedes, millipedes, crustaceans and arachnids.
Bacteria	Microscopic unicellular organisms, some of which are disease causing agents.
Biological insecticide	An insecticide in which the active ingredient is a micro-organism.
Breeding site	The place where insects proliferate, where they lay their eggs and where the eggs hatch.
Carbamate	A chemical which is formed from carbonic acid and amide which is used widely as insecticide.
Causative agent	The pathogen.
Concentration	The weight of active ingredient present in a given weight or volume of a formulation.
Contamination	When the environment is polluted or infected by the introduction of pathogens or chemical substances which can present lasting damage to both the environment the health of those in contact with it.
Cyclops	A minute predatory crustacean with a single central eye.
Cysts eggs	The structures containing the larva of a parasite.
Ecosystem	A biological community of organisms and the environment in which they interact and live.
Ectoparasite	A parasite which lives on the surface of the body of its host.
Endemic	The constant presence of a disease in an area or community.
Endophilic	Insects that are normally found indoors.

Entomology	The study of insects.
Epidemic	A widespread occurrence of a disease in a community.
Excreta	Waste products discharged from the body, comprising faeces and urine
Exophilic	Insects that are normally found outside buildings.
Formulation	A mixture of active ingredients and other materials which make a pesticide or insecticide easy to use, safe to transport and store. Formulations can be liquids, powders, concentrates, ready-to-use, all depending upon the need of the consumer.
Genus	A kind or class of animals with common characteristics which are unique and different from other classes.
Host	An animal or human which has a parasite living and developing on or in it.
Insect	A six legged arthropod of the class Insecta having one or two pairs of wings. They are the most numerous of animals with over 1 million species.
Immunity	The ability of an organism to resist specific infections.
Knockdown effect	Immobilising with an insecticide, killing immediately.
Larvicide	A chemical or biological compound which specifically kills insect larvae.
Lcd	Litre per Capita/person and per Day.
Lethal dose (LD50)	The LD50 is the LETHAL DOSE of the quantity expressed in milligrams of the active ingredient (insecticide) per kilogram of body weight of an animal needed to kill 50 % of the same animal population (Chavasse and Yap, 1997) - i.e. the oral LD50 of the active ingredient for rats with DDT is 113 mg/kg of body weight, although with another pesticide such as Temephos, the LD50 for rats is 8,600 mg/kg of body weight.
Maggot	A soft bodied, legless larva which is found in decaying flesh.
Morbidity	A measure of how many people are affected by a disease.
Mortality	A measure of how many people die from a disease.
Organochlorines	Man-made organic pesticides containing chlorine.

Organophosphates	Man-made organic pesticides which contain phosphorus.
Parasite	An organism which lives in or on the body of, and feeds off another organism (host).
Pathogen	A disease producing organism.
Pests	Troublesome or annoying animals (especially insects and rats) which attack crops or livestock and can spread disease.
Pesticide	A chemical or biological compound which is used to control or kill pests.
Pyrethroid	A man-made insecticide derived from the dried flower heads of Chrysanthemum (pyrethrum) plants.
Reservoir	The host (could be soil, insects, rats, humans) which contains the pathogen (bacteria, parasites, worms, viruses).
Resistance	The ability of an organism to survive after receiving a certain toxic dose of an insecticide which should normally have killed it.
Residual spraying	Spraying of insecticides which have the ability to continue to kill for longer periods of time.
Rodenticide	A pesticide used to kill rats or mice.
Sullage	Wastewater from personal and domestic activities that does not include excreta.
Space spraying	Spraying of insecticide over large surface areas using specialised equipment.
Tapeworm	A parasitic flatworm with a small head and long, ribbon-like body, the adult of which lives in the intestines of the host.
Vector	A carrier of disease, e.g. rat, fly, mosquito etc.
Vector control	The control of pests and insects by chemical, biological and environmental measures.
Vector-borne diseases	Diseases which are transmitted by vectors.
Virus	A sub-microscopic agent which can only multiply inside living cells.

1.

Introduction

1.1 Background

Each time there is a natural or man-made disaster the affected population tends to take flight into the surrounding areas. This rapid change of environment: loss of homes, livestock, family and friends, causes great stress to individuals and the weakening of health throughout the population (PAHO, 1982). In addition to this, people are often forced into crowded and insanitary conditions. Overpopulation in confined areas, without adequate water supply, health services, food, shelter and sanitation favours an increase in arthropods and domestic rodents, and the spread of the associated communicable diseases (PAHO, 1982).

Aid workers faced with problems of vector control in an emergency do not always have the experience and knowledge necessary for assessing the medical and entomological situation, designing, and implementing an appropriate project for their control.

1.2 Purpose

This handbook has been written with the specific objective of providing practical guidance and an overview of vector control in emergency situations for relief workers and local personnel. It will enable them to develop the skills required to plan and implement a vector control project in an emergency situation, where there is a vector-borne disease epidemic, or where the risk of an epidemic is high.

WARNING!
The reader must be aware that vector control is a specialist subject requiring detailed knowledge of the transmission dynamics of individual vectors. Untrained workers may be able to deal with ecto-parasites such as lice, scabies, or universal filth insects such as, filth flies and cockroaches based on the context of this book but projects to control major disease vectors such as mosquitoes, tsetse flies, blacks flies and others should always be designed and managed by skilled specialists (Thomson, 1999).

1.3 The Handbook

This handbook does not provide solutions to specific problems, rather it guides the user through a process by which the reader can develop an appropriate strategy for controlling the problems being faced.

Chapter two gives an overview of the principal vectors of medical importance. It is most concerned with the biology and the behaviour of arthropods, rodents, and water snails found in refugee and displaced person camps.

Chapter three deals with the vector control strategy and profiles several types of specific control methods applicable to an emergency situation; these include environmental measures, chemical measures, biological measures, and individual and family protection.

Chapter four assumes that the decision to carry out a vector control programme is based on a specific health problem in the camp. It helps to identify the causes and suggests solutions for reducing the health risks.

Chapter five guides the reader through the practical implementation of a vector control strategy. A logical framework used for project design provides a synopsis of the main features of the vector control programme. Details for purchasing pesticides, equipment, and an overview about the personnel organisation and infrastructure needed are described.

Technical appendices and a glossary with scientific terms are provided at the back of the handbook.

1.4 Methodology

This handbook is based on extensive literature review and analysis, personal communications with leading experts and the authors' experience of vector control in refugee camps.

Chapter 2 is written from research, citing current authors on entomology. Salient biological and ecological information is also included.

Personal communication through interviews, a questionnaire survey and the use of an e-mail discussion provided data and practices currently being used in emergency situations.

2.

Main Vectors

2.1 Introduction

The scope of this chapter is to provide an overview of the main vectors of medical importance encountered in refugee/displaced person camps.

Three types of vectors are discussed; arthropods, snails and rodents. These are the major causes of disease in many tropical and subtropical countries. They can result in a high rate of morbidity and mortality, particularly in temporary settlements.

2.2 Some definitions

2.2.1 Vector

A vector may be any arthropod (insect or arachnid, see Table 2.1.) or animal which carries and transmits infectious pathogens directly or indirectly from an infected animal to a human or from an infected human to another human. This can occur via biting (e.g. mosquitoes, tsetse flies), penetration (e.g. guinea worm), or the gastrointestinal tract (e.g. contaminated food or drink).

2.2.2 Biological vector

The pathogens (parasites or arboviruses) in the infested host, are ingested by the vector where they undergo change and multiplication in order to mature to an infective stage. This usually takes several days before they are capable of being transmitted to a new host (e.g. human malaria parasite).

2.2.3 Mechanical vector

Mechanical vectors transmit diseases by transporting the causative agent from contaminated material (e.g. faeces) on their feet or mouth parts and then spreading the pathogens or parasites on to human food, drink, faces or eyes.

2.2.4 Arthropods

Arthropods are small animals with jointed legs, which include insects (class Insecta – e.g. mosquitoes, flies), arachnids (class Arachnida – e.g. ticks, and mites), crustaceans (e.g. Cyclops, guinea worms), and centipedes/millipedes; all of which differ in respect of their antennae, wings, or legs.

Table 2.1. Classification of the main arthropods of medical importance

ARTHROPODS	
INSECT **Class Insecta** *Identification* 1. Three distinct body regions (head, thorax, abdomen) 2. Three pairs of legs 3. Often have wings 4. One pair of antennae 5. Segmented abdomen	**ARACHNIDS** **Class Arachnida** *Identification* 1. Two distinct body regions (cephalothorax, abdomen) 2. Four pairs of legs (except larval mites, which have three pairs) 3. Never have wings 4. No antennae 5. Abdomen usually not segmented
Order Diptera ■ Mosquitoes ■ Flies	Order Acarina ■ Mites ■ Ticks
Order Heteroptera ■ Bugs	Order Araneida ■ Spiders
Order Anoplura ■ Lice	
Order Siphonaptera ■ Fleas	Order Scorpionida ■ Scorpions
Order Dictyoptera ■ Cockroaches	

Source: Sabatinelli, 1996

2.3 Main vectors often involved in vector-borne disease epidemics

2.3.1 Mosquitoes

Mosquitoes are a large arthropod group with 3,100 species occurring in the world. Only about a hundred of them are vectors of human disease. Mosquitoes can be divided into two subfamily groups;

1. The **anopheline subfamily** including the most important mosquito genus *Anopheles* which is responsible for transmitting malaria. Anopheles are also involved in transmission of filariasis in West Africa.

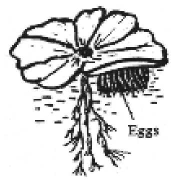
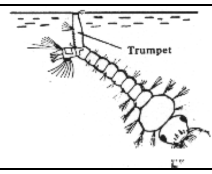
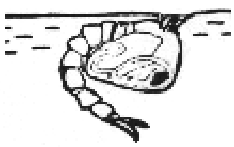
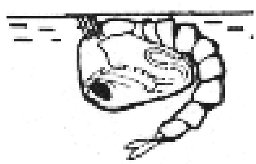
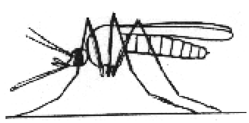
2. The **culicine subfamily** where the important genera *Aedes, Culex*, and *Mansonia* belong. Several diseases are transmitted by them such as yellow fever, and dengue by *Aedes*, encephalitis virus by *Culex*. All of these mosquitoes are also involved in the transmission of filariasis (Table 2.3).

Both male and female mosquitoes feed on sugary secretions such as nectar from plants. In all species, only the female mosquito takes blood-meals from animals and/or humans. The female mosquitoes are attracted by the odour, the carbon dioxide and the heat from animals and humans. The blood sucked is used to provide proteins to mature batches of eggs.

The life cycle of the mosquito consists of four stages (Table 2.2.): the immature stages of egg, larva, and pupa require an aquatic environment. The adult develops in aerial and terrestrial environments.

The females are able to lay between 30 and 300 eggs at a time, according to species. The anopheline mosquitoes lay their eggs separately over the surface of any kind of unpolluted water. The culicine mosquitoes, *Culex* and *Mansonia*, lay their eggs on water as an egg-raft form. The eggs of *Aedes* mosquitoes are laid just above the water line or in wet mud. Provided that they are kept dry they can survive for 3 to 4 years and hatch only when flooded by rising water levels or heavy rain (OMS, 1973).

Table 2.2. Characteristics of the different life stages of the mosquito

SUBFAMILIES			
Anopheline	**Culicine**		
Genus Anopheles	Genus Aedes	Genus Culex	Genus Mansonia
Eggs			
 float	 do not float	 raft of 25 - 100 eggs	 Aquatic plant
Larval stage			
			
Pupal stage			
			
Adult stage			
 Long palps	 Short palps		

Source: Adapted from Cheesbrough, 1987

Table 2.3. Behaviour of mosquitoes and diseases they transmit

Genus	*Breeding site*	*Place found*	*Disease and distribution*
Anopheline mosquitoes Anophelines breed in non polluted water Biting period : NIGHT	edges of rivers, swamps, impoundments, ditches, tanks, saltwater habitats protected from wave action, rice fields, temporary rainpools, hoofprints.	Worldwide	▪ Malaria: Tropical and sub-tropical areas ▪ Bancroftian filariasis: Asia and Africa ▪ Brugian filariasis: Asia ▪ O'nyong nyong virus: Africa
Aedes mosquitoes One species lives in close association with man, in any kind of human settlement. The *A. aegypti* breeds in any small water collection. Aedes spp. are primarily forest mosquitoes. Biting period : DAY	Tin cans, plastics, car tyres, gutters, ornamental ponds, tanks, jars, any type of container, waste disposal areas, tree holes.	Worldwide	▪ Yellow fever: Africa and Americas ▪ Dengue: Africa, Americas, Asia ▪ Dengue Haemorrhagic fever: Americas, Asia ▪ Bancroftian filariasis: Pacific ▪ Other arbovirus: Africa, Americas, Asia
Culex mosquitoes *C. quinquefasciatus* breed in any dirty water in urban and rural areas. Other species are also very common in rice fields in Asia. Biting period : NIGHT	*C. quinquefasciatus* Waste water ditches, latrines, septic pits, cesspools, drains, waste disposal.	Worldwide	▪ Bancroftian filariasis: Most tropical areas ▪ Encephalitis virus: Africa, Americas, Asia, Europe
Mansonia mosquitoes Mainly associated with aquatic plants, in rural areas where irrigation canals occur. Biting period : NIGHT It is a vicious biter	Ditches, ponds, irrigation canals, swamps.	Essentially tropical Worldwide	▪ Brugian filariasis: Asia ▪ Other arbovirus: Rare in Africa and Americas

Sources: Adapted from Birley, 1991; Thomson, 1995; Sabatinelli, 1996; Chavasse and Yap, 1997; Rozendaal, 1997

At tropical temperatures the larval period is 4-7 days, after which time it become a pupa. The larvae feed on bacteria and small aquatic organisms. All larvae need to come to the surface to breathe, except for the larvae of Mansonia mosquitoes which extract oxygen from the roots of certain aquatic plants.

The pupal stage lasts 1-3 days in warm areas. The pupa does not feed, it breathes air and turns or twists its body with short writhing movements. Rapid metamorphosis occurs inside the pupa.

Male adults which are recognisable by their hairy antennae, generally emerge first and wait to fertilize the emerging female mosquitoes.

2.3.2 Non-biting flies

Domestic flies, including the housefly are probably the most widespread insects in the world and certainly the one most closely associated with man. Like mosquitoes they belong to the order Diptera. All of these species, *Musca domestica* (Housefly), *Musca sorbens* (Facefly), and *Chrysomya spp.* (Blowfly) are considered to be of medical importance because they transmit diseases by transporting pathogens between people or from faeces to food causing diarrhoeal diseases and trachoma.

The life cycle of the fly consists of four stages : egg, maggot (larva), pupa and adult. The female lays her eggs in moist, organic material. These eggs hatch after 8 to 48 hours and become maggots which thrive on organic matter, animal or human excrement. After a few days to several weeks, depending on the temperature, quantity of food, and the species, the maggot moves underground where it becomes a pupa. It takes 2 to 10 days for the maggot to be transformed into an adult within the pupa. The female rarely lays more than 100 to 150 eggs in each batch, 4 to 5 of which are produced during her lifetime (Busvine, 1980). Adult flies have a lifespan of one to two months depending upon the species and life conditions.

Musca domestica

The housefly, *Musca domestica,* tends to breed in animal excrement in rural areas. In urban areas they breed in organic domestic waste such as vegetable matter. They land on both faeces and human food, and feed on both. Contrary to popular belief, these flies do not lay their eggs in latrines (Chavasse, 1997). The high density of flies associated with a crowded human popula-

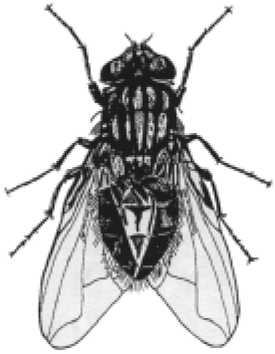


Figure 2.1.
***M. domestica*, (WHO, 1997)**

tion, in unsanitary conditions such as refugee camps, increases the risk of transmission of disease and can cause epidemics.

M. domestica is about 6 to 7 mm long and has a wing span of 13 to 15 mm. It is recognisable due to its greyish colour, and 4 dark longitudinal stripes along the back of the thorax.

As a mechanical vector this species of fly may be responsible for carrying pathogens which cause diseases such as infantile diarrhoea, shigellosis diarrhoea, dysentery, typhoid, and also intestinal worm eggs. It has been proved in Pakistan (Chavasse, 1998) and in the Gambia (Emerson, 1999) that fly control reduced incidence of diarrhoea by about 24 %.

Musca sorbens

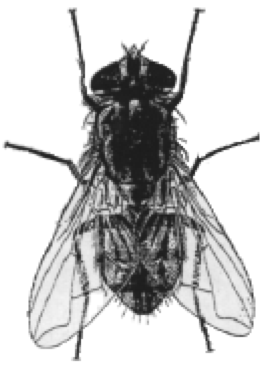


Figure 2.3.
***M. sorbens* (WHO, 1997)**

M. sorbens or facefly also acts as a mechanical vector in the transmission of diseases. It has a worldwide distribution in the tropics. These flies breed, amongst other things, in human faeces around settlements. They are also known to feed on the secretion produced by eyes of people, especially children. They do not breed in latrines. The density of these flies may be very high in unsanitary conditions (Chavasse, 1997).

M. sorbens is 6 mm long and has a wing span of around 15 mm. It is grey and has 2 dark stripes on the back side of the thorax.

M. sorbens is responsible for carrying diarrhoeal diseases but it is often implicated in the transmission of the eye disease trachoma, and it has recently been shown in the Gambia that fly control reduced incidence of trachoma by 70 % (Emerson, 1999).

Chrysomya spp.

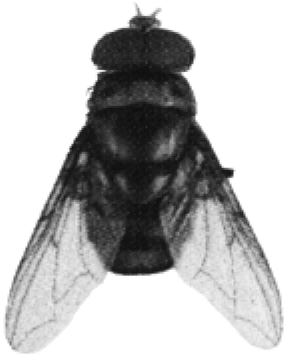


Figure 2.4.
***Chrysomya spp.* (UNHCR, 1996)**

Chrysomya spp. or blowfly is distributed worldwide. It has a strong preference for breeding in all kinds of open latrines, decomposing meat or fish, garbage, and animal excrement. In refugee camps the simple pit latrines often have no lids on the defaecation holes, offering an ideal breeding site for these flies. Blowflies do not enter houses, but are very active in market places. The density of the blowfly population may rise as the number of simple pit latrines in a camp increases (Chavasse, 1997).

The blowfly is robust and measures 10 mm in length with a compact body. Its colour varies between a shiny blue and a shiny green.

Chrysomya spp. act as a mechanical vector and may be responsible for carrying pathogens causing diarrhoeal diseases such as dysentery, and also intestinal worm eggs. If pit latrines are humming with blowflies and crawling with their maggots this will probably be a deterrent for using them.

2.3.3 Lice

Three species/subspecies of human louse occur in the world. They are all, male and female, blood-sucking ectoparasites. The body louse (*Pediculus humanus humanus*), the head louse (*Pediculus capitis*) and the pubic or so-called crab louse (*Pthitrus pubis*) have approximately the same biology. Three stages constitute their life cycle; egg, nymph, and adult. Only the body louse is a vector of disease (typhus). The others do not transmit disease but may cause irritation and severe itching. Lice are spread by close contact between humans.

Pediculus humanus humanus (Body louse)

The body louse is found attached to clothing in close contact with the skin. The females lay and glue their eggs (also called nits) at a rate of about 10 eggs a day onto fibres of clothing, especially on woollen material. They never attach their eggs to human body hairs (Busvine, 1980). Eggs hatch

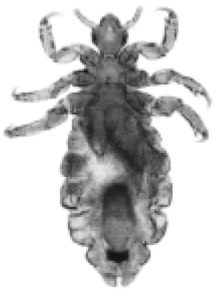


Figure 2.5.
Pediculus humanus humanus
(UNHCR, 1996)

after one week. The nymphal stage lasts from 8 to 9 days. The adult stage lasts up to 10 days during which many blood meals are taken.

The adult body louse is between 3 to 4.5 mm long. It is wingless and has a flattened body.

The body louse is responsible for the transmission of typhus, not directly by biting, but by causing itching in the human host. Scratching favours the penetration of the contaminated faeces of the louse or the contaminated louse itself into the skin, which may cause epidemic typhus. It can also carry relapsing fever and trench fever.

2.3.4 Mites

Mites belong to the order Acarina (Class Arachnida). There are over a thousand species which are parasitic on mammals, birds, and some species on humans. Two species of human mite are of medical importance; the biting mites called "chiggers" (Trombiculid mites), and scabies mites (*Sarcoptes scabeie*). Scabies mites are common in human settlements such as refugee camps.

Mites have eight legs and a body with little or no segmentation. They are very small, 0.5 mm to 2 mm in length. In most species, their life cycle consists of four stages; egg, larva, nymph and adult. Transmission of scabies mites between humans occurs by direct contact.

Biting mites (trombiculid mites)

After emerging from the eggs the larvae crawl onto vegetation or into woodlands seeking an animal or human host. They attack and feed on the skin of reptiles, mammals, birds and humans. On human they seek out areas where clothing is tight against the skin. The larvae feed on the host only once, then between two days and one month later the larvae drop to the ground and enter the soil to develop into nymphal and adult stages (Rozendaal, 1997). The nymph and the adult never feed on animals or humans. They feed on small insects and their eggs or on other mites.

These mites transmit rural typhus in Asia and Pacific, known as scrub typhus.

Scabies mites

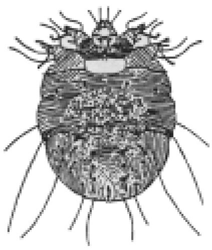


Figure 2.6.
Scabies mite (UNHCR, 1996)

Almost the complete life of the scabies mite is spent on and in the human skin where they feed, procreate and lay their eggs. The adult *Sarcoptes scabeie* burrow winding tunnels of 1.5 mm in length in the surface of the skin. Scabies mites are found everywhere on the body. Scabies disease results from an allergicreaction to the infection of the skin caused by the burrowing of the mites.

2.3.5 Fleas

The fleas, both male and female are blood-feeding and belong to the order Siphonaptera. Around 3,000 species occur worldwide, but only a dozen species take a blood-meal on humans. Rat fleas (*Xenopsylla cheopis*) and human fleas (*Pulex irritans*) are the most important from a medical viewpoint. They jump from the ground to the lower parts of human legs, but can bite them anywhere on the body. Fleas are able to survive more than one month without having a meal and their lifespan may reach 17 months while taking regular blood meals (Sabatinelli, 1997).

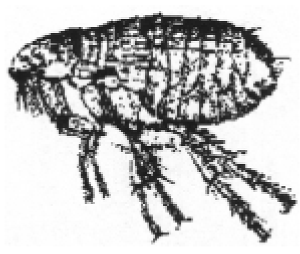


Figure 2.7.
A female flea (WHO, 1997)

Four stages constitute the life cycle of fleas; egg, larva, cocoon (where it pupates), and adult. Eggs are dropped on the ground near to the sleeping place of the host. They hatch after a period of 2 to 14 days. Eggs produce larvae which live among debris, dirt and dust, organic debris provides the main food. The larva spins a silken cocoon over a two to three week period and then pupates for one to two weeks before becoming an adult (Service, 1986).

The adults vary in size from 1 mm to 4 mm. The body is compressed and flattened laterally. Black or dark brown are the main colours. Fleas do not develop wings but they have powerful hind legs to propel them through jumps of 20 cm vertically and 30 cm horizontally.

Fleas can act as vehicles for parasitic tapeworms (in humans). They cause irritation and sometimes allergies and they are also involved in bubonic plague and murine typhus.

2.3.6 Rodents

Rats are located in almost all human communities. Three species of medical importance have been found and may present a danger to the human population. They belong to the family Muridae, and are *Rattus norvegicus*, *Rattus rattus* and *Mus musculus* (Table 2.4.). All are very close to man, and found in rural and urban areas.

Table 2.4. The three main rodents of medical importance

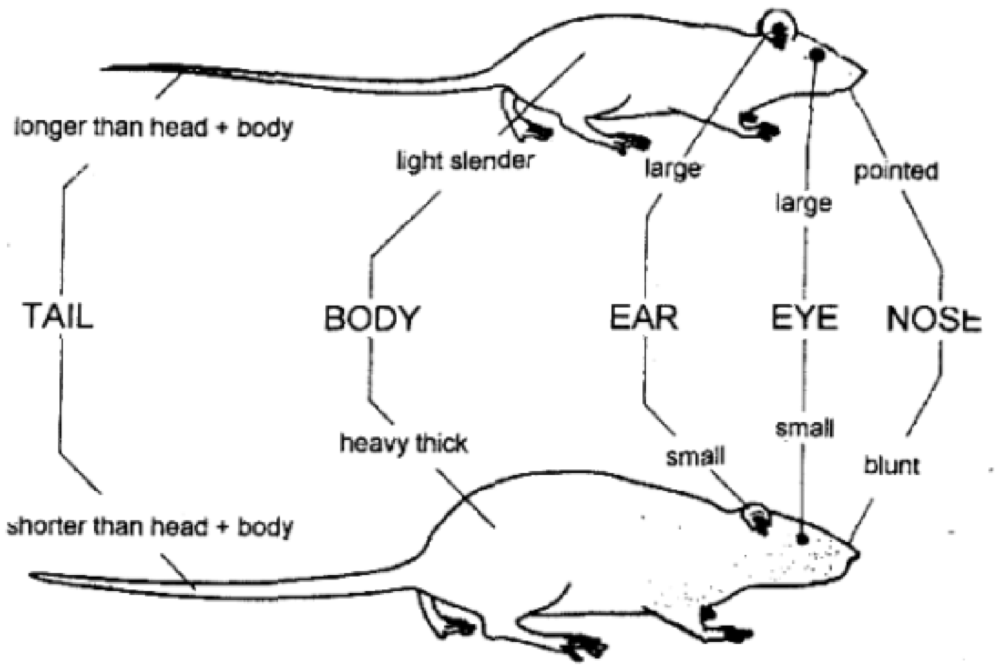
Species	*Rattus norvegicus*	*Rattus rattus*	*Mus musculus*
Other name	Brown rat or Norway rat	Roof rat or Black rat	House mouse
Weight	500 g	250 g	20 g
Length	45 cm	40 cm	18 cm
Habitat	Principally in sewers and holes and feeds on garbage.	Under the roof of any type of building.	Around supplies of grain, cereals, and flour.

Source: Sabatinelli, 1996

Rats feed on any kind of food. They cause destruction of foodstuffs by contamination through urine, faeces, or by simple contact. This can result in important financial and nutritional losses to the population, especially in emergency situations when essential supplies are already critical (Pan American Health Organization, 1982).

Female rats give birth to 5-8 young which become adult and reach sexual maturity in two months.

Roof Rat - *Rattus rattus*



Norway Rat - *Rattus norvegicus*

Figure 2.8. Morphological differences between rats
Centre for Disease Control, US Public Health Services, Atlanta

Rats may transmit diseases such as Lassa and leptospirosis to humans through contact with faeces, urine, and nasal or oral secretions of infected rats. They also act as reservoirs for pathogens which cause Murine typhus, and plague (through fleas), lyme disease, and relapsing fever (through ticks) (Chavasse and Yap, 1997).

2.3.7 Other vectors

The vectors described in Table 2.5 are of medical importance in certain areas. If a camp is located where these arthropods exist they may cause problems depending upon the sanitary conditions of the affected people.

Table 2.5. Vector description and main diseases they transmit

Vector (genus)	*Particularity*	*Breeding sites and habits*	*Disease and distribution*
Tabanid or Horsefly *1. Chrysops*	They are very robust Length; 6 to 10mm	Only the female feeds on any animal. She lays 100 to 1000 eggs according to species. They breed in moist and wet ground.	▪ *Loa loa* filariasis: West and Central Africa
Tsetse fly Glossina *Mortisans group* (savannah flies) *Palpalis group* (river bank flies)	Very long proboscis wide wings 9 to 25mm in length	Both males and females suck blood. Tsetse flies are viviparous. They deposit their larvae in damp ground and arid areas.	▪ Sleeping sickness: Africa
Sandfly *Phlebotominae*	Less than 3mm long Very long legs	The females only are blood-sucking at night. They are located in the tropics and subtropical areas south of Europe. They breed in moist and wet ground.	▪ Cutaneous and visceral (Kala Azar) Leishmaniasis occur in Sudan, Latin Americas, India, Asia, Middle East, and Southern Europe
Bedbug *Cimex spp.* Reduviid bugs	7mm long brownish insects flat and oval body	They lives in temperate and tropical zones. They are active only at night where they feed on humans and animals.	▪ Bedbugs cause nuisance such as itchiness: Worldwide ▪ Chagas disease is transmitted by triatomine bugs in South and Central Americas, and in some parts of Caribbean
Blackfly *Simuliidae*	Small insect, 1 to 6mm in length	They bite during the day. Only the female sucks the blood of animals and humans. They breed and live in all kinds of unpolluted water, vectors in Africa breed only in fast flowing oxygenated streams or rivers. They have a worldwide distribution.	▪ Onchocerciasis or river blindness: Africa, and some parts of Latin America

Vector (genus)	*Particularity*	*Breeding sites and habits*	*Disease and distribution*
Cockroach	5 to 73mm in length two pairs of wings flattened appearance Yellow-brown to dark colour	These insect are very agile and fast and live in colonies. They have a preference for man-made structures where it is warm. In the tropics they may live and breed outdoors. Latrines may be infested in a refugee camp. They are particularly active at night.	▪ Cockroaches act as mechanical vectors and may transmit diarrhoeal diseases, typhoid fever, dysentery, viral diseases: Worldwide
Tick Hard tick Soft tick	7 to 20mm in length Hard back Soft back	Both males and females feed on warm-blooded animals and humans. They are attracted by the carbon dioxide from their prey. Hard ticks are located in vegetation and soft ticks live in close association with available prey. They can survive several years of starvation.	▪ Relapsing fever: Worldwide ▪ Q-fever: Africa, Americas ▪ Lyme disease Arbovirus diseases: Worldwide Ticks are very painful biters and can cause serious loss of blood
Cyclops (Cyclopidae family)	Small crustacean 0.5 to 2mm in length	These are the intermediate host of the guinea worm. They live in any artificial or natural accumulation of stagnant water which may be used as drinking water.	▪ Guinea worm or Dracunculiasis: Africa
Water snail (mollusc) 1. *Biomphalaria* 2. *Bulinus* 3. *Oncomelania*	Aquatic snails	Snails are found in all suitable types of water except for salty and acidic waters. Snails serve as an intermediate host of shistosomiasis worms.	▪ Shistosomiasis (or bilharzia): In the tropics, mainly in Africa and East Asia

Source: Adapted from Birley, 1991; Thomson, 1995; Sabatinelli, 1996; Chavasse and Yap, 1997; Rozendaal, 1997

3.

Principal Control Measures

3.1 Introduction

Control of vector-borne disease transmission is a question of strategy. Nowadays, tools and methodologies are available to control vector-borne disease and their vectors. The problem at hand is the selection of the most suitable and appropriate methodology to control the transmission of disease, which must be both effective and economically acceptable. Generally vector control measures are more suitable for long term projects than for short term emergency situations (Guillet, 1995), such as occur in refugee or Internally Displaced Person (IDP) camps. For this reason vector control measures need to be adapted in order to be effective and to keep the vector population below a level at which it becomes a high risk for an epidemic or where epidemic diseases already occur (Guillet, 1995).

3.2 Environmental control measures

> The authors would like to stress the importance of this chapter. Although the handbook focuses on chemical control measures in an emergency situation, both managers and field workers should keep in their minds that chemical control measures should always complement environmental control measures. Environmental control measures on its own is a large subject and is difficult to cover fully in such a small space. However, in this sub-chapter, the subject has been summarised, and some references have been listed for each topic which should allow the field workers or managers to find more detailed information regarding environmental control measures.

In the acute phase of an emergency, care and attention must be given to all aspects of environmental sanitation. The agency in charge should provide immediate safe facilities for the affected population such as excreta disposal, solid waste management, wastewater disposal, site drainage, and vegetation control.

3.2.1 Camp organisation

What an outsider cannot see at first glance is that IDP or refugee camps are often the image of social stratification of home villages or suburban areas. This constitutes the political organisation of the camp: it then becomes very helpful to identify camp leaders and, through them, involve the affected population in improving the organisation of the camp. Consideration should be given to the cultural background and livelihoods of the affected population. The needs of a rural population are not necessarily the same as those of an urban population.

Setting up and planning a camp should take several factors into account. The camp should be set up with respect to the environmental protection measures. The space provided for the camp should suit the number of affected people and meet the minimum standard facilities required. 45 m^2 per individual should be allowed for the new site settlement. This includes roads, any hygiene facilities, water supply, firebreaks, market places, shelters, health services, schools, and food storage (Sphere Project, 1998).

Refer to: *Sphere Project (1998), Chapter 6*

3.2.1.1 Shelter

Shelter in the context of a refugee or IDP camp is a basic urgent need. Shelter protects the affected population from any climatic conditions. It is often improvised using traditional technology and available local materials such as wood, clay, sticks, stones, grass, and mud. These types of shelters are often associated with parasitic problems such as mites, flies, ticks and other pests. Nowadays tents and plastic sheeting should be available. Shelter should ensure enough warmth, fresh air, privacy and security to provide for the welfare and dignity of affected people. The average shelter surface area available per person should be 3.5-4 m^2 (Sphere Project, 1998).

Refer to: *Sphere Project (1998), Chapter 6*

3.2.1.2 Food Storage

At community level food can be stored in large warehouses which generally give adequate protection against bird and rodent intrusions. Food storage at the family level is more problematic because people either do not know the risks of contamination by vectors, or they do not have enough dishes or containers to protect their food. In any case, food stores should be protected against insects, rodents, and bird pests. For example, jars, plastic containers, or pots with lids to protect drink and food from any contamination and predators.

> ***Refer to:*** *Davis J. and Lambert R. (1995)*

3.2.2 Safe excreta disposal

Many diseases are transmitted by human excreta. In refugee or IDP's camps the environmental contamination by human excreta will favour the proliferation of some vectors. Various safe excreta disposal technologies can be used to overcome the problems. This will depend on socio-cultural aspects of the affected people and site conditions.

Generally, at the early stage of the emergency shared or communal facilities will be provided as it may not be possible to provide family toilets. However, if the conditions are right (space, materials, etc.) the ultimate goal should be to provide family facilities. Furthermore, equal attention has to be paid, not only to the quantity but also to quality and usage of facilities.

The minimum standard for excreta disposal facility is one cubicle for 20 persons maximum. They should be located at least 50 metres from any shelter. The use of toilets should be organised by the family leader(s), and/or segregated by sex (Sphere Project, 1998). Consideration should also be given to vulnerable groups such as pregnant women, children and disabled people.

> ***Refer to:*** *Sphere Project (1998), Chapter 3*
> *Baghri S. and Reed R. (1999)*
> *Davis J. and Lambert R. (1995)*
> *Ferron, Morgan, and O'Reilly (1997)*
> *Pickford J. (1995)*

3.2.3 Solid waste management

In a refugee camp, household wastes are generally few and mainly of organic matter. These may constitute a health risk for the affected population especially in crowded and unsanitary situations. The uncontrolled dumping of waste will encourage the breeding of flies, attract rats, and may risk polluting any watercourses and/or groundwater. Solid waste disposal technologies are numerous, and the emphasis should be to keep the environment free of solid waste contamination, depending on site conditions and the availability of land. The affected people should have the possibility to dispose of their domestic waste conveniently, free of trouble, and effectively.

Generally, shelters should be at least at 100 metres from communal refuse pits and at least 15 metres from a garbage container or household refuse pit. Where waste cannot be buried, a container of 100 litres per 10 families should be provided. Solid waste management should also be provided at any public place such as market places (Sphere Project, 1998).

Refer to: *Sphere Project (1998), Chapter 3*
MSF (1994)
Davis J. and Lambert R. (1995)
Ferron, Morgan, and O'Reilly (1997)
Pickford J. (1995)

Medical waste has to be segregated from general waste and be treated separately on the site of any health centre. Safe disposal such as burning, incinerating or burying will depend on available technology at the health centre or in the affected area.

Refer to: *MSF (1999)*

Disposal of dead bodies will depend on the cultural behaviour and religious beliefs and practices of the affected people. The burial and/or cremation site should be available to the affected population. From an early stage of the emergency, shrouds, appropriate tools, equipment and fuel should be available for families who want to wrap their dead before the funeral ceremony or cremation. A morgue may also be provided.

Refer to:	*Baghri S. and Reed R. (1999)*

3.2.4 Wastewater management and site drainage

Wastewater may be generated by households, health centres, water distribution points, latrines, sewers, rain water and rising flood water. Such a circumstance will favour the spread of vector breeding sites. Appropriate technologies are available depending on the nature of the soil and the space available. The emphasis should be on keeping the new settlement free from any flood water, storm water, standing bodies of water, domestic water, and medical wastewater. Tools should be available in sufficient quantities to help the affected population to keep their facilities safe and clean.

In cesspits and pit latrines the breeding of Culex mosquitoes can be semi-permanently prevented by application of less than 1 cm thick floating layer of expanded polystyrene beads. A 98% reduction of the adult population of these mosquitoes by has been achieved in this way.

Refer to:	*Sphere Project (1998), Chapter 3* *Davis J. and Lambert R. (1995)*

3.3 Water supply

Water in any situation should be available in large quantities and must be close to the quality defined by the World Health Organization. In an emergency the crowded population increases the risk of pollution and the likelihood of vector-borne disease epidemic transmission.

3.3.1 Quantity and quality of water

The quantity of water provided to the affected population depends on the climate, water sources available, and the behaviour of the population. In the case of a serious shortage, 5 lcd must be considered temporarily until the time water engineers are able to increase the needs to 10-15 lcd and more if possible (House and Reed, 1997).

In terms of vector control, insufficient water (apart from drinking water) will lead to lack of personal hygiene resulting in skin diseases, louse-borne diseases, scabies and faecal-oral diseases. The drinking water may be of poor quality as it contains pathogens such as Cyclops, or shistosomiasis.

Technology is available for mechanical and chemical water treatment.

Refer to:	*House, S. and Reed, R.A. (1997)* *Sphere Project (1998), Chapter 3* *Davis J. and Lambert R. (1995)*

3.4 Chemical control measures

Chemical control measures should supplement any environmental control measures. In situations where the risk of an epidemic is high, or where disease-epidemics occur, immediate action must be carried out to obtain a 'knockdown' effect. This means that the effectiveness of a control measure has to be clearly understood by its executors. Effective chemical control needs a clear understanding of the ecology and the behaviour of the species to be destroyed. Such a project has to be strongly supported by good management, logistical organisation and safety measures.

3.4.1 Residual spraying

This method consists of the application of a residual insecticide (active against adult insects) to the inside surfaces of the shelter to be treated and according to the species to be destroyed. This method is suitable for vectors and pests which are known to rest long enough in the resting place to pick up the lethal dose. This method is suitable indoors in the case of malaria control but needs to be closely supervised. Residual spraying is generally carried out with a hand-compression sprayer or knapsack motorised sprayer (see Chapter 5). It is preferable to implement a residual spraying programme in the early morning or evening.

3.4.2 Space spraying

Space spraying may be used to cover a large area where an emergency vector control programme is imperative. This method is the outdoor application of insecticides as mists or fogs. It can be applied from the ground where specific equipment is required such as portable fogging machines, knapsack mist-blower machines, vehicle-mounted fogging machines, or from an aircraft to spread the chemicals over a wider area. Space spraying is usually not suitable for malaria control because most anopheles mosquitoes rest indoors . This method needs expert knowledge and could be very expensive. The spread and the placement of chemicals is less accurate from a plane than with machines used from the ground. Space spraying has to be carried out in the early morning or evening as the atmosphere will favour the spread of the insecticide. During the other times of the day, implementing such a programme will be less effective.

3.4.3 Larvicide

Killing eggs and larvae before they can reach the adult stage could have a significant impact on the vector population. In order to implement a larvicide programme it is essential that the breeding sites of the relevant vectors are accurately known. However, larviciding is of limited use for malaria unless the breeding site is very focal. The breeding site may be a source for drinking water, so careful attention must be given to the chemical used. Larvicide may be spread on water from an aircraft, from a lever-operated sprayer, and/or by hand. A larvicide programme can be implemented at any time of the day.

3.4.4 Dusting

Dusting is the application of an insecticidal dust, powder or any solid material. This method is generally used against vectors such as lice and fleas. Hand-operated dusters and hand-carried dusters are suitable and commercially available. The insecticide is applied directly into the infected clothes in contact with the skin of the infected person.

3.4.5 Chemical classification of the four main pesticide families and their compounds

All of these pesticides kill arthropods by contact or by ingestion.

3.4.5.1 Organochlorines (OC)

Organochlorines are the oldest group of synthetic pesticides. Their excessive use in agriculture has had very negative consequences for the environment resulting in an imbalance of the ecosystem (Coosemans, 1995). It seems that possible adverse effects on humans occur but there is still no proof of this today (Coosemans and Carnevale, 1995). They have a residual effect lasting between six and eight months.

3.4.5.2 Organophosphates (OP)

Some Organophosphorus compounds can have a very high toxicity for mammals and conversely, others have a very low toxicity. Their residual effects last for a short period that can be less than three months, particularly on mud and plaster surfaces.

Table 3.1. Main organochlorine compounds

Insecticide	***Characteristics***
DDTEX "DDT" (Dichloro-diphenyl-trichlorethane)	It has been prohibited in most countries but due to its low cost and its low human toxicity a few countries still use it for public health programmes. DDTEX "DDT" can be used for indoor spraying. Effective against mosquitoes, where there is no resistance, and ectoparasites. **CAN BE USED EXCEPTIONALLY**
Metoxychlor	Similar to DDTEX "DDT" , partially biodegradable and has a very low vertebrate toxicity.
Cyclodiene family: Dieldrin, Chlordane, Endrine, Endosulphan, high toxicity for mammals	
Dieldrin	It was used for Anopheline mosquito control but resistance rapidly appeared. Very toxic. TO BE AVOIDED
Chlordane	Very effective against cockroaches and cattle ectoparasites
Endrine	Still in use for GlossinaEX "Glossina" control
Endosulphan	Still in use for GlossinaEX "Glossina" control
HCH Hexachlorocyclo-hexane	Less persistent and more toxic than DDTEX "DDT"

Source: Coosemans, 1995

Table 3.2. Main organophosphate compounds

Insecticide	***Characteristics***
Malathion	Medium persistence. High toxicity for fish and moderate for mammals. Smells of fish. Low cost. Effective against mosquitoes and lice.
Fenitrothion	Currently used in malaria control programmes as a larvicide and adulticide.
Fenthion	High fish toxicity. Effective against mosquito larvae in urban areas.
Temephos	Low toxicity. Effective against domestic culicine larvae in drinking water. Problem of resistance in blackflies (Simuliidae).
Dichlorvos	High toxicity, it is used against domestic arthropods as a residual fumigant in the form of impregnated strips of resin.
Chlopyriphos	Use as a larvicide against urban Culex.
Chlorphoxim	Use as larvicide (mosquitoes and Simuliidae).
Parathion	Very toxic for man. **TO BE AVOIDED.**

Source: Coosemans, 1995

3.4.5.3 Carbamates (C)

Carbamate insecticides have a residual effect lasting between two and three months. They are a little more toxic than the organophosphates for mammals and are much more expensive. They are generally used for adult insects.

Table 3.3. Main carbamate compounds

Insecticide	*Characteristics*
Propoxur	Low toxicity. Effective against domestic arthropods (mosquitoes, flies, cockroaches). Very expensive.
Bendiocarb	Very high toxicity, especially for fish. Effective against anophelines. Exposure restriction for the operators .
Carbaryl	Use against encephalitis vectors. Problem of resistance.

Source: Coosemans, 1995

3.4.5.4 Synthetic pyrethroids (PY)

The synthetic pyrethroids are highly toxic to fish and are low to moderate in mammal toxicity. Pyrethroids have a residual effect lasting up to a year. They are easily broken down by sunlight.

Table 3.4. Main pyrethroid compounds

Insecticide	*Characteristics*
Permethrin Deltamethrin Lambda-cyhalothrin Cyfluthrin	Biodegradable. Long persistence on treated walls (3 to 12 months). Very effective for mosquito control. Good for impregnating mosquito nets. Effective against Glossina.

Source: Coosemans, 1995

3.4.5.5 Toxicity and hazard

All pesticides are toxic to some degree. Some of them will affect humans and animals and may act as a potential hazard for the environment.

The measure of the toxicity of the pesticide to man or animals is expressed by the acute oral and/or dermal LD_{50} values. These are statistics used to indicate the degree of toxicity.

The LD_{50} is the LETHAL DOSE of the quantity expressed in milligrams of the active ingredient (insecticide) per kilogram of body weight of an animal needed to kill 50 % of the same animal population (Chavasse and Yap, 1997) - i.e. the oral LD_{50} of the active ingredient for rats with DDT is 113 mg/kg of body weight, but with another pesticide such as Temephos, the LD_{50} for rats is 8,600 mg/kg of body weight.

THE LOWER THE LD_{50} VALUE, THE GREATER THE TOXICITY OF THE PESTICIDE USED

Table 3.5. Pesticide classification according to the degree of hazard

Class level of hazard		***User restriction category***	
Ia	Extremely dangerous	Operator must have a special licence	1
Ib	Highly dangerous	Operator must to be trained, educated and under strict supervision	2
II	Moderately dangerous	Operator must to be trained and must carefully respect the safety measures	3
III	Slightly dangerous	Operator has to observe normal safety measures but still with attention	4
0	Not dangerous in normal use	Any person taking care to observe labels and to follow proper hygiene	5

Source: WHO, 1995

Table 3.6. Rate toxicity, LD_{50} for rats (mg/kg body weight)

Class level	***Oral toxicity***		***Dermal toxicity***	
	Solids	*Liquids*	*Solids*	*Liquids*
Ia	<5	<20	<10	<40
Ib	5-50	20-200	10-100	40-400
II	50-500	200-2000	100-1000	400-4000
III	>500	>2000	>1000	>4000
0	-	-	-	-

Source: Disasters, 1981

According to the risks of toxicity and hazards that are presented to health after a given period, the WHO has developed the five-level classification of pesticides above.

The measure of the toxicity LD_{50} of any pesticide, however, cannot be used solely to measure the degree of risk (or hazard). Attention should also be given to the following:

1. Method of formulation
2. Type of packaging
3. Concentration of the pesticide in the finished formulation
4. Application method
5. Surface to be treated
6. Dosage needed
7. Behaviour of humans in the treated area, and animals exposed
8. Pesticide from a manufacturer where the oral/dermal LD_{50} may have values which differ from the World Health Organization norms.

3.5 Biological insecticide (BI)

Biological control is the process of introducing the natural enemies of vectors to reduce and kill them. Bacterial insecticides are safe to use, and non-polluting. Mosquito and fly larvae which eat the bacterial larvicide are killed by a toxin that it releases. This process may be effective in mosquito breeding sites but the persistence is usually shorter than that of synthetic larvicides. In over-crowded populations where faecal matter increases rapidly in pit latrines, the effect of the biological control may be insignificant (Sabatinelli, 1996).

Table 3.7. Effectiveness of bacterial larvicides on mosquitoes and flies

Bacterial Larvicide type	*Mosquitoes*	*Flies*
Bacillus thuringiensis israelensis or serotype H-14	Anopheles[1] and Aedes	Blackflies
Bacillus thuringiensis israelensis or serotype H-1	-	*Chrysomya*
Bacillus sphaericus	Culex[2]	-

[1] Except for the Anopheles gambiae.

[2] Very effective against C. quinquefasciatus in polluted water.

Source: Adapted from Chavasse and Yap, 1997

3.6 Traps

Traps vary in design according to the species to be controlled. Some of them do not present a risk of pollution. They can be used with or without insecticide. These methods are highly selective and efficient where there is no vector control programme, and can be used to cover a large area, for specific insect groups only, e.g. tsetse flies.

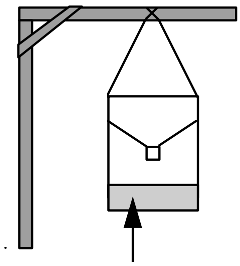


Figure 3.1.
Fly trap using bait

3.6.1 Non-biting fly traps

Within the scope of non-biting fly control in a refugee camp, the concept of the fly trap is very simple and works well around latrines and food areas. The trap consists of a plastic bottle the upper side of which has been cut and placed down into the other part of the bottle (Figure 3.1.). The bottom contains a mixed solution of water and glucose, or fish meal, which attracts flies who are then trapped inside the bottle. The traps must be hung at a minimum of 2 metres above the ground, and located at 15 metres from health centres, food distribution points, and 5 metres from any larval sites such as latrines and garbage collection points. The bait has to be changed every 2-4 weeks (Chavasse et al, 1998).

In Pakistan, although non-biting fly traps caught lots of flies they had no effect on disease (Chavasse et al, 1998).

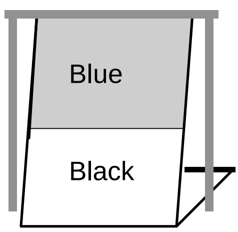


Figure 3.2.
Impregnated screen to control tsetse flies

3.6.2 Tsetse fly traps

Tsetse control involves specific and different types of traps. Trap design differs for different species in different part of Africa (OMS, 1991). The most simple to prepare is the impregnated screen (Figure 3.2.) which has been proven to provide good results. The trap consists of two pieces of cloth. The upper piece of cloth is **blue** and the bottom one is **black**. The screen is impregnated with a synthetic pyrethroid compound and the colours are proven to attract the tsetse. When they contact the pesticide, it is rapidly absorbed though their legs. The surface of the screen should be $1m^2$ suspended vertically from any support. The efficiency of the trap may be increased with the addition of attractants such as cow urine placed in an open tube located in a pocket on the screen, or open bottle of acetone, octenol, buried at the front base of the screen. Cloth made of synthetic fibres is preferred for the traps, allowing retreatment every two or three months. A hand-operated sprayer may be used. Four traps are required per km^2 (Sabatinelli, 1996).

3.7 Individual and or family protection

There is a range of personal and family protection methods against vectors. The efficiency of these methods depends upon their acceptance and proper use by the affected population. The most popular are mosquito nets, mosquito coils, and repellents which can be spread over the skin, mixed in soap, or sprayed onto clothing and bedding. Generally these types of protection are widely available.

3.7.1 Mosquito nets and curtains

Impregnated mosquito nets and curtains act as a mechanical barrier between humans and mosquitoes, or other biting insects. Mosquito nets are used indoors and may significantly decrease the incidence rate and mortality due to malaria if well used. Impregnated curtains may be fixed at the windows or the entrance of the dwelling to prevent insects from coming inside. Loose curtains are less effective.

Different sizes of mosquito nets are available in the market. They can be bulk purchased for about $4 each and most people want to use them when they are affected by indoor biting insects (mosquitoes or bedbugs). The distribution of mosquito nets has to be implemented with the affected community and accompanied with an informative programme to explain their correct use. The largest mosquito net will protect two adults and the smallest, one child. Several mosquito nets must be provided per family.

3.7.2 Mosquito coils

Mosquito coils can be found world wide and are not expensive for one night but in the longer term are much less cost effective than nets. The mixture of the insecticide used, generally a pyrethroid compound, with different types of matter such as coloured coconut husks or dust, constitute the mosquito coil. When the coil burns, it frees particles of the active ingredient with the smoke produced and discourages any biting insects from coming into the dwelling.

The presence of the burning mosquito coils may decrease the rate of mosquito bites by up to 80% (Chavasse and Yap, 1997).

3.7.3 Repellents

Repellents are used against outdoor biting insects. Many brands of repellents are available, and many cultures have traditional repellents which can be effective. They are found as creams, lotions, liquids, soaps and sprays. These are products which are applied directly onto the exposed skin or clothing to prevent and deter any biting insects. These products are expensive and should not be considered for refugee or displaced persons camps. Soap mixed with permethrin compound is cheaper and when applied to the skin offers several hours of protection.

3.7.4 Hygiene promotion

Hygiene should be promoted and taught at the early stage of the emergency even if there are insufficient latrines and other sanitary facilities, and inadequate supplies of soap.

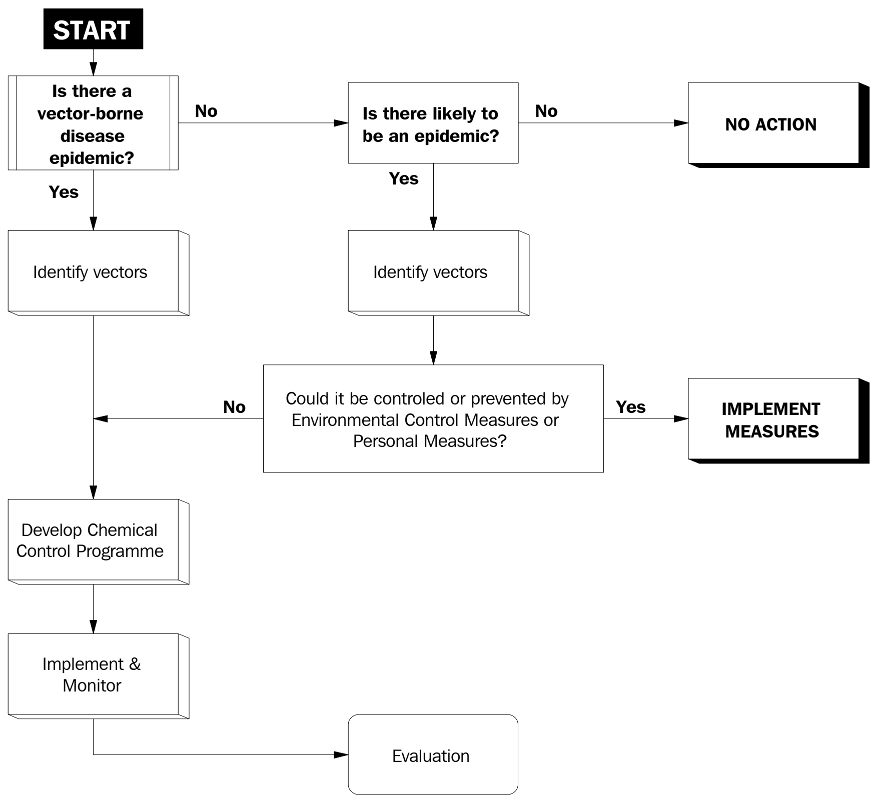
The implementation of such a project has to be clearly defined with all the partners involved within the camp; Medical NGOs, local authorities, international agencies, and the committee of the affected population. Together they must all work with the community representatives to educate and promote hygiene in ways that are both effective and efficient. One of the major components of a successful hygiene promotion programme is the training of women to educate others and this must be given careful consideration. Using women as promoters is the best way to get across the importance of hygiene. It is more likely that the mother of a family will listen to another woman rather than a man explaining the merits of hygiene.

People must be encouraged to practice good hygiene such as washing hands after using latrines, washing daily if water is available, hygienic food preparation and protecting food and water from contamination. They must also be encouraged to use the sanitary facilities provided for them.

4.

Overall Process for Implementing a Vector Control Programme

4.1 Introduction



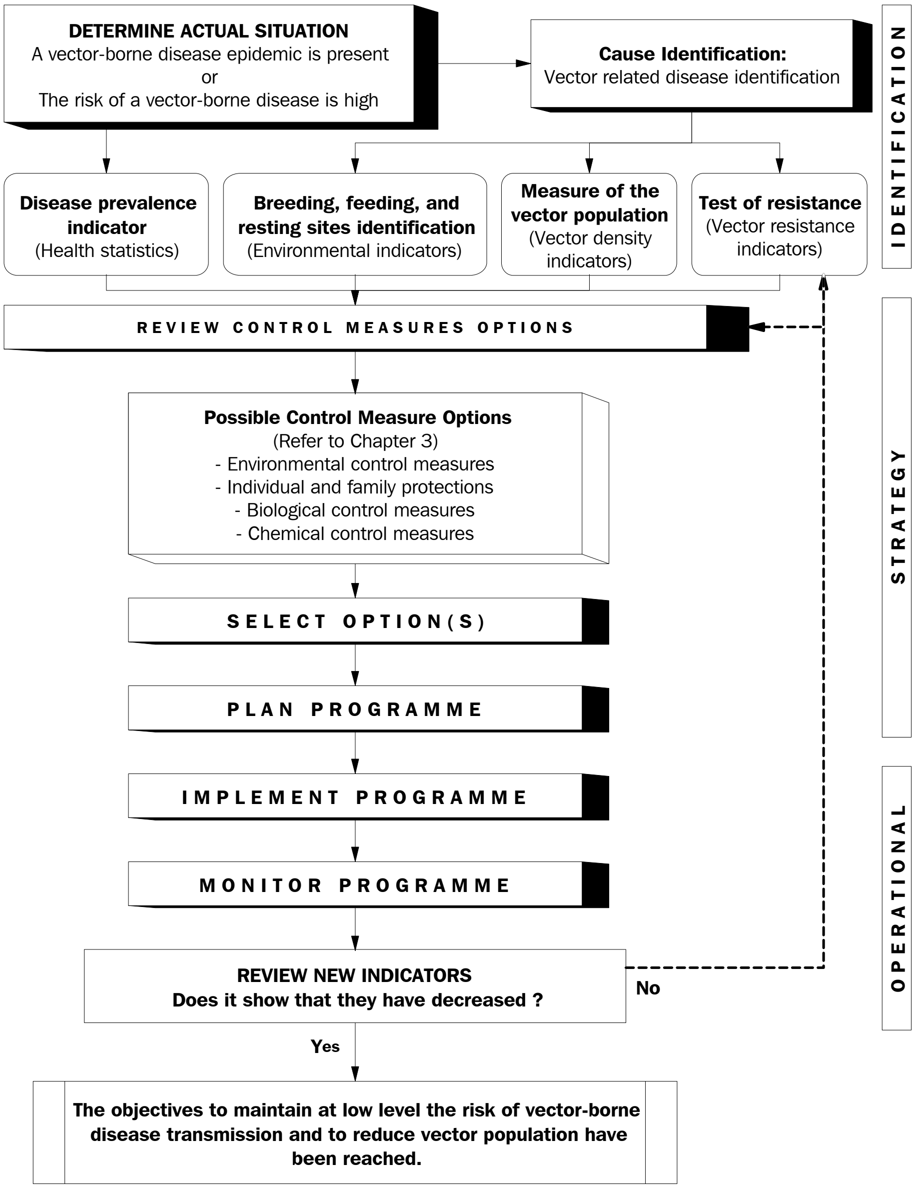
Flowchart S1. Decision to carry out a Vector Control Programme based on a specific health problem within the camp

Propagation of insects and rats is favoured by the breakdown of sanitary facilities following a natural disaster, a conflict, or by the environment created in a settlement of a refugee emergency situation. In such cases, transmission of vector-borne diseases to the affected population will increase, and may result in an epidemic. Environmental control measures combined with facilities for personal hygiene, should be appropriate for the long term control of vectors and disease transmission. However, these long term control measures are not appropriate enough for the needs of an emergency short term action where an epidemic is already happening or about to happen. To face the threat of an epidemic, the principal approach should be to obtain a rapid and maximum control of vectors. Chemical control measures may be required to supplement long term control measures and to prevent epidemic disease outbreaks. Although chemical control measures should supplement any sanitary measures, in the case of an epidemic, a chemical control measure programme is still the most appropriate and suitable strategy depending upon which vectors need to be targeted.

The decision to implement a vector control programme should not always be based only on health statistics- if the field worker waits for health statistics to indicate an epidemic situation the crisis may have reached its peak and passed by the time the epidemic response activities have been initiated. This is what normally happens. However, many epidemic diseases are highly predictable, for example, the arrival of persons without immunity to malaria into an area of high risk for malaria- e.g. former Zaire, 1996. People fleeing the fighting from the mountainous areas of Masisi, where there is no malaria, to the malarial Goma/Sake lowland. Under such circumstances it is disastrous to wait for the predictable epidemic to occur before undertaking malaria control activities. Similarly, heavy body lice infestations in camp environments risk epidemic typhus and many deaths. Vector control should not wait for the sick and dying to be recorded (Thomson, 1995).

The objective of this chapter is to provide a tool for collecting and recording indicators which should help the field engineer to have a clear understanding of the actual situation, and to reach appropriate conclusions to develop, implement and monitor chemical control measures.

4.2 Steps for implementing a vector control programme



Flowchart S2. Steps for implementation of a Vector Control Programme

4.3 Identification (Flowchart S2)

This consists of collecting indicators which should help field workers to understand and get an overall picture of the actual situation, and also to design a response to control vectors and the diseases they transmit. The two most common and simple indicators to measure are disease prevalence and vector counts (Sphere Project, 1998).

4.3.1 Health statistics indicators

In an emergency situation it can be very difficult to get proper health statistics as diagnostic facilities, such as field laboratories, may not yet be available. That is why malaria and other diseases may often be listed in the category of "fever of unknown origin". A vector control programme should be based on a good understanding of the disease, its potential contribution to morbidity and mortality, the local environment and the population involved; and of course, health statistics should be used to monitor the situation and, where problems are not highly predictable, should be used to trigger activity (Thomson, 1995).

When collecting health indicators it is better to try to get health statistics per district within the camp to identify which part of the camp population is the most affected and this should help to locate the source of the problem. Health statistics should be collected with the support of any medical officer. Morbidity rates and mortality rates are needed in order to appreciate the medical situation.

4.3.2 Vector identification *(Refer to Chapter 2)*

Once the vector-borne disease has been identified, it becomes easy to know the vector species involved in the transmission of that disease- e.g. Yellow fever is transmitted in urban areas by the *Aedes aegypti* and by seven other *Aedes* species in rural areas, and by *Haemugogus* species in jungle areas in Latin America. Simple reference texts can also be used to help the field worker in the task of vector identification. Additional data based on the known geographic distribution and ecology of the vector should confirm the identification. In any case, the biological identification should be done with an experienced technician, or a vector specialist such as an entomologist if available.

4.3.2.1 Breeding, feeding, and resting sites

Once the vector species has been targeted and its behaviour has been studied, it should be easy to locate their habitat, feeding, and resting sites. These must be carefully identified and removed if possible. Each located breeding site should be recorded and mapped to monitor the number of them. Breeding sites will increase with the arrival of the rainy season for some insects such as mosquitoes and certain flies.

4.3.2.2 Vector population density

The vector population density depends on the local climatic conditions and the environment made by human presence. Temperature, humidity and particularly rainfall, will significantly increase the number of certain vectors such as mosquitoes and flies. The estimation of vector population density is quite difficult for an inexperienced person to undertake, and the accuracy of this counted sample may not be reliable enough. The number of vectors to be targeted can be estimated by counting the vector population within localised samples and using some unit of measurement such as the number of vectors per surface area, per unit period of time or per individual person. For example, lice: percentage of persons found positive upon inspection. Non-biting flies: number of landings counted on a standard surface grill within a given time period. Traps and insecticides can be used for collecting specimens. Procedures for estimating vector population are given in Appendix 3.

4.3.2.3 Resistance to insecticide

Resistance can be defined as the ability of a given organism to survive after it has received a certain toxic dose of an insecticide which should normally have killed it. Before the implementation of a vector control programme, the susceptibility of the targeted vector to an insecticide has to be carried out to determine which insecticides and/or larvicides are going to be used. There is no point in considering a vector control programme if resistance tests of the insect to the insecticide have not been carried out. If vector resistance has not been tested there is a considerable chance that the programme will fail. During the on-going programme, it is also necessary to regularly monitor the susceptibility of the targeted insects to an insecticide. With this kind of monitoring system, if the insect becomes resistant the field engineer has the option to move to another insecticide or to use a different mode of application. However, different factors may be responsible for the failure of a vector control programme or may contribute to the development of a resistance. These include:

- inappropriate strategy;
- poor quality of spray application;
- change in behaviour of the targeted arthropods; and

- bad coverage of the spraying.

The World Health Organization (WHO) has developed a standardised susceptibility test kit. The principle is to place a group of the targeted insects into an exposure tube containing insecticide-impregnated paper for a period of 1 hour. The group of insects is then removed to an other tube to observe their recovery during 24 hours. If 20 % or more of the insects are still alive then resistance to the insecticide must be considered (Chavasse & Yap, 1997). The test may seem easy to implement, but the analysis of the result may be more difficult and has to be carried out within a strict and good understanding of the scientific problems that the test imposes (Thomson, 1995). Although a note book is provided within the kit, an experienced technician is required to carry out this test properly.

Implementing organisations should be aware that **it is unrealistic for an inexperienced person or a non specialist to implement any resistance test without the specific and scientific knowledge that these resistance test kits impose**. However if there is no specialist to implement such a test, The WHO has developed a World Programme of Surveillance of Insecticide Vector Resistance which should be able to provide the information on insecticide resistance at a regional scale anywhere in the world. The information provided by this should be more accurate than a beginner implementing a resistance test which may jeopardize the test itself and the project.

Resistance development may be reduced or avoided by using insecticides which have a short persistence (2/3 months). Insecticides and/or methods of application should be alternated (Sabatinelli, 1996).

4.3.2.4 Mapping the indicators collected

It is essential to display all the data collected onto a map as this will give an overview and a better understanding of the actual situation to be monitored. Every detail must be provided in the map such as communication routes, access to vector habitats, natural and man-made breeding sites, health centres, defaecation areas, latrines, uncontrolled waste disposal - any place where water is present including water collection points within the camp, rivers, swamps, water holes, leaking water supply and vegetation. Places where vector population measurements have been recorded must figure in the map and be dated. The map and details should be done according to the vector targeted at an appropriate scale which allows for easier reading and evaluation of the map.

Table 4.1. The main known examples of vector resistance

Vectors	Geographical distribution	Known resistance
Anophelines mosquitoes *A. gambiae s.l.* *A. funestus*	Africa	DDT and cyclodiene (OC)
A. arabiensis	Sudan	malathion (OP)
A. gambiae s.s.	West Africa	permethrin (PY)
	Asia	most of the vectors are resistant to DDT, but DDT is still considered useful in India because it drives malaria vectors outside.
A. stephensi	India, Iran, Pakistan	malathion (OP)
A. culicifacies	India, Sri Lanka	malathion (OP)
A. sinensis	China, Japan, Korea	some organophosphate compounds (OP)
A. albimanus *A. pseudopunctipennis*	South America and Central America	some organophosphate compounds (OP) and carbamates (C)
Aedes mosquitoes *A. aegypti*	Americas, Asia	DDT, some organophosphate (OP), some pyrethroids (PY)
A. albopictus	Madagascar	DDT, some organophosphate (OP), some pyrethroids (PY)
Culex mosquitoes *C. pipiens* *C. quinquefasciatus*	Urban areas Europe, Brazil, India	A large variety of insecticides and biological larvicides
C. tritaeniorhynchus	South East Asia, China, Japan, Korea, Sri Lanka	organophosphate (OP) organochlorine (OC)
Mansonia mosquitoes *M. annulifera* *M. indiana*	Thailand	organophosphate (OP)
Simuliid fly *Simulium damnosum*	West Africa	chlorphoxim, temephos (OP) pyrethroids (PY) carbamates (C) DDT (OC)
Phlebotomine flies *Phlebotomus papatasi* *Phlebotomus argentipes*	Africa (kenya) India Turkey	DDT
Cockroach *Blatella germanica*	Worldwide	DDT (OC) and resistance to other insecticide in USA, Europe and Japan

Source: Adapted from Guillet, 1995

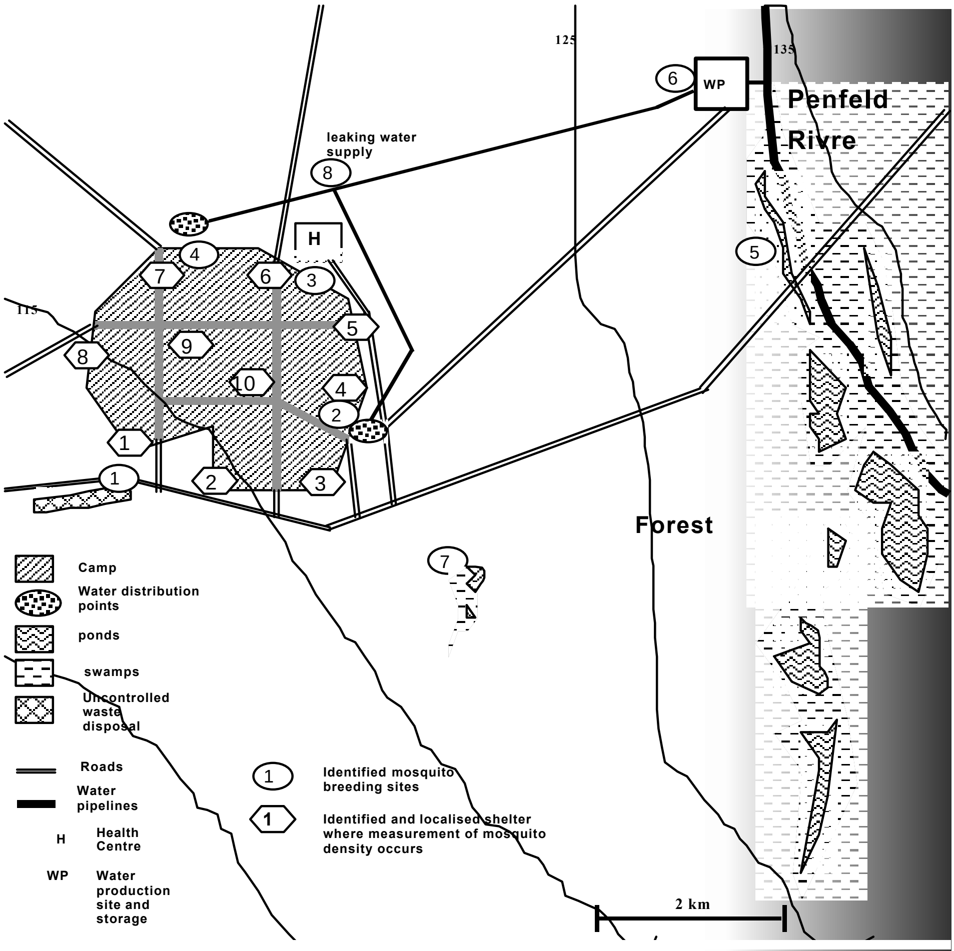


Figure 4.1. Indicators for malaria control (Lacarin, 1999)

The example of an indicator mapping in Figure 4.1 shows the indicators for malaria control. It seems that most of the breeding sites are man-made within the camp. They are easily located and may be removed rapidly. Shelters where the measurement of the vector population density will take place are carefully chosen and recorded on the map so these same shelters can be periodically measured for vector population density, in order to monitor the effectiveness of the spraying programme. Malaria health statistics indicators may be added on the map, per district if possible. This will show the districts which are most affected by the disease and should help to identify the source(s) of the problem, and where the control activities should start.

4.4 Strategy (Flowchart S2)

The decision to carry out vector control measures should be based on clinical evidence that a vector borne disease epidemic is occuring, or a high risk of one occurring in the near future. There are 7 main reasons why the affected population may be more susceptible to disease than the host community.

1. They have a low immunity
2. They have fled through or to an infested area where disease is endemic
3. Their camp is situated in an area which the local population have avoided
4. They have lost their livestock
5. They are malnourished
6. They have suffered injuries and trauma resulting in blood loss
7. They are living in crowded and insanitary conditions

The objective is to target any arthropods of medical importance to reduce and maintain them at a level at which they do not present a danger of disease epidemic transmission to the affected population.

The field worker involved in an emergency situation must bear in mind that chemical control measures should be used as a supplement to any good environmental control measures. Environmental control technology such as safe excreta disposal for controlling flies, and drainage of any standing water for controlling mosquitoes, will have some pertinent impact on these vectors of medical importance. However, these technologies may not be sufficient to reach all breeding, feeding, and resting sites within the settlement and its surroundings.

Chemical control measures and/or individual protection measures should be carried out in anticipation of, or during a vector-borne disease epidemic. The setting up of all the hygiene facilities such as safe excreta disposal, solid waste management, wastewater disposal, site drainage will take from a few weeks to months before benefiting the majority of the affected population.

When people are sick and dying because of a vector-borne disease epidemic the only way to reduce the vector population to a level at which it presents no major epidemic risk is by immediate chemical control measures.

4.4.1 Select options

Chemical control option strategies and technologies are numerous. The effectiveness of a vector control programme will be based on a clear scientific and technical understanding of the problem given and the appropriate response to deal with it. These must include the following factors:

1. A clear understanding of basic entomology and identification of the vector(s).
2. A clear understanding of chemical selection, chemical use and its dangers.
3. Knowledge of application equipment.
4. Knowledge of safety measures.

(see Chapter 5)

Flowcharts S3 and S4 provide a simple and basic synopsis which should help the decision-maker in selecting appropriate and suitable control measures according to circumstances. Although these afford a comprehensive general survey to select option(s), the final decision must include and be based on the analysis of the factors given above.

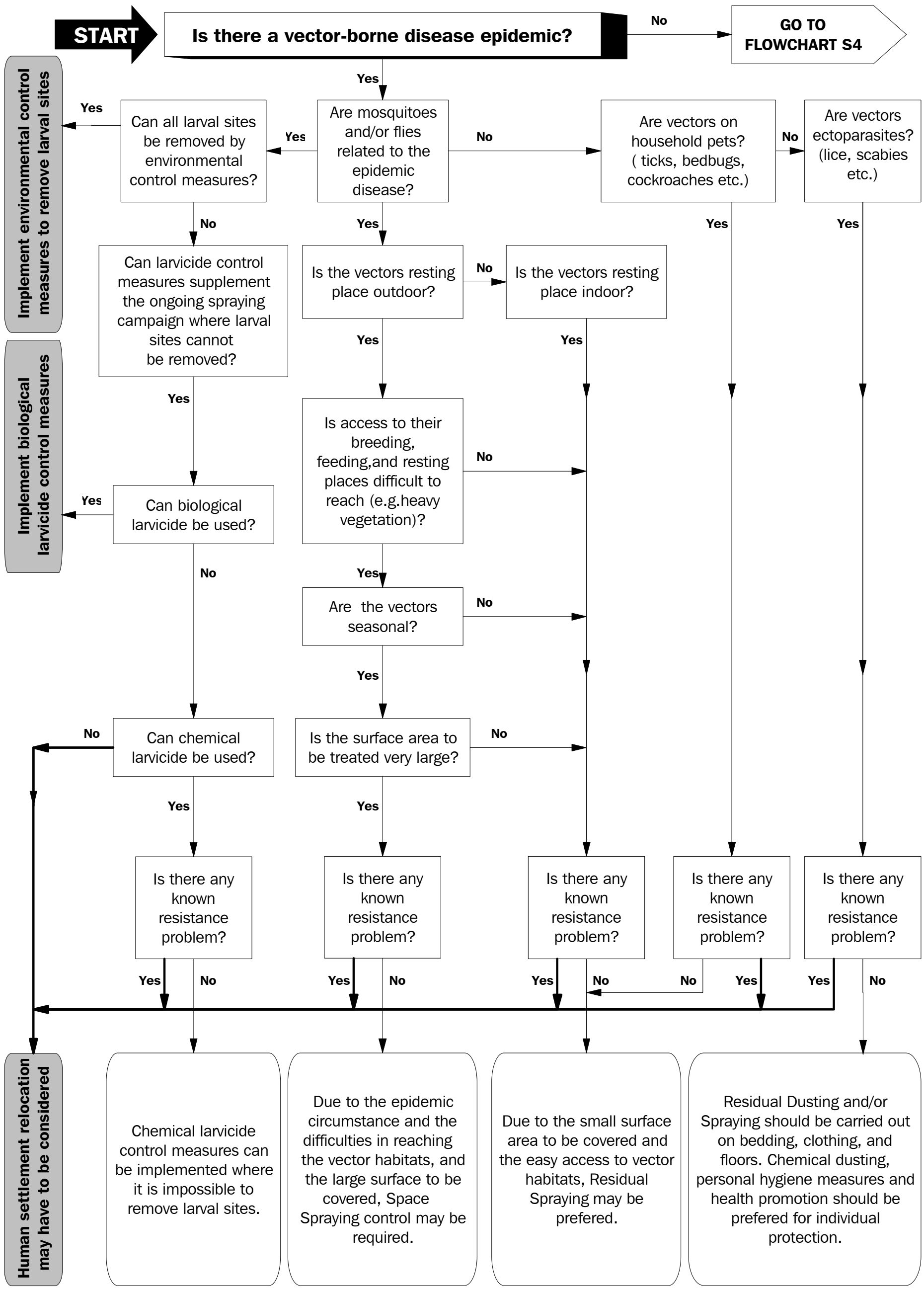
Appendices 1 and 2 provide suitable chemical control methods categorised by vectors with application procedures.

4.4.2 Plan programme

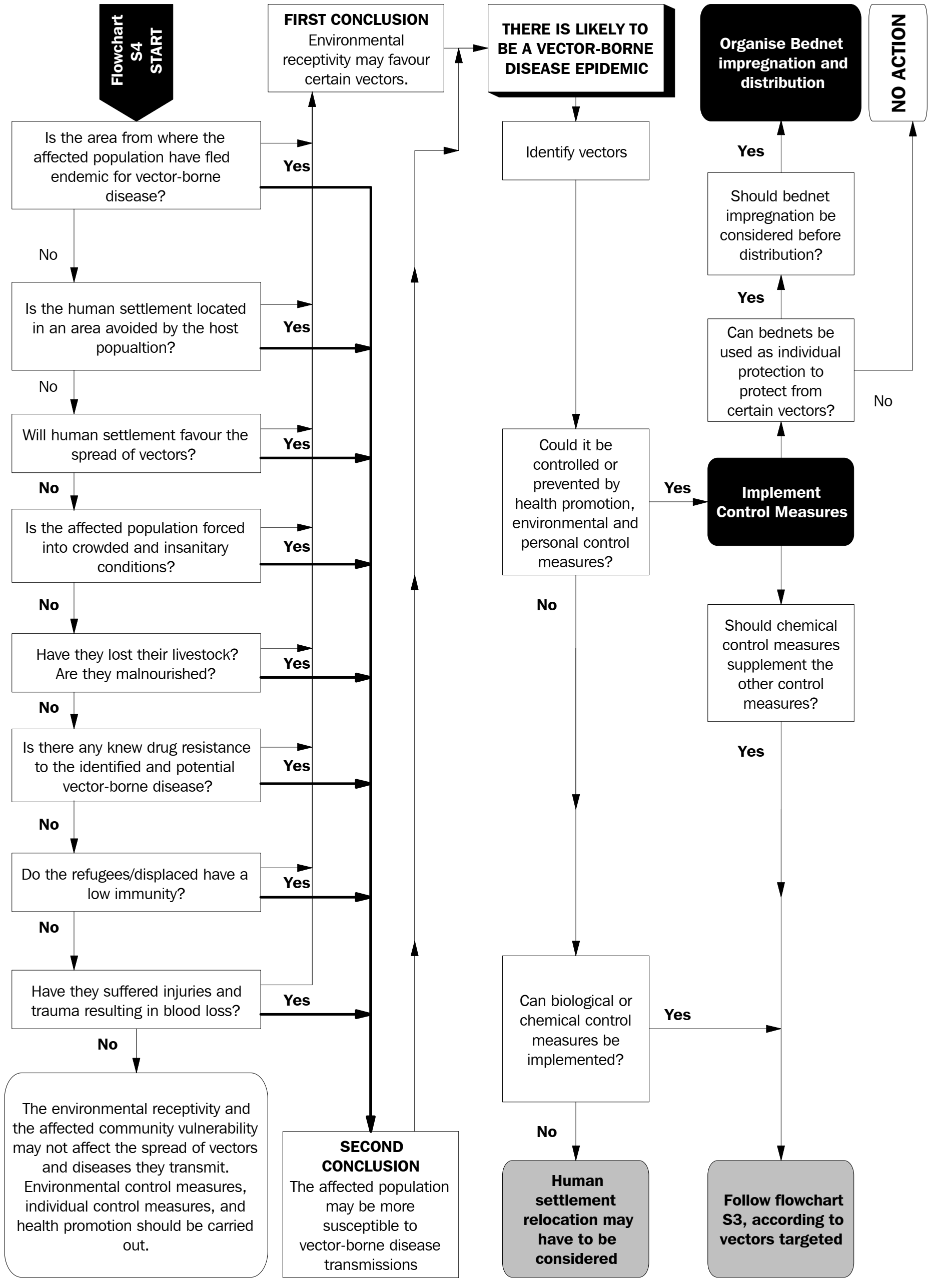
In order to plan a programme, the objectives and the control method options must be clearly defined. Also additional information needed such as the country's chemical regulations, logistical needs, available specialists and personnel related to vector control should be identified (see Flowchart S5).

4.4.3 Host country role and regulations

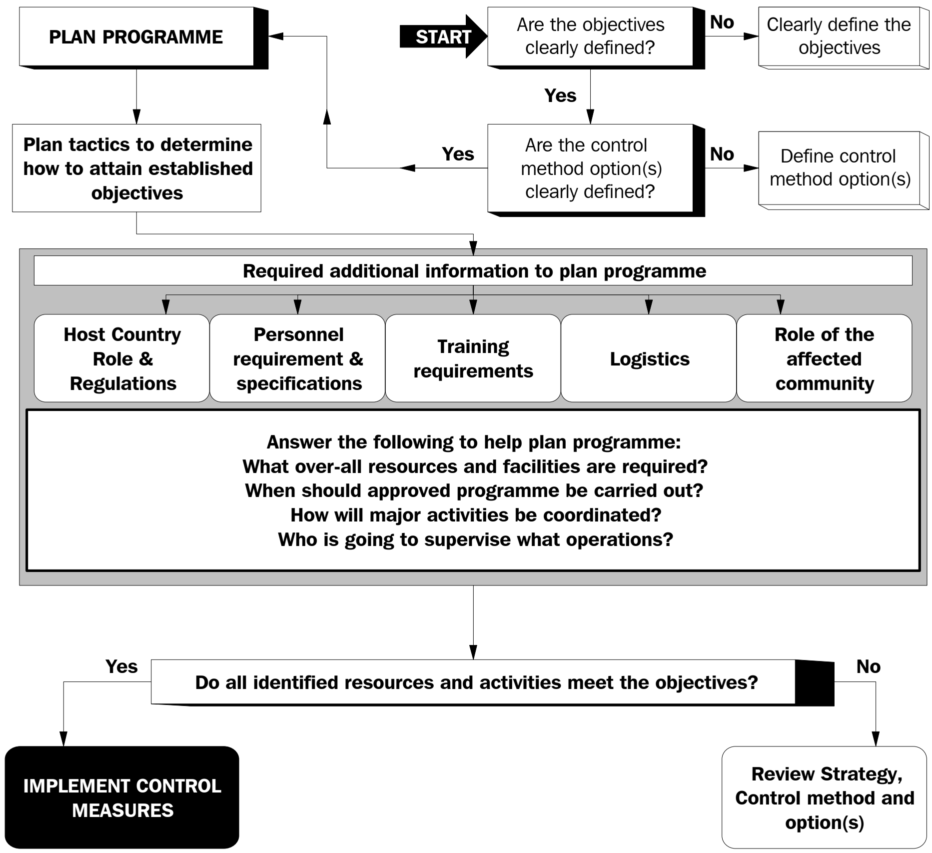
Before implementing any vector control project, the host government must be contacted. This could be the Ministry of Health, the Ministry of Agriculture, or any other department of the government involved in a vector control programme. Under circumstances where war occurs it may be difficult or impossible to approach them.



Flowchart S3. Chemical option strategy choice during epidemic



Flowchart S4. Flowchart for assessing risk of a community to risk of a vector-borne disease epidemic



Flowchart S5. Process to plan programme

The host country may have its own national control programme. Many countries in Africa, Asia, Americas and Europe have set up control programmes, but many of them are still without a national control programme, especially when the use of insecticides is required. Many countries cannot afford such a programme.

When consulting the host country authorities it is important to ask relevant questions such as :

- Is/was there a national control programme already in place?
- Is there information on identification of the targeted vector?
- Are there problems of resistance?

- Which insecticide is authorised by the regulations of the country?
- Where is equipment available?
- Are national experts and qualified personnel available for support?

Certain insecticides are no longer in use for agriculture, but under epidemic conditions authorisation from the host country may be required for their use in a public health vector control programme. In any case, only those insecticides designed for public health purposes should be used if available.

Under vector-borne epidemics the implementing organisation must be aware that the host government will normally only concentrate their resources on protecting their nationals from the disease rather than the refugees (Thomson, 1995).

4.4.4 Personnel requirement and specifications

Personnel recruited with previous experience in controlling vectors of medical importance or of agricultural importance will be a great advantage for vector control implementation.

Personnel at senior level should have at least a degree in science and/or health engineering, and labourers should have at least a basic education.

The number of personnel will depend on the gravity of the situation and the space to be treated. Personnel specifications are developed in Appendix 4.

4.4.5 Role of the affected community

The affected people, even if they are physically unfit and mentally traumatised, are very concerned with their own health, and therefore should normally be willing to provide information, assistance and personnel. Refugees or Internally Displaced People representatives may be very useful in providing, if available, people who have had previous experience in vector control programmes.

The community can be successfully involved within the control programme in providing information on man-made and/or natural potential breeding sites, in taking part in the monitoring project such as in preventive control measures, and in providing personnel from their community for implementation of projects.

4.4.6 Training needs

Suitable material and equipment should be identified for training courses. Training should be an integrated and compulsory part of a vector control programme. Even people with previous experience should have refresher courses on practical implementation of pesticide control programmes. Courses should be as practical as possible and adaptable to each person's level of qualification.

Training courses are developed in Chapter 5.

4.4.7 Logistic needs

The success of the control programme will also depend on the response of the logistics department in providing the required equipment, insecticides and other logistical support.

Reliable suppliers must be identified and located. The equipment and spare parts, personal protection such as clothing, and insecticides must be provided in enough quantity to cover the surface area to be treated, and for the duration of the control programme.

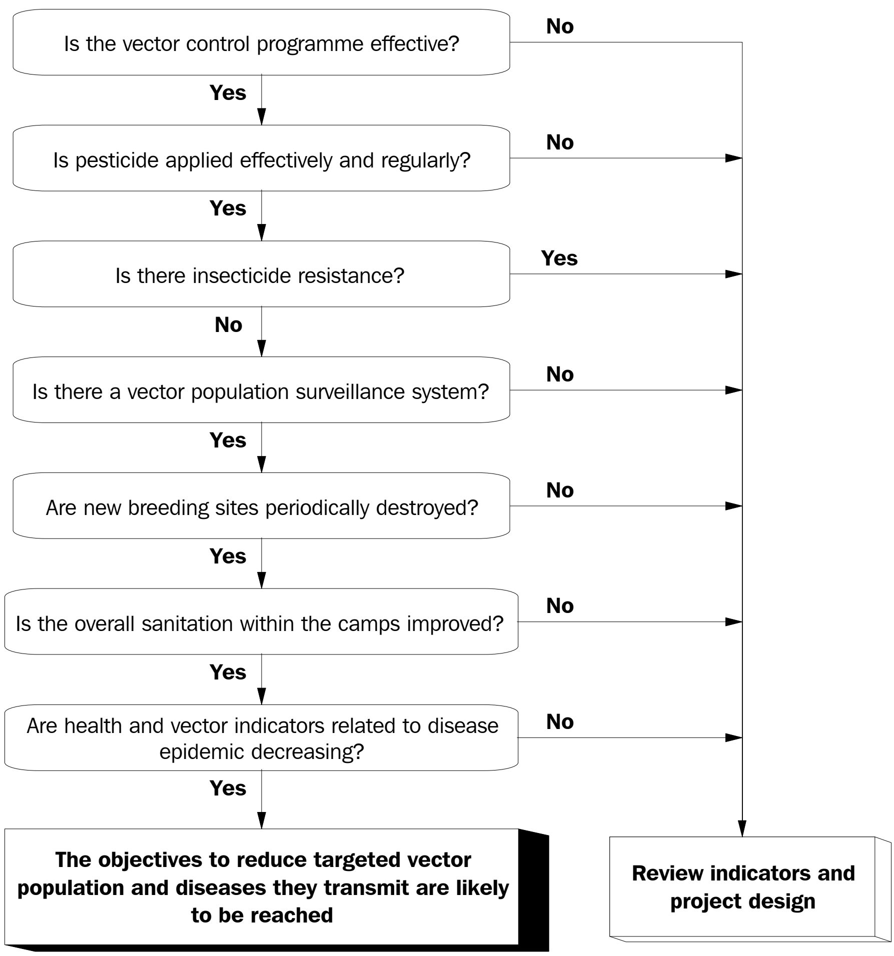
International orders may take several weeks or months, and once in country may be held up by customs, which could delay the projects. Good logistical support is vital to sort out such problems should they arise.

The site of the vector control centre must be discussed with the local authorities and the camp representatives. It must be located at least 1 km from any settlement. The material needed for the construction of the control programme centre must be identified. The construction includes a warehouse for storing the pesticides and machinery, an area for cleaning the equipment, water and hygiene facilities for the personnel, soakaway pits for disposal of the polluted water, and another water facility for the preparation of the solutions.

The transport of the personnel, equipment and the chemicals must be clearly defined according to the regulation of the host country and international regulations.

4.5 Operational implementation *(Flowchart S2)*

Water and sanitation engineers, public health engineers, and sanitary engineers have to manage and plan operational activities. These include required specific schedules for each activity; choosing site and construction of the vector control centre, determination of number of personnel and their individual assignments, personnel recruitment, training, purchasing spray equipment and insecticides, execution of the spraying campaign, continuous provision of service (operation and maintenance), monitoring of project results (evaluation), and preparation of progress reports. Practical Implementation is developed in Chapter 5.



Flowchart S6. Simple questionnaire survey for programme evaluation

4.5.2 Monitoring and evaluation

Under the circumstances prevailing in an emergency refugee/displaced person camp, the epidemiological data recorded in the health centres and the counts of targeted vectors constitute the best sources of information needed for a small and simple survey. Although that data may not be completely accurate for any number of reasons, these will at least give a trend of diseases occurring and the vector population needed to be targeted (Thomson, 1995). A system of surveillance should be carried out to monitor the programme by the collecting of data and information at least once a week.

Flowchart S6 should guide the field engineer with appropriate questions to evaluate the control programme.

5.

Practical Implementation

5.1 Introduction

This section has been organised as follows:

1. Main features of a Vector Control Programme; a logical framework to show the overall plan to implement the control programme.
2. Criteria for purchasing chemicals and equipment for spraying programme.
3. Labour, including manpower, personnel training, personnel protection and safe use of pesticide.
4. The Vector control Centre providing facilities for the workers, chemicals and equipment storage.
5. Pesticide calculation for amount of chemical required for application.

This Chapter provides specific information linked with the practical implementation of the vector control programme. Main features of such a programme are described through the logical framework (Table 5.1.). A range of the most common insecticide formulations, spray machinery to be purchased, and labour required are detailed. These are based on typical usage for an emergency situation. Criteria for purchasing chemicals and other equipment have been considered for the overall implementation of the programme. Infrastructure and hygiene facilities are also detailed, such as storage for chemicals and equipment and personnel facilities, such as changing rooms. Safety measures are provided and should not be neglected by the personnel involved in the control programme. Calculations for the preparation of the insecticide solutions are also explained.

5.2 Main features of a Vector Control Programme

The logical framework used for project design, and presented in Table 5.1 provides a synopsis of the main features of the vector control programme and the means by which progress will be judged.

The overall ***goal*** and specific ***purposes*** (also called objectives) are achieved through identified ***outputs*** produced from the ***activities*** (Summary column).

The activities require ***inputs/resources***; what materials, equipment, human resources, are to be provided, at what cost, and what time frame is required.

The achievement of the control programme outputs, purposes and goals is shown by the ***measurable indicators*** (measurable indicators column), these show quantity, quality and time required to produce the outputs, and in order to achieve the purposes.

Means of information, indicates where the information for measuring success can be found.

The column ***Important assumptions*** indicates the external factors, which are outside the control of the programme, that may affect project success.

Table 5.1. Logical framework for implementation of the programme

Summary	*Measurable indicator*	*Means of information*	*Important Assumptions*
Goal: To stop or to prevent a vector-borne disease epidemic in a temporary human settlement.	Health statistics; morbidity and mortality rate.	Hospital. Health centre.	
Purpose: To reduce vectors to below a level at which they do not present a danger of disease transmission to the affected population.	Vector prevalence. Surface area treated. Reduction of breeding sites.	Internal evaluation of the control programme, daily, weekly and monthly reports.	Susceptibility of the vector targeted. Host country regulations do not authorise certain chemicals for public health use.
Outputs: A. Good logistical support for the control programme is provided with the VCC[1]. B. Training programme has provided skilled personnel. C. Efficient spraying campaign. D. System of surveillance has been set up.	A. Vector Control Centre is operational. B. Quantity of skilled personnel. C. Quantity of chemicals used, good spraying, and coverage of the surface area or units to be treated. D. Health statistics and vector count.	Internal evaluation of the control programme, daily, weekly and monthly reports. Medical services and Vector control Programme.	Resistance of the vector targeted. Host country regulations do not authorise certain chemicals for public health use.
Activities: Field Investigation and breeding site mapping. Establish the needs of the control programme and prepare a plan of action. Get appropriate authorisation from country host representatives. Purchase of equipment and chemicals.	**Indicators:** Health statistics, vector count, vector resistance. **Quantity of equipment:** Spray machinery, spare parts, individual protective equipment and clothing, pesticides, vehicle(s), stationery.	Host country representatives. Affected population. UN agencies. International NGOs. Local NGOs. Local inhabitants. Local government.	Resistance of the vector targeted. Host country regulations do not authorise certain chemicals for public health use. International order and delivery may delay the control programme. Long delays in customs. Local traders not reliable.

Site selection for the VCC. Construction of the VCC. Personnel recruitment. Personnel training. Spraying campaign. Monitor control programme. Evaluate the campaign.	**Infrastructure:** Material for construction. Vector Control Centre for logistical support, storage, facilities for workers. **Quantity of personnel:** Management staff and labour related to control programme. **Training:** Training site, training equipment, stationery. **Cost:** Equipment and chemical costs, logistical costs, salary, taxes. Time required	Ministry of Health. Ministry of Agriculture. Traders.	

[1]VCC: Vector Control Centre

5.3 Criteria for purchasing insecticides commonly used in emergencies

An insecticide is generally not usable in its purest form, which is why it needs to be formulated. This operation consists of mixing or diluting a small amount of pure insecticide/active ingredient (a.i.) with another chemically inert material. This process is industrially manufactured. The result obtained is an insecticide formulation which will allow for the chemical to be transported and applied with less danger for the population, the operator, and the environment. Nowadays, many pesticides/insecticides are biodegradable.

For the same insecticide formulation, physical properties may differ depending upon where and how the product has been manufactured. When purchasing insecticides the following criteria must be considered:

1. The insecticide must be suitable for the targeted organism. Suitable insecticides categorised by vectors are summarised in Appendix 1.

2. The insecticide must be rapidly available and in enough quantity to perform the control campaign.

3. The insecticide to be used must be registered in the country of use. If not, an exceptional authorisation may need to be obtained for public health use.

4. The manufacturer providing the insecticide must be well known and referenced.

5. Only new stock must be purchased, and donations avoided. The insecticide must not have passed its expiry date.

6. The name of the insecticide must be associated with an ISO number (International Standardisation Organisation), as it is a quality label, e.g. ISO 14000.

7. The insecticide should have a WHOPES number, which means that it has been tested by the WHO Pesticide Evaluation Scheme (WHOPES) and that it has been accepted according to WHO specifications, e.g. permethrin has the WHOPES number OMS-1821, malathion: OMS-1.

8. The active ingredient concentration required must be expressed in g/kg or g/l.

9. Insecticide must be supplied with safety instructions, recommendations and notice book in case of poisoning.

10. The package quality of the insecticide must be appropriate for transport; waterproof, and airtight.

11. Insecticide must be compatible with the spray equipment.

12. Cost.

Several types of formulation are available, but this Chapter concentrates only on insecticide formulations commonly used in emergencies. These are Dustable Powder (DP) *(International Coding)*, Wettable powder (WP), Emulsifiable Concentrate (EC), Suspension Concentrate (SC), Ultra Low Volume liquid (UL), and Granules (GR).

Table 5.2. Types of formulation: advantages and disadvantages

<table>
<tr><th colspan="2">Dustable Powder (DP)</th></tr>
<tr><td colspan="2">The active ingredient (a.i.) is mixed with an inert carrier powder such as talc or gypsum. Used for ectoparasite control such as fleas, lice and also cockroaches.</td></tr>
<tr><td>Advantages:
■ Ready to use. No need for water, particularly adapted for dry climates.
■ Depending on the type of duster, possible to treat large surfaces.
■ Possible to treat where access is difficult.
■ Not expensive.</td><td>Disadvantages:
■ The homogeneity of the deposit is difficult to obtain, hence overdose and/or underdose of the surface to be treated.
■ The cloud emitted by the duster is uncontrollable.
■ Difficult to obtain a deposit which adheres to the surface, and therefore need to repeat the operation.
■ Good storage needs to be provided in a humid climate.</td></tr>
<tr><th colspan="2">Wettable Powder (WP)</th></tr>
<tr><td colspan="2">Formulation generally used for malaria control and residual surface treatment. The formulation is a concoction where the a.i. (50% to 80%) is mixed with an inert powder and a wetting material. Before spraying the formulation is mixed with water to obtain the spraying solution. The solution must be continually agitated to keep suspension. This formulation must not be mixed with an emulsifiable concentrate. The formulation is very effective on substrates such as mud, bricks, concrete or organic material.</td></tr>
<tr><td>Advantages:
■ Adaptable to all types of active ingredients. Crushing the a.i. will increase the biological effectiveness.
■ Good homogeneity on the treated surface.
■ No storage problem.
■ Not expensive.</td><td>Disadvantages:
■ Weighing the powder to be transferred into the spraying machine is difficult for manufacturer.
■ White deposit left by the WP on painted walls may be not acceptable to the population.</td></tr>
<tr><th colspan="2">Emulsifiable Concentrate (EC)</th></tr>
<tr><td colspan="2">Use for residual spraying. The formulation contains the a.i. (2.5 to 25 %) mixed with a petroleum-based solvent and an emulsifier. The formulation is mixed with water before spraying. Cannot be used as ULV as the solvent is too volatile.</td></tr>
<tr><td>Advantages:
■ Very easy to manipulate.
■ Allows a large distribution of the a.i..
■ The presence of the solvent helps the penetration of the a.i. into vegetation.</td><td>Disadvantages:
■ Can only be used with soluble active ingredients and/or solvents.
■ Danger of toxicity and phytotoxicity appears when using organic solvents.
■ Very sensitive to the cold during storage.
■ Expensive.</td></tr>
<tr><th colspan="2">Suspension Concentrate (SC)</th></tr>
<tr><td colspan="2">The a.i. is mixed with a liquid, (not an organic solvent). These are stable active ingredients suspended in a liquid to be used after dilution in water, in a suspended form.</td></tr>
</table>

<table>
<tr><td>Advantages:
■ Easy to manipulate.
■ Particle size very small, hence better coverage of the treated surface.</td><td>Disadvantages:
■ Perfecting the formulation can be very delicate.
■ Can be a storage problem.
■ Very costly.</td></tr>
<tr><td colspan="2">Ultra Low Volume Liquid (UL)</td></tr>
<tr><td colspan="2">Homogeneous liquid ready to use with an ultra -low-volume spraying machine. Very good under epidemic conditions. The operator should already have good experience in using this spraying machine, and needs some specific knowledge regarding the security and the safety of the operator himself and the population.</td></tr>
<tr><td>Advantages:
■ Formulation ready to be used.
■ Large surfaces treated in a short period of time.
■ Possible to treat places of limited access.
■ Very good penetration where the vegetation is dense.
■ Fast biological action, ‘Knockdown effect’.</td><td>Disadvantages:
■ Wind can provoke a drift of the spray.
■ Care must be taken to ensure the safety of the operator and the population.
■ Very costly.</td></tr>
<tr><td colspan="2">Granules (GR)</td></tr>
<tr><td colspan="2">Granules are inert materials such as kaolin, sand, or clay, into which the active ingredient has been impregnated. They are used for larviciding. Granules are directly applied to water by hand or with motorised and converted mistblowers.</td></tr>
<tr><td>Advantages:
■ Easy and ready to use, no storage problem.</td><td>Disadvantages:
■ Expensive.</td></tr>
</table>

Sources: Adapted from Henriet, 1995; Thomson, 1995; Chavasse and Yap, 1997

5.4 Criteria for purchasing spraying equipment

Two types of spraying equipment are used in vector control. There are sprays used for residual treatment or larviciding, and sprays which produce mists or fogs used for space spraying. Residual spraying equipment is easy to manipulate, unlike space spraying material which requires specific knowledge of use and careful attention to safety.

Equipment for spraying is available worldwide depending upon the type of pesticide formulation used and the targeted vector. Indoor residual spraying is more effective and has a greater impact on malaria transmission than the direct treatment of mosquito breeding sites, because the longevity and the density of the vector population is widely reduced. Hand-compression sprayers are generally preferred for interior residual treatment. Space spraying is the most suitable and immediate strategy in an emergency to control vectors of yellow fever or dengue epidemics, and to control fly disease transmission. The type of machinery used for space spraying depends upon the surface areas to be treated and the vector targeted. Vehicle-mounted thermal foggers, back-pack mist blowers and hand carried thermal foggers are generally appropriate for these spraying operations. Suitable equipment for spraying programme are categorised by targeted vectors in Appendices 1 and 2.

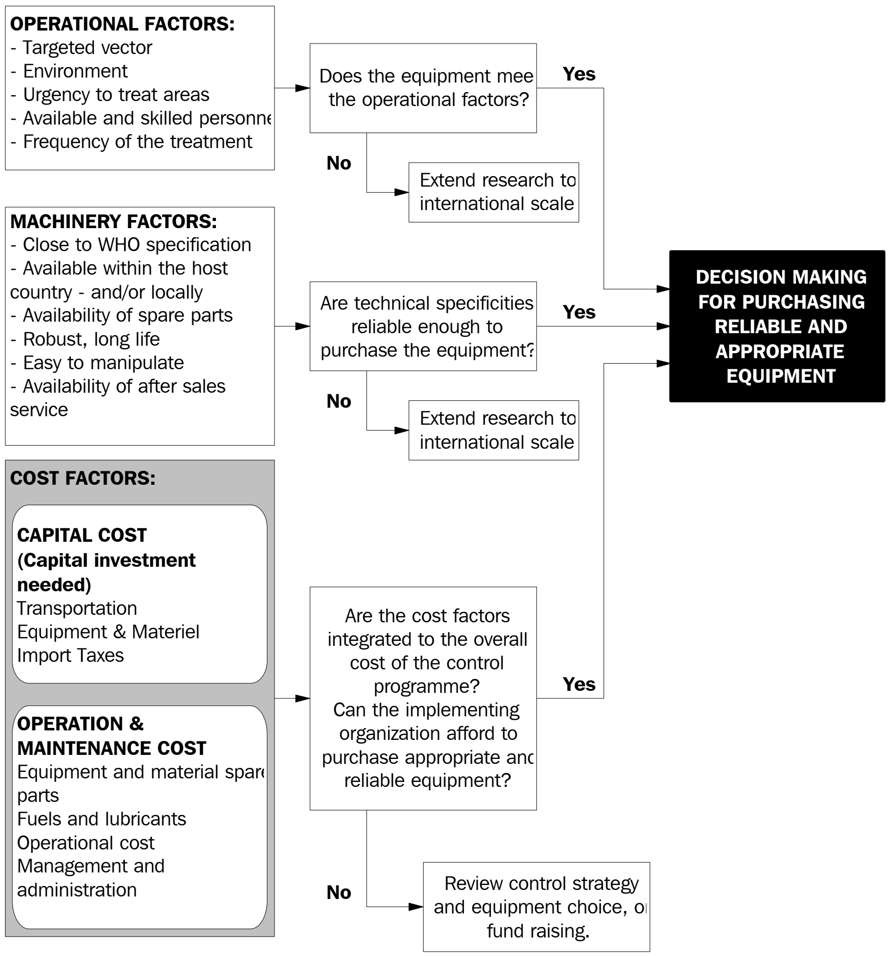
The choice of the equipment is based on several factors (Flowchart S5.1.), such as operational factors, the equipment itself and the capital cost required for the control programme. Equipment must be reliable and appropriate.

Operational factors

These will depend upon the chosen spray strategy (residual spraying, space spraying, and larviciding) according to the targeted vector and its ecology. The surface of areas to be treated, the urgency of the spray campaign, the availability of specialists, skilled persons and labourers, the frequency of insecticide Application and the daily coverage of different delivery systems spray machine, will all have a great impact on the choice of equipment needed.

Machinery factors

Purchasing the right equipment will depend upon the availability of the equipment within the host country. The purchased equipment must be of a good quality and guaranteed. An after sales service must be provided where machinery is bought. Spare parts must be available in large quantities. Some spray machines have been designed for use with specific formulations or where a diluent is added. Be sure to check these specifics. Machines must be appropriate according to the spray solution being used. Machines must be easy to use and to maintain. The life of the machinery will depend on the reliability of the personnel, and the maintenance given. (Thomson, 1995).



Flowchart S5.1. Considered factors for purchasing spray equipment

Cost factors

The overall cost of a vector control programme includes machinery costs. Purchasers must be aware that for the same type of machine the price may differ widely. Maintenance costs must be included within the budget. Good maintenance will keep the equipment working for several years, and will save money in the long run.

5.4.1 Types of nozzles for sprayers

The choice of nozzle will increase the quality of the spraying depending on the control strategy chosen and the vector targeted. Sprayers for residual treatment use different types of nozzle which produce droplets with diameters of 100 to 300 µm (microns). Space sprayers using mistblowers must have a nozzle which produces droplets of 50-100 µm in diameter. Other machinery used for space spraying and in particular the thermal fogging machine are able to produce droplets or particles with sizes of less than 20 µm in diameter. This machine however, requires a well experienced operator. Nozzles for residual spraying play a very important role. The nozzles should allow a certain quantity of liquid, 0.76l per minute to be discharged under a certain pressure, 25-35 psi. In addition, a uniform, fan-shaped spray will be ensured by this given pressure (Sabatinelli, 1996).

Table 5.3. Types of nozzle for residual spraying machine

Type of nozzle	*Application*	*Type of spraying*	*Control*
Solid stream	Cracks and crevices	Residual spraying	Cockroaches, soft ticks, bedbugs, ants
Flat fan	Wall spraying	Residual spraying	mosquitoes and flies
Hollow cone	Breeding sites in vegetation	Residual spraying and/or larviciding	mosquitoes, ticks, mites
Solid cone	Breeding sites	Larviciding	mosquitoes

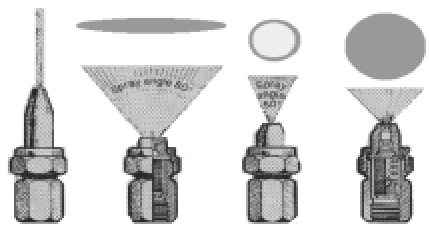


Figure 5.1. Nozzles for residual spraying machinery (WHO, 1997)

5.4.2 Hand-compression sprayer

Hand-compression sprayers are suitable for residual surface treatment and they are also used for spreading larvicide once the appropriate nozzle has been fixed. They constitute the basic equipment for a control programme. Hand-compression sprayers have a large cylinder tank with a capacity of 7.5-

10 litres. The insecticide formulation is pressurised by an attached hand pump system. The liquid is pressurised by the pumped air and then it is projected outside through the hose with a cut-off valve, the lance, and the nozzle. To maintain the pressure and the flow rate during the spraying, the tank needs to be pumped several time as the liquid decreases inside the tank. A pressure control gauge can be added to know with precision and to monitor the pressure needed (25-55 psi). If there is no pressure-gauge then counting the number of strokes of the pump will indicate the initial pressure needed. Solid tanks should be preferred over light plastic ones and if they are well maintained they can be used for several years. The sprayer is carried on a person's back with an attached harness (Sabatinelli, 1996).

Figure 5.2. Hand-compression sprayer

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5.4.3 Lever-operated sprayers

This type of sprayer is generally made of plastic and the tank has a capacity of around 15 litres. The lever has to be manipulated all the time to action the piston or the membrane pump and to maintain the pressure during the spraying. The spreading of the insecticide is not very accurate because the operator has to simultaneously action the lever with one hand and operate the sprayer with the other. It is carried on the back with two attached shoulder straps. Lever-operated sprayers are generally used in larval and mollusc control.

Figure 5.3. Lever-operated sprayer

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5.4.4 Backpack motorised mistblowers

Backpack motorised mistblowers are used for space spraying and are very effective during epidemics, on outdoor resting places in dense vegetation, indoors and around shelters. Space-spraying machines involve the use of ultra low volume liquid formulation. Backpack motorised mistblowers work with gasoline engines of 25-77 cc and are very noisy. They are carried on the back with two attached shoulder straps.

The engine drives a centrifugal fan producing a very high air current which is linked to a flexible hose onto which a centrifugal or pneumatic nozzle has been fixed. A part of this air is directed into the insecticide tank where the air exerts a constant pressure on the liquid to be forced out. The insecticide is ejected and sprayed out in a form of very small droplets between 50 to 100 µm in diameter. Used for treatment of adult insects, the very fine droplets remain suspended in the air for a long time and therefore kill more flying insects. Bigger droplets, 100 to 300 µm, produced by mistblowers are used for larvicide and molluscicide treatments.

Figure 5.4. Backpack motorised mistblowers
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Some companies have manufactured motorised mistblowers which can be converted into dusters by removing some parts of the equipment.

5.4.5 Portable fogging machines

Portable fogging machines work with a pure petrol engine. The exhaust provides the heat and gas needed for the working of the thermal nozzle. The petrol tanks and the insecticide are pressurised by the pumped air. The insecticide drops into the nozzle and it is carried out with the gas produced by the heat of the exhaust. Thermal fogging machines produce droplets of less than 50 µm in diameter. Other models of thermal fogging machines can be carried on the back of a pick-up truck. This engine demands particular attention due to the high risk of fire. A trained operator is required to use it safely. A fire extinguisher should be available with the operator (OMS, 1991).

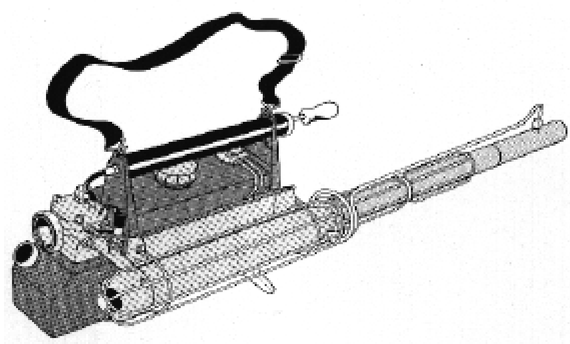


Figure 5.5. Portable fogging machine (WHO, 1995)

5.4.6 Hand-carried dusters

Hand-carried dusters are also used for the application of solid materials. The tank containing the formulation and the pump attached to the tank constitute the two main bodies of the hand-carried duster. Air is pumped into the tank which forces the insecticide out through the nozzle tip.

Figure 5.7. Hand-carried dusters

Reproduced with the kind permission of H. D. Hudson Manufacturing Company, 1999

5.4.7 Hand-operated puff-duster

These are used for the application of solid materials. Insecticide dust is applied to clothing with this small puff-duster by hand pressure which blows the solid material onto the surface to be treated.

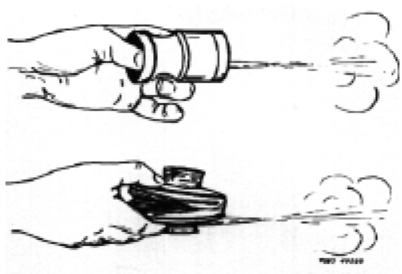


Figure 5.6. Hand-operated puff-duster (WHO, 1995)

5.4.8 Average treated surface areas for different types of spraying

The type of the machine to be used will depend on the surface area to be covered and the degree of the emergency occurring. The surface areas covered by different machines are described in Table 5.4.

Table 5.4. Daily treated area coverage of different types of spraying

Types of spraying	*Surface area treated*
Vehicle-mounted thermal fogger	150 ha
Backpack mistblowers	5-30 ha
Hand-carried thermal fogger	5 ha
Hand-compression sprayer	0.18 ha

Source: Adapted from Bres, 1986; 1 hectare or ha = 10,000 m^2 or 2,471 acres.

5.5 Labour

The quality, efficiency, and reliability of the vector control programme will depend on its personnel and the financial resources available. The water and sanitation engineer should have both the experience necessary to successfully manage the project and to select appropriately skilled and trained workers. The need for personnel and the degree of difficulty in planning the work will increase in proportion to the surface area to be treated. As the dimensions of the project increase, so do staff numbers and difficulties. The organisational flowchart, Figure 5.8., shows a typical example of a vector control team for residual spraying. Job descriptions for each level of responsibility are described in Appendix 4.

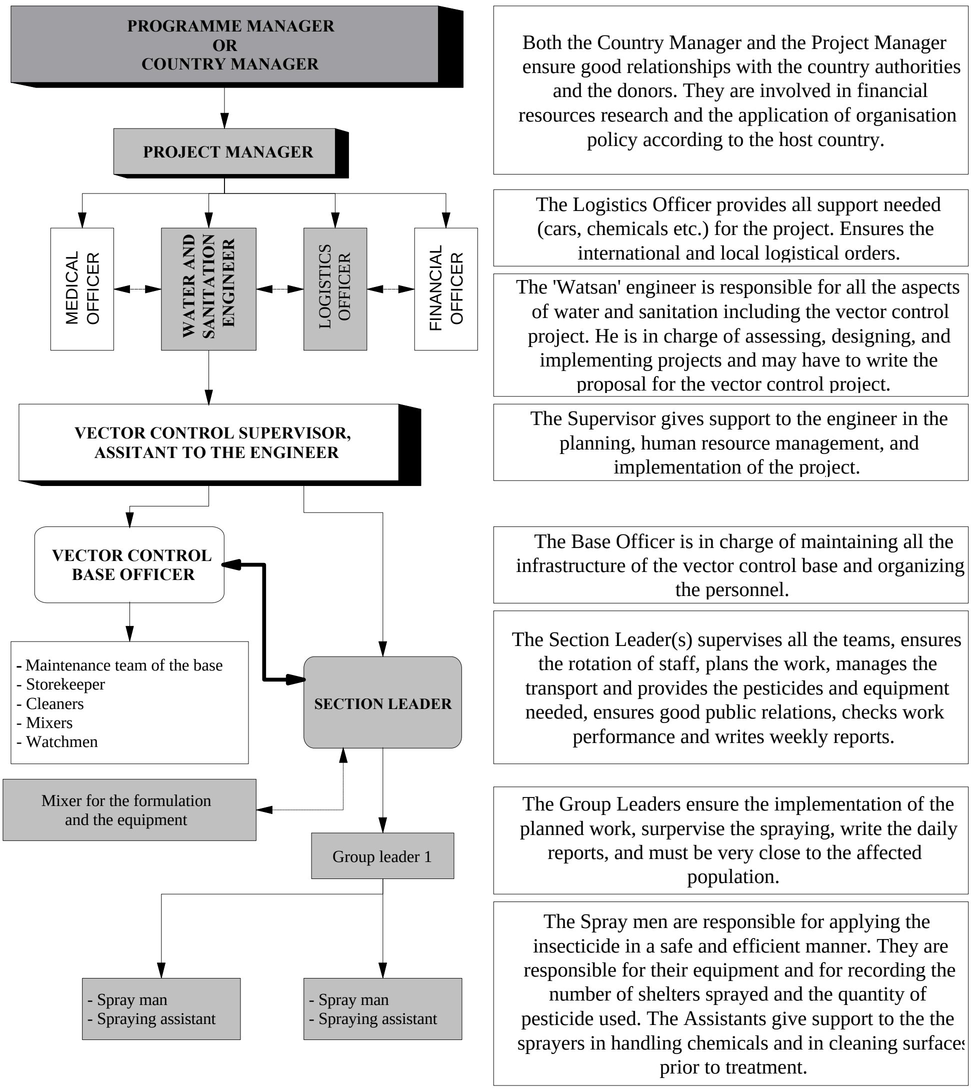


Figure 5.8. Organisational overview of a Vector Control Programme.

5.5.1 Manpower

The personnel required will depend on the degree of the emergency, the size of the surface area to be treated, the field conditions (e.g. accessibility to the area). There is no standard for organisation of manpower, as this will based on the experience and the skills of the field engineer in organizing personnel. The number of spray men needed is based on the surface area or the number of units (shelters, latrines) to be treated and the daily coverage of the selected spraying machine (Table 5.4.). The day work of the spray man is four hours maximum, to avoid contamination and poisoning. This time comprises the following factors:

1. Weight of the spraying machine to be carried.
2. The spraying speed.
3. The surface area or the number of facilities (shelters, latrines) to be treated.
4. Explanations or instructions that the worker has to provide to the family before spraying.
5. Time needed to remove or protect food, drink and persons from the shelter, before spraying can begin.
6. The walking around the facility when spraying it.
7. The time to move from one facility to the next.
8. The time to refill the empty spray machine with the pesticide and/or petrol if motorised.
9. The support that the VCC may give to provide pesticide and/or petrol on time.

In the case of a space spraying programme, the surface area to be treated is obtained by multiplying the length of the area by the width. The surface area to be treated divided by the daily surface area that one sprayer with a motorised spraying machine is able to cover, will provide the number of spray men and spraying machines need. The following formula can be applied;

$$\mathbf{((L \times W) \div 10000) \div C}$$

L: length of the surface area to be treated (m)
W: width of the surface area to be treated (m)
C: average daily coverage of the spraying machine being used (ha) (Table 5.4)

Example: *Surface area of the surface to be treated: 30 ha (1 ha = 10,000 m^2). A backpack motorised mistblower has been chosen and has a daily coverage of 5 ha/day.*

In this example, 6 spray men and 6 mistblowers will be required to treat this surface during one day of work. The space spraying may also be spread over several days which will reduce the number of personnel and equipment required, e.g. 1 spray man, 1 mistblower over 6 days, which means that the camp should have been divided into 6 identifiable parcels of 5 ha.

Assistant(s) should assure that the spray man has insecticide and petrol available when needed. The assistant should also assist the sprayer in his work (see Appendix 4).

Residual spraying using a hand-compression sprayer involves more personnel, more equipment, and may require heavy logistics (The logistics needed in a large camp situation may not be in place to make a residual spraying program feasible, however in small camps where less logistics is needed, residual spraying should be considered to prevent epidemic disease). Personnel used for residual spraying may be up to 150 workers including management staff, spray men, assistants and other personnel related to the control programme.

The number of spray men required may be defined as the following formula:

$$\mathbf{((A_{(u)} \times B) \div 10000) \div C}$$

A: Total number of units (shelters, houses, latrines, etc.) to be treated
B: Average surface area for one unit to be treated (m^2)
C: Average daily coverage of the spray machine being used (ha) (see Table 5.4)

Example: *Determine the number of spray men to treat 12352 shelters having an average surface area of 43 m^2. Hand-compression sprayers will be used for the spraying programme.*

$$((12352 \times 43\ m^2) \div 10000) \div 0.18\ ha = 295$$

295 spray men will likely be impossible to manage. The spraying campaign can be spread over several days. e.g. 20 days of spraying campaign will

require 14 sprayers per day of work, this figure is more reasonable to manage, and the personnel organisation could be as described in Table 5.5. This figure may be repeated for several camps.

Table 5.5. Personnel organisation involving 14 spray men.

Rank	Personnel distribution	
Section Leader: 1 person	Section Leader 1	
Group Leader: 2 persons	Group Leader 1	Group Leader 2
Teams: 28 workers	7 teams comprising 1 spray man and 1 assistant	7 teams comprising 1 spray man and 1 assistant

5.6 Training

Training is very important to the success of the spraying programme and the safety of the application. 3 to 5 day training courses should be enough to cover spraying techniques. In addition to this a basic course on simple health education, safe use of insecticide including first aid, and equipment maintenance should be carried out.

A theoretical training course should be provided before implementing practical training courses. The following training practice should be provided:

1. Proper use of the protective clothing.
2. Spraying equipment knowledge. The operator must be able to take to pieces and to re-assemble all parts of the spraying machine. He should be able to identify which piece of his machine is defective in the event of it not working. Every single piece should be cleaned and maintained properly at least once a week.
3. Checking the quality of spraying.
4. Spraying practice should be carried out on a training wall, or on a shelter similar to the camp, to put the spray man in real work conditions.
5. First Aid practice for all the personnel.

In the training area which has been set up, each spray man must be trained to spray a surface area of 19 m^2 in 1 minute. 9 vertical strips including 8 overlapping strips must be sprayed.

The spray man should face the surface area to be treated, and spray at a uniform rate starting at the left bottom corner of the wall upward to the top. A distance of 45 cm must be kept between the nozzle tip and the surface area to be treated (Figure 5.9). To keep this distance in training, a piece of wooden stick can be attached to the lance (Figure 5.10.). Once the first strip is done then the worker moves one step to the right without stopping the spray, down to the bottom. The previous strip should be overlapped by a minimum of 5 cm. This operation must continue until the entire area is covered.

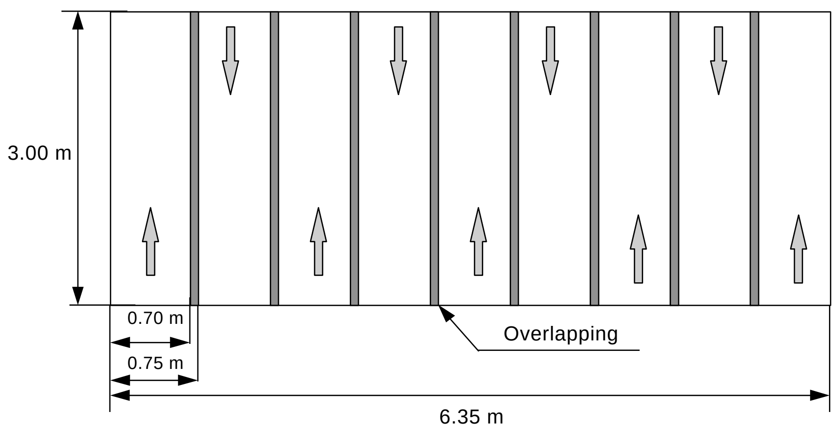


Figure 5.9. Training wall for spraying programme (WHO, 1997)

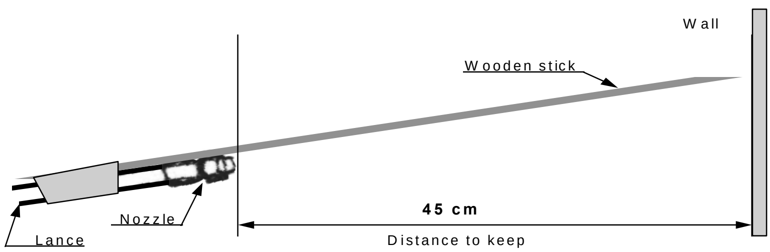


Figure 5.10. Wooden stick fixed on the lance (Lacarin, 1998)

The quality of spraying will depend on the spraying speed. The operator should be able to determine the amount of the liquid being sprayed during one minute of time. A standard figure is 0.760 l/minute. A measuring cup can be used to measure this amount. The general requirement for spraying is 0.04l of insecticide per m^2. This means that 0.760 l/minute divided by $0.04l/m^2$ should cover a surface area of 19 m^2 during one minute of time. This is a figure given for an optimal situation. Hence this wall of 19 m^2 of surface area is used for practice.

Under the same conditions as described above the time required to spray a latrine where the surface area to be treated is 7.38 m^2 including walls and floor, will required $[7.38\ m^2 \div 19\ m^2] \times 60$ seconds = 23 seconds. In a case of latrine spraying programme, the spray man should not spend more than 23 seconds per latrine.

Table 5.6. Personnel training required for Vector Control Programme

Personnel	Training required
Water and Sanitation Engineer **Public Health Specialist** **Sanitary Engineer**	He/she should have training in public health engineering, and should have a clear understanding about what vector control programmes involve. He/she should have been in training prior to arrival in the affected area. A 2 month training course is a minimum required for implementing entomological assessment and resistance test kit, and safe use of pesticide. Must be trained to give first aid in case of poisoning and must be able to use appropriate antidote including auto-injector of atropine only if medical services not available.
Supervisor of Vector Control Programme	He/she should have training in public health engineering, also covering theory of vector control, vector identification, health promotion, training of vector control personnel, supervision, maintenance of machinery, safe use of pesticide. Must be trained to give first aid in case of poisoning and must be able to use appropriate antidote including auto-injector of atropine only if medical services not available.
Vector Control Centre Officer	He/she should have training in safe use of pesticide, storage of pesticide, spraying machine, spare parts, clothing, supervision and maintenance of the centre, and organise watchman rotation. Must be trained to give first aid in case of poisoning.
Spray men and assistants	They must have training in basic health education, safe use of pesticide, and must have a good practical training in spraying methods and operation. Must be trained to give first aid in case of poisoning.
Other personnel related to the control programme	People must have received information about the danger related to chemical use. They must be trained with a good basic education on safety measures for dealing with chemical pesticide.

5.7 Personnel protection and safe use of pesticide

All pesticides involving chemicals are toxic to some degree. Those responsible for the use of pesticides in public health programmes for vector control have to apply strict rules concerning the safety measures of their personnel and the population where chemical control measures occur. Care in handling chemicals by the people spraying should be considered as routine practice. The recommendations described below must be respected.

5.7.1 Individual protective clothing

Personnel involved in control programmes must wear protective clothes. Spray men and the other workers should have two complete sets of clothing and individual protective equipment. This allows them to have one set in use while the other is being washed, because these protective clothes need to be carefully washed after each use to avoid any unnecessary exposure to chemicals. All parts of the body must be protected with work clothes, removed immediately after the work is finished.

Protective clothing must be related to toxicity of insecticide. The list in Table 5.7 would not be necessary for a bednet dipping programme using permethrin. Excess clothing in the tropics increases sweating which increases absorption of insecticide (Thomson, 1999).

Table 5.7. Individual protective clothing items

Items	*Materials and functions*	*Quantity*
Large hats	Should have a large brim to protect the face and neck from droplets. It should be of impervious material	2
Masks	Generally made of gauze and avoid dermal exposure of the face and reduce inhalation of the spray. The masks must be given in a large quantity to the spraying team.	Large quantity
Respiratory mask with filter (Space spraying use)	Only used for fogging, the mask is fitted on the face very closely. Filter cartridge must be renewed regularly.	1
Goggles	Plastic, protect eyes from droplet exposure.	1
Dungarees with long sleeves	Should be made of durable cotton fabric. Protect the body from exposure. Need to be washed after each spraying use.	2
Aprons	Should be made of rubber or PVC to protect from any spills of insecticide	2
Gloves	Made of PVC[1], rubber, or cotton. They protect the hands when handling chemicals and spraying.	several
Pair of boots	Made of rubber. They protect the lower part of legs where the aprons may not reach.	1

[1] PVC gloves are not usable for the manipulation of pyrethroids as these chemicals are absorbed by PVC (Chavasse and Yap, 1997).

Table 5.8. Individual protective equipment categorised per job function

Job Functions	Item distributions							
	Large hats	Masks	Goggles	Dungarees	Aprons	Gloves	Boots	Respirat'y mask
Supervisor				√			√	
Section leader	√	√	√	√	√	√	√	
Base officer				√		√	√	
Group leader	√	√	√	√	√	√	√	
Spray man	√	√	√	√	√	√	√	√
Spray man assistant	√	√	√	√		√	√	
Mixer	√	√	√	√	√	√	√	
Cleaner		√	√	√		√	√	
Storekeeper				√		√	√	
Maintenance team				√		√	√	

Job functions are described in Chapter 5.5 and Appendix 4.

5.7.2 Precautions for use and storage

In order to minimise the risk of exposure when manipulating chemicals and equipment, all personnel must be made aware of their responsibilities, including personal hygiene, personal protection and the correct use of safety measures. Each level of the control programme must be well supervised.

1. All personnel must receive a training course, for the chemical use and the manipulation of the equipment. Safety measures must be provided and personnel examined to verify that they understand the risks.
2. All personnel should wear protective clothing and individual equipment. Clothes must be removed immediately after work.
3. Smoking or eating during operation should not be permissible.
4. Avoid long exposure of the person spraying, 4 hours is a maximum and team rotation should be planned.
5. Never spray in windy conditions.
6. Hygiene facilities (such as showers, taps and soap)must be provided in sufficient numbers. Workers must take showers after work, and immediately after accidental contact with chemicals.

7. Each worker should leave his/her protective clothing at the base to be properly washed by skilled personnel.
8. Each worker is responsible for the cleanliness of his/her equipment, and any fault should be reported to the maintenance team. Spraying equipment must be kept in good condition.
9. Chemicals and equipment may be stored together in a ventilated room, but protective clothing and other individual equipment must be stored separately from them in a separate store. The store must protect the insecticides against excess cold, and heat (chemical indications on the boxes or instructions of chemicals indicate their tolerance for cold and heat). Chemicals should be stored in a safe place that can be locked and that is not accessible to unauthorised personnel or children.
10. Never keep or transport insecticides in unmarked containers.
11. Never store and transport chemicals with food, drink or persons. Chemicals should be transported by vehicle according to the international regulations and the chemicals must be in their original containers, separated from each other and well secured to avoid falls and spillage. Always check for any container damages after transport.
12. Empty containers must be cleaned and buried.
13. Chemicals must be provided with warning instructions and explanations of what to do in case of exposure and/or poisoning, and if possible in several international and local languages.
14. Ensure that the closest medical services have been warned and have the items necessary in case of poisoning, e.g. injection of atropine for organophosphate poisoning. This must be discussed with the medical services before implementing the control programme.
15. A First Aid Kit must be available in the base.

5.7.3 Precautions for shelter treatment

An indoor residual spraying campaign requires that clear information and instructions should be provided to the inhabitants of shelters about what they have to do before and after their shelters have been treated. Drinking water and foodstuffs have to be removed or well-covered with a plastic or cotton protective sheet before the spraying starts. People must be kept out of the shelter during spraying, especially children who may try to see what is happening in their shelter. Before finishing the spraying of the shelter, any spillage of the insecticide on the floor must be swept or washed away.

5.7.4 Symptoms in case of poisoning

When poisoning or exposure occurs symptoms appear rapidly, generally 30 to 60 minutes after exposure. Symptoms of poisoning by exposure onto the skin may also give outward signs 2-3 hours later (Sabatinelli, 1996), so be sure that all workers know the risks and symptoms involved with chemical exposure or poisoning.

Symptoms of exposure to organophosphate and carbamate are similar (Chavasse and Yap, 1997). The first symptoms include excessive sweating, headache, narrowed pupils, vision out of focus, muscle weakness, increased fatigue, nausea, excessive bronchial secretion, hypersalivation, vomiting, stomach pains. Later, diarrhoea may occur, convulsion, loss of reflex, coma, respiratory arrest, and death.

Paralysis of the face and hand, irritation of the upper respiratory tract, salivation, and allergic reactions are symptoms of pyrethroid poisoning (Chavasse and Yap, 1997). Absorption of more than 15g via the oral route is poisonous to man (Sabatinelli, 1996). Pyrethroid poisoning has not been reported in humans as a result of vector control operation (> 500 cases reported from agricultural use of pyrethroids in China) but there have been reported cases with organophosphates (Sabatinelli, 1996).

5.7.5 First aid

All staff involved in a vector control programme must have been trained to give first aid in cases of poisoning. They must be able to administer the first aid quickly in an emergency. Once poisoning has been diagnosed, information about the accident must be recorded and reported to the medical services. This must include the name of the pesticide, its toxicity, quantity taken, route of exposure such as mouth, skin, eyes etc., time since the accident, whether the poisoning was intentional, accidental, caused by overexposure while spraying and other information related to the poisoning.

Table 5.9. Safety instructions for pesticide poisoning

First Aid	*Decontamination*
Remove the patient from the chemical.	The patient and the rescuer must be protected from solvent and the active ingredient. Gloves must be worn and a perimeter of security should be provided around the chemical.
Keep patient at rest.	Place the patient in the recovery position (on his/her side)only if still breathing.
Remove contaminated clothing if poisoning occurred through the skin.	The affected skin must be washed with soap and flushed with large amount of water.
Give plenty of water to drink if the chemical has been swallowed.	If medical activated charcoal is available induce vomiting of 10g in 100-250 ml of water. Vomiting should only be induced by a trained person when there is no readily available medical assistance. The patient must be conscious.
If breathing has stopped, start artificial respiration (CPR) immediately.	Remove all vomit and saliva from the patient's mouth if mouth to mouth is practised. Place a piece of tissue or a handkerchief between the mouth of the patient and the rescuer.
Get medical assistance	The patient must be taken to the medical centre where antidotes have been provided. This health centre located in the refugee camp must be known of all the control programme staff.
For eye contamination, clean with water	Immediately flush massive amounts of fresh water for more than 10 minutes and keep the eyes wide open.

Sources: Adapted from Thomson, 1995; Chavasse and Yap, 1997

5.7.5.1 Antidote

Antidotes must be available in the main health centre of the refugee camp. This must have been clearly discussed with the medical services, according to the chemical used, and before any spraying actions start. Guidelines and protocol for treatment of poisoning should be available in the appropriate language(s).

Table 5.10 provides some information which should be used by medical services only.

5.7.5.2 Testing blood of workers

Each person involved in a control programme should have been checked for the level of cholinesterase in their blood. Cholinesterase allows the normal transmission of nerve impulse. The cholinesterase, which is an enzyme, is deactivated by organophosphate compounds when overexposure occurs. The blood analysis will reveal the normal rate of this enzyme in the worker's blood before the programme starts, and this blood analysis must be carried out every week to monitor if the level of cholinesterase has dropped. If it is the case, especially when the level of cholinesterase has dropped to 50 % or more of the initial analysis, then the worker must be moved away from any chemical contact until the original amount of cholinesterase has been recovered (Thomson, 1995).

Table 5.10. Antidotes

Antidote names	Treatment applications
Activated charcoal	It induces vomiting, only used when chemical has been swallowed and the patient is still conscious.
Atropine sulphate	For organophosphate and carbamate poisoning. ▪ For adults 2-4 mg of atropine should be given intravenously. For children, 0.5-2 mg, according to weight. ▪ Every 15 minutes, 2 mg for 2-12 hours or longer in severe cases. Auto-injections of atropine in solution are available, and may be used by the supervisor of the control programme only if medical services are not readily available.
Pralidoxime chloride	For organophosphate poisoning only and within 12 hours of poisoning.
Diazepam	For pyrethroid poisoning. ▪ After a severe intoxication, intravenous injection of 5-10 mg should be given. ▪ It is to reduce anxiety.
Phenobarbitone	To reduce anxiety.
Vitamin K1	It is used for anticoagulant rodenticides.

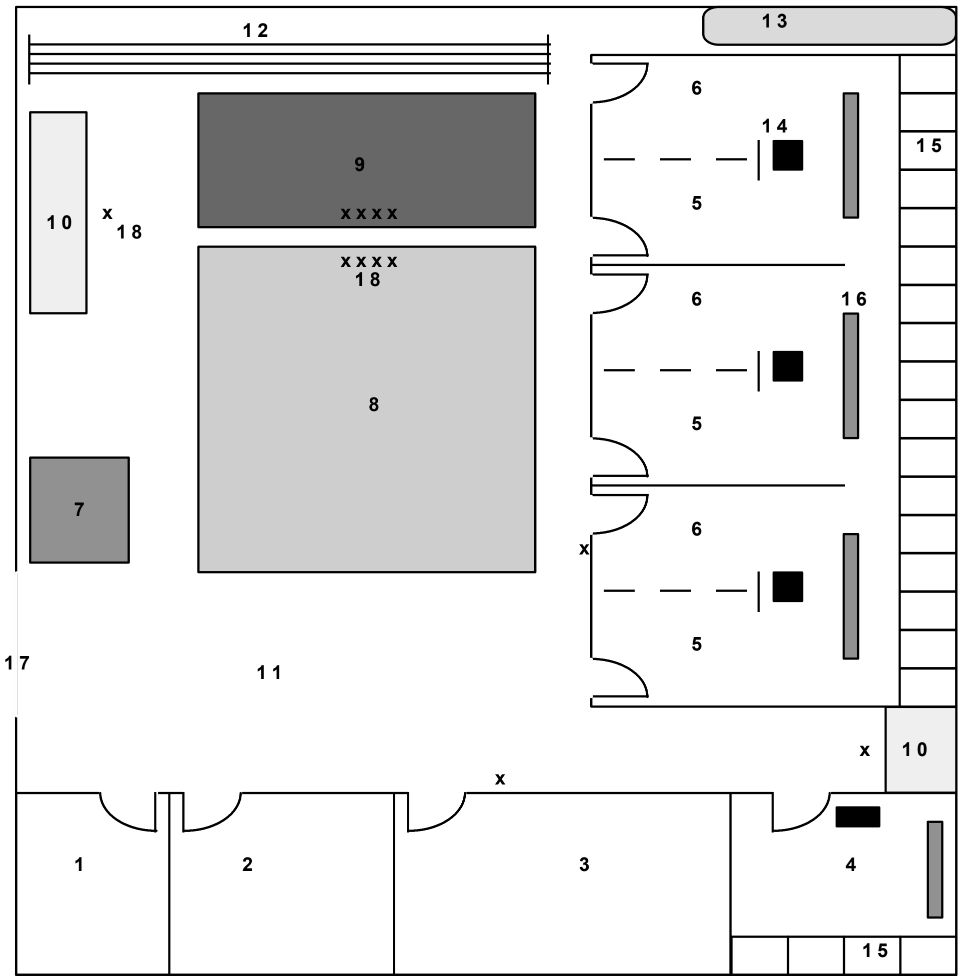
Sources: Adapted from Thomson, 1995; Chavasse and Yap, 1997

5.8 Vector control base layout

Agencies involved in vector control programmes must provide all installations and safety measures necessary to ensure a safe, secure and clean workplace for their workers.

The layout in Figure 5.11. shows an example of a typical base layout for a 3 group vector control scheme. An office (1) for the base officer and the storekeeper must be provided with the stationery needed. For the base personnel a changing room (4) is located apart from the external worker's changing rooms. Chemicals and spray equipment can be stored together in the same store (3), but all the personal equipment such as overalls, gloves, face-masks, boots, protective glasses, aprons, etc., must be stored separately from the chemicals (2). A large sentry-box (7) situated just at the main entrance houses the watchmen who control the entrance and the exit. Safe excreta disposal must be provided according to socio-cultural requirements of the personnel (10). At each point such as the preparation area (8), washing area

(9), latrines (10), and water-taps (18), soap and towels should be available. There must always be enough water to wash with after working.



1 Office
2 Individual equipment store
3 Chemical and machinery store
4 Changing room for permanent staff
5/6 Changing room spray teams
7 Sentry-box
8 Preparation area
9 Laundry area
10 Latrines
11 Vehicle area
12 Drying area
13 Elevated water tank, 15 m^3
14 Covered receptacle for dirty clothes
15 Showers
16 Benches
17 Entrance/exit
18 Taps

Figure 5.11. Vector control base layout (Lacarin, 1998)

A changing room (5, 6) with all the furniture needed such as benches (16), bins and coat-stands or hooks for clothes should be provided. The changing rooms for each group are divided into sections, one is for personal clothes that the worker can leave in a safe place (5), such as in a locker, and the other section (6) is for hanging work clothes that are not yet in need of washing. The worker arrives in the morning, changes from his civilian clothes into his work clothes. When breaking for lunch, or when finishing a spraying shift, these clothes are removed. After work, when the clothes have been exposed to chemicals and are in need of washing, the worker leaves the preparation area, removes and deposits the clothing in a covered receptacle (14), enters directly into the showers, and can then change into civilian clothes again. Towels should be available for the workers. This system protects the civilian clothes from any risk of contamination by the work clothes contaminated with the insecticide. A minimum of 10 litres of water must be available per worker for washing. The work clothes will be properly washed by skilled personnel at the laundry area (9) and dried (12). This precaution is taken to avoid any risk of exposure or poisoning of any members of the worker's family.

A large space has to be available for the reception of any vehicle such as truck or 4 x 4 car (11).

5.9 Pesticide application

The information provided in this section should help the operator to correctly prepare the appropriate volume of insecticide solution required for spraying. The calculation concentrates mainly on residual spraying applications. Generally, insecticides used for space spraying such as ultra low volume liquid are bought in a ready to use formula. The steps required for the calculation are detailed below with examples. The application procedure is developed in Appendix 1.

5.9.1 Determination of the quantity of formulation and liquid needed for the treatment programme

The volume of the insecticide formulation and the quantity of water needed for the global treatment programme must be established. The following steps should help the person responsible to determine these amounts.

Example: Determine the quantity of insecticide formulation and the quantity of water needed for a residual spraying programme to treat 2000 shelters of having an average surface area of 50 m^2. Insecticide formulation required is the deltamethrin 2.5 WP (Wettable Powder). The dose to be applied is 0.025 g of a.i. (active ingredient) per m^2.

Step 1:

The following factors must be considered:

1. The number of shelters to treat, e.g. 2000 shelters (A);
2. Average surface area (m^2) per shelter to be treated (ceilings and walls) e.g. 50 m^2 (B);
3. Quantity of the a.i./m^2 required, e.g. deltamethrin, 0.025g of a.i./m^2 (C);
4. Percentage of weight of the a.i. within the formulation, e.g. deltamethrin 2.5 WP, which means there is 2.5% of a.i. within the total amount of the formulation or that there is in 1000 g of the insecticide formulation 25 g of a.i.;
5. The amount in litres of the spraying solution/m^2 required. The value of 0.040l/m^2 (D) of the insecticide solution is generally taken.

Step 2 :

Determine the amount of the water needed to treat 2000 shelters.

Calculation

(D) × (B) = 0.040l/m^2 × 50 m^2 (1 shelter) = 2 litres

hence, 2 litres × (A) = 2 litres × 2000 shelters = **4000 litres or 4 m^3 of water**

Step 3 :

Determine the quantity required of a.i. for one shelter when a dose of 0.025 g of a.i/m^2 is required.

Calculation

(B) × (C) = 50 m^2 × 0.025 g = 1.25 g (E)

Step 4 :

Determine the amount of the insecticide formulation needed to treat one shelter.

Calculation

2.5 WP = 2.5% = 2.5 g of a.i. for 100 g of insecticide formulation, what quantity of formulation represents 1.25 g of a.i. ?

100 g ⇒ 2.5 g of a.i.

x? ⇒ 1.25 g of a.i.

then

(100 × (E)) ÷ 2.5 = (100 × 1.25 g) ÷ 2.5 = 50 g of insecticide formulation (F)

Step 5 :

Determine the total amount of formulation needed to treat 2000 shelters.

Calculation

(A) × (F) = 2000 shelters × 50 g of formulation = 100000 g = **100 kg**

The quantities needed for the spraying programme to treat 2000 shelters are:
4000 litres of water and 100 kg of deltamethrin 2.5 WP

Source: Adapted from Sabatinelli, 1996

5.9.2 Determination of the optimal a.i. concentration for use in a sprayer

(The calculations provided here are applicable for insecticide Formulations such as Wettable Powder (WP), Water-Dispersible Powder (WDP), Emusifiable Concentrate (EC)).

The principle is to determine the quantity of the ***insecticide concentration*** needed to be added to 1 litre of water to obtain the dose of a.i./m^2 required for 0.040l/m^2. of spray.

The steps required for the calculation of the quantity of the insecticide concentration to be added in the water are detailed below through an example.

Example: In order to spray 0.040l per m^2 of solution containing a dose of 0.025g of a.i, what is the quantity of the **insecticide concentration** required in the solution, having deltamethrin 2.5 WP formulation?
Step 1 : The following factors must be considered : The quantity of a.i./m^2 to be sprayed, e.g. 0.025 g/m^2 (A); The speed of the spraying should be constant to spread 0.040l (B) per m^2 containing 0.025 g of a.i.; The formulation is deltamethrin 2.5 WP, that means 2.5% or 2.5 g of a.i. per 100 g of formulation.
Step 2 : Determined the amount of a.i. per 1 litre of solution *Calculation* 0.04l of solution to be spray must contained 0.025 g of a.i. then, 1 litre ÷ (B) = 1 litre ÷ 0.040l = 25 (C) hence, (A) × (C) = 0.025 g × 25 = 0.625 g or 0.0625% of a.i. **0.625g or 0.0625% of the insecticide concentration must be mixed with 1 litre of water allowing the insecticide solution to be sprayed at a dose of 0.025 g of a.i. per 0.040l and per m^2 .**

Source: Adapted from Sabatinelli, 1996

5.9.3 Preparing the spraying solution from an insecticide formulation

(The calculations provided here are applicable for insecticide formulations such as Wettable Powder (WP), Water-Dispersible Powder (WDP), Emusifiable Concentrate (EC)).

The principle is to prepare the insecticide solution from a powder or an emulsifiable concentrate formulation. In other words, it is to determine the

amount of the insecticide formulation to be added to a large quantity of water to obtain the spraying solution at the insecticide concentration required.
The following formula must be applied :

X = (A ´ B ´ D) ¸ C

X ⇒ Quantity of formulation needed to be mixed with the water

A ⇒ Required insecticide concentration expressed in percentage (%), as explained in 5.7.2

B ⇒ Quantity of the insecticide solution desired

C ⇒ Concentration of a.i. in the formulation, expressed in percentage (%)

D ⇒ = 1, if X and B are expressed in kg or litres;
= 8.33, if X and B are expressed in pounds or US gallons;
= 10, if X and B are expressed in pounds or imperial gallons (UK).

Example: What is the quantity of deltamethrin 2.5 WP formulation required for 300 litres of insecticide solution wanted, at an insecticide concentration of 0.0625 %.

Calculation

$X = (A \times B \times D) \div C = (0.0625 \times 300 \times 1) \div 2.5 = 7.5$

Therefore 7.5 kg of insecticide formulation has to be mixed with 300 litres of water to obtain the solution at the concentration required.

Source: Adapted from Sabatinelli, 1996

5.9.4 Preparation of emulsions from emulsifiable concentrates (EC)

The principle is to prepare an insecticide solution (an emulsion solution) from an emulsifiable concentrate.

The following formula must be applied :

X = (A ¸ B) - 1

X = parts of water to be added to 1 part of emulsifiable concentrate

A = concentration of a.i. in the emulsifiable concentrate formulation, expressed as percentage (%)

B = required concentration of the final insecticide formulation, expressed in percentage (%)

Example: What is the number of parts of water required for 1 part of the pirimiphos-methyl 50% EC formulation at a concentration of 2.5%.
Calculation
X = (A ÷ B) - 1 = (50 ÷ 2.5) - 1 = 19
Therefore 19 parts of water is required to 1 part of the insecticide formulation.
i.e. 1 part insecticide : 19 parts water (1 : 19)
if 1 part insecticide = 2 litres, then 19 parts water = 38 litres of water
which means 2 litres insecticide + 38 litres water = 40 of insecticide solution

Source: Adapted From Chavasse and Yap, 1997

5.9.5 Impregnation of curtains and mosquito nets

The principle is to calculate the amount of the insecticide formulation to be impregnated into a mosquito net. The following considerations have to be taken into account :

1. The surface area of the curtain or the mosquito net to be impregnated, expressed in m^2
2. The percentage (%) of the insecticide formulation
3. The active ingredient required per m^2, (a.i./m^2)
4. The capacity for water absorption by one curtain or one mosquito net

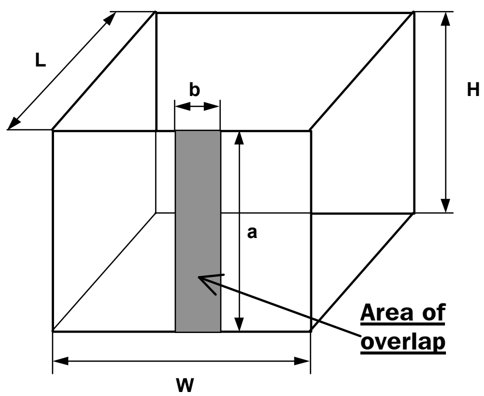


Figure 5.12. Surface area detail of a mosquito net

Example: Calculate the quantity of insecticide and water needed to impregnate 100 mosquito nets where the height is 1.5 m, the length 2 m, and width 1 m. The overlap band measures 0.30 m of width The required dose of a.i. is 0.2 g/m^2 using a permethrin 50 % EC formulation.

Step 1 :

Calculation of the surface area (Sm) of the mosquito net.

H = height = 1.5 m

L = length = 2 m

W = width = 1 m

Sm = (L × W) + (H × L × 2) + (H × W × 2) + (a × b) = (2 × 1) + (1.5 × 2 × 2) + (1.5 × 1 × 2) + (0.30 × 1.5) = **11.45 m^2**

Step 2 :

Calculation of the quantity of the insecticide formulation (M) required according the following formula :

M = T ¸ (C ´ 10) ml/m^2 of netting

T - target dose, this must be expressed in mg/m^2 , therefor 0.2g of a.i./m^2 = 200 mg of a.i/m^2.

C - insecticide concentration of the formulation, e.g. permethrin 50 EC formulation, C = 50. (Where the insecticide formulation concentration is given in g/litre, this should be divided by 10 to convert it to a percentage, e.g. 500g/l ÷ 10 = 50 EC = 50%).

Then M = T ÷ (C × 10) = 200 ÷ (50 × 10) = 0.4 ml/m^2

Therefore 0.4 ml/m^2 × 11.45 m^2 = 4.58 ml per mosquito net

4.58 ml of permethrin 50 EC formulation are required for one mosquito net having a surface of 11.45 m^2 .

Step 3 :

This is to determine the absorption capacity of water of the mosquito net. This operation consists of :

Dipping the mosquito net into a bucket containing 2 litres of water for 2-3 minutes;

Taking out the net and wringing out the water over the bucket;

Measuring the water left in the bucket, e.g. 1.470 l;

Determining the quantity of water absorbed by the mosquito net, which is 2.000 l (initial input) - 1.470 l (water left)= 0.530 l.

The absorption capacity of one mosquito net is therefore 0.530 l or 530 ml.

Step 4 :

Quantities required for 100 mosquito nets :

100 × 0.52542 litre = 5**2.542 litres of water**

100 × 0.00458 litre = **0.458 litres of insecticide formulation**

The absorption capacity of a mosquito net will depend upon the textile type, e.g. a cotton mosquito net may absorb 1.5 - 2 litres and a nylon one, 0.4-0.8 litre.

Sources: Adapted from Sabatinelli, 1996 and Chavasse and Yap, 1997

Table 5.11. Recommended target doses/m^2 for different pyrethroids

Pyrethroids	*Dose mg/m^2*
permethrin	200
deltamethrin	20
lambda-cyhalothrin	10
alphacypermethrin	20
cyfluthrin	50

5.9.6 Determine the quantity of molluscicide for use in a river

To determine the amount of molluscicide needed to be thrown into a river of a certain flow rate, the following factors must be considered :

1. The cross section area (A) of the river, expressed in m$^{2.}$ .Choose a section of the river or stream that is straight and has a uniform cross section.
2. The surface flow velocity of the river (V_s), expressed in m/second
3. The stream velocity of the river (V_m)
4. The discharge (D_q) of the river, expressed in m^3/second
5. The concentration of the molluscicide required, expressed in mg/l or g/m^3 of **water (1 mg/l of molluscicide means that 1g of molluscicide is required per m^3. In a river with a flow rate of 1 m^3/second, or 3600 m^3/hour, 3.6 kg/hour will therefore be required to obtain this concentration** (Sabatinelli, 1996).
6. The percentage of the molluscicide formulation, e.g. niclosamide 70%

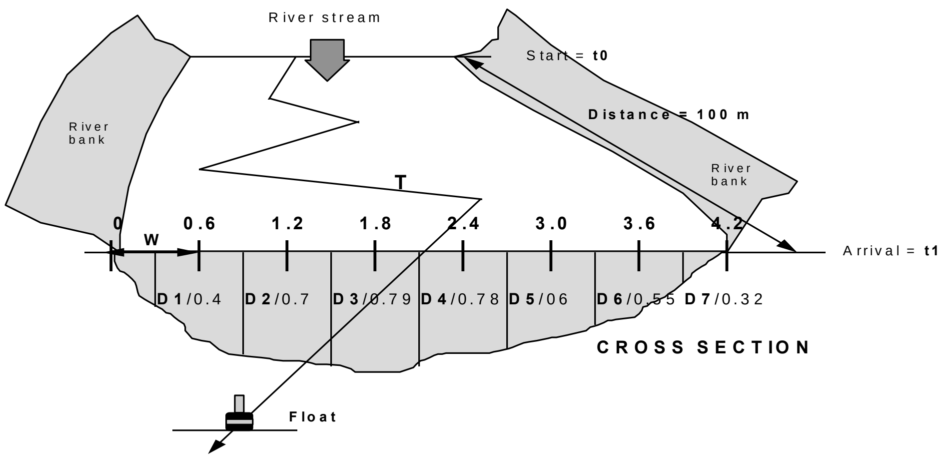


Figure 5.12. River flow measurement scheme (Lacarin, 1999)

Example: Determine the quantity of molluscicide required to treat the river with 70% niclosamide formulation, and where 4 mg/l of concentration is required. The product has to remain in the water for 9 hours to eliminate the molluscs.

Step 1 :

Calculation of the cross section area of the stream (A).

The cross-sectional area of flow for the stream can be calculated using the trapezium rule. Calculate the area of flow between adjacent measurements of depth (D), and add these individual areas together to calculate the total area.

The formula is **A = W ´ (D1 + D2 + D3 + D4 + D5 + D6 + D7.........)**

W = distance between measurements of depth (must be kept constant)

D1, D2.... = depth measurements

The example assumes that the measurements have been done, see figure 5.12, the measures are expressed in metres.

Therefore the cross section area is **2.48 m^2** (A)

A = W × (D1 + D2 + D3 + D4 + D5 + D6 + D7)

A = 0.6 × (0.4 + 0.7 + 0.79 + 0.78 + 0.6 + 0.55 + 0.32) = 2.48 m^2

Step 2 :

Calculation of the surface flow velocity (**V_s**).

The following formula must be applied :

$V_{s\ (m/second)} = D_{(distance\ expressed\ in\ metre)}$ ¸ $T_{(second)}$

This operation consists in measuring the period of time (T) that a float will take to travel a given distance (D) given. In this example D = 100 metres and it assumes that the time measured is 169 second.

then V_s = D ÷ T = 100m ÷ 169 second = **0.591m/second**

Any buoyant material may be used as a float such as a lemon, an empty bottle, a ball etc. Several measurements should be carried out and averaged.

Step 3 :

Calculation of the stream velocity (**V_m**).

The following formula must be applied :

$V_{m\ (metres/second)} = V_{s\ (metres/second)}$ ´ $C_{(constant\ coefficient)}$

C value is a constant. However this value may change under the stream characteristics. Generally the value given to C is 0.85 and 0.93 for rivers with sandy bed and depths of more than 3 metres.

then V_m = V_s × C = 0.591 m/second × 0.85 = **0.502 m/second**

Step 4 :

Calculation of the discharge (D_q) of the streams

The following formula must be applied :

D_q (m^3/second) = V_m ´ A

then D_q = V_m × A = 0.502 m/second × 2.48 m^2 = **1.24 m^3/second or 4481 m^3/hour**

Step 5 : Determine the concentration of 4 mg/l of 70% of molluscicide formulation required for one hour at a flow of 1 m^3/second. *Calculation* 1g of molluscicide is needed per 1m^3/second means that 3.6 kg of product per hour is required to obtain the desired concentration. then 3.6 kg/h × 4 mg/l × [100 ÷ 70] = 20.6 Therefore 20.6 kg of product per hour is required.
Step 6 : Determine the quantity of 70% niclosamide molluscicide required per hour in the river with discharge of 1.24 m^3/second and where the product has to remain in the water for 9 hours to eliminate the molluscs. *Calculation* [20.6 kg × 1.24 m^3/second] x 9 =230kg **230 kg of 70% niclosamide will be required for 9 hours.**

Source: Adapted Sabatinelli, 1996

5.9.6.1 Molluscicide required for use in stagnant water

The standard concentration required for treating stagnant water including ponds, dams, swamps, is 0.4 mg/l of 25% EC (emulsifiable concentrate) niclosamide formulation and 0.6 mg/l of 25% WP (wettable powder) niclosamide formulation (Rozendaal, 1997). The molluscicide can be sprayed in water by using hand-compression sprayers or knapsack motorised sprayers.

The amount of the molluscicide to be sprayed over the surface will depend on the volume of water in the ponds, swamps or dams.

To measure this volume, multiply the average depth by the length and width. A long stick weighted at the bottom can be used to measure the depth. The volume of the water body is expressed in cubic meters (m^3), 1 m^3 = 1000 litres.

Small water bodies should be treated by spraying the molluscicide equally over the whole surface. For large ponds, the spraying can be done along the edges of the pond. (Rozendaal, 1997).

Appendix 1

Suitability of Chemical Controls Categorised by Vector and Application Procedure

The chemical list provided here does not constitute all pesticides being used in epidemic conditions or simply for public health purposes. The pesticides presented here are only those most commonly used by implementing organisations and field workers involved in vector control in IDP or refugee camps.

A1.1 Cockroaches

Table A1. Insecticides for use against cockroaches.

Insecticide	*Chemical type*	*Formulation*	*Concentration g/l or g/kg*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
chlorpyriphos	OP	Liquid	5	135
deltamethrin	PY	Liquid	0.3-0.5	135
		Powder	0.5	135
malathion	OP	Liquid	30	2100
		Powder	50	2100
permethrin	PY	Liquid	1.25-2.5	500
		Powder	5	500
propoxur	C	Liquid	10	95

C : carbamate; OP : organophosphate; PY : synthetic pyrethroid
[1] a.i. : active ingredient

Source: Chavasse and Yap, 1997

Application procedure: A hand-compression sprayer is generally used to spray the liquid insecticide solution. A solid stream nozzle should be used to spray the insecticide into cracks and places where it is difficult to reach. A flat fan nozzle should be used for spraying surface areas. 4 litres per 100 metres is the rate to be applied within a 0.30-0.50 m band of spray. Emulsifiable concentrate and wettable powder formulations are often used. Cockroaches are localised in latrines and places where food is found. The spraying should be undertaken at the same time as hygiene promotion programme. The treatment should be repeated after one month (Chavasse and Yap, 1997).

A1.2 Fleas

Table A2. Insecticides for use against fleas.

Insecticide	*Chemical type*	*Formulation*	*Concentration g/l or g/kg*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
deltamethrin	PY	liquid[2]	0.5	135
		powder[3]	0.3	135
permethrin	PY	liquid[2]	1.25	500
		powder[3]	5	500

PY : synthetic pyrethroid
[1] a.i. : active ingredient
[2] Liquid formulation is more practical for large scale treatment, though powders are equally effective (Sabatinelli, 1996).
[3] Powders are commonly used for the control of rodent fleas (Chavasse and Yap, 1997).

Source: Chavasse and Yap, 1997

Application procedure: In association with improved hygiene measures the treatment should be effective for up to six months. Hand compression sprayers are generally used in spraying the insecticide solution. Emulsifiable concentrate may be considered for large-scale treatments. The insecticide must be applied onto the floor and into beds. The spraying should be carried out early in the morning on sunny days allowing the bedding to dry before night (Sabatinelli, 1996).

A1.3 Non-biting flies

Table A3.1. Insecticides for use against non-biting flies in residual spraying control programmes

Insecticide	*Chemical type*	*Formulation*	*Concentration g/l or g/kg*	*Dose : g of a.i.[1] per m^2*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
bendiocarb	C	SC	2-8	0.1-0.4	55
cyfluthrin	PY	SC	1.25	0.03	250
deltamethrin	PY	EC/SC	0.15-0.30	0.0075 0.015	135
fenitrothion	OP	WP/EC	10-50	1.0-2.0	503
malathion	OP	WP/EC/SC	50	1.0-2.0	2100
pirimiphos-methyl	OP	WP/EC/SC	12.5-25.0	1.0-2.0	2018
permethrin	PY	SC	1.25	0.0625	500

C : carbamate; OP : organophosphate; PY : synthetic pyrethroid
[1] a.i. : active ingredient
WP : Wettable Powder; EC : Emulsifiable Concentrate; SC : Suspension Concentrate

Source: Chavasse and Yap, 1997

Application procedure: Hand-compression sprayers or power-operated sprayers are used to spread the insecticide solution. Absorbent and smooth surfaces should be treated with 40-80 ml of insecticide solution per square metre. 250 ml/m^2 may be required for treating refuse tips or refuse collection areas. Effectiveness lasts from a few weeks to 2-3 months depending on the insecticide used, the surface to be treated, the climatic condition, and the resistance of the flies. Latrines should be treated every 2 months during the rainy season, and every 3 months during the dry season. Refuse areas or garbage pits should be treated every week (Sabatinelli, 1996).

Table A3.2. Insecticides for use against non-biting flies in space treatment programmes

Insecticide	*Chemical type*	*Dosage of a.i.[1] g/ha[2]*
deltamethrin	PY	0.5-1.0
malathion	OP	672
permethrin	PY	5-10
pirimiphos-methyl	OP	250

OP: organophosphate; PY: synthetic pyrethroid
[1] a.i.: active ingredient
[2] ha = hectare = 10000 m^2

Source (Chavasse and Yap, 1997)

Application procedure: Space treatments should be carried out in the camps every day for a period of two weeks and then once a week, and also at the market each evening at closing time. Space treatment is used to quickly reduce the adult fly population and to avoid them spreading to new development sites where garbage is found. A motorised backpack mistblower may be used for treatment using liquid formulation (Sabatinelli, 1996).

Table A3.3. Larvicides for use against non-biting flies

Larvicide and IGR	*Dose : g of a.i.[1] per m^2*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
cyromazine (IGR)[2]	0.5-1.0	3300
diflubenzuron (IGR)[2]	0.5-1.0	4640
pyriproxyfen (IGR)[2]	0.05-0.1	>5000

[1] a.i.: active ingredient
[2] IGR, Insect Growth Regulator

Source: Chavasse and Yap, 1997

Insect Growth Regulator is a chemical which may be used as a larvicide. IGRs are divided into two families; the Juvenoid family which affect the growth process of the insects, and the Chitin Synthesis Inhibitors which disrupt the transformation processes. In general IGRs are safe to fish, mammals, birds and most aquatic non-target organisms. They have a very low human toxicity.

Application procedure: Hand-compression sprayers and/or power-operated sprayers can be used to spread the larvicide solutions (solution or emulsion). Refuse pits, any dumping areas, and latrines should be treated weekly.

A1.4 Blackflies (*simulium spp.*)

Larviciding is the most suitable and feasible method of blackfly control. In the West African Onchocerciasis Control Programme (OCP), temephos is the preferred larvicide due to its effectiveness and safety to non target animals (Chavasse and Yap, 1997).

Table A4. Insecticides used in rotation for Simulium blackfly (larval) control.

Insecticide	*Chemical type*	*Concentration g a.i. [1]/ litre*	*River discharge litre/m³/sec*	*Oral toxicity for rats (LD₅₀ of a.i.[1] (mg/kg) body of weight)*
carbosulfan	C	250	0.12	250
permethrin	PY	200	0.045	500
phoxim	OP	500	0.16	1975
pyraclofos	OP	500	0.12	237
temephos	OP	200	0.72	8600

C : carbamate; OP : organophosphate; PY : synthetic pyrethroid
[1] a.i. : active ingredient

Source: Chavasse and Yap, 1997

Note: Never use pyraclofos in a river where the discharge is less than 15 m^3/sec (Rozendaal, 1997).

Application procedure: Aircraft application is employed for treating large and/or medium rivers. In smaller areas simple methods have been used such as using a 200 litre barrel with a hole in the bottom over the river flow to spread the larvicide into the water. In tropical climates, streams should be treated every week, but in areas where water is temperate or cool, every 10-14 days is sufficient to reduce blackflies to an acceptable level (Chavasse and Yap, 1997).

A1.5 Tabanid and *Chrysops* flies

These flies may cause severe annoyance, *chysops* flies transmit loa loa disease. Residual spraying and space treatment may be considered as described in Table A3.1 and Table A3.2.

A1.6 Tsetse flies

Table A5. Insecticides for use against tsetse flies in residual spraying control programmes.

Insecticide	*Chemical type*	*Formulation*	*Dose : g of a.i.[1] ha[2]*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
cyfluthrin	PY	WP/EC/SC	1.25	250
deltamethrin	PY	WP/EC/SC	12-60	135
lambda-cyhalothrin	PY	WP/EC/SC	0.7	56

PY : synthetic pyrethroid
WP : Wettable Powder; EC : Emulsifiable Concentrate; SC : Suspension Concentrate
[1] a.i. : active ingredient
[2]ha = hectare = 10000m^2

Source (Chavasse and Yap, 1997)

Application procedure: Wettable powders are suitable for dry seasons but should not be used during the rainy season. Emulsifiable concentrate and suspension concentrate are better options for residual treatments in humid areas and during the rainy season (Chavasse and Yap, 1997). Hand-compression and power operated sprayers can be used for the application of the insecticide solution for residual treatment from the ground. Aircraft or helicopters should be considered for large scale treatment using ULV insecticide. Residual applications from the ground should be carried out on specific types of vegetation such as riverine vegetation, forest islands, transitional vegetation between different types of woodland, savannah habitats, in vegetation surrounding villages, and around plantations such as coffee or cocoa. The application should be carried out during the dry season. The insecticide should be persistent for at least two months (Chavasse and Yap, 1997).

A1.7 Sandflies

Sandflies can be controlled in the same way as mosquitoes. Environmental management should be carried out, such as removing garbage, filling in tree holes, and filling in crevices in walls. Sandflies normally bite only at night, and in Sudan they are evening biters. They may be outdoor biting (Thomson, 1995) and also indoors where impregnated mosquito nets should be considered. Hand-compression sprayers or knapsack sprayers can be used for indoor residual spraying. The same insecticides used against mosquitoes can be applied at the same rate and frequencies (table A8). Wall surfaces of the dwelling should be sprayed, and particular attention should be given to spraying cracks and crevices. Diazinon insecticide should be used for treatment of garbage at the rate of 40 g of a.i./l. Retreatment should be carried out every 3-6 months according to the insecticide used. Space spraying such as thermal fogs (table A9) may also be considered. The application of the insecticide should be carried out in public places such as markets. In the case of leishmaniasis epidemics, aerial spraying may be justified (Chavasse and Yap, 1997).

A1.8 Lice

Table A6. Insecticides used against human lice.

Insecticide	*Chemical type*	*Formulation*	*Concentration g/l or g/kg*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
Bioallethrin	PY	lotion shampoo aerosol	3-4 3-4 6	700
carbaryl	C	dust	50	300
deltamethrin	PY	lotion shampoo	0.3 0.3	135
Lindane	OC	lotion shampoo	10 10	100
malathion	OC	lotion shampoo	10 5	2100
permethrin	PY	dust shampoo lotion	5 10 10	500
propoxur	C	dust	10	95
temephos	OP	dust	20	8600

C : carbamate; OC : organochlorine; OP : organophosphate; PY : synthetic pyrethroid
[1] a.i. : active ingredient

Source: Chavasse and Yap, 1997

Application procedure: Hand carrier dusters or puff dusters can be used for the application of the insecticide powder. Between 30-50 g are needed to treat a person in the case of body lice infestation. The treatment consists in applying the insecticide to the entire surface of clothing which is in direct contact with the skin. The insecticide should be applied in underclothing, around the collar, the sleeves, in hats or head-dresses, in hair, and in waist-bands of clothing. Retreatment should be carried out after 8-10 days. The impregnation of clothing with a pyrethroid insecticide may provide very long protection as the insecticide persists for 6-8 launderings (Rozendaal, 1997).

A1.9 Mites and ticks

Table A7. Acaricides used against mites and ticks.

Insecticide	*Chemical type*	*Formulation*	*Concentration g/l or g/kg*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
deltamethrin	PY	EC/SC/Dust	0.25	135
diazinon	OP	EC/SC/Dust	5	300
lambda-cyhalothrin	PY	EC/SC/Dust	0.25	56
malathion	OP	EC/SC/Dust	20	2500
permethrin	PY	EC/SC/Dust	2.5	500
pirimiphos-methyl	OP	EC/SC/Dust	10	2018
propoxur	C	EC/SC/Dust	10	95
temephos	OP	EC/SC/Dust	20	8600

C : carbamate; OP : organophosphate; PY : synthetic pyrethroid
EC : emulsifiable concentrate; SC : suspension concentrate
[1] a.i. : active ingredient

Source: Chavasse and Yap, 1997

Application procedure: The dwelling to be treated should be cleaned prior to applying the insecticide over all surfaces and spaces. The application of the acaricide may be carried out with a hand compression sprayer. Carpets, bedding, rugs, curtains and other soft furnishings must also be treated. Re-treatment may be considered after 1 to 2 months.

A1.10 Scabies mites

The chemical treatment should be preceded by a hot bath with the use of soap. Sulphur ointments at a concentration of 10% for adult treatment and 2% for children , in paraffin. This treatment is very cheap and does not present a danger for children and pregnant women. The application should be carried out 3 times to eliminate the parasites (Sabatinelli, 1996). 20-25% benzylbenzoate emulsions or permethrin 10-20g/l in liquid paraffin are also effective for skin application. All members of the family should be treated at the same time. Repeat the treatment after 3 days. Bedding and clothing may require dusting with an acaricide such as temephos 20g/kg (2%) (Chavasse and Yap, 1997).

A1.11 Mosquitoes

Table A8. Insecticides used against mosquitoes for residual treatment

Insecticide	*Chemical type*	*Formulation*	*Dose : g of a.i.[1] /m²*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
cyfluthrin (3-6 months)[2]	PY	EC/WP	0.02-0.05	250
DDT (6 months and more)	OC	EC/WP	1-2	113
deltamethrin (3-6 months)	PY	EC/WP	0.05	135
malathion (2-3 months)	OP	EC/WP	2	2100
permethrin (2-3 months)	PY	EC/WP	0.5	500
pirimiphos-methyl (2-3 months)	OP	EC/WP	1-2	2018

OC : organochlorine; OP : organophosphate; PY : synthetic pyrethroid
EC : emulsifiable concentrate; WP : wettable powder
[1] a.i. : active ingredient
[2] (x -x months) : Duration of effective action of the insecticides

Source: Chavasse and Yap, 1997

Application procedure: Hand compression sprayers are generally used for indoor residual spraying. The application should be carried out on the walls of the dwellings and shelters. NEVER use dieldrin and fenthion for indoor spraying as they are very toxic to humans and animals. Wettable powder formulations are very cheap and effective on porous surfaces. Retreatment depends on the duration of the effective action, and this could be 2 to 6 months according to the chemical applied.

Table A9. Insecticides used against mosquitoes for space spraying treatments.

Insecticide	*Chemical type*	*Dose :g of a.i.[1]/ha[2]* *Cold aerosol*	 *Thermal fogs*	*Oral toxicity for rats* *(LD_{50} of a.i.[1] (mg/kg) body of weight)*
cyfluthrin	PY	1-2	2	250
deltamethrin	PY	0.5-1.0	-	135
fenitrothion	OP	250-300	270-300	503
Insecticide	*Chemical type*	*Dose :g of a.i.[1]/ha[2]* *Cold aerosol*	 *Thermal fogs*	*Oral toxicity for rats* *(LD_{50} of a.i.[1] (mg/kg) body of weight)*
lambda-cyhalothrin	PY	1.0	1.0	56
malathion	OP	112-663	500-600	2100
permethrin	PY	5	10	500
pirimiphos-methyl	OP	230-330	180-200	2018

OP : organophosphate; PY : synthetic pyrethroid
[1] a.i. : active ingredient
[2] ha = hectare = 10000 m^2

Source: Chavasse and Yap, 1997

Application procedure: Space treatment is very expensive and only effective if applied in the correct location. The targeted species may be exophilic which means that the treatment should be carried out outdoors wherever the vector mosquito rests. If the mosquitoes are endophilic, the treatment should be applied indoors as well as outdoors (Chavasse and Yap, 1997). Space treatment, constitutes one of the best strategies when control is to be completed in a short period of time, and during mosquito-borne epidemics such as yellow fever and dengue fever. Backpack power operated mistblowers, thermal fogging machines, or vehicle mounted ULV equipment may be used for space spraying applications. Inhabitants of the camp should leave windows and doors open during the application to aid the penetration of the insecticide. Retreatment should be considered weekly during peak malaria transmission, and every 2-3 days during a period of 10 days for controlling outbreaks of diseases from Aedes and Culex mosquitoes.

Table A10. Insecticides used against mosquitoes for larvicide treatment

Insecticide	*Chemical type*	*Formulation*	*Dose : g of a.i.[1]/ha*	*Oral toxicity for rats (LD_{50} of a.i.[1] (mg/kg) body of weight)*
deltamethrin (1-3 weeks)[2]	PY	EC	2.5-10	135
diflubenzuron (2-6 weeks)	IGR	GR	25-100	>4640
malathion (1-2 weeks)	OP	EC/GR	224-1000	2100
methoprene (2-6 weeks)	IGR	slow release	100-1000	34600
permethrin (5-10 weeks)	PY	EC	5-10	500
pirimiphos-methyl (1-11 weeks)	OP	EC	50-500	2018
pyriproxyfen (4-12 weeks)	IGR	EC/GR	5-10	>5000
temephos (2-4 weeks)	OP	EC/GR	56-112	8600

IGR : insect growth regulator (see also table A3.3. for IGR definition); OP : organophosphate; PY : synthetic pyrethroid
EC : emulsifiable concentrate; GR : granules
[1] a.i. : active ingredient
[2] (x -x weeks) : Duration of effective action of the larvicides

Source: Chavasse and Yap, 1997

Application procedure: Hand-operated compression sprayers and motorised sprayers are suitable for application of the larvicide solution into localised breeding sites, such as latrines, for the elimination of culex mosquitoes. Jars, tyres, or any kind of open container should be treated against *Aedes* mosquitoes. Residual applications should not be considered where fish and other wildlife are found. Temephos should be used where water is used for drinking (Chavasse and Yap, 1997).

A1.12 Molluscs (snails)

Niclosamide is currently the best available molluscicide. It is very effective and commercially available. No resistance to this has developed since its use in the 1960s.

Wettable powder (WP) formulation containing 70% of a.i, and the emulsifiable concentrate (EC) formulation with 25% of a.i. are the two main formulations being used for treatment of stagnant water such as ponds, borrow pits or small dams, and for rivers and streams. Niclosamide has a very low toxicity, LD_{50} = 5000 mg/kg. Hand operated sprayers can be used to spray the solution, 0.2 g/m^2, onto river or stream banks to kill the snails which are not in the water. 4-8 mg of niclosamide formulation is required per 1 litre of water to treat snails living in the stagnant water. The solution may be prepared in a bucket and then thrown over the stagnant water. The chemicals remain in the treated water in effective concentrations for at least 8 hours (Sabatinelli, 1996).

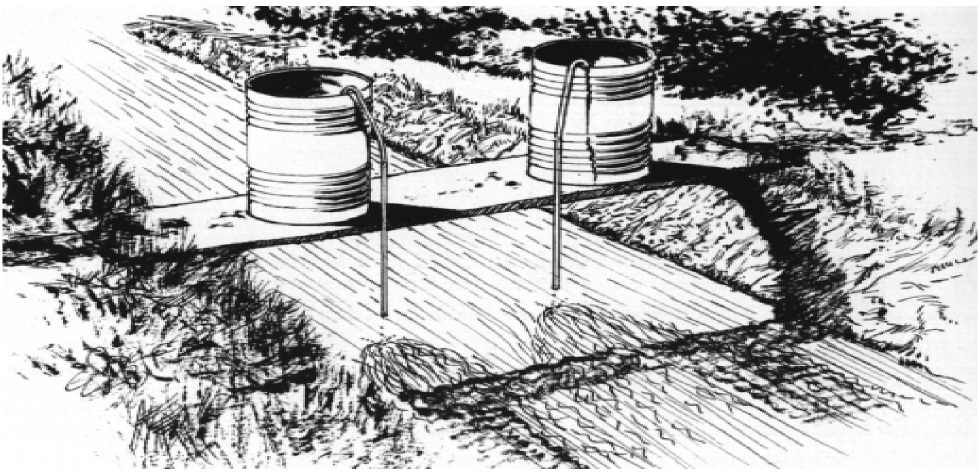


Figure A1.
Molluscicide slowly released from drums into the stream
(WHO, 1997)

To treat flowing water, drums or barrels filled with molluscicide can be placed over the stream on a plank of wood and with a hose (that has one end in the molluscicide and the other in the water) or taps allowing the molluscicide to leak into the water at a constant flow for several hours. The drums should be filled with the amount of molluscicide solution in water required for constant application over eight hours (see Chapter 5.9.6. to determine the quantity of molluscicide for use in river). The flow rate to release it over a certain period of time can be obtained by adjusting the tap or by widening or narrowing the diameter of the hose with an adjustable clamp (Rozendaal, 1997).

A1.13 Cyclops

Temephos 50% emulsifiable concentrate formulation is the most commonly used insecticide for Cyclops control programmes. The application should be carried out at a rate of $2ml/m^3$ of water to be treated. Ponds, small dams, and other small bodies of water should receive the correct amount of temephos formulation which is mixed in a bucket with enough water to spread the mixture over the entire surface of the water (Rozendaal, 1997).

A1.14 Rodents

Table A11. Common anticoagulant rodenticides for rodent control

Rodenticide	*Formulation*	*Concentration*	*Oral toxicity for rats (LD_{50} mg/kg body of weight)*
bromadiolone	bait, oil-based, wax block, powder concentrate, tracking powders	0.005%	1.12-1.8
calciferol	bait	-	43.6-56.0
difenacoum	wax block, bait	0.005%	1.8
warfarin	concentrate tracking powder, bait	0.5-1.0% 0.025-0.05%	10.0-20.0

Source: Chavasse and Yap, 1997

Rodenticides are found in various forms. They can be mixed with bait according to the trap requirements and to the species targeted. Rodenticides are extremely dangerous for direct application within the camp. It is obvious that the rodenticide represents a considerable danger to non-targeted animals and to children, and so to limit accidental poisoning, the poison should be placed in identified rat holes and spread along known pathways and hiding places of rodents. In the event of bubonic plague, flea control should precede rodent control programmes, to avoid the risk of plague-infected fleas moving from dying rats to human hosts (Sabatinelli, 1996).

Appendix 2

Recommended Control Method

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedure*	*Treatment Cycle*	*Precaution*
Cockroaches	Indoor residual spraying	Hand-operated dusters Hand-operated sprayers	Latrines, into cracks, crevices, in any wet and dark place	Monthly	Avoid contact with food, food preparation surfaces, and drinking water
Fleas	Indoor and Outdoor residual treatment	Hand-operated dusters Hand-operated sprayers	On humans and animals, bedding, floors, carpets, cracks, crevices	A single treatment should be enough to control an infestation	Avoid contact with food, food preparation surfaces, and drinking water
Non-biting flies	Outdoor and indoor residual treatment	Hand-operated dusters Hand-operated sprayers	Refuse tips, refuse collection areas, any waste disposal, latrines	Every 2 months during rainy season	
	Outdoor and indoor space treatment	Backpack motorised mistblowers Portable fogging machine	Vegetation, latrines, and any resting places	Every day during a period of two weeks and then once a week	Avoid contact with food, food preparation surfaces, and drinking water
	Larvicide, IGR, or biological larvicide	Hand-operated sprayers	Latrines, dumping areas, refuse tips	Weekly	

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedure*	*Treatment Cycle*	*Precaution*
Blackflies (Simulium)	Larvicide	Hand-operated dusters Hand-operated sprayers Backpack motorised mistblowers Aircraft spray equipment	Rivers, streams	In areas where water temperature is low, 10-14 days after the first spray At 7-day intervals after the first treatment where the water is warm	Fish and invertebrates may be at risk, the insecticide should be degradable and should have minimal toxicity
Tabanids	Outdoor residual spraying	Hand-operated dusters Hand-operated sprayers	Refuse tips, refuse collection areas, any waste disposal, latrines	Every 2 months during rainy season.	Avoid contact with food, food preparation surfaces, and drinking water
Tabanids	Outdoor space spraying	Backpack motorised mistblowers Portable fogging machines	Vegetation, latrines, and any resting places	Every day during a period of two weeks and then once a week.	Avoid contact with food, food preparation surfaces, and drinking water
Tsetse flies	Outdoor residual spraying Outdoor space spraying	Hand-operated dusters Hand-operated sprayers Helicopter spray equipment	Riverine vegetation, forest islands, transitional vegetation, savannah	Every 2 months Every 2 months	Fish and invertebrates may be at risk Potentially harmful to the environment

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedure*	*Treatment Cycle*	*Precaution*
Tsetse flies	Traps	Impregnated screens Impregnated Cattle : Cattle dipped in deltamethrin are used to control tsetse populations in some areas, e.g. Zimbabwe	4 impregnated screens per km^2	Every 2-3 months	Protect the screens from children and animals
Sandflies	Indoor residual treatment	Hand-operated dusters Hand-operated sprayers	Areas around doors and windows, stone and mud surfaces of dwellings, entrances, hallways, sleeping areas	Retreatment after 3-6 months	Avoid contact with food, food preparation surfaces, and drinking water
	Outdoor space spraying	Backpack motorised mistblowers Portable fogging machines	When leishmaniasis epidemic occurs, market places and where sandflies are prevalent		
Hair lice	Hair treatment	Hand-operated puff dusters	Hair, bedding	Retreatment may be required after 3-4 weeks	Avoid contact with eyes
Body lice	Body and clothing treatment	Hand-operated puff duster Lotion Hand-operated sprayers	Body, clothing, bedding, floor	Retreatment after 1-2 weeks	Avoid contact with people who have dermatology problems
Pubic lice	Body and clothing treatment	Hand-operated puff dusters	Body, clothing, bedding, floor	Retreatment at 4-7 day intervals	Avoid contact with people who have dermatology problems

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedure*	*Treatment Cycle*	*Precaution*
Biting mites	Outdoor residual treatment	Hand-operated sprayers Power-operated sprayers	Woodland, bush areas, around shelters and pathways	Every week for non-residual treatment	Avoid contamination of any watercourses
Scabies mites	Personal hygiene	Soap Lotion	Bedding, mattresses, sheets and clothes, infested part of the body	Retreatment after 3 days	-
Anopheline mosquitoes	Indoor residual spraying	Hand-operated sprayers Backpack motorised sprayers	Walls, porous mud-walls, field huts, shelter surfaces	every 2-3 months	Avoid contact with food, food preparation surfaces, and drinking water
	Outdoor space spraying	Backpack motorised mistblowers Portable fogging machines Vehicle mounted fogging machines	Outdoor and indoor spraying in resting places	Weekly treatment under malaria epidemic	Avoid contact with food, food preparation surfaces, and drinking water
	Larvicide	Hand-operated sprayers Backpack motorised sprayers Helicopter spray equipment	Identified breeding site (unpolluted water)	10-14 days after the first one	Do not exceed the recommended dosage when the water is for drinking by humans or animals
	Individual protection	Mosquito nets	Impregnation of the mosquito net with an insecticide	Every 3 to 6 months, depending upon insecticide used	Do not exceed the recommended dosage when the water is for drinking by humans or animals

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedure*	*Treatment Cycle*	*Precaution*
Aedes mosquitoes	Outdoor space spraying	Backpack motorised mistblowers Portable fogging machines Vehicle mounted fogging machines	Outdoor and indoor spraying in resting places	Under yellow fever and dengue epidemics, treatment should be carried out at 2-3 day intervals during 10 day period	Avoid contact with food, food preparation surfaces, and drinking water
	Larvicide	Hand-operated sprayers Backpack motorised sprayers Helicopter spray equipment	Identified breeding site, containers, stagnant water, tree holes, bamboo sections, tins, cans, water tanks	Once during an emergency should be enough	Do not exceed the recommended dosage when the water is for drinking by humans or animals
Culex mosquitoes	*Culex* mosquitoes have developed resistance to organophosphate and organochlorine everywhere. It is a domestic mosquito with over 50% resting on non-sprayable surface on shelter or any type of housing. Residual spraying is of limited use. Larvicide tends to be the principal method of chemical control. Breeding site can be identified in polluted water and irrigated rice fields. Environmental sanitation is certainly the most effective control (Chavasse and Yap, 1997)				
Ticks	Indoor residual treatment	Hand-operated sprayers Power-operated sprayers	Floor, cracks, crevice, mud walls	Several treatments may be required	Avoid contact with food, food preparation surfaces, and drinking water
	Outdoor residual treatment	Hand/power-operated sprayers	Borders of the footpaths in the camp, gardens, recreational areas	Treatment remains effective for one month	Avoid contamination of any watercourses
Snails	Molluscicide	Hand-operated sprayers Mechanical system	Any kind of water body used for drinking water, irrigation scheme areas	Depends on the infestation	No danger to population because the insecticide used has a very low toxicity to humans

Vectors	*Recommended chemical control type*	*Equipment*	*Application procedures*	*Treatment Cycle*	*Precautions*
Cyclops	Treat water body with the temephos insecticide	Hand-operated sprayers Buckets	Stagnant water pools, ponds, and other water breeding sites	Treat periodically only drinking water	Avoid overdose toxic to humans
Rodents	Rodenticides	Dusters, traps, baits	Identified rodent holes, along known pathways and hiding places of rodents	Depends on the infestation	Prevent from accidental poisoning of humans and non-targeted animals

Appendix 3

Estimate Vector Population

Vector	*Indicators (collecting and sampling)*
Mosquitoes	To evaluate the average density of vector population of the adult mosquito, several shelters in the camp should be selected. In order to evaluate the effectiveness of the control programme, these same shelters must be measured at the same time of the day after control measures have taken place. Procedure for collecting : In the shelter, close all openings, windows, holes, etc.. Spread a white sheet on the floor of the rooms. Spray the insecticide and wait 20 minutes until the insecticide has killed the mosquitoes. The sheet can be removed from the shelter after the killed adult mosquitoes have been counted. The number of persons living in the shelter must be recorded. The following can then be determined: 1 - The number of killed adult mosquitoes divided by the number of inspected shelters will give the average mosquito density per shelter. 2 - The number of killed adult mosquitoes divided by the number of persons occupying each shelter will give the average number of mosquitoes per person. 3 - The number of mosquitoes found .with blood in their abdomen (red or black colour) divided by the number of person living in the shelter will give the average number of bites per person. The collected mosquitoes should be sent to a laboratory for identification.
Non-biting flies	Butterfly nets or traps can be used for collecting the adult flies for identification and for counting the number of flies present. The other procedure is to count the average number of flies that land on a grill placed where flies congregate during three 30-second periods. The time of day and the weather must be identical in order to compare the results with the others taken from other locations in the camp.
Blackflies	Number of specimens collected per person per day, daily capture occurs on human bait
Sandflies	Number of specimens collected per trap, oiled-paper or light trap

Vector	*Indicators (collecting and sampling)*
Fleas	Rat fleas : A rat should be captured and killed, place in a plastic bag and the number of fleas living on the dead body counted. This should be carry out per individual rat and then the percentage of rodents carrying fleas and the average numbers of fleas per host can be determined. Human fleas : number of specimens collected per light and/or carbon dioxide trap. These can also be captured during the day by hand from bedding. The use of mouth-operated sucking tubes or so-called aspirators must be avoided due to the potential high risk of disease transmission (Sabatinelli, 1996). Specimens captured should be preserved in 70% alcohol and 3% saline solutions for identification and bacteriological research.
Lice	Percentage of persons found positive on inspection
Scabies mites	Percentage of persons found positive on inspection. Detection of scabies is virtually impossible before the itching starts, about 3 weeks after infestation
Ticks	Number of specimens collected on sweeping cloth. In resting places such as grassland, use a piece of light coloured fabric and sweep the vegetation. The ticks will attach themselves on the fabric. Ticks should be removed with tweezers, and preserved in 70% alcohol for later identification.
Bugs	Percentage of houses infected. Nymphs and adults bugs live in colonies in dark shelters. They feed at night on humans and animals but it is easy to dislodge them during the day by spraying with a pyrethroid.

Appendix 4

Job Description and Responsibilities

Water & Sanitation Engineer,(or Public Health Specialist and/or Sanitation Engineer):
Education & Qualification required: Previous experiences, degree in Science, or public health engineering, with strong understanding in project management. He/she is responsible for the overall water and sanitation projects including environmental health management, water supply and water quality, Health promotion, chemical control. These also include project appraisal, design and implementation. He/she should at least have access to pertinent literature in regard to vector control involving chemical measures.

Supervisor, assistant to the water and sanitation engineer:
Education & Qualification required: Previous experiences, degree in Science, or public health engineering, or equivalent. He/she supervises the Vector Control Programme and assists the engineer. In this specific task he/she is the Control Manager for the vector control programme.

1. Reports to the engineer
2. Executes all tasks relating to project management
3. Organises weekly meetings with the Base Officer and the Section Leader(s)
4. Organises meetings with the camp representatives to inform the population of what chemical control involves and how it relates to them
5. Analyses and comments on weekly reports from the Section leader(s)
6. Writes the monthly reports including spreadsheets
7. Organises field visits every two weeks
8. Organises meetings with all the personnel at least once a month
9. With the engineer participates in the training programme
10. Responsible for all aspects of logistics for the control programme including chemicals, personnel, hygiene facilities, equipment, vehicles, etc.
11. Looks for new recruitment
12. Ensures the efficiency of the chemicals being used, and determines treatment frequencies
13. Assesses, designs, implements, monitors, and evaluates the control programme
14. Ensures the correct use of safety procedures
15. Controls the work at each level of the programme
16. Inspects the storage and equipment
17. Gives the salary to the workers
18. Must be able to use the Auto-injector of atropine in solution only if medical services are not available
19. May write new proposals

Section Leader(s):

Education & Qualification required: Previous experiences, degree in Science, or public health engineering, or equivalent.

The Section Leader(s) is responsible for one or several Group Leaders. He/she is responsible for implementing the control programme according to the policy and the plan fixed by the supervisor and the engineer.

1. Reports to the Supervisor
2. Participates in the weekly meeting with the supervisor and Base Officer
3. Prepares the work plans for the following week
4. Collaborates with the Base Officer for the quantity of insecticide solution needed, spare parts needed for the maintenance of sprayers, and also for all aspects of individual and protective clothing needed for the personnel
5. Ensures rotation of staff and supervises the staff
6. Co-ordinates the transport of the chemicals and the personnel
7. Supplies insecticide
8. Participates in the meeting with the camp representatives to inform the population of what chemical control involves and how it relates to them
9. Ensures good relations with the public in the field, especially where spraying occurs
10. Writes weekly reports and fills weekly forms
11. Organises short meetings with group leaders and workers
12. With the engineer, participates in training programmes
13. Responsible for reporting any incident and/or accident involving chemicals, he/she must write the accident report
14. Ensures the efficiency of the work
15. Ensures the correct use of safety procedures
16. May be required to help the supervisor in giving the salary to the workers
17. Must be able to use the Auto-injector of atropine in solution only if medical services are not available

Group Leader(s):

Education & Qualification required: Previous experience, degree in Science, or public health engineering, or a strong education. He/she is responsible for at least 5 teams including one sprayer and one sprayer's assistant.

1. Reports to his Section Leader
2. Supervises the sprayers
3. Implements the work plans
4. Controls the quality of the spraying, looks at the quality of the solution being used
5. Asks the Section leader for more insecticide
6. Ensures good relations with the public in the field especially where spraying occurs
7. Fills daily forms
8. Organises short meetings with the sprayers and the assistants
9. Responsible for reporting any incident and/or accident involving chemical
10. Ensures the correct use of safety procedures
11. Checks that the equipment is well maintained and clean after work
12. Reports any problems encountered

Spray man:

Education & Qualification required: Previous experience not necessary, good basic education.
He/she is responsible for applying the pesticide in a safe and efficient way. He/she is always with a person to assist him/her.

1. Reports to the Group Leader
2. Applies the insecticide
3. Notes the number of shelters treated daily
4. Notes the quantity of insecticide used daily
5. Responsible for maintaining his/her spraying machine(s)
6. Reports any problems encountered

Spray man assistant:

Education & Qualification required: Previous experience not necessary, good basic education.

1. He/she is responsible for assisting the sprayer
2. Carries the insecticide solution
3. Ensures the transfer of the insecticide to the spray machine
4. May help the sprayer to clean the surface to be treated
5. Must cover the food, drink and other goods of the shelter to be treated
6. Keeps people, and especially children, away from the danger of exposure to spray
7. Reports any problems encountered

May carry an extinguisher when thermal fogging machine is involved

Base Officer:

Education & Qualification required: Previous experience in management storage, good knowledge in logistical support, strong education.
The Base Officer manages the installation required for the vector control personnel. He/she is responsible for the storage of the equipment, chemicals, and responsible for the permanent workers belonging to the base.

1. Reports to the Supervisor
2. Collaborates with the Section Leaders who request their needs for insecticide solutions and other goods related to the spraying programme
3. Responsible for the stores and the storage. He/she must inform the supervisor about the quantities of pesticide remaining and any equipment required.
4. Ensures the rotation of the watchmen
5. Is responsible for the cleaners, the mixers, and the maintenance team (for the base)
6. Ensures that all hygiene facilities are clean and equipped with soap
7. Ensures that detergent is available for cleaning the dungarees and others
8. Commands the storekeeper to give necessary items ordered
9. Ensures the correct use of safety procedures
10. Gives the salary to his/her personnel
11. Reports any problems encountered

Mixer:

Education & Qualification required: Previous experience will an advantage, good basic education. They work under suppervision of the Base Officer as they are permanently in the base. They are in charge of preparing the insecticide solution for the spraying programme.
The Base Officer communicates the amount of insecticide solution needed for the team sprayer. This is worked out according to the formulation of the insecticide, and the type of spraying.

1. Reports to the Base Officer
2. Mixes the chemical with appropriate liquid to prepare the insecticide solution
3. Prepares the insecticide solution in large quantities to be used during the day of work
4. Notes the amount of chemical used daily
5. Notes the total amount of insecticide solution prepared daily
6. Notes the amount of insecticide solution given daily to the sprayman
7. Reports any problems encountered
8. Cleans empty containers before burying them

Cleaner:

Education & Qualification required: Basic education.
Cleaners belong to the base personnel. They are responsible of collecting and cleaning the clothes used by the sprayers after work. These are skilled personnel who clean protective clothing in the correct manner to remove any contamination.

1. Reports to the Base Officer
2. Must use soap and detergent for cleaning
3. Reports any problems encountered

Additional Information

Useful addresses

Centre for Disease Control and Prevention (CDC)
Public Health Programme Office
Atlanta GA 30333 - USA
Tel. (1) 404 639 3311
Fax: (1) 404 488 7772
Public enquiries :
Tel. (1) 404 639 3534
Fax. (1) 800 311 3435
http://www.cdc.gov
Provide relevant information on biology and control methods for vectors.

International Pesticide Application Research Centre (IPARC)
Imperial College at Silwood Park
Buckhurst Road
Ascot, Berkshire
SL5 &PY - UK
Tel: (44-1) 344 294 234
Fax: (44)-1) 344 294 450
http://www.bio.ic.ac.uk/research/iparc/iparc.htm
Provides information and expertise on insecticide application technology.
Runs courses on vector control.

Liverpool School of Tropical Medicine
Pembroke Place
Liverpool L3 5QA - UK
Tel: (44) 0151 708 9393
Fax: (44) 051708 8733
http://www.liv.ac.uk/lstm/lstm.html
Provide relevant information on biology and control methods for vectors.
Runs courses suitable for relief workers.

London School of Hygiene and Tropical Medicine
Keppel Street
London WC1E &HT
UK
Tel: (44) 171 636 8636
Fax: (44) 171 436 53 89
http://www.LSHTM.ac.uk
Provide relevant information and expertise on biology and control methods for vectors.

Médecins Sans Frontières
8 rue Saint Sabin
75 544 Paris Cedex 11 - France
Tel: (33) 1 40 21 29 29
Fax: (33) 1 48 06 68 68
http://www.msf.org
This organisation has experience in implementing vector control programmes using chemical control measures, for public health purposes.

ORSTOM
Institut Français de Rechercher Scientifique pour le Développement en Coopération
Centre de Montpellier
911 Avenue Agropolis
34 032 Montpellier France
Tel: (33) 4 67 61 74 00
Fax: (33) 4 67 54 78 00
http://www.orstom.fr
Provide relevant information on biology and control methods for vectors. Run courses suitable for relief workers.

United Nations High Commissioner for Refugees (UNHCR)
Engineering and Environmental Services Section (EESS)
Case postale 2500
CH-1211 Genève 2 Dépôt
Switzerland
Tel: (41) 22 739 88 43
Fax: (41) 22 739 7371
http://www.unhcr.ch

They may have access to relevant unpublished reports and expertise on vector control within refugee camps.

World Health Organization (WHO)
World Programme of Surveillance for Insecticide Vector Resistance
Cluster of Communicable Disease
Avenue APPIA, 1211 Geneva - Switzerland.
This address provides a complete catalogue of the resistance kits per targeted group of vector and should provide information on resistance anywhere in the world.

The standard WHO test kits and insecticide-impregnated papers at a range of doses are available from the
Division of Control of Tropical Diseases
World Health Organization
1211 Geneva 27 -Switzerland.
Tel. (41) 22 791 21 11

Spray Machinery Manufacturers

E. Allman & Company LTD
Birdham Road
Chichester
West Sussex - PO20 7 BT - UK
Tel: (44) 1 243 512 511
Fax: (44) 1 243 511 171
Email: sales@allman-sprayers.co.uk
http://www.allman-sprayers.co.uk
Knapsack sprayers, Motorised knapsack Mistblower/Duster.

H.D. Hudson Manufacturing Company
500 N. Michigan Avenue
Chicago IL 60611-3748
Tel: 1 800 745 23 92
Fax: 1 312 644 79 89
http://www.hdhudson.com
Large range of hand-compression sprayers, motorised sprayers, ultra-low volume sprayers.

SOLO Kleinmotoren GmbH
P.O. Box 60 01 52
D-71050 Sindelfingen
Tel: 49-7031/3 01-0
Fax: 49-7031/3 01-130
Email: info@solo-germany.com
http://www.solo-germany.com
Large range of hand-compression sprayers, motorised sprayers.

References and Bibliography

Baghri S. and Reed R., (forthcoming), *Assessment and Programme Design for Emergency Sanitation:* WEDC, Loughborough University, UK.

Bres, P., (1986), *Public Health Action in Emergencies Caused by Epidemics,* World Health Organization, Geneva.

Birley M.H., (1991), *Guidelines for Forecasting the Vector-borne Disease Implications of Water Resources Development,* PEEM Guidelines Series 2, World Health Organization, Geneva.

Busvine J.R., (1982), *Control of Domestics Flies,* Ross Institute Bulletin No. 5., London.

Busvine J.R., (1980), *Insects and Hygiene: The biology and control of insect pests of medical and domestic importance,* Third Edition, Chapman and Hall, London.

Chavasse et Al, (1998), *Reported Complete Failure to Control flies with Traps.* UK.

Chavasse D., (1997), *Planning for Fly Control in Sanitation Programme, Sanitation Promotion Kit,* Department of Infectious Diseases and Tropical Disease, London School of Hygiene and Tropical Medicine, UK.

Chavasse D.C. and Yap H.H., (1997), *Chemical Methods for the Control of Vectors and Pests of Public Health Importance,* WHO/CTD/WHOPES/ 97.2, World Health Organization, Geneva.

Cheesbrough M., (1987), *Medical Laboratory Manual for Tropical Countries, Volume 1,* Second Edition, Tropical Health Technology, UK.

Coosemans M., (1995), *Lutte Contre les arthropodes Vecteurs,* unpublished lecture notes, Institut de Médecine Tropicale Prince Léopold, Antwerpen, Belgium.

Coosemans M. and Carnevale P., (1995), *Malaria Vector Control : A critical Review on Chemical Methods and Insecticides,* Unpublished lecture notes, Prince Leopold Institute of Tropical Medicine, Antwerpen, Belgium.

Cornwell P.B., (1968), *The Cockroach,* Volume 1, Hutchinson, London.

Davis J. and Lambert R., (1995), *Engineering In Emergencies: A practical guide for relief workers,* IT publications (on behalf of RedR), London.

De Poerck D., (1987), *Control of Insect Vector in Refugee Camps,* Unpublished Diploma Project, WEDC, Loughborough University, UK.

Disasters, (1981), 'Medical Care in Refugee Camps', *Disasters* vol. 5 No. 3, International Disaster Institute, Foxcombe Publication, London.

Drummond R., (1990), *Ticks, and what you can do about them,* Wilderness Press, Berkeley.

Emerson P. et al, (1999), Lancet 353 1401-03

Ferron, Morgan, and O'Reilly, (1997) *Hygiene Promotion for the Great Lake Region*, CARE (UK), Review Draft.

Guillet P., (1995), *La lutte contre les vecteurs dans les camps de réfugiés,* unpublished lecture notes, ORSTOM, Montpellier, France.

Guthrie D.M. and Tindall A.R., (1968), *The Biology of the Cockroach,* Edmond Arnorl, London.

Henriet J., (1995), *Pesticides: Chimie, Normes et Formulations,* unpublished lecture notes, Institut de Médecine Tropicale Prince Léopold, Antwerpen, Belgium.

House S. and Reed B., (1997), *Emergency Water Sources; Guidelines for selection and treatment,* WEDC, Loughborough University, UK.

Ince M., (1997), *Water and Environmental Health,* Unpublished lecture notes, WEDC, Loughborough University, UK.

Ince M., (1997), *Water, Sanitation and Health: Human Parasites and Disease Vectors*, Unpublished lecture notes, WEDC, Loughborough University, UK.

Lacarin, C.J. (1998) *Vector Control in Emergency Situations After a Population Influx.* Unpublished MSc Project Report, WEDC, Loughborough University, UK.

Lehane M.J., (1991), *Biology of Blood-sucking Insects,* Harper Collins Academic, London.

Lucas A.L. and Gilles H.M., (1990), *A New Short Textbook of Preventive Medicine for the Tropics,* Third Edition, Edward Arnold, London.

Médecins Sans Frontières, (1999), *Medical Waste Disposal,* Unpublished, MSF, Brussels.

Médecins Sans Frontières, (1994), *Public Health Engineering in Emergency Situation,* First Edition, MSF, Paris.

Médecins Sans Frontières, (1988), *Eau, Hygiène, Assainissement dans un Camp,* Module 3, Cred/MSF, Brussels.

Ministry of Agriculture, Fisheries and Food, (1980), *Control of Rats and Mice: Reference manual for pest control personnel,* ADAS, HMSO, London.

Organisation Mondiale de la Santé, (1991*), Matériel de Lutte Contre les Vecteurs,* Troisième Edition, OMS, Genève.

Organisation Mondiale de la Santé, (1973*), Lutte Antivectorielle en Santé Internationale,* OMS, Genève.

Oxfam, (1995), *The Oxfam Handbook of Development and Relief,* Volume 2, Oxfam Publication, Oxford, UK.

Pan American Health Organization, (1982), *Emergency Vector Control after Natural Disasters*, Scientific Publication No. 419, PAHO, Washington.

Pickford J., (1995), *Low-cost Sanitation : A survey of practical experience,* Intermediate Technology Publications, London.

Pike E.G., (1987), *Engineering Against Schistosomiasis/Bilharzia,* Guideline towards control of the disease, Macmillan, London.

Reed R.A., (1995*), Sustainable Sewerage: Guidelines for community schemes,* Intermediate Technology Publications in association with the Water, Engineering and Development Centre, London.

Rozendaal J.A., (1997), *Vector Control : Methods for use by individuals and communities,* World Health Organization, Geneva.

Sabatinelli G., (1996), *Lutte Antivectorielle dans les Camps de Réfugiés,* PTSS/HCR Genève, ISS/OMS, Rome.

Schreck C.E. and Self L.S., (1985), *Treating Mosquito Nets For Better Protection From Bites and Mosquito-borne Diseases,* Unpublished Report, WHO/VCB/85.914, World Health Organization, Geneva.

Service M.W., (1986), *Blood-Sucking Insects: Vectors of Disease,* Studies in Biology No. 167, Arnold, London.

Soltice L., (1993), *L'eau et son Utilisation,* Unpublished lecture notes, Institut de Formation et d'Appui aux Initiatives de Développement, Bordeaux, France.

Thomson M., (1995), *Disease Prevention through Vector control: Guidelines for relief organization,* (Oxfam Practical Health Guide No. 10), Oxfam, Oxford, UK.

UNHCR, (1994), *Technical Approach: Environmental Sanitation,* United Nation High Commissioner for Refugees, Geneva.

Weber W.J., (1982), *Diseases Transmitted by Rats and Mice: Health hazards to humans and domesticated animals,* Thomson Publication, London.

Winblad U. and Kilama W., (1985), *Sanitation Without Water,* Revised and Enlarged Edition, Macmillan, Basingstoke.

WHO, (1993), *Parasitic Diseases in Water Resources Development: The need for intersectoral negotiation,* World Health Organization, Geneva.

WHO, (1988), *Urban Vector and Pest Control,* Technical Report Series No. 767, World Health Organization, Geneva.

WHO, (1982*), Manual on Environmental Management for Mosquito Control* with special emphasis on malaria vectors, (World Health Organization Offset Publication No. 66), Geneva.

WHO, (1980), *Environmental Management for Vector Control,* Technical Report Series No. 649, World Health Organization, Geneva.

Young A.M., (1982), *Population Biology of Tropical Insects,* Plenum, New York, London.

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