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APPLICATION AND DISPERSAL OF PESTICIDES

Fourteenth Report of the WHO Expert Committee on Insecticides

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Note : The methods, specifications, use descriptions, etc., drafted by the Committee have been assembled for publication as a separate volume *Equipment for vector control.*

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APPLICATION AND DISPERSAL OF PESTICIDES

Fourteenth Report of the WHO Expert Committee on Insecticides

The WHO Expert Committee on Insecticides met in Geneva, Switzerland, from 19 to 25 November 1963, to discuss the problems of equipment for the application and dispersal of pesticides for vector control. Dr P. Dorolle, Deputy Director-General of WHO opened the meeting. Mr. A. E. H. Higgins was elected Chairman and Dr M. Privora, Vice-Chairman. Mr. L. B. Hall was appointed Rapporteur.

1. INTRODUCTION

The Committee reviewed the various types of equipment available at the present time throughout the world for the application of pesticides. Recommendations were prepared for the use of suitable equipment for each insecticide used to control specific vectors of disease as listed in the thirteenth report of the WHO Expert Committee on Insecticides [1]. Existing equipment specifications have been reviewed and brought up to date. Where possible new specifications have been prepared for a wide range of devices used in different parts of the world, particularly those used for the control of vectors in emergency situations. Where knowledge does not yet permit a detailed specification to be prepared, a use description has been established.

To assist understanding between diverse geographic areas, particularly those with developing technologies, a list of standard nomenclature has been prepared with a view to the eventual development of an international thesaurus on the subject. Standard methods of evaluation of equipment were considered from both the physical and statistical aspects.

The attention of the Committee was called to the need for the development of equipment to apply molluscicides for the control of bilharziasis. This problem was found to be highly complex in view of the wide range of snail habitats, the various economic problems, and the developing technology in this field. Attention was therefore given to the suitability of

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1963, **265**.

existing equipment in relation to each type of habitat, molluscicide, and formulation. Consideration was given to the growing need for further research and to the requirements and specific needs of training in the application of pesticides.

The Committee was of the opinion that work invested in finding solutions to the problems of pesticide application would be more than repaid in terms of monetary savings to programmes, increased biological efficiency, and decreased toxic hazards.

In its deliberations, the Committee bore in mind earlier reports of the WHO Expert Committee on Insecticides dealing with insecticide resistance and vector control,[1] toxic hazards of pesticides to man,[2] the disinsection of aircraft,[3] and equipment for the application of pesticides,[4] as well as the specifications already published by WHO in book form.[5]

2. A GUIDE TO THE MAJOR ITEMS OF EQUIPMENT USED FOR THE APPLICATION OF PESTICIDES

The need for a standard terminology for equipment used for the application of pesticides has been recognized for many years. In 1951, at a meeting of the WHO Expert Committee on Insecticides,[6] a limited terminology was established, and at the same time a recommendation was made that work on standardizing the terminology be continued. The principal difficulty encountered in pursuing this matter was that the terminology in general use has developed partly from scientific publication and partly from commercial sales literature, with the result that the names by which the various items of equipment are known differ not only from one part of the world to another but also locally. This situation has been aggravated in recent years, following a considerable extension of vector control activities other than malaria eradication. Serious difficulties have arisen amongst scientific workers, not only at meetings and conferences, but also in correspondence about their work. Difficulties have furthermore become obvious in communications between the scientist, the field worker, the procurement officer, and the manufacturer.

These difficulties have led to misinterpretation of data in reports and other published material, and there is a danger not only of economic loss, but also of failure to achieve control as a result of the procurement of unsuitable or completely wrong items of equipment. All this could be re-

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1960, **191**.
[2] *Wld Hlth Org. techn. Rep. Ser.*, 1962, **227**.
[3] *Wld Hlth Org. techn. Rep. Ser.*, 1961, **206**.
[4] *Wld Hlth Org. techn. Rep. Ser.*, 1956, **110**.
[5] World Health Organization (1961) *Specifications for pesticides*, 2nd ed., Geneva.
[6] *Wld Hlth Org. techn. Rep. Ser.*, 1952, **46**.

solved if complete specifications were prepared for all the items of equipment required for vector control purposes. However, this would be an almost insuperable task and is not considered to be practical.

The solution proposed by the Committee takes into account the terminology in current use in national and local areas, but establishes a reference guide (with appropriate illustrations) to the major items of equipment as they exist at present. This will provide all concerned with information on the basic functions of the equipment currently available, including the technical characteristics and performance of each individual unit.[1]

The advantage of this approach lies in the fact that it will assist those workers planning new vector control projects or participating in established ones to know what apparatus may be of use in their particular situation. This is especially important when emergency situations arise and where improvization and adaptation of locally obtainable equipment may be necessary as an immediate solution.

The Committee realized that constant revision of this guide will be required and recommended that in making future revisions as many synonyms and local terms as possible be added. It was realized that this would involve a great deal of work and time, but the Committee believed that this procedure would greatly assist future vector control work and eventually lead to a more practical and economic approach to the problems associated with the equipment for the application of pesticides. The Committee recommends that the terms for equipment given in the guide be incorporated in any future lists of terminology of malaria issued by WHO.

3. RECOMMENDED EQUIPMENT FOR VECTOR CONTROL

In its thirteenth report,[2] the WHO Expert Committee on Insecticides reviewed and revised its " Recommended methods for vector control ". These provide information on the insecticides, formulations and dosages that might be expected to bring about control or eradication of insects in different situations. However, no details are given of the equipment that might be used to apply the insecticides. The present Committee has summarized in tabular form a series of recommendations to health authorities and field workers regarding equipment to be used in vector control for various types of insecticidal application.[3]

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[1] See : World Health Organization (1964) *Equipment for vector control*, Geneva (Part I).

[2] *Wld Hlth Org. techn. Rep. Ser.*, 1963, **265**.

[3] See : World Health Organization (1964) *Equipment for vector control*, Geneva (Part II)

The Committee recommends that these charts be kept up to date and re-issued at appropriate times. It is also proposed that the charts be expanded in the future to include information on the most suitable nozzle to be employed in each situation and with each unit and on the selection of equipment considered to be the most suitable for the application of different formulations in varying situations.

4. SPECIFICATIONS FOR EQUIPMENT FOR THE APPLICATION OF PESTICIDES

4.1 Revision of existing specifications for spraying and dusting equipment

In the eight years since a WHO Expert Committee on Insecticides last considered specifications for equipment to be employed for the application and dispersal of pesticides, considerable attention has been paid to improving the efficiency and safety of the types used in mass campaigns, such as malaria eradication. A number of innovations have appeared and have been tried out in the field. The number of sprayers used in vector control work has greatly increased, and the experience gained in using this equipment has shown weak points in design. In addition, the WHO Sprayer Evaluation Team has collected data suggesting the need for certain improvements.

On the basis of laboratory and field reports and the personal experience of its members, the Committee revised the specifications for hand-operated compression sprayers (Specification WHO/EQP/1.R2), intermittent hand-sprayers (Specification WHO/EQP/2.R1), stirrup-pump-type sprayers (Specification WHO/EQP/3.R.2), hand-carried hand-activated plunger-type dusters (Specification WHO/EQP/4.R2), and front-carried hand-activated rotary dusters (Specification WHO/EQP/5.R1).[1]

4.2 Establishment of new specifications for aerosol dispensers

In the eleventh report of the WHO Expert Committee on Insecticides,[2] single-use aerosol dispensers were recommended for the disinsection of aircraft for international quarantine purposes. The Committee noted that the multi-use dispenser used for domestic purposes also has a place in vector control in some situations. In addition, the attention of the Committee was drawn to the fact that the specification for multi-use aerosols for the disinsection of aircraft contained in section 2.3 of the above-

[1] See : World Health Organization (1964) *Equipment for vector control*, Geneva (Part III).

[2] *Wld Hlth Org. techn. Rep. Ser.*, 1961, **206**.

mentioned report has frequently been wrongly used for the manufacture of domestic aerosols.

The Committee therefore decided that the position requires clarification and established three new provisional specifications, one for single-use aerosol dispensers for the disinsection of aircraft (Specification WHO/EQP/6) one for multi-use aerosol dispensers for the disinsection of aircraft (Specification WHO/EQP/7) and one for multi-use aerosol dispensers, domestic type (Spécification WHO/EQP/8).[1]

4.3 Establishment of use descriptions of selected items of equipment used for the control of vectors of public health importance

The Committee recognized that a variety of equipment is currently in use for the application of pesticides. Much of this is referred to in the " Recommended methods for vector control " contained in the thirteenth report of the WHO Expert Committee on Insecticides.[2] As a guide to purchasing agencies and field workers, the Committee considered each of the recommended methods individually and drafted use descriptions [3] for the following items of equipment for which full specifications are not available : building screens; bait boxes, liquid; shaker bottles, liquid; hand-sprayers, continuous; simple plastic sprayers; trombone sprayers; knapsack sprayers; double-acting force pumps; power sprayers, hydraulic, conventional system; power sprayers, hydraulic, air-carried system; power sprayers, gaseous energy; centrifugal energy sprayers; aerosol generators, thermal fog type; bait boxes, dust; hand dusters, bellows; power dusters; compressed-air dusters; granule applicators, manual and power; and aircraft applications.

These descriptions are intended to indicate the uses and purpose of these items of equipment and some of the general features as a guide to their utilization in the field.

5. EQUIPMENT FOR THE APPLICATION OF MOLLUSCICIDES

5.1 Introduction

The transmission of bilharziasis is strongly influenced by human habits and water use practices. In areas where this disease is endemic, schemes for the development and conservation of water resources often

[1] See : World Health Organization (1964) *Equipment for vector control*, Geneva (Part III).

[2] *Wld Hlth Org. techn. Rep. Ser.*, 1963, **265**, Annex 17.

[3] See : World Health Organization (1964) *Equipment for vector control*, Geneva (Part IV).

play a role that cannot be overlooked. These schemes bring about great benefits by making possible perennial irrigation and resulting in more intensive farming, but they also increase human contact with surface water and usually promote water-borne diseases such as bilharziasis.

At present, bilharziasis control leans principally on chemical molluscicides. Experience with molluscicides, especially since 1945, has shown that they can effectively control the snail intermediate host in many types of habitat. Moreover, there is evidence that the use of molluscicides has resulted in a decline of human schistosome infections.

The development of new molluscicides in recent years and the growing efforts directed towards the control of bilharziasis by molluscicides have created a demand for more effective equipment for their application. Noting this, the WHO Expert Committee on Bilharziasis, in its second report,[1] expressed the opinion that there is a need for improvement in the design and operation of existing molluscicide dispensers, and for the development of new devices.

5.2 General considerations on the characteristics of molluscicide dispensing equipment

The selection and design of molluscicide dispensing equipment should be carried out using the following criteria :

5.2.1 *Performance*

The equipment will be used under varying and complex situations, comprising a number of factors that may limit its performance :

(*a*) the habitat of the mollusc vector;

(*b*) the nature of the molluscicide;

(*c*) the formulation of the molluscicide;

(*d*) the labour and skill available.

In addition to these points, the equipment should satisfy requirements regarding its proper functioning. The following points should receive special attention :

(*a*) capacity;

(*b*) accuracy of the application;

(*c*) portability;

(*d*) reliability;

(*e*) simplicity and ease of operation;

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1961, **214**, 36.

(*f*) ease of maintenance;

(*g*) safety;

(*h*) economic factors.

5.2.2 *Habitat*

The various habitats and media to be treated with molluscicides can be characterized as follows :

(*a*) dry and damp land areas;

(*b*) shallow inundated areas (marshes, swamps);

(*c*) still water of various extents, depths and configurations;

(*d*) flowing water of various extents, depths and configurations.

It will be observed that snail habitats in any given geographical region may include also a combination of the above. It is not uncommon to find a stream, interrupted by numerous pools and accompanied occasionally by marshes along its course.

The existence and density of aquatic and semi-aquatic vegetation is an additional ecological factor affecting the feasibility and success of the molluscicidal application in all the above-mentioned habitats. In some cases it would be appropriate to remove or cut the vegetation before molluscicide. A compound exerting both a herbicidal and a molluscicidal effect or a mixture of chemicals with this combined effect may find application under some conditions.

5.2.3 *Molluscicides*

The molluscicides to be dispensed represent a great variety of chemical compounds. The possibility of attack on, or corrosion of, various parts of the equipment caused by the molluscicide should be duly considered. The molluscicides at present available are : sodium pentachlorophenate; copper sulfate; Bayluscide (5-chlorosalicyclic acid 2-chloro-4-nitroanilide); Aqualin (acrolein); dinitrophenol derivatives.

It is noted, however, that new promising chemicals, such as ICI 24223 (isobutyltriphenylmethylamine) and Shell WL 8008 (*N*-tritylmorpholine), are under test and may become available in the future.

5.2.4 *Formulation*

From the point of view of application, the molluscicides are either in solid or in liquid state. The molluscicides on which experiments have been carried out have been formulated as : (*a*) crystalline solids; (*b*) powders; (*c*) granules, pellets and briquettes; (*d*) water-dispersible powders; (*e*) water solutions; (*f*) emulsifiable concentrates.

It is expected that other hitherto untested formulations will be added to the list in the near future.

5.2.5 *Characteristics of design*

Having considered the conditions under which the equipment will be used, additional requirements involving design, construction and function will require consideration, including :

(1) *Capacity*

The capacity of the equipment will be governed by the maximum dispersing rate required, This, is turn, will depend on the flow of the stream, or on the volume of the snail habitat.

(2) *Accuracy*

The dispensing rate of the equipment should be capable of adjustment. Underdosing will result in ineffective treatment, whereas excessive overdosing is uneconomical.

(3) *Portability*

The equipment is normally used in numerous locations throughout some administrative area. Therefore, the ease with which the equipment can be moved will affect its operating cost and utility. It is noted that the accessibility of snail habitats may vary widely, even within a small area.

(4) *Reliability*

The equipment should produce consistent results and be capable of successful operation with the number and quality of field personnel available.

(5) *Simplicity and ease of operation*

Complexity should be avoided if possible. Parts that can be removed or disassembled are liable to accidental loss. Simplicity of operation is essential for equipment that is handled by unskilled, mostly temporary field workers, sometimes under difficult conditions and occasionally without adequate supervision.

(6) *Ease of maintenance*

Attention should be paid to accessibility of all parts of the equipment, which should be cleaned after each period of work. Worn or damaged parts should be easily replaceable.

(7) *Safety*

Sharp edges and projections should be aovided as far as possible. The equipment frequently has to be carried and operated in rough terrain and any sharp edges may cause injury in the event of a slip or fall. Any equipment using air or gas under pressure must be designed and constructed to eliminate the danger of bursting. All such equipment should be tested before use, and periodically afterwards.

(8) *Economic factors*

When considering expenditure for equipment, one may decide to purchase cheap, expendable equipment for short-term application; equipment of moderate life, with provision for replacing worn or damaged parts; or equipment of high quality, according to certain specifications which provide for a definite period of life.

It has been shown that careful selection of equipment will result in savings in other directions, such as labour or materials.

(9) *Availability*

Much equipment will have to be manufactured in central workshops, but provision will also have to be made for certain ancillary equipment which may have to be made locally. Under many conditions, however, equipment that has already been developed for pesticides in other fields of work could be employed or adapted.

5.3 Equipment items in present use

The present practice of bilharziasis control involves the use of a variety of special equipment, mostly for the purpose of dispensing and distributing molluscicides. Many equipment items primarily intended for agricultural and insect control use have been adapted to bilharziasis control. For situations peculiar to bilharziasis work, a number of devices have been developed by the control agencies themselves.

Since many of the existing bilharziasis control devices were designed with some other use in mind, it frequently happens that minor alterations will render them appreciably more effective. A simple example is the selection of sprayer nozzles; the fan spray used on compression sprayers for malaria work may be replaced by a straight jet for applying molluscicide to the chains of pools formed by streams during low flow periods. However, encouragement should also be given by WHO to the further development of equipment which has been evolved during bilharziasis control programmes, so that its full potential can be realized.

The following is a description of equipment in current use :

5.3.1 *Equipment for dispensing liquid molluscicide formulations*

(1) *Manual hydraulic energy nozzle sprayers*

Several types of manual sprayers have found wide application. Knapsack sprayers, generally lever operated, have been used to distribute chemicals in swamps and along stream banks. Stirrup pumps have also been employed for this purpose, as well as to spread molluscicides over ponds and into streams.

(2) *Powered hydraulic energy nozzle sprayers*

Powered equipment is employed in the same habitats as the manual sprayers, generally with appreciable advantage where maintenance facilities are available. The pumping units are usually stretcher-carried, or otherwise portable.

(3) *Recirculating pump suction*

An excellent method for the application of molluscicides to flowing waters is the introduction of the chemical into the suction side of a centrifugal pump which recirculates water from the stream. A needle valve and rotameter are used to control and measure the feed rate. This method of application is especially convenient for volatile liquids having irritating vapours, because the opportunity for release of the vapour to the atmosphere is minimized.

(4) *Gravity feeders*

In flowing waters one of the oldest and simplest methods of applying molluscicides is to allow the liquid chemical to flow from a reservoir through a valve or orifice. Devices of this nature have been almost invariably constructed by the users themselves for research or actual control purposes. A variety of features have been incorporated to obtain a constant rate of feed, and provision has sometimes been made for automatic adjustment of the feed rate to changing stream flow.

One device of this type at present being developed by WHO is a simple dispenser capable of being fabricated in small shops at reasonable cost. A working model has been constructed and tested in an African control area. Modifications in the design have been made during construction and testing, so that after a small amount of further development it will be possible to circulate plans to interested control agencies.

5.3.2 *Dispensing of solid formulations*

Briquette and powder formulations are normally distributed by manual broadcasting for which no particular equipment is required. Another technique is to suspend fabric bags filled with solid chemicals in flowing waters.

5.4 Equipment items used for other purposes considered adaptable to bilharziasis control

Equipment has been developed in several technological fields which might be adapted to bilharziasis work. It has already been mentioned that most of the sprayers in current use are models manufactured primarily for insect control. Extensive work has been done on the development of devices for application of agricultural chemicals, and some of this equipment offers new promise for molluscicide distribution. Another source of equipment adaptable to this purpose is the handling of industrial chemicals. In particular the following items should be given consideration and trial.

5.4.1 *Equipment for applying liquid formulations*

(1) *Power-operated gaseous energy sprayers (mist blowers)*

These machines might provide some solution to the problem of distributing molluscicides over expanses of swamp or ponds which would be difficult of access by vehicles or boats owing to the soft terrain or density of the vegetation.

(2) *Aircraft*

Fixed wing and rotary wing aircraft might be used to spread molluscicides over large inaccessible areas. However, their use may have to await the advent of more economical and effective molluscicides.

(3) *Metering pumps*

Small diaphragm pumps are widely used for feeding chemicals in industrial processes. They offer the advantages of accuracy, adjustable output, and freedom from stoppages. However, they must be operated at a known constant speed, which in bilharziasis work would require a portable source of power.

5.4.2 *Equipment for applying solid formulations*

(1) *Dry-chemical feeders*

For applying molluscicides to flowing waters, it would be a distinct advantage if solid formulations could be fed in directly without first making them up into solutions or suspensions. Dry-chemical feeders of both gravimetric and volumetric types are available for industrial use, but existing models are far too heavy and expensive for bilharziasis control. A suitable device would have to be portable and of simple design; it is also most important that the calibration should remain reasonably accurate after use with different lots of the various formulations.

(2) *Manually operated and power-operated dusters*

There is some possibility that dusting machines widely employed in agriculture could be used for the distribution of solid molluscicides over extensive areas, especially moist ground and shallow water. Dusters may be manually operated or powered, and may be transported in a variety of ways.

(3) *Granule and pellet applicators*

Granule or pellet dispensers might offer a number of possible advantages in all habitats. Used instead of dusters for large areas they would reduce toxicity hazards and possibly permit more uniform distribution, although on land habitats the larger particles might not provide sufficiently complete coverage. In flowing waters, the pellets or granules could be projected to provide distribution of the chemical across the width of the channel, in addition to being metered out.

(4) *Aircraft*

Aircraft may be appropriate for treating extensive or inaccessible areas with solid molluscicides, as well as with liquid formulations.

5.4.3 *Other equipment*

Screens of about $\frac{1}{8}$ in (3 mm) mesh have been used across canals to restrict the passage of drifting snails.

5.5 New equipment items suggested for development and trial

5.5.1 *Porous containers*

For the application of molluscicides to flowing waters, and possibly to still waters as well, the chemical might be placed in a porous-walled container from which it would slowly escape by diffusion. This is similar in principle to the ancient procedure of suspending burlap bags of copper sulfate in the flow, but a porous-walled vessel of suitable design might eliminate chemical particle size as one of the variables affecting dispensing rate, and might also permit a relatively constant rate. The attraction of this method is its extreme simplicity and the fact that the containers could be completely submerged in the environmental water where the likelihood of their being molested while left unattended would be minimized.

5.5.2 *Suspension feeders*

A problem of some immediate importance is that of dispensing a wettable powder into flowing water. While a suitable dry feeder would

be one solution, an alternative is to feed the material as a water suspension. The liquid dispenser in this case should embody some provision for agitating the suspension or otherwise preventing it from separating.

5.5.3 *Electrolytic formation of copper ion*

While the results obtained with copper ion as a molluscicide have not always been encouraging, there are some control areas in which it appears to have been used successfully and economically. It has been customary to introduce the copper ion as copper sulfate, but it is probable that the same effect can be achieved more economically and with greater control and reliability by the electrolytic dissolution of metallic copper direct into the flow. The method is suggested mainly for fixed or semipermanent molluscicide stations, since the large power requirements would make the use of storage batteries impractical.

5.5.4 *Electric snail barriers*

Recently it has been observed that an electric current of certain characteristics passed though the neighbourhood of submerged aquatic snails causes their rapid migration towards one electrode. It has been suggested that this phenomen might be utilized as a control measure, for example, to prevent the migration of snails past given points in a stream system. It is recommended that the phenomenon be further investigated and equipment developed as practical ideas emerge.

5.6 Conclusions and recommendations

The Committee was aware of the difficulties imposed upon the use of molluscicide equipment by external factors, such as the type and extent of the snail habitats, lack of transport facilities, corrosive action of the molluscicide, lack of skilled workers for operation, toxicity hazards, maintenance and/or repair of the equipment.

The Committee noted that the possibility of using equipment developed for pesticide work in other fields has not yet been fully explored and that application may be improved by suitable formulations of the molluscicide, taking into account the equipment available for dispensing herbicides, adulticides and/or larvicides.

The Committee also noted that most of the equipment used up to the present in molluscicide application was manufactured locally, attention being therefore given only to the simplicity of construction and availability of material, without consideration of other engineering aspects. Also, data are lacking on the performance of existing equipment under different field conditions and on other important characteristics, such as durability, maintenance, safety, and cost.

In view of these facts, the Committee was of the opinion that a long-term programme of research on the development of simple, efficient and effective equipment for the application of molluscicides should be initiated. The objectives of this research should be :

(1) The adaptation to the application of molluscicides of existing equipment used for other pesticides and/or improvements in such equipment.

(2) The development of molluscicidal formulations that will permit more rapid and/or efficient application.

(3) The design of suitable equipment for mollusciciding under conditions where adaptation of existing equipment is not feasible.

(4) The construction of new equipment prototypes.

(5) Laboratory testing of both existing and newly constructed equipment.

(6) Field testing of improved versions of existing equipment and of newly constructed equipment under various conditions and for appropriate periods of time.

(7) Collection and evaluation of laboratory and field data on all equipment used in molluscicidal work.

(8) Drafting of specifications for mollusciciding equipment.

It is recognized that the effective practice of bilharziasis control requires the collaboration of several professional disciplines, and that such collaboration should form a part of the proposed equipment development programme. While basic ideas for new equipment must be accepted from all sources, priorities and basic design requirements should be established by biologists and engineers familiar with control work across the globe. The design and construction of prototype equipment can be carried out in private or institutional laboratories. Efforts should be made at this stage to secure the co-operation of small manufacturers. Field testing may be handled by laboratories engaged in bilharziasis research and located in endemic areas. The personnel of such laboratories normally include biologists, engineers, and chemists.

6. CONTROLLED FIELD TESTS OF EQUIPMENT FOR THE APPLICATION AND DISPERSAL OF PESTICIDES

The Committee noted with satisfaction the work of the WHO Sprayer Evaluation Team, which, between 1959 and 1962, conducted field testing of the following products: (*a*) five models of compression sprayers, (*b*) two

models of stirrup-pump type sprayers, (*c*) six models of mechanical pressure regulators, (*d*) one rubber-disc flow regulator, and (*e*) four makes of fan-type nozzles.

As it was breaking new ground in this work, the Sprayer Evaluation Team devoted considerable attention to developing simple, direct methods of evaluating equipment under ordinary field conditions. This required trained, but not necessarily skilled, operators who used the equipment in regular anti-malaria operations. It also required a good plan of action, and someone familiar with the equipment and able to devote his full time to the tests. It is believed that in future, using testing protocols developed by the team, field tests of other new equipment could be carried out in connexion with regular vector control projects.

In judging the suitability of a given piece of equipment for use in vector control operations, it is necessary to consider both what may be called the users' criteria, i.e., comfort, safety economy and efficiency, and the engineers' criteria, i.e., strength, durability and accuracy. " Users " include the operators, the squad leaders, the mechanics, and the administrators of the programmes where tests were conducted, and field testing provides the first opportunity to collect information on users' opinions.

Field testing is also intended to give some quantitative answers to the questions " how strong is it ? ", " will it stand up to hard field use ? " and " will it produce accurate dispersal of pesticide throughout a given period of field use ? ". To this end, frequent periodic examination of each tested unit in the field is arranged, and enough spare units are provided so that units that are defective can be immediately replaced. Record cards showing days in use, volume or weight of pesticide actually discharged, and —if important—number of work units completed (houses sprayed, persons dusted, etc.) are kept separately for each unit. Details are also recorded of the breakdowns occurring, measurements made (pumping force, discharge rate observed, etc.) and reason for final withdrawal from service, if this occurs during the course of the tests.[1]

It was the opinion of the Committee that controlled field testing of new equipment for the application and dispersal of pesticides will be of great importance in future, and that the experience gained from the work of the WHO Sprayer Evaluation Team furnishes useful guides for such work. Chief among these were noted :

(*a*) The need for a clear idea of what qualities and attributes of the equipment can and should be examined in the field. Quantitative evaluation of the strength and durability under field conditions must be made,

[1] For an outline of field tests for compression sprayers and a suggested questionnaire for compression sprayer users, see : World Health Organization (1964) *Equipment for vector control,* Geneva (Part V).

but one should be cautious in drawing conclusions from data on a relatively small number of units.

(*b*) Importance is laid on "users' opinions" of equipment, which should be collected as systematically as possible.

(*c*) Field tests need a good plan of action, someone in charge who can devote full time to this work, and an adequate supply of replacement parts for tested units.

7. PACKAGING OF PESTICIDES FOR SHIPMENT

The Committee noted that the WHO Expert Committee on Insecticides had previously established requirements for the packaging of pesticides for shipment and that these had in general proved to be satisfactory.

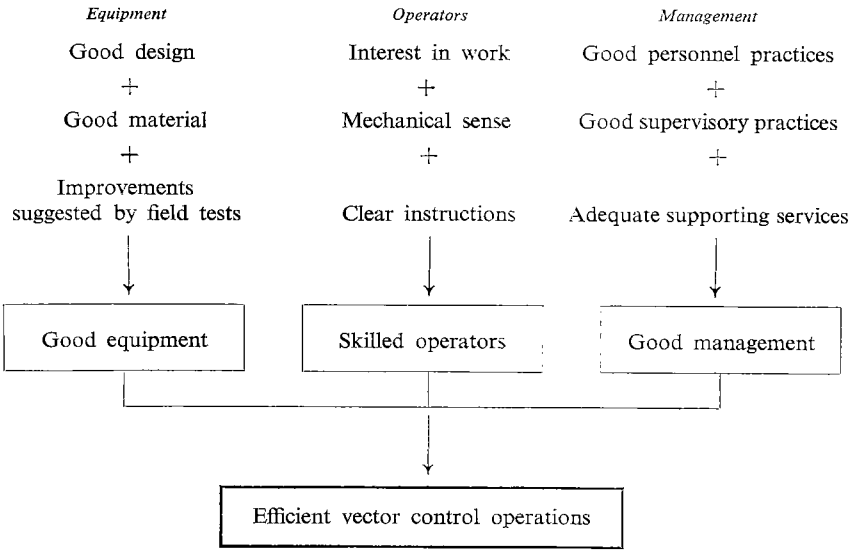
The Committee was informed of recent research on the development of rectangular containers as a substitute for the currently used fibre drum. This work has indicated that rectangular units can be manufactured that are as effective as the fibre drum; although these cost almost as much as the drums, they may facilitate handling and, in addition, prove more economical, since the space taken up by the boxes is less than that taken up by the drum.

The Committee understands that shipping trials are at present being carried out with the rectangular containers and recommends that when these trials have been completed and the containers shown to be acceptable from all points of view as alternatives to the fibre drums, consideration be given to the establishment of a specification for rectangular containers.

8. TRAINING IN THE APPLICATION AND DISPERSAL OF PESTICIDES

Training of personnel is of prime importance in the organization of efficient vector control operations. Most pesticides are expensive and many, if used improperly, may be dangerous to operators, or to human and animal populations. On the other hand, dosages of pesticides insufficiently toxic to the disease vector may result in failure of control. In the world-wide malaria eradication programme much attention has been paid to training personnel, and it is considered that the remarkable results already achieved in a number of countries can be credited in large measure to insistence on training at all stages of the programme.

The Committee's attention was particularly focused on the problem of developing skilled field operators. Their place in an efficient vector control operation can be shown as follows :



Although pesticide-application equipment is often basically simple and easy to use, operators need to be given clear instructions and adequate opportunity for supervised field practice before being put on the job. The following are examples of training required by spraying squad personnel in a malaria eradication programme and the consequences of inadequate instruction :

Instruction needed by operators of compression sprayers	*Possible consequences of inadequate instruction*
Sprayer nomenclature	Failure to understand operating instructions and to report breakages accurately
Method of disassembly and reassembly	Incorrect assembly, breakages
Functions of sprayer parts	Failure to localize operating troubles
Correct method of carrying sprayer	Breakage of projecting parts, failure to agitate suspension, fatigue
Mixing of suspensions	Wrong dilution, use of dirty water, lumpy suspensions
Filling of tank	Incorrect use of strainer, spillage, incorrect volume of tank contents, sediment in mixing bucket, splashing of sprayer parts

Instruction needed by operators of compression sprayers	*Possible consequences of inadequate instruction*
Correct tank pressure, and how to judge it	(*a*) *Sprayer without pressure regulator:* incorrect discharge rate (*b*) *Sprayer with pressure regulator:* operation below critical tank pressure, wasted energy in pumping
Pumping of tank	Damage to plunger, fatigue
Adjustment of pressure regulator, measuring discharge rate	Wrong discharge rate
Preparation of room for spraying	Wasted time, poor coverage
Correct stance and manipulation of lance while spraying	Incorrect or uneven dosage, fatigue
Method of compensating different distances from sprayed surface by different speed of lance	Incorrect dosage, waste of insecticide
Judging correct swath width	Excessive overlap, waste of insecticide
Estimation of sprayable surfaces by eye and pacing	Failure to detect incorrect spraying speed
Designation of sprayable surfaces in local terminology	Incomplete or excessive coverage
Correct recording of sprayed house on house-record card and daily report	Inaccurate spraying records
Locality sketching, reading and correcting	Failure to spray designated houses, or to record new, missing or closed houses
Safe handling of insecticide	Intoxication of operator, contamination of household eating utensils, contamination of local water supply
Routine cleaning and lubrication of sprayer	Poor functioning of sprayer, loss of time
Correct preparation of sprayer for transport, or for storage	Damage from blows or corrosion, non-availability when needed
Spare parts needed and method of replacement; individual responsibility for good condition and functioning of sprayer	Improper maintenance, frequent breakdowns, loss of time, inefficient application

It was emphasized that efficient and conscientious work can be expected only from operators who know how their equipment functions, what they are supposed to do, and what are the reasons for doing it. The sprayman must have some conception of programme objectives and be able to explain them to local people whose co-operation is needed.

Training and supervision of field operatives are the responsibilities of enginneers and sanitarians who in turn need training. The principle has been established in malaria eradication work that all staff concerned with field operations, from programme director down to sprayman, should know how to handle a compression sprayer properly and effectively. In any well-run vector control scheme, the officers must spend time in the field checking the organization of work, logistics, and condition of equipment. They must not neglect the last of these, nor fail to call operatives to task when defective equipment is discovered. For these reasons the theoretical and field training of vector control programme officers should include adequate coverage of the following subjects :

(1) Proper choice of equipment, according to the vector, the pesticide, the size of operation, and available personnel.

(2) The important features and specifications of different types of equipment, and the equipment specifications and standards established by WHO.

(3) The description, size, principal uses, operation, and care of the various types of equipment, including actual practice in the field.

(4) Proper maintenance, both corrective and preventive, in order to ensure good performance and long effective life of equipment.

(5) Importance of training the personnel who handle the equipment in order to secure efficiency and safety.

In view of the anticipated increase in vector control programmes throughout the world, the Committee recommended that WHO should give consideration to the organization of courses on an intercountry basis for the training of national specialists who will be sorely needed in these programmes. In the proposed training courses for vector control personnel, maximum use should be made of staff already trained in malaria eradication techniques when they become available in the later phases of malaria eradication programmes. Such a development is already taking place in India and is anticipated in several other countries. A number of national training centres exist where such courses might be organized with WHO help. WHO participation might include providing :

(1) Examples of different kinds of pesticide-application equipment, pesticide containers, and incidental equipment meeting WHO specifications or use descriptions.

(2) Additional units of commonly used kinds of equipment in sufficient quantity for class study and field experience.

(3) Basic testing devices for pesticide-application equipment (precise pressure gauges, patternators, etc.).

(4) Text books, publications, documents and teaching aids.

(5) Visiting lecturers.

(6) Fellowships.

The Committee recommended that WHO should establish the essential contents and standards for training courses and that these syllabuses should then be followed in all WHO-assisted vector control training courses.

9. RESEARCH ON THE APPLICATION AND DISPERSAL OF PESTICIDES

The Committee considered the needs for research on and technical developments in the application and dispersal of pesticides. Although the monetary value of equipment used in vector control is small, efficient equipment has a vital influence upon the economy and efficiency of programmes. The expenditure of funds for research directed towards the improvement of equipment is therefore well justified. The Committee considered that the following lines of research are likely to be most fruitful at the present time :

(1) To reduce to a minimum any toxic hazards, effort should be devoted to developing more accurate control of dosage and to avoiding, as far as possible, any waste of insecticide. The emphasis now being placed on the hazards to man, domestic animals, and wild life created by the promiscuous use of insecticides makes it imperative that attention should be given to equipment design.

(2) One of the more promising methods of reducing wastage and ensuring a more even application of toxicant is by use of the rubber-disc flow regulator [1] which has become available during the last two years. The original production models of this device, which provided uniform liquid discharge rate despite varying pressures and nozzle erosion, were reported upon favourably, following field trails in malaria eradication programmes in Central America. In subsequent field tests, however, certain difficulties were observed, mainly due to loss of elasticity of the disc and the narrowing of the spray swath. The Committee was informed that these faults are believed to have been overcome and that new models have now successfully passed laboratory tests and are available for controlled field trials. It is recommended that these trials should be carried out as soon as practicable and that if the results are favourable the improved flow regulators should be placed in general use in malaria eradication

[1] Hall, L.B. & Taylor, J.E. (1962) *Bull. Wld Hlth Org.*, **27**, 279.

programmes. They may also be of use in other vector control programmes if there is sufficient demand to justify the cost of production of units with the characteristics required.

(3) Concurrently with research aimed at improving control of insecticide applications, equipment should be simplified, reduced in weight, and made sturdier and more reliable. In every case, the aim should be to ensure maximum safety, both physical and toxicological, for the operator.

(4) The Committee was also of the opinion that research devoted to the development of new power sources of high capacity and light weight might be productive. Energy developed by the release of gases from liquids such as Freon or from explosive fuels offers promise.

(5) The design of satisfactory methods for regulating flow from stirrup pumps is also considered to be important.

(6) Further investigations to determine the advantages and disadvantages of various droplet sizes and discharge rates, in particular to evaluate the following two suggestions regarding low-pressure nozzle discharge characteristics :

(*a*) a claim that the larger droplets produced at the usual discharge rate of 757 ml/minute used in malaria eradication programmes are more effective for residual sprays against *Anopheles* than the smaller droplets produced at higher pressures;

(*b*) a suggestion that the production of large droplets on sprayed surfaces slows down work if efforts are made to wet the surface completely, and that this disadvantage can be overcome by increasing the discharge rate to around 1000 ml/minute.

(7) The Committee particularly urges that research and development be undertaken to produce detailed specifications for items of equipment for which only general descriptions are now available and that the entire programme be facilitated by a more fully developed and expanded reference guide to equipment and terminology. Other specification needs include the development of better and less expensive packaging methods for the shipment of insecticides (see section 7).

(8) There is an urgent need for the development of new and improved equipment for the application of molluscicides, especially for use with the new formulations which it is anticipated may shortly become available (see section 5 for details of molluscicide equipment).

(9) Investigations should be extended to the response of snails to electric currents of various frequencies and wave forms, in order to determine the possibility of using such techniques to limit the migration of snails or to kill them.

10. PROTECTION AGAINST EXPOSURE TO PESTICIDES

The Committee noted with satisfaction the recommendations made by the WHO Expert Committee on Insecticides in its twelth report [1] (Toxic Hazards of Pesticides to Man) and emphasized that these should be observed by all authorities applying chemicals for vector control. Adherence to the precautionary measures described, together with use of the correct type of equipment (see section 3, page 5), will do much to reduce the dangers to spraymen.

However, the Committee suggested that the establishment of more detailed procedures to be observed during the application of insecticides in houses, in the disposal of containers and residues, in the cleaning of equipment, and in the safe custody of chemicals, would be valuable, and it recommended that this matter should be given consideration by any future committee dealing with the toxic hazards of pesticides to man.

11. SAMPLING, TESTING AND APPROVAL OF EQUIPMENT

The Committee reviewed the problems confronting purchasers in obtaining equipment of high reliability. It was recognized that although this characteristic is vital in operating programmes, the number of items purchased and the monetary value involved are insufficient to justify large investments in specialized production machinery or in a programme of strict quality control.

On the other hand, it is recognized that statistical confidence in the reliability of equipment cannot be obtained by testing only a very limited number of units. For this reason, it is recommended that (1) to ensure maximum reliability high factors of safety be built in where possible, (2) reliability be measured as far as possible by testing in the laboratory, (3) reliability beyond that measured in laboratory tests be studied in field trials, and (4) the ethics and reputation of the manufacturer be taken into account. To implement this method of obtaining reliable equipment the Committee recommends a procedure in which the purchasing agency establishes a *Qualified Products List*. To obtain listing on the *Qualified Products List* the products shall pass through a number of steps, during any one of which it can be rejected by the purchasing or approving agency.

1. *Design review*

The design of the product shall be reviewed to determine its suitability for the required task, its function, its safety and its compliance with specifi-

[1] *Wld Hlth Org. techn. Rep. Ser.*, 1962, 227.

cations. This should in no case be done from drawings only. The manufacturer should be required to supply a prototype model for this purpose.

2. *Prototype tests*

Three prototype models should be submitted to the purchasing or approving agency for testing. Any failure of the prototype to comply with specifications should be grounds for rejection until a prototype is supplied that complies. The following flow chart indicates how this may be done for compression sprayers :

FLOW DIAGRAM FOR PROTOTYPE TESTING

Unit I	*Unit II*	*Unit III*
Subjected to Leakage Test	Subjected to Leakage Test	Kept intact until all tests on Units I & II are completed. In the event of any simple failure coming to light as a result of the testing of Units I & II, Unit III is then available for rectification or modification and subsequent testing. Should no such rectification or modification be required, Unit III is available for any rechecking or testing if desirable but is otherwise retained as a standard against which to examine the production model.
↓	↓	
Stripped of all items not essential in Fatigue Test and these items added to Unit II →	Checked against the specifications for : Construction Capacity Dimensions Weight Markings Straps Strap hangers Clips Filler hole Strainers Pump Pressure gauge	
↓	↓	
Fatigue Test	Identical items from Units I & II subjected to the following tests : Strap Drop Test Constant-Pressure-Valve Test (if applicable) Nozzle-Pattern Test Liquid-Volume Distribution Test Cut-Off-Valve Actuation Tests Cut-Off-Valve Reliability Test Hose Aging Test Hose Hydrostatic-Pressure Test Hose Swelling Test Gasket Immersion Test	
↓	↓	
Drop Test	Tank of Unit II tested as for Unit I as additional check	
↓		
Further Fatigue Test		

3. *Production tests*

The approving agency should then select at random six units from production. These should be submitted to full tests for quality of workmanship and for compliance with the specifications at a laboratory designated by the approving agency. Failure to comply should result in rejection, although resampling and retesting may be allowed in borderline cases at the discretion of the laboratory. Full compliance should result in *Provisional Certification* on the *Qualified Products List.*

4. *Fields tests*

As soon as possible after the model, as tested above, has gone into full production, further units should be submitted to field tests. These should consist, at a minimum, of observation and reporting of failures occurring in field use. Preferably the tests should be formalized in execution and reporting as described in section 6 of this report. Failure of the model in the field or serious question of its suitability should be cause for cancellation of its *Provisional Certification.* Complete satisfaction with the results of these field tests should result in the product receiving full *Certification*, although continuing production tests, as described below, should be performed, where appropriate, as long as the model is on the market.

5. *Field history*

Any unit of equipment purchased from a manufacturer and used in large numbers over a period of years will acquire a reputation, as time passes, for its quality or lack thereof. Failure of a model to develop a reputation for reliability and adherence to the specification may be cause for the purchasing or approving agency to reduce the *Certification* to *Provisional Certification* or to remove it completely from the *Qualified Products List.*

6. *Continuing production tests*

Where large numbers of units are purchased, the responsible agency may wish to perform continuing production tests. In such situations, sampling and testing should be continued on a limited basis in order to detect any deviation from the approved production models. If it is not possible to test a sample of significant size, some safeguard might be obtained by testing at random one sprayer out of every 200, at the discretion of the purchaser.

7. *Production control*

At the discretion of the purchasing agency, certain samples may be taken before acceptance of delivery to verify quality, the number of units

in each sample to be decided by the purchasing agency. These units should be submitted to laboratory tests and evaluation for compliance with the specification, with particular emphasis on safety.

Any product ordered in small quantities (size to be specified by the purchasing agency) may be purchased on the basis of a certificate from the manufacturer to the effect that the units have been made in accordance with the appropriate specification. Preference might be given to manufacturers who are able to produce evidence of testing of an identical type by an outside laboratory within a previous period of 12 months.

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