USE AND APPLICATION OF MOSQUITO CONTROL MEASURES IN MALARIA ERADICATION

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INTRODUCTION

The control of malaria in the past was based on attacking the parasite in man by drugs or on preventing the contact between mosquito and man, or on eliminating or incapacitating the vectors by various means. The process has gone through many trials and changes in the past decades. To eradicate the disease, however, attack on the parasite in man alone proved insufficient, as did also attack on the vectors alone without the use of other means available to reduce the reservoir of infection or to wipe out the last cases of the disease. A combination of the two methods has therefore been used in the various phases of a malaria eradication programme. The attack on the vector mosquito aims at the interruption of transmission through the decrease of over-all longevity of the vector population, while the attack on the parasite helps to reduce the sources of infection and to wipe out the last infective cases.

MOSQUITO CONTROL MEASURES IN MALARIA ERADICATION

The attack on mosquito vectors nevertheless constitutes the principal measure employed in a malaria eradication programme. Though directed mainly against adult anophelines, it may involve larval stages as well. Due to its complexity however, larval control alone has very seldom been the method of choice in a programme unless imagicidal operations failed to produce effective results. The malaria eradication

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programme is a gigantic undertaking involving almost two-thirds\(^1\) of the population of the globe in the most remote and underdeveloped areas and therefore complicated, highly technical and costly methods cannot be used for its implementation.

**Imagical measures.** Of all the imagical measures used in mosquito control operations, indoor spraying of insecticides is by far the most commonly used in malaria eradication programmes. Limited peridomestic fogging (Venezuela, 1964) in conjunction with other methods, is being used in certain programmes when indoor spraying no longer provides adequate control of vectors. Also in nomadic areas of southern Iran dipping of nomads' tents in insecticides (Institute of Parasitology, Iran, 1963) was tried out as a means of controlling infective mosquitoes. Field experiments have also been made with dichlorvos (DDVP) vapour in Northern Nigeria (Poll et al., 1965). Due to the high rate of air exchange in houses necessitating a large number of dispensers and the consequent cost involved, these trials were discontinued but further trials in other parts of the world with different housing, climatic and epidemiological conditions are being executed or planned.

**Indoor spraying of insecticides.** The indoor spraying of insecticides in malaria eradication programmes is not an all-out attack against all the vector mosquito populations. Nor is it meant to be a basic method of controlling mosquitoes. It is designed only to deal with a selected group - the potentially infective population - for a period of time long enough to permit the natural depletion of the parasite reservoir. In practice, however, only that portion of the mosquito population which comes in sufficient contact with the sprayed surfaces will be affected and therefore success in indoor spraying much depends on the habits and behaviour of the vector mosquitoes.

Indoor spraying of insecticides as compared with other mosquito control measures has the following advantages in a malaria eradication programme:

**Simpler.** It needs no complicated techniques or equipment, specialized or highly skilled manpower.

**Practicable.** It can be carried out almost everywhere and under virtually any conditions with a high degree of efficiency.

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\(^1\) Estimate does not include population from China (mainland), North Korea and North Viet-Nam, from which no information is available. (Off. Rec. Wld Hlth Org., 1964, 173.)
Effective. In most cases complete interruption of transmission of the disease can be achieved.

Cheaper. The comparative annual and total cost is generally considerably lower than that of the achievement of the same goal by other methods.

Experience has shown that when the spraying is of total, complete, sufficient and regular coverage with an effective insecticide, it has been generally successful in interrupting transmission within the expected period. There have been setbacks however due to technical factors:

the mosquito vectors were not domestic, i.e. they were outdoor resting (exophilic) or outdoor biting (exophagic), or

they have become deterred or irritated by sprayed surfaces, or

there has been physiological resistance, or

certain factors affecting human behaviour and ecology such as nomadism, outdoor sleeping, human dwellings without walls, etc.

Some of these difficulties have already occurred in certain parts of the world, rendering the indoor spraying of the presently available insecticides in those limited problem areas largely ineffective. The extent of such problem areas is indeed very limited. Nevertheless, search for new insecticides is actively under way and other available methods of mosquito control are also receiving serious consideration.

OTHER MOSQUITO CONTROL MEASURES IN MALARIA ERADICATION PROGRAMMES

The eleventh report of the Expert Committee on Malaria (WHO 1964b) paid special attention to the increasing need for the application of other methods of vector control in malaria eradication programmes, especially in areas where the response to residual insecticides in vector species is unsatisfactory, and stated that: "The present trend indicates a greater use of larval control in the near future and therefore urgent action is required."

The Committee formally recommended: "That larval control be used more fully in special circumstances and that its further improvement should be studied especially in those areas that are refractory to residual spraying operations."
At the present time only very limited larval control operations and source reduction activities are carried out in malaria eradication programmes. They are usually applied in addition to spraying operations because of their economic or technical benefits, as for example in the protection of large towns in malarious areas by the application of larval control measures in and around them. In such circumstances these measures can be efficiently applied and supervised at a much lower cost than house-spraying. The measure most frequently used is larviciding with materials such as oil or Paris green. Application by hand or by portable equipment is still the common practice. In most cases, power equipment or airplanes are yet to be introduced. Source reduction activities have also been carried out with most elementary methods and equipment. Judicious drainage and filling have been used on an extremely limited scale in a few programmes.

Although prior to the development of malaria eradication programmes with indoor residual spraying of insecticides, a number of successful malaria control programmes had operated using other measures than residual spraying leading to the eradication of malaria, e.g. Cyprus (Aziz, 1948; Shelley & Aziz, 1949), Sardinia (Logan, 1953), United States of America (Fed. Sec. Agency, 1947), more recent instances where, for technical reasons, other mosquito control measures than spraying have been used are not very numerous. The programme in Jordan had to resort to larviciding and source reduction in addition to house spraying in order to control A. sergenti, a secondary exophilic vector, in the Jordan Valley.

The experience in the Jordan Valley showed, however, that while in other areas the attack phase using house spraying was completed within three to five years, larviciding failed to produce a total interruption even after 13 years. The problem lay in finding and delimiting the changing breeding areas, in applying the right dosage of larvicides and in maintaining the dosage adequately and evenly. Further, there were difficulties with organization and supervision in a changing situation.

In recent years, especially with the emergence of problem areas, serious attention has been paid to mosquito control measures other than spraying. A field trial was organized in El Salvador to assess the value of some of the newer insecticides and larvicides (e.g. fenthion) and newer equipment in interrupting malaria transmission. The results, although inconclusive due to movement of population and other epidemiological factors, showed the marked superiority of fenthion over Paris green and DDT; this insecticide is already in use in larviciding operations in the malaria eradication programme in Nicaragua.
Outside malaria eradication programmes, however, there has been growing interest in larval control and source reduction. Mosquito control organizations, particularly in the United States of America, have the greatest share of the enormous progress achieved in this field. Newer, more potent larvicides have been tried out and better equipment and techniques have been developed. Extensive use has been made in the United States of America of aerial and ground power equipment to cut down cost and raise efficiency. The use of modern excavating and earth moving equipment has rendered source reduction a financial and operational possibility. This wealth of experience could be used with advantage in malaria eradication for dealing with certain problem areas where larval control or source reduction measures are indicated (Gray, 1954; Merced District, 1960; Mulla, 1960; Mulla et al., 1962; Turlock District, 1963).

Need for planning. Unlike spraying operations, larval control measures cannot be applied to every situation and condition alike. The field is so wide and the methods and material used are so numerous and different that their wide application and use in malaria eradication requires careful planning and preparation. The available methods should be carefully studied and tested before being selected and applied in a programme. Most important in planning the work is a knowledge of local conditions which may vary greatly from one area to another. Information on the vectors, and their biology, on the type of water and on the conditions, extent and accessibility of breeding places should be made available in detail. This implies that personnel in the field should be taught the methodology and techniques involved and call for a reorganization of the training programme in malaria eradication especially in areas where these operations are being, or are expected to be, carried out (Shawarby, 1963).

Larval control or source reduction activities are normally costlier than spraying and therefore in situations where they may need to be applied, the comparative cost of the various methods available should be considered.

Assessment of suitability of the present methods. The present mosquito control measures in operation should be studied and their suitability for application in malaria eradication assessed. They can be classified as:
(a) Physical methods

(b) Chemical methods

(c) Biological methods

(a) **Physical methods.** These comprise source reduction such as drainage, filling, land reclamation, water management and impoundment, flooding etc. The results are mostly of a permanent nature, and provide extra land and water for agriculture or recreational activities, and the work does not involve the risks and hazards of the use of pesticides. Fish and wild life will be preserved and in most cases the reclaimed land and the drained water can be utilized by the local inhabitants, thereby eliminating the need for costly maintenance work. The methods would be specially popular, and would gain public support. However, the capital expenditure involved restricts the use of this method to limited areas only.

Today there exists on the world market modern and highly efficient equipment for use in this type of work. In many countries this equipment is already in use in engineering projects for construction of roads, dams, etc. In such cases the malaria eradication services may be able to make internal arrangements for partial use of the equipment. In the United States of America, with the use of modern equipment, source reduction activities have now been tremendously accelerated, breeding places have been flooded under millions of gallons of water, de-watered, filled in or drained in a matter of hours or days.

Even in programmes with no immediate problem with spraying, where economically feasible these measures could be considered for specific areas in view of their obvious long term advantages.

(b) **Chemical methods.** In this field great progress has been made. Newer and more potent chemicals have been developed and successfully used in actual field operations. Also better formulations and more efficient equipment for their application have been utilized.

In the field of larvicides, in the United States of America increasing use is made of organo-phosphorus compounds, mainly parathion-methyl, and recently fenthion. Fenthion is usually used in urban mosquito control due to its lower toxicity, while parathion is used in agricultural areas. These chemicals can be very conveniently
used in malaria eradication larviciding work. Due to the low dosages employed, the operator carries only a small amount of concentrate sufficient for a few weeks' consumption, which he mixes on the spot with water. Furthermore, the compounds mentioned will not affect the development of resistance from compounds at present used for indoor spraying, namely chlorinated hydrocarbon insecticides.

The use of chlorinated hydrocarbon insecticides for larviciding in malaria eradication programmes may increase the chances of appearance of the resistant vector population, and is, therefore, generally contra-indicated. In special circumstances, however, use can and has been made of these compounds, e.g. dieldrin pellets in water tanks in eastern Nigeria (Bruce-Chwatt, 1957).

Paris green is still used in certain projects. However, newer formulations have increased its efficiency. Some of the vermiculate formulations of Paris green, especially the low release type, are used in certain programmes. There are also a number of new compounds, both carbamates and phosphorus, under test which, when proved suitable, effective and safe, can be used for similar purposes in malaria eradication.

In the field of equipment, airplanes and lately helicopters have been used extensively in the United States of America for mosquito control. Newer models have eliminated many deficiencies of the past, including high cost. In malaria eradication, if extensive breeding places have to be treated, the use of aircraft may even prove to be more advantageous than the manual application of insecticides.

Use of ground power equipment for larviciding in remote areas may not prove entirely satisfactory. Their use, however, in areas with good roads and communications systems should always be considered.

Research work is also being carried out on repellants, attractants and chemo-sterilants which may have a place in control operations.

Serious attention should be paid to safe handling and application of these highly toxic compounds. Mixing and distribution centres should be so designed and operated as to eliminate the human element and thus reduce the chances of toxicity. Special protective equipment and measures should also be used for the protection of operators and inhabitants (WHO, 1962; WHO, 1964a).
(c) **Biological methods.** These include the use of predatory insects and other arthropods, fish and other vertebrates which are natural enemies of mosquitoes as well as pathogenic organisms affecting mosquitoes, such as bacteria, fungi, protozoa or viruses. They also include genetic manipulation or autocidal control. Except for fish which have already been used extensively in malaria control, the other methods have not as yet been used in wide-scale mosquito control operations. In the field of agricultural pest control, there have been cases of the successful use of bacteria for the control of pests. Studies on similar organisms are being actively carried out in the field of mosquito control. There is hope that these may lead to certain measures which could equally be used in malaria eradication operations either alone or in combination with other methods (Laird, 1963).

**Cultural methods** have also been used in the past in malaria control operations by means of large-scale changes of environment e.g. stagnation or flooding, shading or exposure to light, desiccation through afforestation etc. of the breeding places. Some of these methods could well be used in malaria eradication as secondary measures to increase efficiency in operations.

**Geographical reconnaissance.** The principle of total coverage and the need for geographical reconnaissance for this purpose is as important in larval control activities as in spraying operations. The work in larval control operations, however, may prove to be more complex and require much detail. Detailed up-to-date maps of operational areas showing the location and extent of breeding places are essential. Aerial photography would greatly facilitate the mapping of breeding places in areas of difficult accessibility.

**Training.** Training of staff and reorganization of training activities in malaria eradication is a subject requiring constant attention (WHO, 1964a). In order to enable the staff, especially at field levels, to delimit breeding places and show on maps their location, extent and changes, they will need further training on mapping and map reading. They should also receive training on methods, techniques, material and equipment to be used in these operations. As knowledge of local conditions is essential for planning of work, the field staff should be made fully aware of this fact and of the type of information they should report to their higher officers. Health education of the public, especially when highly toxic materials are being used, is an absolute necessity and should be included in the training of staff. Good public relations are just as important, for the work is to be carried out on people's property.
Organizational trends. The organization of additional mosquito control activities in malaria eradication programmes depends very much on the extent and types of measures used. These activities will need to be organized in close co-ordination with the other activities of the programme in order to derive maximum benefit from the present facilities and manpower and to avoid duplications. Some of these activities could be conveniently integrated with the other operations of the programme to save cost and manpower. Others may be partially integrated and share some of the services and facilities. Examples of these latter are larviciding operations for which, through efficient planning, use may be made of the available field supervisory staff, transport and other facilities.

Whatever the organizational trends may be, it is essential that the actual application of work in the field should be within the present decentralized framework of integrated field operations. Examples of these are the present larviciding and source reduction activities carried out in malaria eradication programmes which are planned, organized, implemented and supervised by the divisions of field operations. In certain cases, however, it has been desirable to provide additional supervision and control from other units. In the case of larviciding for instance, entomological checks and assessments have been organized by an entirely separate division to increase reliability and efficiency.

Reporting procedures and processing when larval control methods are employed should follow the usual pattern used in malaria eradication programmes, namely distribution to all sections concerned and analysis in the field offices for an early work correction.

SUMMARY

1. The indoor spraying of insecticides is still the most economical, practical and efficient method of mosquito control for malaria eradication.

2. In areas where, due to technical factors, the vector response to spraying is not adequate, other mosquito control measures are available and may be used to assist.

3. In recent years, there has been great progress in the field of mosquito control, more potent new chemicals, more efficient equipment and better methods and techniques have been developed in the United States of America.
4. Of the other operational mosquito control measures at present available
   
   (a) source reduction
   (b) larviciding, and
   (c) some biological control

   can be selected and organized within a malaria eradication programme.
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RESUME

La lutte antipaludique était fondée autrefois sur des mesures tendant, soit à attaquer le parasite chez l'homme par des médicaments, soit à empêcher le contact entre le moustique et l'homme, soit enfin, à éliminer ou à inhiber les vecteurs par différents moyens. Cette stratégie a subi au cours des dernières décennies de nombreuses modifications dictées par l'expérience acquise. Quand il s'est agi toutefois d'éradiquer le paludisme, il est apparu qu'il ne suffisait plus de s'attaquer au parasite chez l'homme, ou de combattre le vecteur, et qu'il devenait nécessaire de mettre en œuvre d'autres moyens pour réduire le réservoir d'infection ou éliminer les cas résiduels. Aussi a-t-on recouru conjointement aux deux méthodes dans les diverses phases des programmes d'éradication du paludisme.

Les pulvérisations d'insecticides à l'intérieur des habitations restent le procédé le plus économique, le plus pratique et le plus efficace de destruction des moustiques pour l'éradication du paludisme.

Il existe pourtant des régions où, pour des raisons techniques, la réponse du vecteur aux pulvérisations laisse à désirer. Fort heureusement, on dispose d'autres armes contre les moustiques pour remédier à cette situation.

Depuis quelques années en particulier, notre arsenal s'est considérablement enrichi par la mise au point de produits chimiques plus puissants, de matériel plus efficace, de méthodes et de techniques plus satisfaisantes.

Parmi les autres procédés opérationnels dont on dispose actuellement pour lutter contre les moustiques, la stérilisation des foyers, la lutte antilarvaire et certaines ressources de la lutte biologique méritent d'être retenues et exploitées dans les programmes d'éradication du paludisme.
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(a) to acquaint WHO staff, national institutes and individual research or public health workers with the changing trends of malaria research and the progress of malaria eradication by means of summaries of some relevant problems;

(b) to distribute to the groups mentioned above those field reports and other communications which are of particular interest but which would not normally be printed in any WHO publications;

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