What Must We Do to Effectively Control *Aedes Aegypti*

Norman G. Gratz

4 ch du Ruisseau 1291 Commugny, Switzerland

**Abstract:** *Aedes aegypti* and the closely related *Aedes albopictus* are widespread and steadily infesting new geographical areas. The consequence has been a dramatic increase in diseases transmitted by these species, dengue, dengue haemorrhagic fever and dengue shock syndrome, yellow fever and chikungunya. Implementing effective and sustained vector control programs is urgent and essential. There are no easy solutions to the problem of their control. Well planned and budgeted control programs, supervised by well trained professional personnel are necessary. Control can be achieved by an integration of chemical and biological measures and the cooperation of government, local authorities and public in carrying out environmental measures to reduce breeding sources. The costs involved are less than those of hospitalization, medical treatment, lost labor, death and illness that results from doing nothing or doing it poorly.

**Key words:** *Aedes aegypti*, dengue/DHF, vector control programs

**INTRODUCTION**

Few species of mosquitoes are as ubiquitous as *Aedes aegypti* and few are as important as a vector of arboviruses that cause human disease, i.e. yellow fever, dengue and chikungunya. Though now found in much of southeast Asia, the western Pacific and north and south America, *Ae. aegypti* probably originated in Africa where it widely distributed south of the Sahara, in rural and urban areas, breeding in natural containers such as tree holes, leaf axils, rock holes as well as man-made containers as clay pots and drums holding water for domestic use, old tires, tin cans, and virtually any other discarded, artificial water holding container. It is occasionally the vector of urban yellow fever outbreaks in west Africa and the vector of dengue throughout much of Africa. At one time *Ae. aegypti* was also widespread in southern Europe and the Mediterranean area where vestigial populations of it are still found (Pener and Vardi, 1975). More recently, the closely related *Stegomyia, Ae. albopictus* has invaded Italy (Pozza and Majori, 1992) and Albania (Sabatini *et al.*, 1990) amidst concern that it will spread further and establish itself in other countries in Europe (Rodhain, 1993).

*Ae. aegypti* long-ago spread to the Americas from Africa where it became the vector of large epidemics of urban yellow fever and dengue. The species probably reached southeast Asia and the western Pacific in antiquity, perhaps on Chinese and Arab sailing
vessels coming from Africa (Scanlon, 1965). *Ae. albopictus* on the other hand, has spread from Asia throughout the Indian Ocean and the south Pacific and, through the transport of its eggs in shipments of used tires, has invaded and spread widely in the United States (Sprenger and Wüthiranyagool, 1986), Brazil, (Forattini, 1986), more recently into Nigeria (Savage, *et al.*, 1991) and probably South Africa (Cornel and Hunt, 1991).

Because of the importance of *Ae. aegypti* as a vector of yellow fever, dengue/dengue haemorrhagic fever (DHF) and of chikungunya, much effort has been made to control or even to eradicate it in certain areas. In the Americas, because of the threat of outbreaks of urban yellow fever, a hemisphere-wide eradication campaign was started in 1947. Almost all of the countries of the hemisphere were able to eradicate *Ae. aegypti* except Venezuela and the USA and these countries remained a source of reinfestation. Because of funding, technical and administrative problems, most countries were unable to sustain a high level of surveillance once the species had been eradicated from their territory; reinfestations thus often escaped attention for some time and, when discovered, were frequently already wide spread; as time went on, funding and national will were less and less available to attempt to eliminate it again. By 1993 virtually every country in Latin America has been reinfested. Urban yellow fever has not reoccurred, but the virus is widespread in an endemic, jungle cycle and poses a constant threat to the many large urban centers of south and central America where dense populations of *Ae. aegypti* are present. Shortly after the reinfestations occurred, dengue began to appear again and has rapidly spread; its intensity is increasing and DHF/DSS is appearing in more and more countries.

Both *Ae. aegypti* and *Ae. albopictus* are widely distributed in all of the tropical countries of southeast Asia and the western Pacific, usually in high population densities. The rapid, unplanned urbanization that has occurred in many cities of the region has often exceeded the ability of municipal services to provide adequate piped water supplies and resulted in water being stored in a variety of jars and drums in and around homes for domestic use; these containers are important sources of *Ae. aegypti* breeding (Gratz, 1973). Municipal services are also unable to cope with the enormous numbers of waste containers, including discarded, used tires which are also important sources of *Aedes* breeding.

Because of the importance of the species as vectors and potential vectors of disease, there are few dengue endemic cities in Latin America, southeast Asia and the western Pacific regions without a program of some type aimed primarily at controlling *Ae. aegypti* and, to a lesser extent, *Ae. albopictus*. Most of these programs are, frankly, relatively inefficient; if they were not, the relentless increase in the incidence of dengue and especially DHF would be less evident or have stopped. Gratz (1993) has analyzed the *Ae. aegypti* program in Thailand. He found that despite the great amount of research that had been carried out in Thailand on the control of this species by chemical, biological and environmental means, few of the findings were being applied in the country's control program. The program was under staffed, under funded and having little, if any, impact on the incidence of DHF. The picture differs little in most other large cities in the region. It is unfortunate that greater efforts are not made to control the vector of a disease whose
haemorrhagic and shock syndromes are the leading cause of pediatric hospitalization in most of the endemic countries and among the leading causes of death among infants. If one takes into consideration the costs of hospitalization, medical treatment and the value of labor lost through illness, dengue/DHF/DSS causes losses of millions of dollars a year in most of the endemic countries. (It has been estimated that the economic impact of the epidemic of dengue in Cuba in 1981 in which there were 344,203 cases of dengue, 10,312 of DHF and 158 deaths, was about $103 million (Kouri, et al., 1989) and that the cost to Thailand of the 1987 epidemic in which there were 152,840 cases of DHF and 785 deaths, was $16,048,200 in hospitalization alone though only $262,480 was allocated for purchase of insecticides to control the vector (Ungchusak and Kunasol, 1988). Effectively controlling *Ae. aegypti* would seem to make good economic sense.

**THE CONTROL OF *Aedes aegypti***

In an article written in 1988, Halstead asked why we were unable to control *Ae. aegypti*; he observed that even though many control programs were relatively well funded, they failed to achieve adequate control. He believed that the reasons for the failures were: 1. the desire to find easy solutions, 2. the degradation of technical and managerial skills, 3. the increasing scope of the problem, 4. the shortness of human memory and 5. the expectation of failure.

"Easy solutions" are still much sought after for vector control programs, especially those that are as difficult to implement as the control of *Ae. aegypti*. An example of an attempt for an "easy solution" is the excessive and poorly planned use of adulticides, either as thermal fogs or by the application of ultra-low-volume (ULV) insecticide sprays. If properly applied, thermal fogs may achieve a high kill of adult mosquitoes in the treated area; however they have little persistence and must be applied under precise meteorological conditions, preferably in the very early morning hours before the temperature rises and convection currents quickly lift the fogs from the target areas. It has, however, been observed that few people see the fogging applications in the early morning hours and many programs therefore apply the fogs well into the day when they are visible to all—but have little effect on the adult mosquitoes. Studies have shown that ULV applications can achieve a high degree of control of adult vector populations and, if applied sequentially, will reduce vector populations for a matter of months, (Pant et al, 1971, 1974). The technique can be effective in rapidly reducing adult mosquito populations at the time of an epidemic outbreak of *Ae. aegypti*-borne disease, (Gratz 1991). The potential of this method is ill-used when it is applied as a routine measure, at insecticide dosages too low to be effective and without follow-up evaluation.

Use of chemical pesticides is not the only manner by which an "easy solution" is sought. Community participation in source reduction is thought by many to be a low-cost, long-term solution to the *Ae. aegypti* problem. Gubler (1989) has emphasized that it is the correct approach to the control of *Ae. aegypti* populations. He further emphasized that
persons living in houses where transmission takes place must understand that this occurs because they allow mosquitoes to breed in and around their homes (Gubler, 1991). By now, numerous trials have been carried out in which the community is asked to reduce *Aedes* breeding by applying environmental measures. Some of these trials were reasonably effective in reducing vector population densities (Hoedojo and Soroso, 1990); only very few evaluated the effect of the measures on disease transmission. In most studies, the impact on adult mosquito densities was temporary and population densities quickly increased as efforts to support and encourage the community’s participation lessened or when they were no longer sustained by the community (Phanthuachinda *et al*, 1987). The community may not perceive the efforts they are asked to make as being a priority or benefit for them nor understand the reason why preventing mosquito breeding is important; finally, they may simply lose interest in what appears to be an endless task, especially when disease transmission continues to occur and they continue to be bitten by mosquitoes (which are probably *Culex* species). The community may even be asked to do things that, in reality, have little effect on vector densities. Householders are everywhere urged to cover water containers to prevent mosquito breeding; yet in a recent study in a dengue endemic Thai village, Pattamaporn and Strickman (1993) found that 200 litre water jars outside of houses which had covers had greater *Ae. aegypti* infestations than those without covers.

While the participation of the community in control programs is essential, it must be realized that the belief that the community alone can control *Aedes* densities can also be a wish for an easy solution. Obtaining active and satisfactory participation of the community is not necessarily easy and may not provide the degree of control required. Bronfman and Gleizer (1992) in an analysis of community participation in health programs pointed out that the health consequences of community participation are still ambiguous; they emphasize that it should be included in the health program when the population receives clear health benefits. In principal this should include control of *Ae. aegypti* though the best manner in which to do so is yet to be found.

**Achieving Effective Control**

If there is no “easy solution” what can be done to control *Ae. aegypti* populations? There is no global answer; every infested area has its own type of problem requiring solutions adapted to it; there is little likelihood that a single control approach will be everywhere adequate or effective. The only possible, effective approach to the control of *Ae. aegypti*, or *Ae. albopictus*, is through integrating the use of all available, effective and economic methods whether chemical, environmental or biological, applied either by a dedicated control group, the community or any combination thereof which will achieve affordable control at a level likely to reduce transmission of disease.
THE PLANNING OF *Aedes aegypti* CONTROL PROGRAMS

Probably the single, most important reason for the failure of control programs is that they are often planned and carried out by personnel poorly trained in vector biology and control; the persons given the responsibility for control programs may be medical officers or sanitarians but unless the bionomics of the vectors and the complexity of vector control operations are understood, ineffective measures will continue to be applied. It is essential that planning for control be carried out by qualified and experienced entomologists/vector biology and control specialists.

Each control program must have as its base a knowledge of the bionomics of the local vector population including its preferred larval habitats, their frequency and distribution, seasonal variations in the habitat's production of mosquitoes, the insecticide susceptibility of larval and adult populations and the efficacy of available insecticides and their different formulations under local conditions. The epidemiological situation of the target endemic area must be investigated and priority given to neighborhoods or communities where serious transmission of disease is occurring or where there is a high risk of transmission because of high densities of vector populations. If an epidemic of DHF threatens, measures to obtain an immediate reduction in adult vector populations may have to be implemented. These should not depend on the so-called "focal treatments" which can have little effect though they are widely applied around the houses of DHF cases; the control activities should cover as much of the endemic area as resources allow. At the same time, planning must be made for how best to obtain sustained reductions in vector populations, using larvicides along with elimination of larval habitats through source reduction measures carried out by the community to whatever extent it is possible to enlist their cooperation. Finally, the role and responsibility of the environmental services of the municipality in reducing breeding sites must not be neglected; if the community is asked to cooperate by collecting discarded containers and other refuse serving as breeding places for the vector, than the municipality must remove this refuse away from the neighborhood for sanitary disposal elsewhere as the urban dwellers can not do this themselves. If householders are asked to stop storing water, than a dependable and regular piped water supply must be provided. If such a supply is not provided, the population will have to continue to store water in and around their households to make sure that they have a minimal supply.

Whatever control measures are applied must be periodically and frequently evaluated in terms of the reduction they achieve in the most important epidemiological component of the target mosquito population, the adult, biting females. If the reduction is not significant, than the program is not being satisfactorily conducted and improvements must be made.

The type of planning described, its costing, implementation, supervision and evaluation can not be undertaken by the community itself or by poorly trained personnel.
Control programs run by inadequately trained personnel are costly as they expend scarce resources but provide little result in sustained reductions of vector populations or reduction of disease transmission. They disappoint the public, making it difficult to obtain continued cooperation and participation in control measures. Clearly, the first step to take to achieve effective control of *Ae. aegypti* populations is to ensure that the planning and implementation of the program is directed by well trained professionals.

Training of technical and managerial staff

One of the reasons that many *Ae. aegypti* control programs are often left to personnel with inadequate training in vector control, is that ministries of health and municipalities often have little awareness of the extent of the information required as a base for implementing an effective program. To obtain it, the vector control specialist must have a knowledge of many different disciplines involved in establishing an effective vector control program. He or she must understand the epidemiological imperatives making the control program necessary, using them to select the areas to be targeted for control and be capable of planning studies on mosquito vector bionomics as a base for their control. An understanding of biostatistics in designing and evaluating such studies is essential. The supervisor of the program must know what insecticides are available for use and how to determine the susceptibility or cross-resistance of the vector populations to whatever larvicides and adulticides which may be procured. The potential toxicity of the compounds to applicators, to the population, to household animals and to nontargets such as fish and the measures which must be carried out to ensure safe use of pesticides to spraymen and inhabitants and the environment must be part of the training of the vector control specialist. The individual must also be able to select appropriate application equipment and know how it is calibrated and maintained.

It will often be necessary to carry out field trials of insecticides, insecticide application equipment or new methods to determine the efficacy of a material or method under local conditions and how to plan and evaluate such studies will be part of the responsibility of the vector control specialist. A knowledge of health education and of how to ensure that the community understands what is being done and how to obtain their active cooperation in control is also an essential part of the training. The size, cost and number of personnel involved in most vector control programs, requires that the person responsible for a program have basic training in the principles of administration.

Once the methods of control are selected and their cost estimated, the responsible for a program must know how to carefully prepare a detailed budget for submission to the authorities, explaining and justifying the cost of the program and the anticipated benefits to obtain the necessary funding.

Persons with the capability of carrying out what has been described above are few and they must be trained and facilities for doing so must be made available. There are not, at present, many institutions in the region capable of providing this type of training. The Health Sciences Division of the Rockefeller Foundation has recently undertaken an
initiative intended to create and support an advanced, regional, graduate course in applied vector biology and control. This could be an important factor in the improvement of vector control programs in eastern Asia.

Graduates of such a course must be motivated both by the knowledge of the importance of what they are doing and an awareness that secure career positions and the possibility of advancement can be open to them when they complete their training. It is absolutely essential that governments wishing to improve their vector control programs understand the importance of providing a career structure at least as secure as that of other professions within their service.

In recruiting the services of such specialists and in establishing effective control programs, governments must understand that the half measures commonly employed to control *Ae. aegypti* are ineffective and, in the long run, more costly than well planned and implemented programs.

There are well organized programs which have successfully controlled *Ae. aegypti*; while the transmission of dengue has not always been interrupted, it has often been substantially reduced or, in the case of the Cuban program, interrupted (Armada-Gessa and Gonzalez, 1986), Singapore, (WHO, 1986). A current program in Sao Paulo, Brazil is reducing Aedes densities through a well-funded and directed large scale program. Taiwan has carried out an extremely successful control campaign that has greatly reduced the density of the species and transmission of dengue, (Ji-sen Hwang et al., 1992). Armada-Gessa, ibid, in describing the control efforts in Cuba which reduced the *aegypti* house infestation index from more than 11% before the epidemic to less than 0.1% seven months later, comments that the campaign provided a good contemporary example of how aegypti can be successfully controlled given sufficient funds, personnel, equipment government backing and broad public support. The extent to which adequate funding, equipment and well trained personnel will be provided will depend on the priority given by the national or city government.

The way in which mosquito abatement districts in north America and Europe are organized and funded and the possibility that this method could be used in some dengue endemic cities should be considered. Each taxpayer in the area covered pays a modest and affordable annual tax to support the district. The district undertakes the responsibility of ensuring effective mosquito control and are usually very successful in doing so. In a very real sense the community which has organized a mosquito abatement district is participating in its own protection by paying for a control program run by competent professionals who report their progress to the community.

In less affluent countries and cities, the government, national or local, must assume the responsibility for control. In considering the organization of an *Ae. aegypti* control program and its attendant costs, it should be remembered that effective control, particularly in disease endemic areas, will almost certainly be economically and politically more advantageous than doing nothing at all. Where transmission of dengue/DHF is already a problem, the alternative to effective control of the vector is continued increase in the
number of cases, costly hospitalization, costly medical attention, a serious loss of productivity and a human population resentful that inadequate measures have been taken to protect them.

Achieving effective control of *Ae. aegypti* will mean that governments, municipalities and the public will have to work together. Local universities and research institutes can assist greatly in obtaining the information necessary on which to base the control programs and in the training of all levels of personnel of the program, professional and sub-professional.

The forty-sixth World Health Assembly passed a resolution (WHA 46.31) urging member states to strengthen national and local programs for the prevention and control of dengue, dengue haemorrhagic fever and dengue shock syndrome and to concentrate on cost-effective approaches and control measures which can significantly reduce vector density and disease transmission. It urged the member states to increase the numbers of well trained staff at all institutional levels for the planning and implementation of dengue operations.

All member states voted for this resolution—it is now incumbent upon them to implement this as the first step towards effectively controlling *Aedes aegypti*.

REFERENCES


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