

THE PROBLEM OF *Aedes aegypti* CONTROL IN THE AMERICAS¹

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The threat of urban yellow fever and dengue epidemics transmitted by Aedes aegypti mosquitoes poses a serious public health threat in the Americas. This article outlines the nature of that threat and describes the basic measures needed to control and eradicate the vector.

Introduction

The mosquito *Aedes aegypti*, its increasing spread, and the difficulties involved in its control, together pose one of the most serious public health problems facing the Americas today. That problem is compounded by the long-term presence of two dengue virus serotypes (dengue-2, isolated in Trinidad in 1952, and dengue-3, isolated in Puerto Rico in 1963) and by the recent arrival of dengue serotypes 1 and 4, which were respectively introduced into the Caribbean in 1977 and 1981.

Aedes aegypti is the vector of several arboviral diseases, two of which are important to man and usually occur in epidemic form. These diseases are yellow fever, which is fatal to a significant proportion of its victims, and dengue fever, which is not fatal to most victims, but which sometimes causes hemorrhagic symptoms, shock, and death. The urban-dwelling *aegypti*, which was introduced into the Americas around the time of the Spanish Conquest by ships coming from Africa, has been responsible for all urban epidemics of these diseases.

Over the past five years, the incidence of these *aegypti*-transmitted diseases in the Amer-

icas has increased sharply. Not only have two new dengue virus serotypes been introduced, but countries such as Brazil, Bolivia, and Paraguay that had been free of the vector have been reinfested; jungle yellow fever epidemics posing a serious threat of urban epidemics (especially in Colombia) have occurred; and for the first time a major dengue epidemic in the Americas has produced a considerable number of severe and well-documented cases of dengue hemorrhagic fever.

The Distribution of *Aedes aegypti*

Aedes aegypti is basically a domestic mosquito closely associated in the Americas with human settlements. The artificial receptacles produced so abundantly by modern industrial society provide its larvae's principal habitat, and hence are essential for the production and maintenance of large *aegypti* populations. Such receptacles include tires, flowerpots, cans, casks, barrels, concrete blocks, water containers for household use, and practically any other man-made objects that can hold water.

Because *Aedes aegypti* inhabits tropical and subtropical climates and cannot survive low temperatures, its distribution is limited by latitude. In general, it is seldom found beyond the extremes of 45 degrees North and 35 degrees South, limits that appear directly related to temperature; and as these limits are approached, the species gets less common and tends to become seasonal.

Within tropical environments, all else being equal, *aegypti* densities tend to depend on rain-

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fall. That is because increased rainfall tends to raise the number of larval habitats, and this leads to a rise in both the larval and adult populations.

Although *Aedes aegypti* is considered mainly an urban mosquito, recent ecological studies conducted in Colombia by Morales³ have shown it to exist in rural areas far from vehicular roads, in places such as isolated farms usually reached on horseback. It has also been found at high altitudes in Colombia—including many human settlements over 1,600 meters above sea level. The highest settlement found infested to date is Málaga, in Santander Department, at 2,200 meters, where the average temperature is 17°C and where the larval house-infestation index was 12 per cent. Although special circumstances could be responsible for these findings, surveys are continuing in an effort to determine the extent of such phenomena and their possible implications for programs seeking to control and eradicate *aegypti*.

The Hemispheric Eradication Program

The First Conference of the Pan American Health Organization, held in Buenos Aires in 1947, approved a resolution seeking definitive control of urban yellow fever through eradication of *Aedes aegypti*. This was followed by a forceful and well-organized campaign to eradicate the mosquito from the Americas—a campaign that was quite successful until the 1950s, but which slackened thereafter for a variety of reasons. At present, following years of marked deterioration, the hemispheric drive to eradicate *aegypti* faces a wide range of obstacles including the following:

- The low priority and slight resources provided for most control and eradication programs.

- Unwillingness of some governments to join in simultaneous programs for the control and eradication of *Aedes aegypti*, and inadequate compliance with the norms of the International Sanitary Regulations designed to prevent reinfestation of countries free of the vector.

- Deficiencies in the administrative and support services required for anti-*aegypti* activities.

- A scarcity of trained technical personnel, together with recruitment problems arising from lack of appropriate incentives.

- Growing *Aedes aegypti* resistance to the chlorinated insecticides that are relatively non-toxic to humans and that have a prolonged residual impact on the mosquito.

- Limited development of research on bionomics and alternative *aegypti* control and eradication methods.

- Insufficient community participation in control and eradication activities, as well as insufficient health sector and intersectoral support.

- Rapid expansion of international and domestic air and overland traffic favoring the passive dispersion of *Aedes aegypti*, especially in the egg stage.

- Higher costs of materials, equipment, and personnel.

- Inadequacy of public water supply and solid waste collection services in urban centers, due particularly to urban population growth fueled by migration from rural areas.

The various situations currently faced by individual countries of the Americas are as follows:

- 1) Countries or territories free of *aegypti* that are conducting surveillance programs include Argentina, Bermuda, the Cayman Islands, Chile, Ecuador, Panama, Peru, and Uruguay.

- 2) Countries or territories with limited *aegypti* infestations, where the mosquito appears to be under control, include Brazil, Costa Rica, Cuba, Nicaragua, and some island territories in the Caribbean.

- 3) All the other countries in the Americas except Canada have *aegypti* infestations of varying extent and intensity that entail a risk of dengue epidemics and, in some cases, of urban yellow fever.

³See A. Morales, *Aedes aegypti* en zona rural del municipio de la Mesa (Cundinamarca), Colombia, S.A. (4).



Anti-larval measures. Above, a health worker inspects household water drums in Barranquilla, Colombia. Below, sanitation workers remove an old tire in Espinal, Colombia. Elimination of all potential water-bearing containers that can be removed, plus periodic inspection and treatment of the rest, provides the foundation for *A. aegypti* control and eradication. (Photos by J. Moquillaza.)



Dengue Hemorrhagic Fever and Shock Syndrome

Historically, dengue has been recognized as a clinical entity for about 200 years. As already noted, in 1952 dengue-2 was isolated for the first time in Trinidad, and in 1963 dengue-3 was isolated in Puerto Rico. These were the only dengue virus serotypes known in the Americas until 1977, when dengue-1 appeared in Jamaica. The epidemic that resulted from that introduction spread through the entire Caribbean, northern South America, Central America, and Mexico. Occasional cases with symptoms resembling those of dengue hemorrhagic fever and dengue shock syndrome were reported during that epidemic in some countries, including Jamaica, Puerto Rico, Colombia, and Honduras.

Nevertheless, until May 1981 severe dengue cases involving hemorrhagic fever and shock syndrome posed a major public health problem only in the countries of Southeast Asia. From May to October 1981, however, a major dengue epidemic producing many cases of hemorrhagic fever and shock syndrome struck Cuba. The end result: 343,924 reported dengue cases and 156 deaths, most of the fatalities occurring among children under 15 years of age. The agent of this epidemic was dengue-2; however, an epidemic of dengue-1 had occurred in Cuba not too long before, during the years 1977-1978.

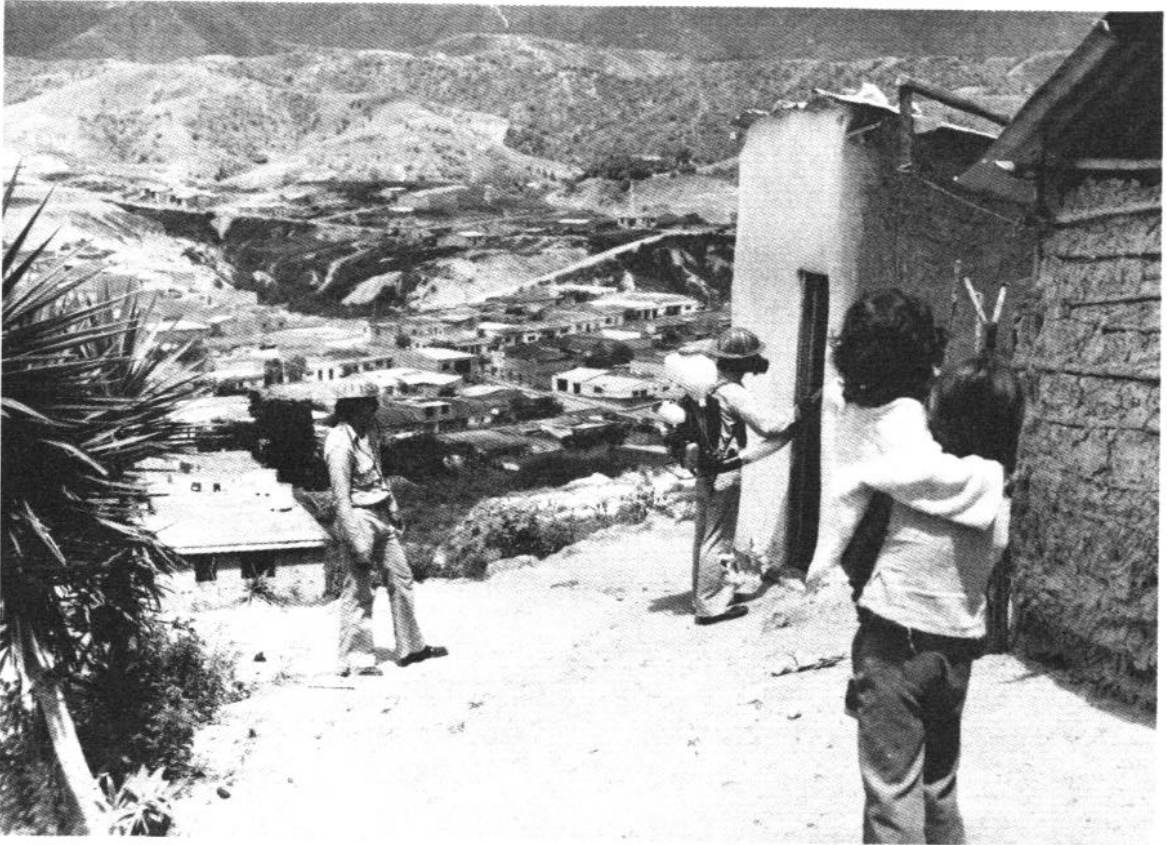
The emergence of dengue hemorrhagic fever and shock syndrome in Cuba has caused considerable alarm in *aegypti*-infested countries of the Americas, especially in those that have not managed to control the mosquito and that have previously experienced dengue epidemics. The outlook is not improved by knowledge that the recent Cuban epidemic had an enormous social and economic impact, entailing a national mobilization of resources to support a major eradication campaign. This latter action soon achieved its aims by halting transmission of the disease and reducing the density of *Aedes aegypti* to near-zero levels. However, in order to achieve quick

results, the eradication campaign was massive and intense. No information is available concerning its total cost, but it is estimated that imported materials and equipment alone involved an expense amounting to US\$4.00 per capita.

Dengue-4 was discovered for the first time in the Americas in early 1981 among United States tourists who had been infected in the Caribbean. Subsequently, a dengue-4 epidemic occurred on Dominica in May-July 1981. No life-threatening complications were reported, but the outbreak reawakened fears of dengue hemorrhagic fever and shock syndrome. Apparently the timely reporting of dengue-4's appearance, the relatively slow spread of the virus, and emergency measures taken to control *aegypti* arrested propagation of the epidemic. Nevertheless, at the same time that dengue-4 was being controlled on Dominica, Cuba was experiencing the first epidemic of dengue hemorrhagic fever and shock syndrome in the Americas.

Urban Yellow Fever

The risk of yellow fever urbanization, absent from the Americas for decades, has re-emerged in some countries as a consequence of *aegypti*'s presence in population centers close to and abutting areas where yellow fever is enzootic, and where epidemic outbreaks of the disease continue to occur. For example, over the last five years Colombia has faced very serious risks of urban yellow fever—as a result of jungle yellow fever epidemics near *aegypti*-infested cities where yellow fever victims went to die or convalesce. Less serious threats of urban yellow fever also occurred in Trinidad in 1979 and in Santa Cruz, Bolivia, in 1980. Moreover, it should be kept in mind that if the present threat of urban yellow fever materializes, improved communication systems—especially air transport systems—can be expected to facilitate dissemination of the disease into most other *aegypti*-infested countries, a point driven home by our experience with epidemic dengue.



Applying adulticides. Above, health workers in Ocaña, Colombia, provide an intradomiciliary treatment. Below, a truck-mounted sprayer makes an ultra-low-volume application of insecticide in Guamo, Colombia. Both house-to-house and open-air spraying are typically directed against *A. aegypti* adults when reduction of the adults rather than local eradication of the species is the aim. (Photos by J. Moquillaza.)

Aedes aegypti Eradication and Control Methods

The *Aedes aegypti* eradication policy approved by the Ministers of Health of the Americas in 1947 has been supported and reaffirmed by numerous resolutions of PAHO's Governing Bodies. Nevertheless, a scarcity of resources in many Latin American and Caribbean countries has permitted only limited mosquito control activities, periodically supplemented by emergency measures to prevent or control epidemics.

The ideal way of controlling *aegypti* populations is to eliminate larval habitats by installing piped water systems (eliminating the need for many water containers) and by instituting rigorous environmental sanitation measures (removing potential habitats, many of them man-made). Nevertheless, experience to date has shown how difficult it is to control *aegypti* in the countries of the Americas.

For one thing, sanitation measures aimed at eliminating breeding places are unlikely to have the desired impact and the necessary continuity unless they are supported by technically advanced health education programs enlisting substantial community participation. In addition, such programs require appropriate use of insecticides to treat actual or potential larval habitats, some of which cannot be removed.

Within this context, however, the effectiveness of insecticides in controlling *aegypti* in the Americas has been abundantly demonstrated. Indeed, the vector has been eradicated from several countries and large territories through the systematic application of chlorinated hydrocarbon insecticides in the past, and by similar applications of organophosphorus insecticides more recently.

The traditional methodology, ideal for eradicating the vector as well as for controlling it during interepidemic periods, consists of treating all possible larval habitats with larvicide, whether or not they contain water. In employing this "focal" method, the correct insecticide dosage and frequency of applica-

tion will depend upon the water-holding capacity of each potential larval habitat and upon the strength and duration of the chosen insecticide's residual effect.

For reasons of effectiveness and safety, a 1 per cent granular formulation of temephos (Abate) is recommended, with a dose of one part insecticide per million parts of water being applied every three months. This focal method should be complemented by perifocal treatments, which consist mainly of spraying the outer and inner surfaces of all likely larval habitats with a residual-action insecticide, so that they are covered with a fine film of the product. This film of insecticide should also cover the surface of any (nonpotable) water that may be found in the places treated, as well as nearby walls up to one meter above or to the side of the habitats. For this latter purpose, eradication programs have been successfully using the insecticide fenitrothion (as a wettable powder at a concentration of 2.5 per cent in the sprayer) or malathion (as wettable powder at a 5 per cent concentration). As noted previously, the prime aim of these measures is to eliminate potential larval habitats provided by receptacles such as barrels, old tires, cans, bottles, jars, and so forth.

Control During Epidemics

Emergency measures taken during an urban yellow fever or dengue outbreak seek to reduce the adult *aegypti* population to the lowest possible levels, thereby interrupting transmission of the virus. An attack aimed at the larval population, however effective, will have only delayed results and will have no effect on the already-infected adult *aegypti* females that can continue transmitting the infection for the rest of their lives. Nonetheless, it must be kept in mind that in order to maintain prolonged and effective control or to achieve eradication, such imagicidal activities must be complemented by systematic antilarval measures.

Control with aerosols. The aim in controlling adult mosquitoes with aerosols is to create a mist of insecticide-containing droplets that

will float in the air and kill flying or resting adult mosquitoes upon contact. These droplets must be of the right size—small enough to maintain good contact with the insects and to keep from dropping onto surfaces where they will have no insecticidal effect, and large enough to keep from rising with ordinary air currents and being removed from the area of operation. In general, it is felt that the optimum diameter for such droplets is somewhere between 5 and 25 microns.

Aerosols can be applied hot, by a method known as “thermal misting,” or they can be applied cold. Both methods may employ either heavy-duty generators (which spray the insecticide from the street) or portable knapsack units for intradomestic treatments. Both methods are effective, but because the hot method requires that the insecticide be highly diluted with petroleum derivatives, it has become very expensive in certain countries where the cost of petroleum fuels is very high.

Ultra-low-volume (ULV) applications. Recent years have seen growing use of equipment designed to apply concentrated or only slightly diluted insecticides, in very small doses and at low volumes, for the control of insects harmful to agriculture and public health. Both ground equipment and aircraft can make such “ULV” applications.

Ground applications are usually made when a temperature inversion exists, because this helps to ensure that the droplets will remain near the point of application for the longest possible time. Even so, however, when wind velocities exceed 10 km per hour or air turbulence exists, open-air ULV aerosol applications are hard to control.

The heavy-duty vehicle-mounted generators that operate from the street are very practical; their coverage, in terms of the average number of houses treated per day, can reach 1,600. However, their effectiveness depends largely on the type of housing in the area treated and upon the cooperation received from the occupants—who need to open their doors and windows to facilitate passage of the

insecticide into their homes. Portable equipment that can be operated inside dwellings has a greater impact and is extremely effective against adult mosquitoes, but its coverage—85 houses per day on the average—makes it less useful in emergency situations.

Aerial application of ULV insecticide offers the quickest and most effective method for reducing adult mosquito populations in emergency situations. However, this method must be limited to urban centers of some size, where the necessary resources—such as aircraft with suitable fittings and experienced pilots—are available. Experimental aerial ULV spraying in the city of Buga, Colombia, in 1979 showed that two applications of 96 per cent malathion six days apart, at a dosage of 485 ml per hectare, reduced the population of adult *aegypti* mosquitoes by 94 per cent.

Monitoring the Vector

Continual surveillance must be performed in any urban or periurban area where *aegypti* exists or has existed. If the species has been eradicated from a given place, control program personnel must be aware of the danger of reinfestation. They must also be able to identify *aegypti* larvae and adults and to determine the extent of any reinfestation in order to take the most appropriate countermeasures. In the case of geographic areas without any current control or eradication programs, it is advisable to prepare maps showing the vector's location, to ascertain its favorite habitats, and to learn about seasonal variations in adult population densities. Information about these latter variations can be obtained by periodic use of resting rates and by distribution and regular inspection of oviposition traps. Resting rates, determined by fixed-time collection of mosquitos resting inside houses, are expressed as the number of mosquitos collected per man per hour. Oviposition traps are small containers of water that are placed around houses, where they attract gravid adults. The traps are examined weekly

for eggs, and the percentage of positive traps yields what is known as an oviposition index.

No effort should be spared to maintain populations of *Aedes aegypti* at their lowest possible levels in regions where yellow fever or dengue fever are endemic, or where there is a substantial risk that outbreaks of these diseases will occur. In any area, environmental sanitation measures designed to reduce the number of larval habitats, public cleanup campaigns, recommendations for the disposal of unserviceable containers (supported by government decrees or ordinances), and health education efforts can make a significant contribution to reduction of the mosquito population.

As in the past, PAHO is cooperating with the infested countries of the Americas, both in dealing with emergency situations and in systematically promoting programs to eradicate the vector. PAHO Project AMRO-0700, based in Colombia and carried out in conjunc-

tion with the Colombian Ministry of Health, provides international training courses for personnel in *Aedes aegypti* control or eradication programs that instruct them about the techniques and methods of vector eradication. It is also doing research on the ecology and biology of the vector, and has a reference laboratory to study the susceptibility of *aegypti* strains to insecticides.

All in all, there can be no doubt that the current distribution and spread of *aegypti* in the Americas presents a public health problem whose impact has already been felt in some countries and which threatens to affect several others. It is therefore to be hoped that the recent dengue and dengue hemorrhagic fever epidemics, combined with the risk of urban yellow fever, will cause health authorities throughout the Region to undertake energetic *aegypti* eradication programs, in a common and definitive effort to prevent serious social harm.

SUMMARY

The threat of serious dengue and urban yellow fever outbreaks, arising from the combined presence of responsible viral agents and the *Aedes aegypti* mosquito vector, poses one of the most serious public health problems in the Americas today. As a result of marked deterioration in the hemispheric drive to eradicate *aegypti*, the vector is now present in many areas from which it was once banned, and in recent years infestation indexes in many areas have been rising. Currently, the only countries or territories in the Americas that are conducting surveillance programs and are believed free of *aegypti* are Argentina, Bermuda, the Cayman Islands, Chile, Ecuador, Panama, Peru, and Uruguay. Those that appear to have *aegypti* infestations under control are Brazil, Costa Rica, Cuba, Nicaragua, and some Caribbean islands. All other countries and territories in the Americas except Canada have *aegypti* infestations that entail some risk of dengue epidemics and, in certain cases, urban yellow fever outbreaks.

Until mid-1981 severe dengue cases involving hemorrhagic fever, shock, and death did not pose a major health problem in the Americas. However,

in the wake of increasing *aegypti* infestations and the introduction of new dengue virus strains, a major dengue epidemic struck Cuba in May 1981. This epidemic, which lasted until October and caused over 300,000 reported cases, produced numerous cases with hemorrhagic symptoms and 156 deaths. It also aroused fears of similar outbreaks in other *aegypti*-infested countries, especially those that had failed to control their *aegypti* infestation and had previously experienced dengue epidemics.

Regarding *aegypti* eradication and control, the traditional way of reducing or eliminating *aegypti* infestations has been to remove or neutralize larval habitats. And since most of those habitats are provided by man-made water-holding containers around human settlements (anything from old tin cans to rain-barrels), this means removing those that can be removed and treating the remainder.

In the event of an actual or threatening dengue or yellow fever epidemic, however, these larval control measures are insufficient—because they fail to kill the existing adult female mosquitoes capable of transmitting the disease. Therefore, it is necessary to supplement the anti-larval measures with emer-

gency aerosol treatments designed to kill the adult insects.

In addition, of course, it is essential to conduct continual surveillance in any settled area where

aegypti exists or has existed, in order to know the existing infestation levels and, if the mosquito has been eradicated, to learn about reinfestations early enough so that they can be snuffed out.

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POLIOMYELITIS IN ARGENTINA

Six cases of paralytic poliomyelitis were reported in Argentina during March-April 1983, bringing the total number of cases reported in the first four months of 1983 to 20. Four of the six cases had their onset during the first three weeks of March. Two of these occurred in Santa Fe Province; the other two occurred in adjoining Chaco Province, where 13 of the 14 previously reported cases had originated. The last two of the six cases, which had their onsets on 5 and 6 April, also occurred in Chaco Province.

The six children afflicted ranged in age from 11 months to 15 years. All but one had received at least one dose of poliomyelitis vaccine, and the two youngest children had received three doses. Laboratory investigations of the outbreak are in progress.

Source: World Health Organization, *Weekly Epidemiological Record* 58(19):147, 1983.