

CHAPTER 9

House-spraying with residual insecticides

One of the most important advances in the control of insects during this century was the development of insecticides that remain active over extended periods. The first insecticide with such long-lasting or residual properties, DDT, was developed during the Second World War. Soon afterwards it was discovered that DDT sprayed on walls and ceilings in houses killed insects for several months.

Spraying with residual insecticide became particularly important in the control of the mosquito vectors of malaria, which often rest on walls before and after feeding. In South America, wall-spraying became the most important method for controlling the triatomine bugs, vectors of Chagas disease, which live in cracks. Residual wall-spraying is also effective against bedbugs and some species of indoor biting sandflies, the vectors of leishmaniasis. It can be used in the control of *Culex* and *Aedes* mosquitos, the vectors of filariasis and dengue, but is not very effective against these species, partly because they tend to rest indoors on objects that cannot be sprayed, like curtains, clothes and furniture.

Cockroaches, fleas, soft ticks, biting mites and other pests can be controlled by spraying residual insecticides on their breeding, hiding and resting places. In Africa, tsetse flies, the vectors of sleeping sickness, can be controlled by spraying their resting and breeding sites in vegetation.

Problems with house-spraying in malaria control programmes

In general, wall-spraying with DDT was effective in reducing malaria wherever it was carried out correctly. However, a number of problems were eventually encountered, among them the following:

- development of resistance by the target insects to DDT and other insecticides;
- outdoor biting and resting habits of some vector mosquitos;
- inadequate sprayable surfaces in some houses;
- custom of people in some areas to sleep outside during the hot season.

Another important problem was poor acceptance of the method by the community. Populations living in areas where house-spraying was carried out often did not see much benefit from spray operations. They became increasingly reluctant to allow spray teams to have access to their living quarters and to accept the sometimes bad-smelling and unsightly insecticide deposits in their houses unless there was a substantial reduction in disease incidence.

Organizing, managing and financing large-scale spray operations over extended periods proved problematic in many countries. To spray large numbers of houses once or twice a year requires considerable organization and many people, vehicles and spraying machines. After an initially successful period many operations became increasingly inefficient and ineffective. The maintenance of such

programmes appeared to be beyond the means of most developing countries. In the 1970s it became clear that malaria eradication by house-spraying was not feasible and that a reorganization of the control programmes was needed. Spraying was continued only in areas with sufficient resources and where it could be expected to be effective. Control programmes no longer aimed to eradicate malaria but to reduce the incidence to such a level that it was no longer a major public health problem. A flexible approach was clearly needed, using a variety of techniques of vector control and disease management.

Organization of spraying

House-spraying was traditionally carried out by specialized spray programmes employing a large number of personnel. It became clear that alternative vector control methods would have to be simpler and cheaper to allow for decentralization and more involvement of district health services and communities.

Although emphasis was placed on finding alternatives to house-spraying, it continues to be one of the most effective vector control methods in a number of places. Changing the way in which spraying operations are organized may solve several of the earlier problems.

Health education is needed to make communities and other groups aware of the responsibility they have for their own health and of the possibilities for taking action. In many areas, farmers possess spray pumps for the spraying of crops. In small communities, farmers could be trained to spray houses, perhaps with some minor modifications to their equipment. In other cases the health services could provide the spraying equipment and community health workers or other community members could be trained to carry out spraying. All the houses in a small community can be sprayed in one or two weeks, and spray equipment could therefore be shared by several communities.

A community-based approach avoids most of the problems related to the transportation of spray teams and equipment. Acceptance and cooperation by house owners are higher with better health education and more involvement in planning. The cost for personnel is much reduced although the local health service or a community-based organization may have to give the spray workers some financial or other compensation. The health services, however, have to be strengthened in order to provide health education as well as the supervision and evaluation of activities. The responsibility for equipment, spare parts and insecticide also has to lie with the health services. Vector control experts are needed to provide advice on spraying techniques and equipment, appropriate insecticides and the time of spraying.

Factors that determine the efficacy of wall-spraying

Mosquito resting behaviour

The longer the indoor resting period, the higher is the efficacy of the spray treatment. A resting period of a few hours is usually sufficient to kill most mosquito and sandfly species. It is also important to know the preferred resting sites: some species only rest on the lower parts of walls, others on roofs. Clearly, only the resting areas need to be sprayed.

Mosquito susceptibility to insecticides

Some mosquito species have developed resistance to certain insecticides, most notably DDT, and other insecticides have to be used. Resistance should be suspected if repeated observations are made of mosquitos that survive after resting on a sprayed surface for at least half an hour. The use of a WHO susceptibility test kit^a may confirm such observations.

Suitability of wall or roof surfaces for spraying

Walls made of unrendered earth or mud absorb much insecticide at the surface where mosquitos rest. Some soil walls contain chemicals that increase the pH, causing rapid breakdown of some insecticides. Roofs made of thatch or brushwood provide openings within which insects rest but where they cannot be reached by sprays. The best surfaces for spraying are non-absorbent, such as hard wood and painted surfaces (see Chapter 1).

Suitability of insecticides

The aim is to kill insects after they land and rest on the sprayed surface. Suitable insecticides should therefore not have a repellent action. A few insecticides kill on contact but also have an airborne effect without repelling the insects (bendiocarb, propoxur, pirimiphos methyl, fenitrothion). Formulation is important: emulsifiable concentrates are not generally suitable.

Cooperation of house owners

Indoor house-spraying has given rise to many problems and misunderstandings between spray teams and house owners. Good health education is needed to explain the reason for spraying. Those who are responsible for planning and carrying out spray activities have to respect local customs and beliefs.

^a Available on request from Vector Control Research Unit, School of Biological Sciences, Malaysia Sains University (USM), Penang, Malaysia.

Insecticides for residual spraying

Insecticides can be directed against the larval stages of mosquitos, which live in water, or against free-living adult stages. In the latter case they can be applied in two ways:

- **Release into the air in the form of a vapour or aerosol**, by means, for example, of mosquito coils and aerosol spray cans and by space-spraying. This method knocks down or kills flying and resting insects immediately after they absorb the particles by inhalation or contact, but offers only brief protection.
- **Application to a surface as a spray or deposit or impregnation for prolonged action**. Residual insecticides kill insects that land on or crawl over a treated surface. The duration of action depends on many factors, such as the nature of the surface, the insecticide, its formulation and the dosage. Examples are insecticidal dusts used against lice and fleas, impregnated mosquito nets and residual spraying of the walls in a house.

Different insecticides are suitable for different application methods. For example insecticides that evaporate quickly at ambient temperature are not

suitable for residual application on walls; they may, however, be suitable for use in vaporizers or space sprays.

Characteristics of good residual insecticides

A residual insecticide should be:

- **Highly toxic to target insects.** Insecticides may lose their effectiveness if the target insects develop resistance. From time to time, samples of the target insect should be collected and checked for the development of resistance. If resistance is observed another insecticide without cross-resistance has to be used.
- **Long-lasting on a given surface.** The toxicity should remain high over a sufficiently long period to prevent the need for frequent reapplication, which is costly and time-consuming.
- **Not repellent or irritant to target insects** to ensure that the insects pick up a lethal dose.
- **Safe to humans and domestic animals.** There should be no danger to spray workers, inhabitants or animals accidentally contaminated with the insecticide during or after spraying.
- **Acceptable to house owners.** Some insecticide formulations are less acceptable because of their smell or because they leave unattractive deposits on walls.
- **Stable during storage and transportation; mix well with water; harmless to spraying equipment.**
- **Cost-effective.** Calculation of the cost should be based on how the insecticide is applied, at what dosage and how many times a year.

Resistance

Resistance is a common result of insecticide use and selection pressure on the insect population. When resistance does emerge, the choice of a replacement insecticide will depend on the mechanism of resistance, known susceptibility, cost-effectiveness and availability. Ideally, the available insecticides should be used as part of an overall strategy to maximize the useful life of each product.

DDT used to be the most commonly applied insecticide and can still be employed where mosquito vectors are susceptible.

Where insects are resistant to DDT, the next insecticide of choice is usually one of the organophosphorus compounds, especially malathion. If the target insects have developed resistance to malathion, fenitrothion, which is more expensive and more hazardous or pirimiphos methyl, which is also more expensive, can be used. The carbamates are also more expensive alternatives. The pyrethroids are normally used when resistance occurs to all other types of insecticide; they are among the safest such products currently available when applied at the recommended dosages. Vector control experts in the local health services or research institutes may be able to advise on locally effective pesticides.

Formulations

Insecticides are rarely applied in their pure form. They are available as special formulations, which are adapted to the requirements of the various application methods.

Residual insecticides for spray application are generally formulated as water-dispersible powders, emulsifiable concentrates or suspension concentrates.

Water-dispersible powder

This is a dry powder of insecticide mixed with a surface-active agent that allows the insecticide to dissolve in water. The insecticide remains in suspension in the water with occasional stirring.

The products are usually packaged as powders containing 5–80% active ingredient. One kilogram of a 75% powder formulation would consist of 250 g of inert material and 750 g of the pure insecticide. Such products are ready for mixing with water to form a spray suspension, normally containing 1–5% of active ingredient.

Emulsifiable concentrate

An emulsifiable concentrate consists of a solvent and an emulsifying agent in which the insecticide is dissolved. When mixed with water it forms a milky, white emulsion composed of finely suspended oil droplets. It remains in suspension with a minimum of agitation.

Suspension (or flowable) concentrate

A suspension concentrate consists of particles of the insecticide with a wetting agent and some water, which can be used to make a water-based suspension. A distinct advantage is that the ingredients are not flammable. The insecticide particles are larger and remain available on wall surfaces longer than those of emulsifiable concentrates. However, the particles are smaller than those of water-dispersible powders, and are therefore less effective on porous surfaces. The residues left on the wall are aesthetically more acceptable than those of water-dispersible powders. This type of formulation is available for several insecticides listed in Table 9.1.

Water-dispersible powder, emulsifiable concentrate or suspension concentrate?

For indoor spraying purposes, the water-dispersible powder is the most effective formulation in most countries. This is because it is most suited for porous surfaces such as brick and mud walls. The insecticide particles are comparatively large and absorption is comparatively slight. More active ingredient therefore remains available on walls to be picked up by resting mosquitos and crawling insects and the residual effect lasts longer.

The water-dispersible powder is also lighter and easier to transport than the emulsifiable concentrate. It can be prepacked for use in the field and is less toxic to humans.

The suspension concentrate is also suitable for rough surfaces, but special care is needed during the formulation process in order to avoid caking of solid materials at the bottoms of containers and, as it is a liquid, it requires relatively expensive containers and careful handling to avoid spillage.

The emulsifiable concentrate is more expensive and used for spraying impervious surfaces and walls with fine coverings because it does not cause spots and stains.

The residual effect of emulsifiable concentrates depends on the absorption capacity of the wall and on the physical properties of the insecticide. Usually, water-dispersible powders and suspension concentrates have a longer residual effect, except on non-absorbent surfaces where the effectiveness and persistence of the three kinds of formulation are equivalent.

Table 9.1
Insecticides used for residual wall-spraying

Insecticide	Dosage (g/m ²)	Duration of effectiveness (months)	Insecticidal action	Safety class of active ingredient ^a
Organochlorines				
DDT	1–2	6 or more	contact	MH
lindane	0.2–0.5	3 or more	contact	MH
Organophosphorus compounds				
malathion	1–2	1–3	contact	SH
fenitrothion	1–2	1–3 or more	contact, airborne	MH
pirimiphos methyl	1–2	2–3 or more	contact, airborne	SH
Carbamates				
bendiocarb	0.2–0.4	2–3	contact, airborne	MH
propoxur	1–2	2–3	contact, airborne	MH
Pyrethroids				
alphacypermethrin	0.03	2–3	contact	MH
cyfluthrin	0.025	3–5	contact	MH
cypermethrin	0.5	4 or more	contact	MH
deltamethrin	0.05	2–3 or more	contact	MH
lambdacyhalothrin	0.025–0.05	2–3	contact	MH
permethrin	0.5	2–3	contact, airborne	MH

^a MH = moderately hazardous; SH = slightly hazardous.

Dosages and cycles

The dosage rate is the amount of insecticide applied to a unit of surface area. It is usually given in grams of insecticide per square metre (g/m²). The optimal dosage rate may vary with place and season, with species of mosquito or other vector and with the material of the sprayed surface. Table 9.1 gives dosage rates which usually provide satisfactory results. Local vector control experts should advise on the most appropriate dosage rates.

The spray cycle is the time between consecutive insecticide spray rounds. In small communities where spraying can be done quickly, houses should be sprayed in the weeks preceding the onset of the transmission season. If this season lasts only three months an insecticide that persists for three months or more needs to be sprayed only once a year.

In areas where transmission occurs throughout the year, several spray cycles may be needed to cover the whole period. Residual effectiveness is normally extended when a relatively high dosage rate is used. A lower dosage can be applied when the transmission season is short.

Type of sprayed surface

The persistence of an insecticide sprayed on a surface varies not only with the type of insecticide and its formulation but also with the nature of the surface. Most insecticides last longer on wood and thatch than on mud. Mud surfaces absorb some insecticide, and certain types of mud may also break it down chemically. For example, malathion sprayed on wood may last three months or more, whereas on some mud surfaces it may last only three weeks.

If local data are not available, it is suggested that for spraying on wood or for short transmission periods the lower dosage rates given in Table 9.1 be chosen. The higher dosage rates may be used for applications on mud surfaces and where long persistence is needed. As discussed above, the persistence of an insecticide is also influenced by its formulation.

Commonly used insecticides

Organochlorines

Of this group of insecticides only DDT is discussed here in detail. Dieldrin was commonly used but, as it is highly toxic to humans and domestic animals, it is no longer available. Lindane has been used in areas where DDT resistance occurs. It is more toxic than DDT but can be applied safely when suitable precautions are taken. It is more expensive than DDT and less persistent, and consequently lindane spraying is rather costly. Because of resistance it is now of limited importance.

DDT

This was one of the first and most commonly used insecticides for residual spraying. Because of its low cost, high effectiveness, persistence and relative safety to humans it is still used for indoor wall spraying. However, the development of resistance and restrictions imposed in a number of countries have led to its replacement by other insecticides that are more expensive. A WHO Study Group met in November 1993 to consider the use of DDT for controlling vector-borne diseases. It concluded that it may be used for vector control, provided that certain conditions are met (1).

Commonly available formulations: 75% water-dispersible powder (the most commonly used) and 50% water-dispersible powder; 25% emulsion concentrate.

Dosage: 1–2 g/m² depending on the surface (more on mud-bricks, less on timber) and the length of the transmission period (the higher dosage lasts longer).

Storage: it is stable and can be stored in tropical countries without deterioration if heat, bright sunlight and high humidity are avoided.

Residual effectiveness: six months or more.

The effectiveness and importance of DDT

The discovery of DDT in the 1940s led to a breakthrough in the control of malaria. The insecticide is highly effective in killing indoor-resting mosquitos when sprayed on house walls. It is cheap and remains effective over a period of many months. In many countries, malaria control programmes achieved substantial success because of the spraying of houses once or twice a year with DDT. However, in many areas the spraying could not be maintained because of the high cost of the operations and declining cooperation of the population. In addition, in many areas malaria mosquitos developed resistance to DDT, necessitating increased costs for more expensive replacement insecticides. Nevertheless, DDT is still an effective insecticide in a number of countries.

However, the use of DDT is increasingly being opposed by environmentalists who correctly point out that it is harmful when used for agricultural purposes. DDT does not break down quickly when sprayed on crops. It remains in the soil for a long time and can enter rivers and water supplies. Animals that eat insects poisoned with DDT or predators further up the food chain slowly become poisoned themselves. Humans eating contaminated vegetables and other products may also accumulate DDT in various tissues. In most countries this has resulted in a ban on the use of DDT.

This situation affects the availability and use of DDT for malaria control purposes. DDT is still one of the cheapest insecticides available (Table 9.2) and, if used for wall spraying, is relatively safe for humans and the environment. In spite of its widespread use in malaria control, there have been no reports of intoxication of humans as a result of wall spraying.

Organophosphorus compounds

This group of insecticides was developed after the organochlorines. Following the development of resistance to DDT the organophosphorus compounds became important as alternative residual insecticides. The most commonly used are malathion and fenitrothion. They are more costly than DDT and have a shorter residual effectiveness (Table 9.2).

Table 9.2

Cost comparison of insecticides as applied in residual spraying, excluding operational costs

Insecticide	Dosage (g/m ²) (technical grade)	Approximate duration of residual effect on mud (months)	Number of applications (6-month period)	Total dosage per 6-month period (g/m ²)	Formulation ^a	Total amount of formulation per m ² per 6-month period	Approximate cost/tonne ^b (US\$)	Cost/m ² (US cents per 6-month period)	Cost ratio (DDT = 1)
DDT	2	6	1	2	75% WDP	2.67	3 000	0.8	1
malathion	2	3	2	4	50% WDP	8	2 100	1.68	2.1
fenitrothion	2	3	2	4	50% EC	8	7 500	6	7.5
propoxur	2	3	2	4	20% EC	20	9 300	18.6	23.25
deltamethrin	0.025	6	1	0.025	2.5% WDP	1	25 000–28 000	2.5	3.125
permethrin	0.125	3	2	0.250	25% WDP	1	30 000	3	3.75

^a WDP: water-dispersible powder; EC: emulsifiable concentrate.

^b Excluding freight costs.

Source: 2.

Malathion

This has become one of the most commonly used residual insecticides, following the development of resistance to DDT in many countries. It is classified as slightly hazardous. The absorption of particles by spray workers through inhalation, ingestion or contact with the skin reduces the activity of the enzyme cholinesterase in the nervous tissue. Signs of severe poisoning are muscle twitching and weakness followed by fits and convulsions. Spray personnel should not work with malathion for more than five hours a day, nor for more than five days a week. If the insecticide is stored for long periods in hot areas, impurities may develop which make the product more toxic to humans. Malathion is the least expensive organophosphorus insecticide and the safest when manufactured according to WHO specifications. It is commonly used as a residual spray in the control of malaria and Chagas disease. Acceptability to house owners is sometimes a problem because of its unpleasant smell.

Commonly available formulations: 50% water-dispersible powder and 50% emulsifiable concentrate.

Dosage: 1 or 2 g/m².

Residual effectiveness: at the higher dose it may last up to six months on thatch or wood but only 1–3 months on mud and plaster surfaces. Mud surfaces with a high alkali content (minerals) tend to break down the malathion most rapidly.

Fenitrothion

Fenitrothion is classified as moderately hazardous and is more toxic than malathion to humans. Spray personnel and workers handling the insecticide must observe strict precautionary measures. As with malathion, repeated exposure may lead to a reduction of cholinesterase in the nervous tissue. Spray personnel should be monitored regularly for blood cholinesterase activity; if the level is low they should stop spraying until it has returned to normal. Fenitrothion is a contact poison but it also has an airborne toxic effect on insects which may last up to two months after spraying. The airborne effect may be useful where target mosquitoes bite but do not rest in houses. It is often effective against pests that have developed resistance to malathion.

Commonly available formulations: 40% and 50% water-dispersible powder; 5% emulsifiable concentrate.

Dosage: 1 or 2 g/m².

Residual effectiveness: on wood surfaces, 1 g/m² may remain effective for up to 2.5 months; on mud surfaces it lasts 1–2 months.

Carbamates

Propoxur

This product is classified as moderately hazardous. If absorbed it reduces cholinesterase activity, which, however, returns quickly to normal once exposure ceases. It is fairly toxic to fish, birds, bees, livestock and wild animals. Propoxur has an airborne effect inside and near houses for up to two months after spraying. It is used in areas where resistance occurs to organochlorine and organophosphorus insecticides.

Commonly available formulations: 50% water-dispersible powder and 20% emulsifiable concentrate.

Dosage: 1 or 2 g/m².

Residual effectiveness: at 2 g/m² it may last 2–3 months.

Bendiocarb

Bendiocarb is classified as moderately hazardous. It is rapidly metabolized after absorption, and metabolites are totally excreted from the body within 24 hours. It inhibits cholinesterase, but recovery is very rapid once exposure ceases. When used with appropriate safety precautions, it is safe for operators, householders and livestock, but ducks are particularly susceptible.

Commonly available formulation: 80% water-dispersible powder in preweighed sachets, one sachet to be used per spray charge.

Dosage: 0.2–0.4 g/m².

Residual effectiveness: remains effective for 2–3 months.

Synthetic pyrethroids

This group includes the most recently developed residual insecticides. The compounds that have been tested for wall-spraying are permethrin, deltamethrin, lambdacyhalothrin, cypermethrin and cyfluthrin. They are used where resistance occurs against the previous groups of insecticides. The pyrethroids are moderately hazardous and under normal conditions of use they are safe for spray personnel and house owners.

Deltamethrin: available as 2.5% and 5.0% water-dispersible powder and as 2.5% and 5.0% emulsifiable concentrate. At a dosage of 0.05 g/m² it usually remains effective for 2–3 months on mud and thatch surfaces, but nine months has been reported for other surfaces.

Permethrin is available as 25% water-dispersible powder. At a dosage of 0.5 g/m² it remains effective for 2–3 months.

Lambdacyhalothrin is available as 2.5% emulsifiable concentrate and as 10% wettable powder in preweighed sachets. At a dosage of 0.025–0.05 g/m² it may remain effective for 2–3 months.

Cypermethrin is available as 5% and 25% emulsifiable concentrate. At a dosage of 0.5 g/m² it may remain effective for four months or longer.

Preparation of insecticide suspension

If the standard spraying procedure (see p. 376) is adopted the spray liquid will be applied at a rate of 40 ml per m² or one litre per 25 m². This amount of suspension normally stays on the surface without run-off.

Water-dispersible powder

One litre of spray suspension can be prepared using the following formula:

$$X = \frac{25 \times Y}{C} \times 100$$

where:

X = weight of water-dispersible powder required (g)

Y = recommended application rate (g/m^2)

C = concentration of active ingredient in formulation (%).

Example

DDT (75% water-dispersible powder) is to be sprayed at a dosage of $2 \text{ g}/\text{m}^2$.

$$X = \frac{25 \times 2}{75} \times 100 = 66.6 \text{ g}$$

For an eight-litre tank, the amount of water-dispersible powder needed is:

$$8 \times 66.6 = 533.3 \text{ g}$$

The insecticide should be packed in small bags containing 533.3 g each. In the field, put water in a mixing bucket until the eight-litre mark is reached. Mix the contents of one bag with the water, using a wooden paddle. Pour the solution into the sprayer through a funnel with a screen, close the tank and shake it.

Emulsifiable concentrate

To prepare an insecticide suspension from an emulsifiable concentrate, use the same formula as for the water-dispersible powder, with:

X = amount of emulsifiable concentrate needed (ml)

Y = recommended application rate (g/m^2)

C = concentration of active ingredient in formulation (%).

To prepare one litre of suspension, add X ml of emulsifiable concentrate to $(1000 - X)$ ml of water.

Example

DDT (25% emulsifiable concentrate) is to be sprayed at a dosage of $1 \text{ g}/\text{m}^2$.

$$X = \frac{25 \times 1}{25} \times 100 = 100 \text{ ml}$$

To prepare one litre of suspension, add 100 ml of emulsifiable concentrate to 900 ml of water. For an eight-litre tank, add 800 ml of emulsifiable concentrate to 7200 ml of water.

Manually operated sprayers

There are many different types of hand-operated sprayer. Most models are used for the control of agricultural pests. With some adaptations such sprayers may also

be suitable for use in public health and for household pest control. The World Health Organization has produced detailed specifications of spraying equipment suitable for residual wall-spraying in order to ensure uniform and safe application of insecticides (3).

Types of hand-operated sprayer

Compression sprayer

Usually considered the standard equipment for residual spraying. However, many models are available and only a few comply with WHO specifications, which are discussed further in the text.

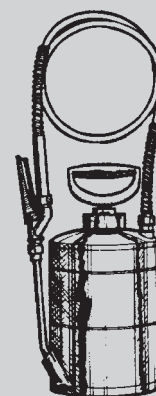


Fig. 9.1
A hand-compression sprayer (© WHO).

Knapsack sprayer

Widely used in agriculture, this is carried on the back. A frame or shield prevents contact between the tank and the back. It is a continuous type of sprayer with a fairly constant discharge rate. The person maintains pressure in the tank by pumping air with a lever with one hand and directs the spray lance with the other. If the sprayer is fitted with a spray control valve, continuous pumping may not be necessary. The knapsack sprayer can be used for spraying breeding sites with larvicides but should not be used for residual wall-spraying.

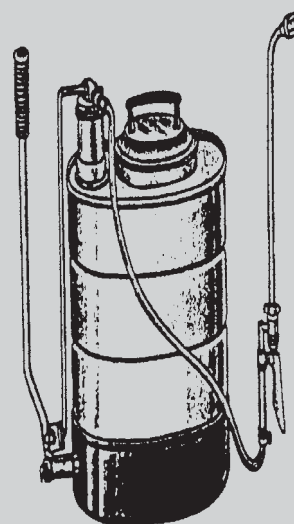
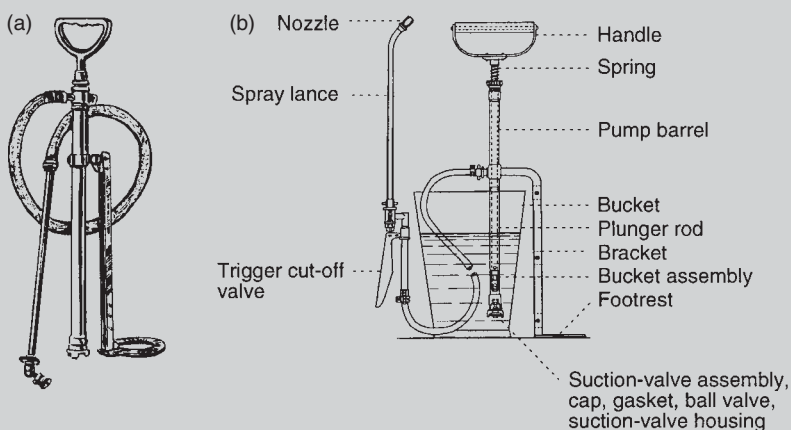


Fig. 9.2
A knapsack sprayer (© WHO).

Stirrup pumps

These are used in some vector control programmes because they are less costly than compression sprayers. The pump, mounted on a footrest or stirrup, is inserted in the spray liquid in a bucket. A hose attached to the pump leads to the spray lance. Two persons are needed, one to pump and one to direct the spray. The pressure varies with the speed of pumping, and so it is difficult to make uniform spray applications. Because of their inaccuracy and because of the risk of spilling insecticide from the open bucket inside houses, stirrup pumps are not recommended. They should not be used with hazardous pesticides.

**Fig. 9.3**

A stirrup pump.

((a) © L. Robertson;

(b) © WHO).

Compression sprayers

Functioning and design

A hand-compression sprayer basically consists of a tank for holding a liquid insecticide formulation, which can be pressurized by means of a hand pump attached to it. The compressed air forces the liquid from the tank via a hose with a cut-off valve, a lance and a nozzle (Fig. 9.4).

Tank assembly (Fig. 9.5)

- **The tank** itself is usually made of stainless steel. Most tanks have four openings on top: a large one for filling, fitted with a removable cover; and openings for the air pump, discharge system and pressure gauge.
- **The tank cover** (Fig. 9.6) consists of: (1) a rubber gasket; (2) a handle; (3) a pressure-release valve, operated by hand or by giving the handle a quarter turn; (4) a chain to prevent the cover from being lost.
- **An air pressure gauge** is used to measure pressure in the tank.
- **The shoulder strap** should be wide enough to prevent it from cutting into the shoulder of the person using the sprayer. It is fastened to the tank with steel buckles. On large tanks it is adjustable.
- When the tank is not in use, the spray lance is held in a **bracket and nozzle cup**, which protects the nozzle from damage.

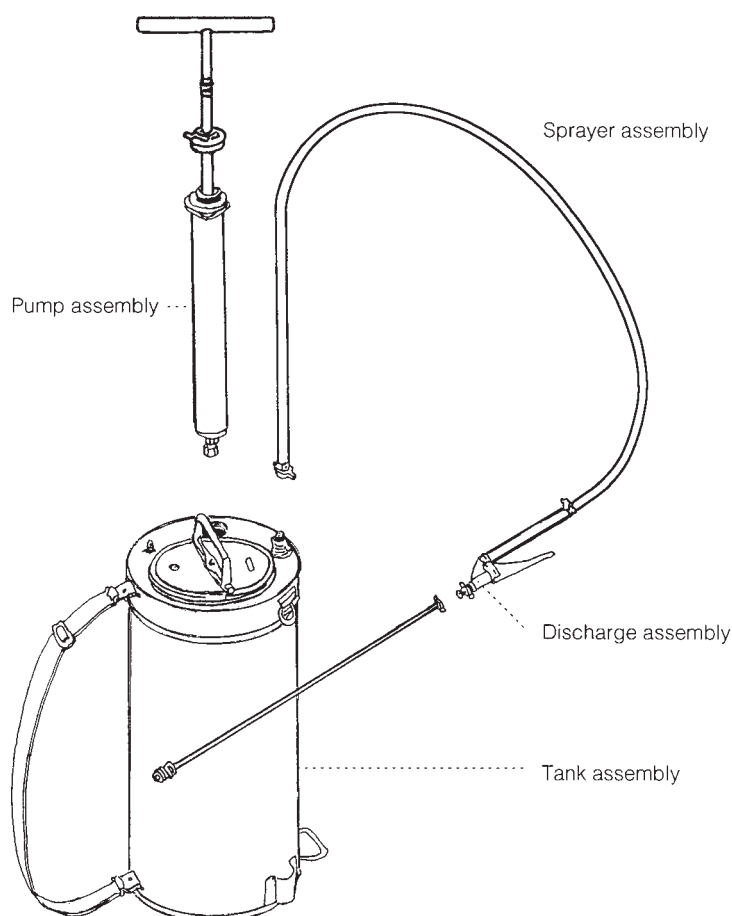


Fig. 9.4
Main components of a hand-compression sprayer (© WHO).

Air pump assembly (Fig. 9.7)

A piston-type pump consists of a plunger operated inside a cylinder. The plunger forces air through a valve at the base of the cylinder. The plunger seal may be made of leather, rubber or plastic, and must be resistant to the chemicals used in insecticide formulations.

Discharge assembly

The main parts are: (1) the dip tube, mounted in the tank with an O-ring gasket; if the gasket is damaged, air may leak from the tank; (2) a flexible hose of a material resistant to chemicals used in pesticide formulations; (3) a filter with housing which filters out particles too large to pass through the nozzle opening; it can be taken out for cleaning or replacement; (4) a cut-off valve that permits the person using the sprayer to close the system; (5) a lance, or extension tube, 40–60 cm in length; some models are telescopic; (6) a nozzle assembly, comprising a nozzle tip, filter, body and cap; the tip may be of stainless steel, ceramic or plastic (Fig. 9.8). The nozzle tip is the most important part of the sprayer. It should deliver a precise

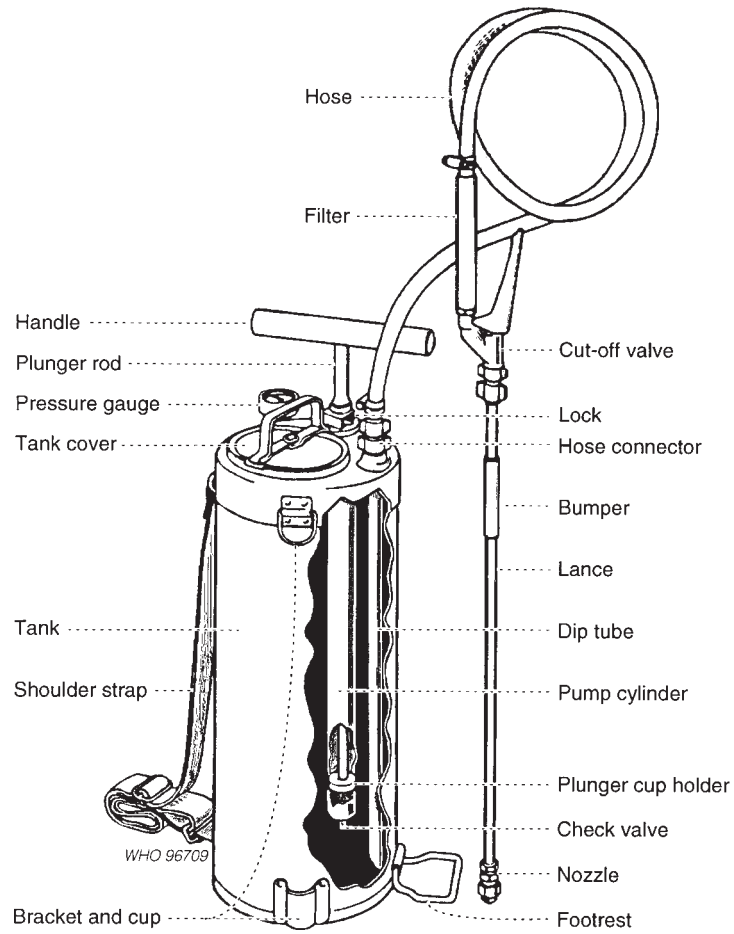


Fig. 9.5
Cutaway diagram of a hand-compression sprayer (© WHO).

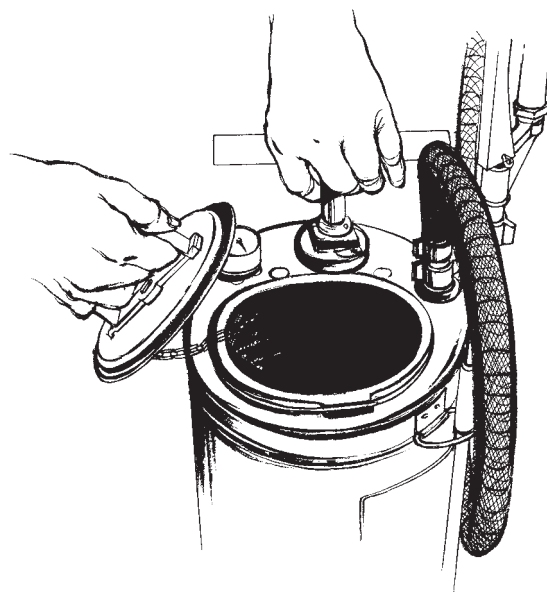


Fig. 9.6
Close-up of upper part of tank with tank cover removed.

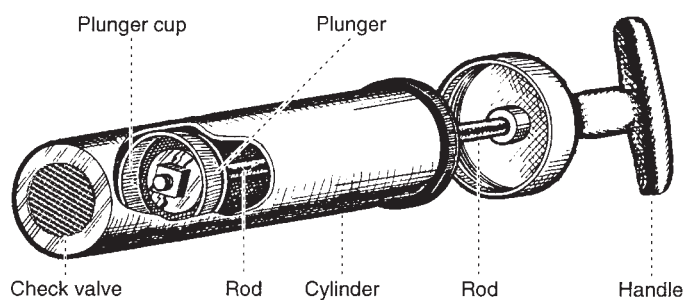


Fig. 9.7
Cutaway diagram of an
air pump assembly (©
WHO).

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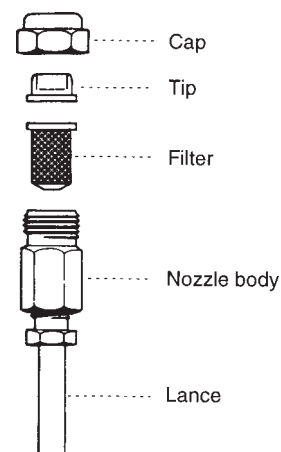


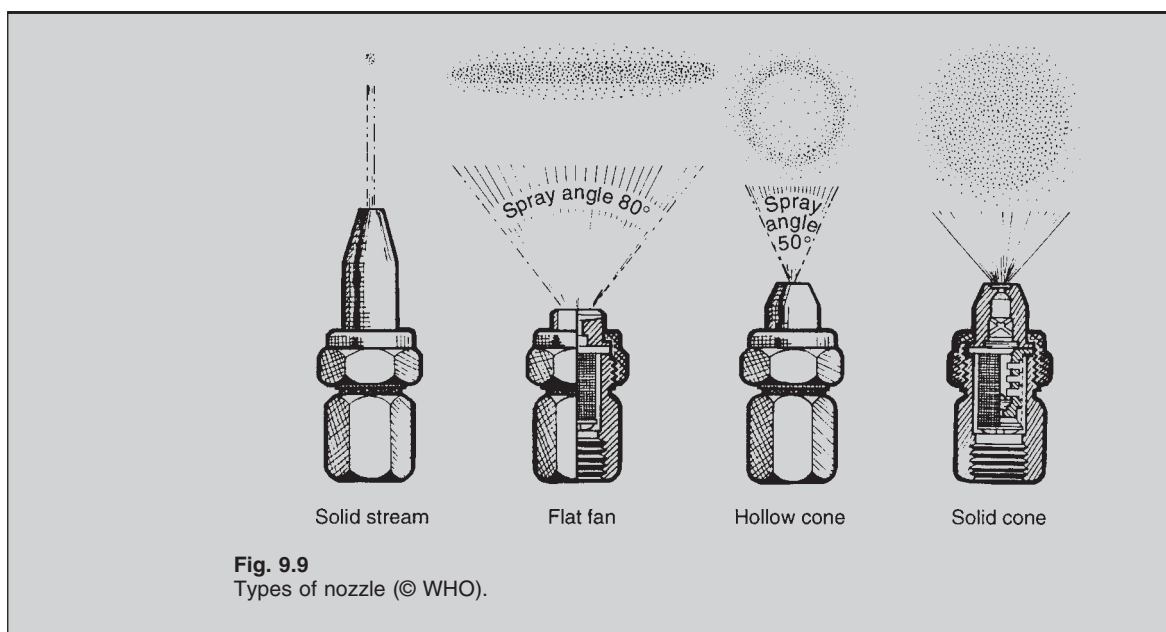
Fig. 9.8
Parts of a nozzle (© WHO).

amount of spray suspension per minute at a certain pressure in the tank, and maintain a uniform spray pattern and swath width. The selection of the nozzle depends on how the insecticide is to be sprayed.

Types of nozzle (Fig. 9.9)

- The solid or jetstream nozzle is used to treat cracks and crevices for control of bedbugs, soft ticks, cockroaches and ants.
- The flat-spray nozzle delivers a fan-shaped spray, and is preferred for residual wall-spraying.
- The hollow-cone nozzle is used to spray breeding sites of mosquitos and tick and mite habitats in vegetation.
- The solid-cone nozzle is used to spray mosquito breeding sites.

The flat-spray nozzle commonly used for wall-spraying produces a spray with an angle of 80° and 757 ml per minute at a standard tank pressure of 280 kPa. It is usually made of specially hardened stainless steel. The nozzle tip is designed with flat surfaces on either side of the orifice so that it can be removed easily.



Use and operation of a hand-compression sprayer

Preparation and addition of pesticide

Pesticides should be carefully handled. Water-dispersible powders should be packaged at a central point before spray operations are started. The correct amount of insecticide should be put into a suitably sized plastic or paper bag (see p. 366 for calculation of insecticide dosage). The people who do this should wear protective clothing (see p. 383). The risks of contamination of personnel, spillage and wastage in the field are thus reduced, as is the workload during spraying activities. Accurate dosing of insecticide is also made easier. Bags and insecticide containers should be disposed of safely after use (see Chapter 10, p. 385).

Mixing

Before the insecticide is mixed, the sprayer should be checked and calibrated with water. In the field, a wooden paddle or stick should be used to mix water-dispersible powders with a small quantity of water to form a smooth paste. This is added to the sprayer tank. More water is used to rinse out the mixing container, the wash is poured into the sprayer tank up to the level required, and stirring is repeated. The mixing container should now be clean. House owners can assist spray personnel by providing water (Fig. 9.10).

Filling

The suspension is poured into the spray tank through a strainer or filter funnel to prevent dirt from entering (Fig. 9.11). If the suspension is not filtered the nozzle tip may become blocked during spraying.



Fig. 9.10
Mixing the insecticide
solution.



Fig. 9.11
Filling the spray tank.

The tank should not be more than three-quarters full. The remaining space should be left for the compressed air. The tank usually has a mark indicating the required amount; for standard sprayers this is 8 or 10 litres.

Shaking

The suspension is kept well mixed by shaking the tank before beginning to spray and from time to time during spraying. This is done by grasping the sprayer by the

pump shaft and the bottom end of the tank. The tank should not be held by the strap, nor should it be swung forward and backward while on the shoulder. Formulations that meet WHO specifications should remain in suspension without extra shaking.

If preweighed pesticide sachets are used, the required amount of water should be poured directly into the sprayer. The contents of the sachet should be added, the sprayer closed, and the contents mixed by turning the sprayer upside down.

Preparation of sprayer

- **To close the tank:** insert the cover vertically into the tank, lift it and fit it into the tank opening; turn the handle across the width of the opening.
- **To open the tank:** push down the air-release valve by turning the handle on the cover; the cover will become loose once the air is at atmospheric pressure.

Pressurizing the tank

Put a foot on the foot rest (if available) and unlock the pump plunger. Pull the plunger all the way up with both hands and then push it downwards (Fig. 9.12). Use full, even strokes.

If the sprayer has a pressure gauge, keep pumping until it registers a pressure of about 380 kPa (55 psi). If the gauge is inaccurate, assume that a full stroke of the pump will provide 1 psi, so normally use 55 full strokes when pressurizing a tank that is three-quarters full. The upper and lower limits for the working pressure are about 380 kPa (55 psi) and 170 kPa (25 psi), giving an average pressure during spraying of about 280 kPa (40 psi).

During spraying, pressure has to be maintained by occasional repumping. Try to get accustomed to the number of pumping strokes required to reach the maximum pressure in case the pressure gauge stops working. Keep the plunger



Fig. 9.12
Pressurizing the spray tank.

shaft in place with the locking lever. Always release the pressure when the sprayer is not in use or when it is being transported.

Application of spray

The insecticide suspension has to be sprayed evenly at the recommended dosage over all sprayable surfaces. The following factors determine how much insecticide is sprayed on a surface:

- the concentration of insecticide in the suspension (calculation of the dosage is discussed on p. 366);
- the air pressure in the sprayer (maintain at 170–380 kPa (25–55 psi));
- the nozzle tip aperture size;
- the distance from the nozzle tip to the surface being sprayed;
- the speed of application over the surface.

Training

The two latter factors imply skill and training, and spray personnel should be trained to spray at the proper rate to cover 19 m² per minute. The wall of a building can be used for practice. Mark an area 3 m high and 6.35 m long, divided into nine bands, the first one 75 cm wide and the remainder 70 cm wide (Fig. 9.13).

The spray nozzle will produce a swath 75 cm wide if kept at a distance of 45 cm from the wall (Figs 9.14 and 9.15). To practise keeping the nozzle 45 cm from the wall, fit a wooden stick or other extension to the lance with rubber bands or string. Make sure the length from the nozzle tip is 45 cm. Extend the right arm and incline the body towards the surface while raising or lowering the right arm so that the end of the stick remains in contact with the surface.

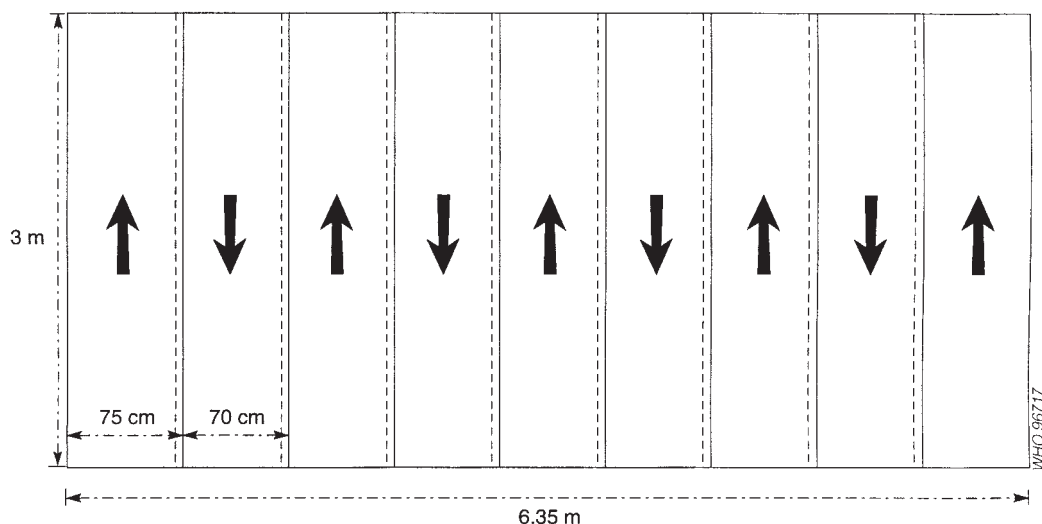


Fig. 9.13 Training board for residual spraying which can be marked with chalk on the wall of a large building (© WHO).

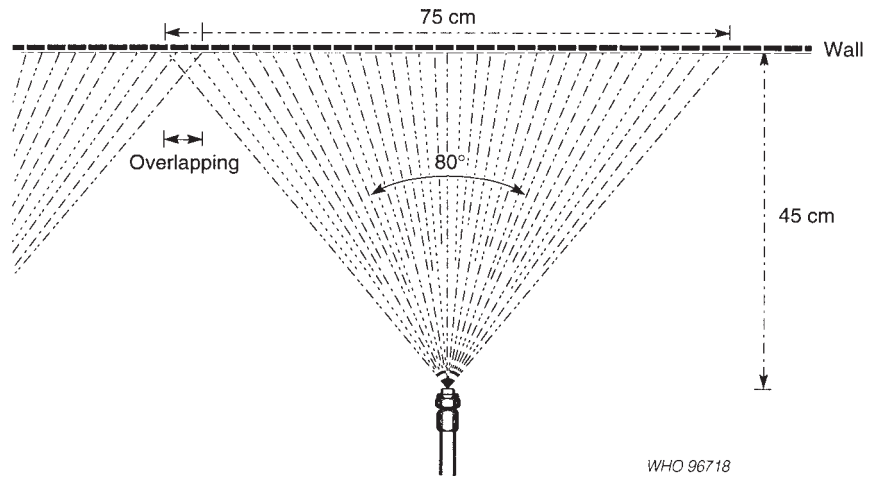


Fig. 9.14
Nozzle discharge pattern (© WHO).

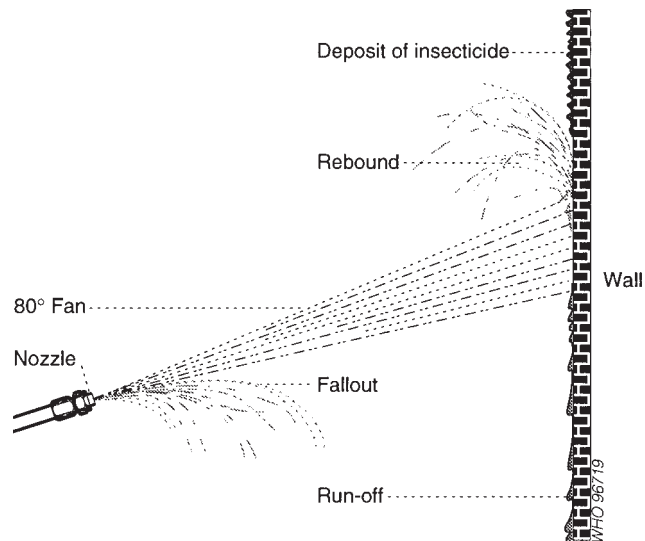


Fig. 9.15
When a vertical surface is sprayed, some of the insecticide particles bounce off into the air; a heavy application results in insecticide run-off down the wall (© WHO).

The spray worker stands directly in front of the wall. If the spray worker is right-handed, the sprayer is carried on the left shoulder and held in place with the left hand; the spray lance is held in the right hand (Fig. 9.16). A helmet or hat and other protective clothing should be worn.

Starting at a bottom corner of the wall and spraying at a uniform rate, move upwards to the top. Continuing to spray, take one step to the right. The next swath should overlap with the previous one by about 5 cm (Fig. 9.13). Spray down to the bottom. Continue in this way until the entire area of 19 m² is covered. Each swath of 3 m in height should be covered in 6.7 seconds so that nine swaths take a minute. The speed can be controlled by counting the seconds aloud or by using a stopwatch.



Fig. 9.16
Correct attitude and protective clothing
for wall-spraying.

If no suitable wall surface is available, an area 1.80 m high and 6.35 m long (11.43 m²) can be used for practice. The area should be divided into nine bands, as described above. Each swath of 1.80 m in height should be covered in 4 seconds so that nine swaths take 36 seconds.

Maintenance and repair

Spare parts

Most sprayers are provided with an illustrated manual giving:

- a description of the equipment;
- operating instructions;
- maintenance instructions;
- information on how to solve problems;
- a list of spare parts.

Spare parts should always be available, especially gaskets and valves. When ordering from the manufacturer or a local supplier, give the sprayer model, the part name and the identification number.

Cleaning

Clean the tank daily after spraying. Do not let pesticide remain in it after use. Rinse the sprayer thoroughly with water and then allow to dry. Do not discard the water in a stream, pond or place where it can be reached by humans or animals; a pit latrine or a hole in dry ground, away from water collection points, rivers, ponds or agricultural land, is the best place for disposal.

Remove, rinse and clean the filter assembly at the control valve. Remove the filter from the valve by grasping it at its base, not by its screen. Twist it slightly on pulling it out (Fig. 9.17).

Reassemble all clean parts except the nozzle. Put clean water in the tank, seal the tank and pump air into it. Open the control valve and let the water flow from the lance to flush the hose, filters, control valve and lance. Remove the tank cover and dry the inside of the tank.

Clean the nozzle tip by washing thoroughly with water (Fig. 9.18). Use a pump to blow air through the orifice, then clean and dry it. Remove any dirt from the orifice with a fine bristle from a brush or with a toothpick; never use metal wire. Dirt can also be blown out by pushing the nozzle against the pressure release valve on top of the tank cover.

Maintenance

Inspect the tank at regular intervals, and replace any worn or damaged part. Inspect the lip of the pump cylinder for cracks that could cause the tank to lose pressure. Check the rubber hose for cracks and weak spots. After some time the hose becomes weakened near the point of attachment to the spray-can or cut-off valve. The weak part should then be cut off and the hose remounted. Put a few drops of clean oil on the plunger cup leather to keep the pump cylinder lubricated and to ensure sufficient pressure. Replace the leather if damaged.

Nozzle tips erode during spraying. They should be replaced when worn. An eroded orifice causes an increase in the amount of pesticide delivered. The discharge rate should be measured from time to time by qualified personnel. A simple method is to spray a suspension on to a dark surface: irregularities in the swath indicate that the nozzle tip needs to be replaced.

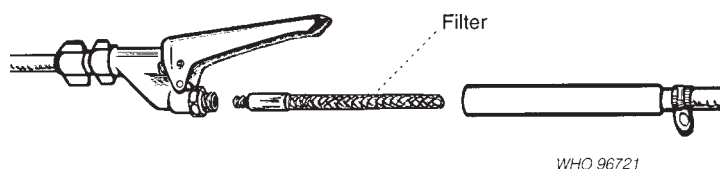


Fig. 9.17
Removing the spray filter for cleaning (© WHO).



Fig. 9.18
Clean the nozzle tip with water (© WHO).

Storage

Check that the tank is empty, put the parts back together and store the tank upside down with the cover lying loosely inside the tank and the plunger locked (Fig. 9.19). Make sure the lance and nozzle cannot fall or be otherwise damaged. Store the cut-off valve locked open.

Problem-solving

- *Pumping does not build up pressure.* Most probably the plunger cup leather is dry or damaged. Apply oil or replace.
- *The sprayer does not spray or sprays irregularly while under pressure.* Release pressure and clean the nozzle (see p. 379). Also check the filter at the spray control valve. Clean if necessary.
- *The sprayer does not maintain pressure; air leaks out.* Check the tank cover gasket and the pump cylinder gasket for leaks. Clean the seating surfaces and replace the gaskets if necessary. If air leaks are difficult to locate, cover fittings with a soapy solution and watch for air bubbles.
- *The sprayer does not shut off.* Release pressure, and disassemble the cut-off valve as indicated in the pump manual. Clean, check and if necessary replace the valve seat, O-ring, spacer, washer and valve-pin packing.

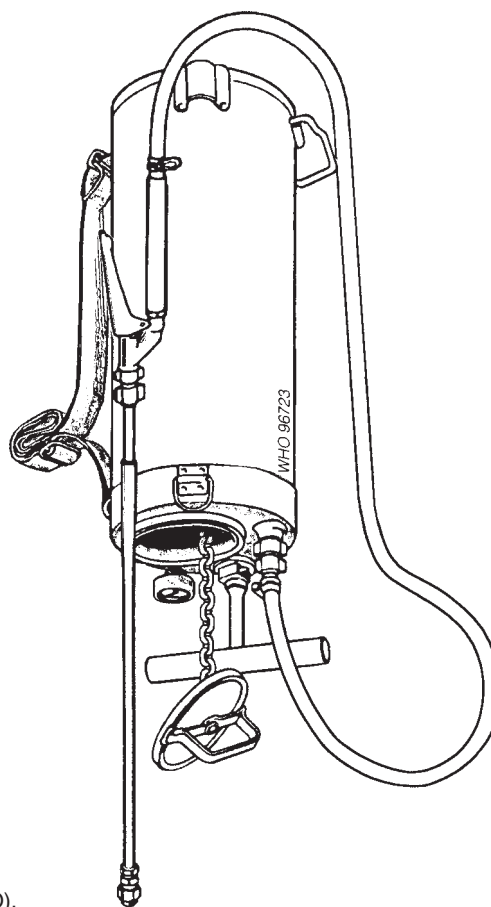


Fig. 9.19
Store the tank dry and upside down (© WHO).

Spraying operations

Where to spray

All known resting or hiding places of the target insect have to be sprayed. Depending on the species, target insects may rest in human dwellings, unoccupied houses, animal shelters, food stores and kitchens. The decision on where to spray should be taken only after consulting an expert on vector control.

Experts also have to indicate whether shops, schools, churches, factories, warehouses and other large buildings in which people do not regularly sleep should be sprayed. In case of doubt such buildings should not be sprayed because of the expense.

In principle, all potential indoor resting surfaces should be sprayed. However, it may be too time-consuming or unacceptable to spray some surfaces, such as under furniture and mats, behind pictures, roof trusses, beams and pillars. It is usually sufficient to limit spraying to walls, ceilings and under eaves.

Selective spraying

Some target insects are known to have special preferences for indoor resting surfaces. For example, some mosquito species rest mainly at the bases of walls, or only on ceilings or under eaves. Spraying only these surfaces will then provide effective control at the lowest possible cost.

In malaria control it is often not necessary to spray buildings in which humans do not regularly sleep. However, temporary shelters used during the planting or harvesting season or for hunting or fishing should be sprayed.

For the control of Chagas disease it may be necessary in some areas to spray not only houses but also peridomestic hiding places for triatomine bugs in animal shelters and food stores.

When to spray

In areas where mosquitos seasonally transmit malaria or other diseases insecticides should be applied just prior to the onset of transmission. This is particularly important when the insecticides used give protection for only a few months. Large programmes may have difficulty in timing spraying properly because of the need to spread the spraying operations equally over the year. In such circumstances, priority should be given to proper timing of spraying in the localities known to have most cases of malaria. This problem does not arise if spraying is organized at community level.

Planning of spraying should take into account the behaviour and customs of the people. Spraying should be carried out when people are expected to be at home. Temporary structures in the field used during the harvesting or planting season should be sprayed shortly after their construction. The timing and frequency of spray rounds may also be influenced by the replastering of walls during certain cultural events.

Planning a spray programme

Individuals can spray their own houses but spraying is generally carried out to control a disease affecting a whole community. Regional or national disease control programmes may be responsible for the spraying of all houses in large areas. Such large-scale operations require detailed plans defining the boundaries of the areas to be sprayed, the methods and procedures of house-spraying, the duration of the programmes, requirements for personnel, supplies and equipment, and the preparation of budgets.

A spraying programme is much simpler to organize for a single community. The following points may then be considered.

- **Effectiveness of method.** Evidence should be provided by the local health authorities that spraying is an effective and locally appropriate method. This should include information on the target insect, its behaviour and its susceptibility to different insecticides.
- **Informing the community.** Community leaders or the local health services should educate community members on the need for a spraying programme and on the responsibility of each community member to collaborate. The agreement of the community has to be sought.
 - The community has to be told:
 - how the insecticide works and what protective effect it will have;
 - that the insecticide is safe to the inhabitants;
 - that walls, ceilings and furniture will not be damaged;
 - that house owners should protect any object they do not want to be sprayed. The inhabitants should cooperate by preparing their houses; furniture, cooking utensils and food should be removed before spraying is carried out; they can be placed outdoors or covered with a sheet of plastic and put in the centre of a room;
 - that house owners should not replaster or wash sprayed walls for a few months after spraying.
- **Estimation of quantity of supplies needed.** These include insecticides, spray pumps, spare parts, protective clothing, gloves, soap and plastic sheets to cover furniture.

Measuring total surface area to be sprayed

It is preferable to start by making a map of the community, indicating the location of all the houses to be sprayed. Each house should be given a reference number, which is marked on the map and painted on the house.

The approximate size and type of each house should be indicated as well as the kind of material used for walls, ceilings and other sprayable surfaces.

If the houses are of similar construction and design, an estimate can be made of the average sprayable surface area per house. A sample of about five houses out of every 100 should be sufficient. The walls, ceilings and other sprayable surfaces in these houses are measured; this can be done with a stick about two metres long which is marked at half-metre intervals.

Calculation of amount of insecticide needed for one round of spraying

The total amount of insecticide (T) needed depends on:

N : the number of houses

S : the average sprayable surface per house (m^2)

Y : the target dosage of insecticide (g/m^2)

C : the concentration of active ingredient in the formulation (%)

$$T = \frac{N \times S \times Y}{C} \times 100$$

Example

A village has 100 houses. The average surface that can be sprayed per house is 200 m^2 . The recommended dosage of DDT is $2 \text{ g}/\text{m}^2$. The DDT is available as a 75% water-dispersible powder.

$$T = \frac{100 \times 200 \times 2}{75} \times 100 = 53.3 \text{ kg of DDT (75\% water-dispersible powder)}$$

It is recommended that at least 10% extra insecticide be held in reserve.

Personnel and equipment required

One person can spray about 8–10 houses a day when working full time. In a community of 200 houses two persons equipped with one spray pump each can spray all the houses in about two weeks. When purchasing the sprayers an adequate supply of the spare parts most likely to be needed should be obtained. It can be assumed that a nozzle tip will have to be replaced after spraying 200 houses. The cost of spare parts can be estimated at 10% of the cost of the sprayers.

The spray workers should be provided with protective clothing and soap (see Chapter 10). A pair of gloves, an apron, a mask and goggles (glasses) are needed for the person who preweighs and packs the insecticide in small bags for later use.

One person, perhaps a community leader or health worker, should supervise spraying operations.

References

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