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# CONTROL OF *AEDES AEGYPTI*[1]

by

C.P. Pant
Scientist/Entomologist, WHO/VBC, Geneva

[1] Background document for reference use at the Technical Discussions on "Control of Vector Mosquitoes of Dengue Haemorrhagic Fever".

CONTENTS

## 1. INTRODUCTION

Aedes aegypti, the important vector of yellow fever, dengue and dengue haemorrhagic fever (DHF) is now widely spread in South-East Asia and the Western Hemisphere. Extensive epidemics of dengue and DHF have occurred in South-East Asia (Philippines, Thailand, Singapore, Republic of Viet-Nam, South and South-East India, Sri Lanka, Burma and, most recently, in Indonesia) and in the Caribbean. Yellow fever epidemics have occurred in recent years in some parts of West Africa. Records of the distribution of Ae. aegypti in South-East Asia show that the species has invaded large parts of the countryside in every country surveyed and perhaps very few sections remain free of this mosquito (Scanlon, 1965; Macdonald and Rajapaksa, 1972; Pant et al., 1973). Rapid urbanization, combined with the essentially rural habit of water storage in man-made containers due to an intermittent, or lack of, city water supply, has resulted in the further spread and build-up of the populations of Ae. aegypti. In the Western Hemisphere, particularly in the areas of lower socio-economic housing, there may be in addition to the water stored in drums, an accumulation of such waste as tyres, tins, discarded bottles and other water-retaining debris which are potential breeding sites.

The physiological resistance of Ae. aegypti to organochlorine insecticides is now an almost universal phenomenon (Brown and Pal, 1971). At present, there are only a few records of higher tolerance levels to organophosphorus insecticides (WHO, 1972), but with the increased use of these chemicals, it may only be a question of time before this poses a serious threat. Therefore, methods of control of Ae. aegypti which can be used over the wide range of its distribution and the different types of problems faced have to be clearly identified and enumerated. The control measure to be used under each set of conditions may be different and has to take into account the following considerations.

## 2. EPIDEMIOLOGICAL CONSIDERATIONS

Particularly in Thailand, DHF has been reported to result when "sensitization" by one dengue infection is followed by a second dengue virus type; four immunological types of dengue virus have been reported. The severity of the disease and the extent of the epidemic is unpredictable unless a complete serological picture of the type of infection and the intervals of infection are known. There is at present no vaccine which can be used for the prevention of the disease and the only method of prevention and actual control is the reduction of the population levels of Ae. aegypti in areas where the risk of transmission of virus throughout the year is high. It is believed that areas with high human and Ae. aegypti densities provide such conditions. Recently it has been reported in some Pacific islands that primary infection produces DHF.

Man is the principal host of dengue viruses and Ae. aegypti the most important vector, especially during epidemics.

## 3. BIOLOGICAL CONSIDERATIONS

Ae. aegypti in South-East Asia and the Western Hemisphere breeds in clean water containers of different types and the reference to breeding sites are too numerous to mention. Despite the occasional breeding in tree holes and leaf axils in South-East Asia (Rao et al., 1969), the bulk of the Ae. aegypti population is supported by man-made containers such as water jars, drums, mandis (Indonesian bath tubs), discarded cans, tyres, and water-bottles. Such containers are often found in or around human habitations, where this mosquito spends all of its life span. The diurnal biting activity has two peaks, one in the morning and another in the afternoon (Yasuno and Tonn, 1970). The adult mosquito rests indoors (Pant and Yasuno, 1970) and the gonotrophic cycle lasts about 3 days (Sheppard et al., 1969; Pant and Yasuno, 1973). Multiple feedings during a gonotrophic cycle have been recorded (Yasuno and Tonn, 1970; Pant and Yasuno, 1973). The first blood meal by the female is taken on an average 24-36 hours after emergence (Pant and Yasuno, 1973).

From the point of view of control, therefore, both the larval and adult mosquitoes are found in the immediate environment of man and the mosquito does not disperse far away from human habitation.

Seasonal patterns of population build-ups were not noticed at a significant level in one study in Bangkok (Sheppard et al., 1969). In another study it was observed that the variation in the number of emerging adults depended on the changes in the mortality of the immature stages. Moralities of both the early and late larval instars were important, and the mortalities of early instars became very important during certain times of the year (Southwood et al., 1972). Small differences in the gonotrophic cycle during the different times of the year may contribute to the seasonal pattern of the disease in addition to other virological and immunological mechanisms (Pant and Yasuno, 1973).

## 4. OPERATIONAL CONSIDERATIONS

The distribution and number of breeding sources in relation to human habitations, extent of the area, accessibility, layout of roads and type of housing can have an important influence in determining the method of choice for the control. The availability of manpower, equipment, and operating budgets must be considered before deciding on the type of control measure. For example, in Thailand the potential numbers of habitats per house may be as 3 times as high as in Indonesia. The absence of many miscellaneous types of habitats in addition to the above would make larviciding operations much simpler in Indonesia than in Thailand.

Ae. aegypti is primarily an urban mosquito. The density of human population, along with other resultant changes in the environment, seem to favour its breeding and spread. Throughout the world, there is a steady growth of urban population. Accelerated population growth, increased urbanization and expansion of new technology sometimes result in irrational arrangements of housing, water supply, water sewerage, etc., resulting in the creation of slums within the cities. These conditions can also influence the choice of control measure.

Storage of water in various containers is not only due to lack of a piped water supply but also has become a cultural pattern in some areas. In Thailand, for example, the various cleansing and washing activities carried out in homes as a routine demand a large supply of water. In some areas, rain-water is considered better for drinking purposes, and hence large quantities have to be stored. In other areas, the ground-water may be saline, hence reliance is placed on rain-water for drinking purposes. The fear of outbreak of fire, particularly in areas where wood is used as the primary material for house construction, also encourages the storage of large quantities of water. These considerations are particularly relevant when efforts are made through health education to persuade people not to store water in containers. Simple health education measures do not generally succeed and until the standards of living are raised above a certain level-and this can certainly be a slow process-it will be difficult to make people discontinue the practice of water storage.

## 5. ECONOMIC CONSIDERATIONS

The primary consideration is generally the availability of funds and the priority given to Ae. aegypti control. Mild dengue fever epidemics which are non-fatal do not motivate many governments to do much in this respect. When epidemics of DHF occur, more concern is felt and, since these cannot be predicted, sufficient funds are not generally available. Crash measures for insecticidal control can be expensive, particularly in large sprawling urban areas.

## 6. CONTROL MEASURES

The WHO Aedes Research Unit in Bangkok conducted a series of investigations on the vector's ecology, biology, and short - and long - term preventive and epidemic control measures from 1966 to 1972. As a result of these investigations, several methods of control have been developed. It is felt that the range of distribution, the magnitude of the problem, the variety of conditions, and the immediate objectives of a control measure at a particular time, occurring in different countries due to the considerations mentioned earlier, are such that it is not possible to have one ideal control measure which may be universally applicable. Consequently, several methods have been developed to choose from so as to fit a particular need.

## 6.1 Antilarval measures

The breeding habits of *Ae. aegypti* make it particularly vulnerable to antilarval measures. The choice of insecticides is extremely limited because some of the water to be treated is potable. Thus toxicity to man and the residual effectiveness in water in containers which are constantly in use, emptied and refilled are the governing factors. In view of the resistance of *Ae. aegypti* to organochlorines and a very thorough testing of a series of organophosphorus compounds of low mammalian toxicity and high insect toxicity, it was demonstrated that 1 ppm of Abate[1], formulated as a 1% sand granule, was the most effective larvicide treatment for *Ae. aegypti* (Bang and Tonn, 1969a). It was also shown that this larvicide has an affinity for the walls of the water jars and perhaps the toxicant was released from the 1% granules and absorbed/adsorbed by the inner walls of the water container and released again when the water was replaced (Bang and Tonn, 1969b). The proximity of the eggs and the first instar larvae to the inner walls of the container when hatched makes this treatment more effective. The interval between the two treatments can be determined by evaluating the larval and adult infestation rates after treatment and the desired length of control, and this will largely depend on the water usage practices in an area (Bang and Tonn, 1969c). An operational field trial was conducted in a suburb of Bangkok in 1969-1970 in an area of approximately 173 hectares and *Ae. aegypti* densities were kept at a very low level for one full year (Bang and Pant, 1972). In Thailand, the interval between two treatments was 2 1/2 - 3 months.

The cost and logistics of the operations would vary from place to place, depending on the total number of containers per house, their size, etc. For example, whereas in Thailand the average number of containers per house was 11.06 and the amount of Abate used per house was 96.4 g (Bang and Pant, 1972), in Semarang, Indonesia, the number of containers per house was only about 3.21 and the Abate required per house would be only 33 g (VRCRU unpublished report to WHO).

The average percentage reductions of the adult landing rates after the four treatments in the Thailand study ranged from 87.4% - 98.0% as compared with the untreated check area and the Breteau indices were reduced by 97% - 99% (Bang and Pant, 1972).

Thus it was shown that it was feasible and possible to use Abate 1% sand granules on an operational basis and it was considered that 2 such treatments, one just before the start of rains in Thailand in April-May and another after 2-3 months, would keep the densities of *Ae. aegypti* at a low level during the entire 6-month period when the epidemics of DHF generally occur.

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[1] O,O,O',O'.-tetramethyl O,O'-thiodi-p-phenylene phosphorothioate

A larvicidal programme with Abate requires a good deal of organization and supervision throughout the entire operations. The programme has to be planned and budgeted for before the epidemics start and due to the unpredictability of the latter, this is not always possible. The cost of importing 1% sand granules, (i.e., 99% sand and 1% active ingredient)from the United States is also a factor to be considered and if formulating facilities are organized in the country of use the costs can be considerably reduced. The larvicidal programme has to be carried out manually, as individual containers have to be treated separately. It, therefore, requires considerable manpower.

Gould et al. (1970) used emulsifiable concentrates of Abate diluted in water for larviciding. The WHO Aedes Research Unit also showed that the emulsifiable concentrates were just as effective as the sand granules. However, in large-scale programmes where inexperienced staff have to give treatment, sand granules are preferable.

It must be remembered that treatment with Abate or the larviciding measures should be employed before the expected epidemic and that this is not a treatment of choice when an epidemic is actually occurring. However, in conjunction with an adulticidal measure, they can also be used for long-term control during an epidemic.

6.2 Anti-adult measures

When an epidemic of DHF is building up, it is more efficient and logical to apply direct anti-adult control measures to kill the infective and infected adults and check the further spread of the disease. Since large areas have generally to be treated at short notice and in as short a period of time as possible, the treatments of choice are insecticidal thermal fogs and aerosols (at ultra-low-volume (ULV) concentration) applied from the ground or air. Adulticidal treatments during epidemics can be spaced from 9 to 10 days apart and theoretically 2 such treatments should interrupt the transmission of dengue virus. Anti-adult measures have also been used as focal or perifocal treatment of houses where cases of dengue haemorrhagic fever have been reported, along with the surrounding houses to reduce Aedes densities and kill the infected and infective insects to ward off further spread of the disease.

6.3 Thermal fogs

Bang et al. (1972) and Bang and Pant (unpublished report from WHO Aedes Research Unit) compared the DDT and malathion thermal fogs applied by Swingfog machine using a 2% and 4% solution of the insecticides in diesel oil at the calculated dosage rates of 420 ml/ha. The reduction of the Ae. aegypti populations was 60% to 99% for malathion as compared to 25% to 45% for DDT. When malathion thermal fogs were used alone and in conjunction with Abate larvicide, 6 to 24 weeks of control were achieved, depending on the areas immediately surrounding the treatment plots.

The capacity of the Swingfog is limited and for larger areas equipment such as TIFA (vehicle-mounted fogging machine) can be used. This treatment has been used in Thailand, for example, for treating houses with reported cases of DHF and the surrounding houses or even treating whole neighbourhoods where an epidemic is building up. Recently the method was also used with success in some parts of Indonesia (at Padang in 1973). Due to the visible nature of the fogs, this treatment is very acceptable to inhabitants of an area. However, to maintain control, it has to be repeated more frequently.

Thermal fogs require a considerable amount of solvents (96% to 98%), thus increasing the cost of the treatment. They also produce dense fogs which may constitute a traffic hazard when townships are being treated. For economy and efficiency, thus, it would be more desirable to utilize the technical grade materials directly as aerosols in ULV quantities. This has also been termed "cold fog."

## 6.4 Insecticide aerosols applied in ULV quantities

### 6.4.1 Aerial ULV

Technical grade malathion at 3 to 6 US fluid oz/acre (219-438 ml/ha) has been used from a Cessna or C-47 aircraft (Kilpatrick *et al.*, 1970; Lofgren *et al.*, 1970). The twin-engined aircraft has certain advantages and proved superior to single-engined aircraft in the degree of control obtained. Recently during an epidemic of DHF in Semarang, Indonesia, a single-engined Gelatik aircraft with 4 micronair jets was used to spray a 50% EC of malathion. This was probably the first use of aerial insecticide application to suppress an epidemic of DHF. The treatment was very successful in reducing the *Ae. aegypti* densities and seemed to have very good all-round results. In Kuala Lumpur during 1973, several localities were treated by ULV malathion applied from a helicopter for the control of *Ae. aegypti*.

Lofgren *et al.* (1970b) have described the method of mounting the spraying equipment on a C-47 aircraft, showing that the spraying machinery could be installed in 2-4 hours and removed in about half an hour.

### 6.4.2 Ground ULV aerosols

Non-availability of suitable aircraft at short notice, lack of trained pilots and ULV spray systems, the high cost of operation and the distribution of the disease in time and space could be the critical factors governing the use of aerial ULV. Particularly in South-East Asia, the scarcity of aircraft and pilots and the administrative details of making these available may limit the use of this technique. Moreover, the recent distribution of cases is rather widespread and epidemics have not been limited to big cities only.

Consequently, Pant *et al.* (1971) adapted the use of ground vehicle-mounted equipment, LECO cold fog generator, for use in the towns and villages. Excellent control of adult mosquitoes was obtained at the dosage rate of 438 ml/ha. This treatment on a smaller scale has the advantage of mobility, speed of organization, lower costs and can be operated easily. Areas or sections of the towns which cannot be approached by a vehicle can be treated with portable equipment such as Fontan or Mity Moe (Samutrapongse & Pant, 1973; Pant & Mathis, 1973). Recently, the Department of Medical Sciences in Bangkok used LECO and a combination of portable ULV equipment during an epidemic of DHF to treat Chantaburi with malathion successfully.

The efficiency and performance of ground aerosols can be improved by the incorporation of two new concepts, i. e., sequential treatments by ground aerosols and the limited residual and larvicidal effectiveness of these treatments. Pant *et al.* (1973) and Samutrapongse and Pant (1973) used the principle of sequential treatments, using fenitrothion (Sumithion) with LECO and Fontan machines and achieved long-term control of *Ae. aegypti* in two suburbs of Bangkok after 4-5 treatments. Sequential applications are particularly suitable for the domestic species with limited flight range such as *Ae. aegypti*. These applications produce mortality of the adult mosquitoes at intervals and consequently reduce the population of the immature insects and retard the recovery rate of the population. In Thailand, it was possible to obtain effective control for 4-8 months using this technique.

Pant and Mathis (1973) showed that the mists of fenitrothion and malathion produced by the portable Mity Moe machine and applied indoors not only killed the adult mosquito population at the time of treatment but also had larvicidal effect and limited residual effectiveness. Thus, not only were the adult mosquitoes reduced in numbers immediately, but also the larval stages whenever the mist fell on the water surface of the water containers which are always inside or near the houses. Droplets of the mist deposited on various surfaces inside the houses such as bed-posts, furniture, hanging clothes, etc., which are normal resting surfaces of the adult mosquito, continue to kill the adults for a few days after the treatment and further reduce oviposition, immature insects and consequently the recovery potential of the mosquito population as a whole. This unique situation in vector control is made possible due to the domestic feeding, breeding and resting habits of *Ae. aegypti*.

Based on this principle, the WHO *Aedes* Research Unit treated one Bangkok suburb twice with fenitrothion mist, using the portable Mity Moe mist blower at 14-day intervals. Excellent control was maintained up to 8 months after treatment. Thus the essentially short-term method of control by adulticiding can be adapted for long-term preventive control. Indoor application of mists has to be carried out with care to avoid exposure to the aerosols by both the operators and the inhabitants. The Mity Moe mist blower needs improvement in design because of the frequent breakdown of the engine. Fontan, a back pack mist blower, is sturdier but also needs improvement in design.

Epidemic control measures were recently discussed during the Technical Advisory Committee on DHF held at Manila in March 1974. Its recommendations for control of DHF and *Ae. aegypti* are obtainable. The guidelines for vector control on a long-term and emergency basis recommended at the above meeting are given in the Annex.

## 7. CONCLUSIONS

Insecticidal control using OP insecticides such as Abate, fenitrothion, or malathion is the only available method of control for *Ae. aegypti*. The prevention of water storage in the houses by health education, improvement of housing and water supply, although ideal, may take a very long time to achieve.

The choice of the method depends on logistic, epidemiologic, economic and entomological factors. Where an essentially preventive control of *Ae. aegypti* is required and the manpower permits, larviciding of all the potential habitats by Abate at 1 ppm may be the most appropriate method. When an epidemic is actually occurring, adulticidal measures such as fogging, aerosol treatment at ULV concentration from the ground or aircraft at 438 ml/ha would be the method of choice. The actual method to be used would depend on the type and size of the area and the availability of equipment and funds.

Mists of insecticides such as fenitrothion and malathion applied by portable ground equipment provide some larvicidal and residual effectiveness in addition to killing the adult mosquito. Due to the domestic and para-domestic habitats and the life cycle of *Ae. aegypti*, immediate and long-term control of this species can be obtained with this method. This approach would be the ideal one because it combines short-and long-range control by one technique. The equipment used for this, however, needs some perfection. Four to five sequential applications of malathion or fenitrothion aerosols at intervals of 10-14 days also produce a long-range suppression of *Ae. aegypti* populations, in addition to immediate control of the adult mosquitoes during an epidemic.

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ANNEX 1

## Guidelines for vector control for long-term and emergency control of Aedes aegypti vector of dengue haemorrhagic fever

I Long-term

(1) Determine priority areas in regard to high vector densities and previous history of outbreaks.

(2) With limited funds and/or personnel, chemical treatments should be made shortly before the expected transmission season.

(3) Proper disposal of discarded cans, bottles, tires and other potential breeding sites not holding drinking water. Emptying of flower vases weekly.

(4) Routine scrubbing of sides of water-storage containers and baths to remove eggs when water level is low. Before refilling, pour out water at bottom of containers to remove any larvae.

(5) Encourage greater reliance on piped water supply.

(6) Health education and legislation should be relied upon to promote the above aims.

(7) Apply abate 1% sand granules to water-storage containers at a dosage rate of 1 ppm (e.g. 10 g of sand granules to 100 litres of water). Repeat treatments may be undertaken at 2-3 month intervals.

(8) Use vehicle-mounted or portable ULV aerosol generators or mist blowers to apply technical malathion or fenitrothion at 438 ml/ha. Five applications made at about 20-day intervals can suppress vector populations for about four to five months.

(9) Use the above equipment (8) and insecticides or swing fogs with 4% malathion in diesel oil or kerosene to spray within a 100 m. radius of houses having cases of dengue haemorrhagic fever before a full-scale epidemic occurs.

II Emergency

(1) Based on epidemiological and entomological information, determine the size of the area (or areas) required to be treated.

(2) Two adulticidal treatments using equipment and insecticides previously described should be made at 10-day intervals if resources are available or if they can be obtained.

(3) It is suggested that moderate-size cities have at least one vehicle-mounted aerosol generator, five mist blowers, 10 swing fogs and 1000 litres of ULV insecticides in order to be prepared to carry out one adulticidal operation over a 20 $km^2$ area rapidly. With limited funds, such equipment and insecticides can be stockpiled in one city for rapid dispersal to other areas when required.

(4) Priority areas for launching ground applications are those having a concentration of cases and also nearby hospitals and schools.

(5) If necessary, ULV operations by local air force C-47 aircraft or smaller agricultural type planes and helicopters can be explored.