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

<table>
<thead>
<tr>
<th>Summary</th>
<th>Measurable indicator</th>
<th>Means of information</th>
<th>Important Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal:</strong></td>
<td>To stop or to prevent a vector-borne disease epidemic in a temporary human settlement.</td>
<td>Health statistics; morbidity and mortality rate.</td>
<td>Hospital. Health centre.</td>
</tr>
<tr>
<td><strong>Purpose:</strong></td>
<td>To reduce vectors to below a level at which they do not present a danger of disease transmission to the affected population.</td>
<td>Vector prevalence. Surface area treated. Reduction of breeding sites.</td>
<td>Internal evaluation of the control programme, daily, weekly and monthly reports.</td>
</tr>
<tr>
<td><strong>Outputs:</strong></td>
<td>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.</td>
<td>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.</td>
<td>Internal evaluation of the control programme, daily, weekly and monthly reports. Medical services and Vector control Programme.</td>
</tr>
<tr>
<td><strong>Activities:</strong></td>
<td>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.</td>
<td>Health statistics, vector count, vector resistance. <strong>Quantity of equipment:</strong> Spray machinery, spare parts, individual protective equipment and clothing, pesticides, vehicle(s), stationery.</td>
<td>Host country representatives. Affected population. UN agencies. International NGOs. Local NGOs. Local inhabitants. Local government.</td>
</tr>
</tbody>
</table>
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.

---

| Site selection for the VCC. | **Infrastructure:**  
Construction of the VCC.  
Personnel recruitment.  
Personnel training.  
Spraying campaign.  
Monitor control programme.  
Evaluate the campaign. |  
---  
Ministry of Health.  
Ministry of Agriculture.  
Traders. |  
---  
| **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 |  
---  

1VCC: Vector Control Centre
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.


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

11. Insecticide must be compatible with the spray equipment.


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>
<thead>
<tr>
<th>Dustable Powder (DP)</th>
<th>Wettable Powder (WP)</th>
<th>Emulsifiable Concentrate (EC)</th>
<th>Suspension Concentrate (SC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
<td><strong>Disadvantages:</strong></td>
<td><strong>Advantages:</strong></td>
</tr>
<tr>
<td>- Ready to use. No need for water, particularly adapted for dry climates.</td>
<td>- Adaptable to all types of active ingredients. Crushing the a.i. will increase the biological effectiveness.</td>
<td>- Weighing the powder to be transferred into the spraying machine is difficult for manufacturer.</td>
<td>- Very easy to manipulate.</td>
</tr>
<tr>
<td>- Depending on the type of duster, possible to treat large surfaces.</td>
<td>- Good homogeneity on the treated surface.</td>
<td>- White deposit left by the WP on painted walls may be not acceptable to the population.</td>
<td>- Allows a large distribution of the a.i..</td>
</tr>
<tr>
<td>- Possible to treat where access is difficult.</td>
<td>- No storage problem.</td>
<td>- Can only be used with soluble active ingredients and/or solvents.</td>
<td>- The presence of the solvent helps the penetration of the a.i. into vegetation.</td>
</tr>
<tr>
<td>- Not expensive.</td>
<td>- Not expensive.</td>
<td>- Danger of toxicity and phytotoxicity appears when using organic solvents.</td>
<td></td>
</tr>
</tbody>
</table>
Advantages:
- Easy to manipulate.
- Particle size very small, hence better coverage of the treated surface.

Disadvantages:
- Perfecting the formulation can be very delicate.
- Can be a storage problem.
- Very costly.

Ultra Low Volume Liquid (UL)
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.

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'.

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.

Granules (GR)
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.

Advantages:
- Easy and ready to use, no storage problem.

Disadvantages:
- Expensive.

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).
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

<table>
<thead>
<tr>
<th>Type of nozzle</th>
<th>Application</th>
<th>Type of spraying</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid stream</td>
<td>Cracks and crevices</td>
<td>Residual spraying</td>
<td>Cockroaches, soft ticks, bedbugs, ants</td>
</tr>
<tr>
<td>Flat fan</td>
<td>Wall spraying</td>
<td>Residual spraying</td>
<td>mosquitoes and flies</td>
</tr>
<tr>
<td>Hollow cone</td>
<td>Breeding sites in vegetation</td>
<td>Residual spraying and/or larviciding</td>
<td>mosquitoes, ticks, mites</td>
</tr>
<tr>
<td>Solid cone</td>
<td>Breeding sites</td>
<td>Larviciding</td>
<td>mosquitoes</td>
</tr>
</tbody>
</table>

![Figure 5.1. Nozzles for residual spraying machinery (WHO, 1997)](image)

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](image)

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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.
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.
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).
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 5.5. Portable fogging machine (WHO, 1995)

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.

![Hand-operated puff-duster](image)

**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>
<thead>
<tr>
<th>Types of spraying</th>
<th>Surface area treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle-mounted thermal fogger</td>
<td>150 ha</td>
</tr>
<tr>
<td>Backpack mistblowers</td>
<td>5-30 ha</td>
</tr>
<tr>
<td>Hand-carried thermal fogger</td>
<td>5 ha</td>
</tr>
<tr>
<td>Hand-compression sprayer</td>
<td>0.18 ha</td>
</tr>
</tbody>
</table>

Source: Adapted from Bres, 1986; 1 hectare or ha = 10,000 m² 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 de-
scribed in Appendix 4.

Both the Country Manager and the Project Manager
ensure good relationships with the country authorities
and the donors. They are involved in financial
resources research and the application of organisation
policy according to the host country.

The Logistics Officer provides all support needed
(cars, chemicals etc.) for the project. Ensures the
international and local logistical orders.

The ‘Watsan’ engineer is responsible for all the aspects
of water and sanitation including the vector control
project. He is in charge of assessing, designing, and
implementing projects and may have to write the
proposal for the vector control project.

The Supervisor gives support to the engineer in the
planning, human resource management, and
implementation of the project.

The Base Officer is in charge of maintaining all the
infrastructure of the vector control base and organizing
the personnel.

The Section Leader(s) supervises all the teams, ensures
the rotation of staff, plans the work, manages the
transport and provides the pesticides and equipment
needed, ensures good public relations, checks work
performance and writes weekly reports.

The Group Leaders ensure the implementation of the
planned work, supervises the spraying, write the daily
reports, and must be very close to the affected
population.

The Spray men are responsible for applying the
insecticide in a safe and efficient manner. They are
responsible for their equipment and for recording the
number of shelters sprayed and the quantity of
pesticide used. The Assistants give support to the the
sprayers in handling chemicals and in cleaning surface
prior to treatment.

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 be 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 needed. The following formula can be applied:

$$((L \times W) ÷ 10000) ÷ C$$

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 m²). 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:

\[ \frac{(A_u \times B)}{10000} \div C \]

A: Total number of units (shelters, houses, latrines, etc.) to be treated
B: Average surface area for one unit to be treated (m²)
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 m². Hand-compression sprayers will be used for the spraying programme.

\[ \frac{(12352 \times 43 \text{ m}^2)}{10000} \div 0.18 \text{ ha} = 295 \]

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.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Personnel distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section Leader: 1 person</td>
<td>Section Leader 1</td>
</tr>
<tr>
<td>Group Leader: 2 persons</td>
<td>Group Leader 1</td>
</tr>
<tr>
<td></td>
<td>Group Leader 2</td>
</tr>
<tr>
<td>Teams: 28 workers</td>
<td>7 teams comprising 1 spray man and 1 assistant</td>
</tr>
<tr>
<td></td>
<td>7 teams comprising 1 spray man and 1 assistant</td>
</tr>
</tbody>
</table>

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 \([7.38 \text{ m}^2 \div 19 \text{ m}^2]\) \(\times 60 \text{ seconds} = 23 \text{ seconds}\). 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

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Training required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and Sanitation Engineer</td>
<td>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.</td>
</tr>
<tr>
<td>Public Health Specialist</td>
<td></td>
</tr>
<tr>
<td>Sanitary Engineer</td>
<td></td>
</tr>
<tr>
<td>Supervisor of Vector Control Programme</td>
<td>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.</td>
</tr>
<tr>
<td>Vector Control Centre Officer</td>
<td>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.</td>
</tr>
<tr>
<td>Spray men and assistants</td>
<td>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.</td>
</tr>
<tr>
<td>Other personnel related to the control programme</td>
<td>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.</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Items</th>
<th>Materials and functions</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large hats</td>
<td>Should have a large brim to protect the face and neck from droplets. It should be of impervious material</td>
<td>2</td>
</tr>
<tr>
<td>Masks</td>
<td>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.</td>
<td>Large quantity</td>
</tr>
<tr>
<td>Respiratory mask with filter (Space spraying use)</td>
<td>Only used for fogging, the mask is fitted on the face very closely. Filter cartridge must be renewed regularly.</td>
<td>1</td>
</tr>
<tr>
<td>Goggles</td>
<td>Plastic, protect eyes from droplet exposure.</td>
<td>1</td>
</tr>
<tr>
<td>Dungarees with long sleeves</td>
<td>Should be made of durable cotton fabric. Protect the body from exposure. Need to be washed after each spraying use.</td>
<td>2</td>
</tr>
<tr>
<td>Aprons</td>
<td>Should be made of rubber or PVC to protect from any spills of insecticide</td>
<td>2</td>
</tr>
<tr>
<td>Gloves</td>
<td>Made of PVC(^1), rubber, or cotton. They protect the hands when handling chemicals and spraying.</td>
<td>several</td>
</tr>
<tr>
<td>Pair of boots</td>
<td>Made of rubber. They protect the lower part of legs where the aprons may not reach.</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^1\) 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

<table>
<thead>
<tr>
<th>Job Functions</th>
<th>Item distributions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large hats</td>
<td>Masks</td>
</tr>
<tr>
<td>Supervisor</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Section leader</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Base officer</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Group leader</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Spray man</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Spray man assistant</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mixer</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cleaner</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Storekeeper</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Maintenance team</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

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 hap-
pening 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

<table>
<thead>
<tr>
<th>First Aid</th>
<th>Decontamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove the patient from the chemical.</td>
<td>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.</td>
</tr>
<tr>
<td>Keep patient at rest.</td>
<td>Place the patient in the recovery position (on his/her side) only if still breathing.</td>
</tr>
<tr>
<td>Remove contaminated clothing if poisoning occurred through the skin.</td>
<td>The affected skin must be washed with soap and flushed with large amount of water.</td>
</tr>
<tr>
<td>Give plenty of water to drink if the chemical has been swallowed.</td>
<td>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.</td>
</tr>
<tr>
<td>If breathing has stopped, start artificial respiration (CPR) immediately.</td>
<td>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.</td>
</tr>
<tr>
<td>Get medical assistance</td>
<td>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.</td>
</tr>
<tr>
<td>For eye contamination, clean with water</td>
<td>Immediately flush massive amounts of fresh water for more than 10 minutes and keep the eyes wide open.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Antidote names</th>
<th>Treatment applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated charcoal</td>
<td>It induces vomiting, only used when chemical has been swallowed and the patient is still conscious.</td>
</tr>
</tbody>
</table>
| 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.

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*

\[(D) \times (B) = 0.040l/m^2 \times 50 \ m^2 \ (1 \ shelter) = 2 \ litres\]

hence, 2 litres \(\times \) (A) = 2 litres \(\times \) 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*

\[(B) \times (C) = 50 m^2 \times 0.025 g = 1.25 g \ (E)\]

**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.

\[100 \ g \ \Rightarrow \ 2.5 \ g \ of \ a.i.\]

\[x? \ \Rightarrow \ 1.25 \ g \ of \ a.i.\]

then

\[(100 \times (E)) \div 2.5 = (100 \times 1.25 \ g) \div 2.5 = 50 \ g \ of \ insecticide \ formulation \ (F)\]

**Step 5:**
Determine the total amount of formulation needed to treat 2000 shelters.

*Calculation*

\[(A) \times (F) = 2000 \ shelters \times 50 \ g \ of \ formulation = 100000 \ g = 100 \ kg\]

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), Emulsifiable 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./m² required for 0.040l/m² 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 m² 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./m² to be sprayed, e.g. 0.025 g/m² (A);
The speed of the spraying should be constant to spread 0.040l (B) per m² 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*

0.041 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 m².

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), Emulsifiable 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:

\[ X = ( A \times B \times D ) \div C \]

- \( X \) ⇒ 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:

\[ X = ( A \div B ) - 1 \]

- \( X \) = 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**

\[ X = \left( \frac{A}{B} \right) - 1 = \left( \frac{50}{2.5} \right) - 1 = 19 \]

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](image-url)
**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/m² 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

\[
Sm = (L \times W) + (H \times L \times 2) + (H \times W \times 2) + (a \times b) = (2 \times 1) + (1.5 \times 2 \times 2) + (1.5 \times 1 \times 2) + (0.30 \times 1.5) = 11.45 \text{ m}^2
\]

### Step 2:
Calculation of the quantity of the insecticide formulation (M) required according the following formula:

\[M = \frac{T}{(C \times 10)} \text{ ml/m}^2 \text{ of netting}\]

*T* - target dose, this must be expressed in mg/m², therefore 0.2g of a.i./m² = 200 mg of a.i./m².

*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 \[M = \frac{T}{(C \times 10)} = \frac{200}{(50 \times 10)} = 0.4 \text{ ml/m}^2\]

Therefore 0.4 ml/m² × 11.45 m² = 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 m².

### 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:

- \(100 \times 0.52542 \text{ litre} = 52.542 \text{ litres of water}\)
- \(100 \times 0.00458 \text{ litre} = 0.458 \text{ litres of insecticide formulation}\)

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

<table>
<thead>
<tr>
<th>Pyrethroids</th>
<th>Dose mg/m(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>permethrin</td>
<td>200</td>
</tr>
<tr>
<td>deltamethrin</td>
<td>20</td>
</tr>
<tr>
<td>lambda-cyhalothrin</td>
<td>10</td>
</tr>
<tr>
<td>alphacypermethrin</td>
<td>20</td>
</tr>
<tr>
<td>cyfluthrin</td>
<td>50</td>
</tr>
</tbody>
</table>

5.9.6 Determine the quantity of molluscide for use in a river

To determine the amount of molluscide 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 molluscide required, expressed in mg/l or g/m\(^3\) of water (1 mg/l of molluscide means that 1 g of molluscide 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 molluscide formulation, e.g. niclosamide 70%

![Figure 5.12. River flow measurement scheme (Lacarin, 1999)](image-url)
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 \( A = W \times (D_1 + D_2 + D_3 + D_4 + D_5 + D_6 + D_7 \ldots) \)

Where:
- \( W \) = distance between measurements of depth (must be kept constant)
- \( D_1, D_2, \ldots \) = 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 m²** (A)

\[
A = W \times (D_1 + D_2 + D_3 + D_4 + D_5 + D_6 + D_7) = 2.48 \text{ m}^2
\]

**Step 2:**
Calculation of the surface flow velocity \( (V_s) \).

The following formula must be applied:

\[
V_s (\text{m/second}) = \frac{D (\text{distance expressed in metre})}{T (\text{second})}
\]

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 \( D = 100 \text{ metres} \) and it assumes that the time measured is 169 second.

then \( V_s = \frac{D}{T} = \frac{100\text{ m}}{169 \text{ s}} = 0.591 \text{ m/second} \)

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:

\[
V_m (\text{metres/second}) = V_s (\text{metres/second}) \times C (\text{constant coefficient})
\]

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 \( V_m = V_s \times C = 0.591 \text{ m/second} \times 0.85 = 0.502 \text{ m/second} \)

**Step 4:**
Calculation of the discharge \( (D_q) \) of the streams

The following formula must be applied:

\[
D_q (\text{m}^3/\text{second}) = V_m \times A
\]

then \( D_q = V_m \times A = 0.502 \text{ m/second} \times 2.48 \text{ m}^2 = 1.24 \text{ m}^3/\text{second or 4481 m}^3/\text{hour} \)
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 $\times$ 4 mg/l $\times$ $\left(\frac{100}{70}\right)$ = 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 $\times$ 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).