Successes and Failures in Dengue Control - Global Experience*

By

Scott B. Halstead**

Adjunct Professor, Department of Preventive Medicine, Uniformed Services, University of the Health Sciences, Bethesda, MD, USA

Abstract

Despite the admirable achievement of the control and near eradication of *Aedes aegypti* in the Western hemisphere in the mid-twentieth century, today this species is more abundant and widespread than at any time in human history. As a result, dengue viruses have spread to be among the most common pathogens on earth. This paper reviews the history of the success and then the failure to control *Aedes aegypti*. Two crucial failures contributed to the dismal story of dengue control: (1) no major educational institution has ever committed itself to solve the problem; and (2) there are no outraged and vocal citizen groups. At least 12 sectors of society have some interest in or responsibility for the control of dengue: national health, city health, environment, urban planning, justice, education, science and technology, the media, private sector and people themselves. The current roles of these sectors in the control of dengue are given. This is followed by a description of the more active roles that might be adopted by each of these sectors. Finally, advocacy methods are described for use by physicians, public health workers and scientists who face the problem of dengue on a daily basis.

Key words: *Aedes aegypti*, DF/DHF, global experience

Introduction

This is not a technical paper. This is a discussion of a framework for approaching the environmental control of dengue. The most important elements of any such framework are a sense of moral indignation at unnecessary suffering and for the leadership to mobilize human will power and resources to take on the task of controlling dengue. In this context, I am pleased to acknowledge the initiative of His Majesty King Bhumipol of Thailand whose sensitivity to the problem of dengue and whose leadership has made inevitable the First International Conference on Dengue and Dengue Haemorrhagic Fever, Chaing Mai, Thailand, November 2000.

Successes

The 20th century has witnessed great triumphs with respect to the control, even eradication, of *Aedes aegypti*, the principal urban cycle mosquito vector of dengue viruses. In the very first year of the 20th century, a team led by Major Walter Reed of the US Army, tested the mosquito transmission hypothesis put forward by Dr Carlos Finley, a Cuban private physician, with supportive data from Dr Henry Carter, US Public Health Service(1). By
December 1900, as a result of Reed’s experiments, *Aedes aegypti* had been convincingly shown to be a yellow fever vector, the intrinsic incubation period in the mosquito was proven, and yellow fever virus had been shown to be of such a small size that it could pass through a porcelain filter. But, the truly inspiring story occurred immediately thereafter. Using source reduction methods made up on the spot, Maj. William Gorgas successfully eradicated urban yellow fever from Havana, a city that had reported cases for over 300 years(2). Gorgas’ improved methods were applied in Panama, permitting the successful construction of the Canal. In 1919, the Rockefeller Foundation funded a Yellow Fever Commission that soon eliminated urban yellow fever throughout the American hemisphere. In Brazil, with the strong support from its President, Dr Fred Soper, of the Rockefeller Foundation, applied imagination, a variety of methods, a disciplined force, meticulous records and sheer force of personality to discover that persistent source reduction could lead to species eradication(3,4).

In 1947, when Soper was appointed Director of the Pan American Health Organization, *aegypti* eradication campaigns were organized throughout the hemisphere. By 1960, using DDT to supplement Soper’s well-described methods(5), *aegypti* were certified as eradicated from all but four of 27 American countries. Sadly, one of these four countries was the United States. From the late 1960s, when the US adopted a surveillance programme instead of species eradication, *aegypti* eggs were exported in used automobile tyres to Central and South America. Today, the distribution of the species exceeds the maximum range recorded earlier in the 20th century.

Success did not entirely cease with Soper’s retirement from PAHO. Using similar methods, Cuba came very close to eradicating *aegypti* following the 1981 epidemic of dengue haemorrhagic fever(6), and Singapore has maintained very low *aegypti* populations for more than 30 years(7). The dengue control movement is gaining some new ground: new, more sensitive and specific measures of entomological surveillance have been proposed(8,9), improved community-based methodologies are available(10), and several pilot or small-scale successes have been obtained with effective community participation(11,12). Most DHF endemic countries have made substantial investments in dengue control. Undoubtedly, at this meeting we shall learn about numerous improvements that have been made in mosquito control programmes.

**Failures**

The remorseless progression of the 20-21st centuries dengue pandemic tells us that large-scale control of *Aedes aegypti* has been among their most conspicuous public health failures. Why is this?

There are many reasons. Among them, limited national and global resources, failure of planners to recognize that dengue imposes an important financial and social burden, the regional nature of the dengue problem, absence of proven and sustainable vector control methods, the confusion caused by the squabble between the proponents of "eradication" and "control" strategies, indecisiveness because of waiting for a dengue vaccine, and the generally doleful support for and leadership by the public health sector. In short, dengue is a paradigm for unsolved 21st century health problems, a subject dealt with at length in a new book by Garrett(13).

**The way forward**

My intention is not to dwell on the reasons for the failure to control *Aedes aegypti*, although a great deal can always be learned by examining the past. Instead, I would like to direct a few personal observations to the following question: what can be done to improve the chances of success of controlling dengue in the new century?

My thinking is framed by four precepts:
The transmission of dengue viruses is basically an urban environmental problem.

Human behaviour contributes importantly to creating and sustaining *Aedes aegypti* breeding sites.

With respect to people and mosquitoes, our scientific and management knowledge base is insufficient to design and sustain successful programmes to control *Aedes aegypti*.

The dengue problem is global and immense.

It follows that successful control of dengue will require a major, sustained, cooperative and well-funded effort. We cannot hope to approach dengue control except by re-prioritizing society’s social goals, creating new partnerships and developing new tools through an imaginative programme of enhanced research.

**Social organizations**

**Educational institutions:** A 1992 study commissioned by the Rockefeller Foundation could find no major university in any dengue-endemic country that offered graduate programmes in *Aedes aegypti* bionomics or control. Many national vector control programmes do not have PhD medical entomologists in leadership positions. Similar voids can be found in programmes designed to modify human behaviour and in the graduate training needed to supply researchers. Those working in the field with graduate degrees usually have obtained them abroad, focusing on topics of little relevance to endemic areas. Thus, there is no academic and research base to supply personnel or complement government interventions.

**Citizen groups:** In Western societies, it is common for aggrieved citizens to form groups to protest against harmful conditions and to fight for the actions and reforms needed to change them. These kinds of groups have been conspicuously absent in the face of the dengue problem. While the absence of such groups may reflect Asian "values" or differences in civil society in the Asian cultural milieu, scholarly and political attention needs to be paid to these social phenomena and the gaps that they leave.

**Partnerships**

At the very least, each of the following sectors or agencies have an important role to play in dengue control:

1. **Public health ministries:** Ministries of public health define the size and impact of dengue as a health problem, provide facilities and manpower for coping with its clinical burden and many provide the manpower and resources to combat *Aedes aegypti* (14). Instead of sustained mosquito control programmes, dengue is controlled through mosquito abatement mounted in response to reported cases, e.g. adulticide sprays. Budgets are often inadequate to support either control or a meaningful research effort.

2. **City health departments:** The modern megacity is often autonomous or semi-autonomous (15). Its health department may organize dengue vector control programmes that are independent of national authorities.

3. **Environment ministry:** In many countries, environment ministries have assumed responsibility for source reduction and the application of pesticides against *Aedes aegypti*. This is consistent with the reality that environmental programmes are needed for dengue control.

4. **Urban planning:** It is not at all clear that past or present generations of urban planners or architects have included as a goal the reduction of breeding sites for *Aedes aegypti* in public or private spaces.

5. **Justice sector:** The design and/or enforcement of laws that regulate human behaviour are usually the responsibility of the justice sector. Sanctions and fines discouraging the breeding of vector mosquitoes by households have been the key to historically successful *A. aegypti* control programmes. Such laws continue to be used effectively in modern-day Singapore, Malaysia and Cuba.
6. **Education sector:** A number of countries have designed, implemented and evaluated curricula for schoolchildren that teach the biology of *Aedes aegypti* and its control, including laboratory and field work. Universities, envisioned by most national leaders as institutions crucial to national development, have failed to respond to the dengue problem\(^\text{(16)}\). A recent survey of Asian universities found almost no graduate education in medical entomology, especially on the bionomics and control of *Aedes aegypti*. Little attention is paid by academia to the human behavioural aspects of dengue control\(^\text{(17)}\).

7. **Science and technology:** Most large dengue-endemic countries offer only limited support to research or vector control and almost none to develop the technical and scientific manpower that such research requires\(^\text{(17)}\). Large industrialized countries do support modest programmes for basic and vaccine research on dengue, but this is not an effort commensurate with the size of the problem.

8. **The media:** The media everywhere make efforts to educate the public on health issues and to be a part of the solution of public health problems. A dramatic example is Ted Turner’s gift to the UN of CNN time dedicated to health and children’s issues. In my own experience, I have noted that the *Bangkok Post* has highlighted dengue and DHF outbreaks in Thailand for more than 40 years. I am not aware that anyone in the dengue control community has acknowledged this contribution publicly.

9. **Private sector:** A significant, but largely unmeasured percentage of effective control of adult *Aedes aegypti* can be attributed to the use of commercial products, e.g. aerosol insect sprays. In some developing countries small private vector control firms have come into existence. In the United States there are many large private firms that provide a wide range of control services against nuisance or vector mosquitoes\(^\text{(18,19)}\). Private foundations, Rotary Clubs and Rotary International have and will continue to support research, training and pilot community-based dengue control programmes\(^\text{(14,17)}\).

10. **People themselves:** A number of pilot studies have explored and demonstrated effective ways to interest and educate people on the problem of dengue and *Aedes aegypti* control. Efforts have been made to encourage people to take greater responsibility for mosquito source reduction. Much has been learned, but much remains to be learned.

Each of the above sectors might and can play a different and more constructive role in the control of dengue:

1. **Public health ministries:** Because dengue is a human health problem, health ministries should serve as coordinator when multiple partners are involved in vector control programmes. Health ministries must maintain essential services such as the care of the sick, surveillance on the vector and on dengue infection, and promote research on improved treatment, dengue surveillance and better methods of mosquito control. But, dengue transmission is largely an environmental problem. The responsibility for vector control must be shared by appropriate agencies.

2. **City health departments:** Because large cities are a major milieu for the transmission of dengue viruses, city health departments must play a central role in dengue control. But, city and national programmes must be tightly coordinated. For example, cities might design, conduct and evaluate pilot control programmes using laboratory support provided at the national level.

3. **Environment ministries:** Several important responsibilities usually delegated to environment ministries are critical to the control of dengue: solid waste management, drainage, regulation of construction sites distribution of safe drinking water and the management of rainwater and gray water drainage in underground culverts.
4. **Urban planning**: Urban planners should assume the central responsibility for creating master plans that include comprehensive dengue control. Crucial elements include the distribution of ample and safe drinking water, the construction of buildings and building codes designed to minimize sites for mosquito breeding, the regulation of construction sites to prevent mosquito breeding and the coordination of these components(15).

5. **Justice sector**: Source reduction requires human behaviour change resembling programmes such as seat belt use or smoking cessation. National legislatures must write laws that provide incentives and disincentives that promote source reduction behaviour; the justice sector should enforce them.

6. **Education sector**: The needed manpower and the intellectual, scientific, research and technical underpinning for dengue control must come from the education sector. In the large dengue endemic countries, universities must adopt affirmative programmes to provide a cohort of leaders in virology, vector bionomics, behavioural sciences, as well as in environmental, legal and architectural fields. As a global problem, major universities in industrialized countries also should assume a prominent role.

7. **Science and technology**: Science and technology funding for the research enterprise must be forthcoming. Where education and science funding come from separate appropriations, coordination between ministries is crucial to attract high-calibre people to the field and to sustain a quality dengue control effort.

8. **The media**: There are many opportunities for explicit partnerships between the media and agents of change. In Puerto Rico, TV telenovellas have told the dengue story. A Rockefeller Foundation pilot project in Mexico worked with a local television station to commission puppet shows that dramatized the problem of *Aedes aegypti*.

9. **Private sector**: The private sector is perhaps the greatest untapped resource that can help with dengue control efforts. Vector control programmes are frequently planned by government workers who are unknowledgeable or uncomfortable with the private sector. The private sector can provide help at any scale, from neighbourhood mosquito abatement to the national level. If work contracts are written carefully and the rewards for success are sufficient, the private sector is capable of delivering sustained mosquito abatement and source reduction imaginatively and competently(18,19).

10. **People themselves**: The biggest lesson of modern history is that effective national development depends upon the strength of a civil society. Authentic participation in decision-making and individual "ownership" of a healthy environment are crucial to bring into existence an informed citizenry who expect much of themselves and make appropriate demands on government. Community-based disease control programmes contribute constructively towards the emergence of civil societies.
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Research

Allocations of funds and scientific manpower are simply not commensurate with the size or complexity of the dengue control problem. Some pressing research topics can be listed:

1. **Bionomics**: Although this mosquito is one of the best-studied, the flight range, survival, biting and breeding behaviour of *Aedes aegypti* need to be studied in many different sites. What is lacking is essential information on the size of mosquito populations that are needed to sustain dengue virus transmission.

2. **Vector control methods**: Many methods are available to reduce or destroy *Aedes aegypti*. Nonetheless, since the days of Dr Fred Soper, no one has found the right mix of methods that matches the resources available and is compatible with today’s legal systems. Are currently available methods simply too labour intensive and expensive? Or, is the failure of *aegypti* control an example of systems failure? Basic research is needed on how to reduce populations and destroy vector capacity.

3. **Control – serological surveillance**: Great emphasis has been given to syndromic surveillance in detecting and controlling dengue. It is abundantly clear, however, that the majority of dengue infections are inapparent. The implications of this observation must be just as clearly understood. The success of the control of dengue transmission must be monitored by measuring dengue infection rates in control areas. This can be done simply by assaying antibodies obtained from finger-tip blood samples, use of statistics to minimize sample size by selecting random populations and use of a well-described single dilution neutralization test\(^{(20-23)}\). An automated and inexpensive antibody test with serotype specificity is an urgent research goal.

4. **Control – human behaviour**: *Aedes aegypti* breeding sites are largely man-made; humans provide the blood essential to the survival of both mosquito and virus. Mosquito breeding is not linked to emotion-laden customs or behaviours. As is the case with malaria, ignorance, traditional practices and carelessness must be overcome to promote appropriate behaviours. Stratagems to motivate behaviour changes need to be devised and tested. What role can schools play in changing behaviour? What messages are appropriate for various target age and sex groups?

5. **Control-systems development**: Above all, dengue control is a test of a system. Disease surveillance and awareness of illness and cost burden are needed to motivate and inform educational interventions and to design interventions in specific localities. Tests need to be made of ways in which the legal system can enforce and re-enforce desired behaviour. Studies need to be made of materials and devices that can be
used by householders that will provide passive prevention of mosquito breeding or killing of larvae or adults.

6. **Control-private/public partnerships**: With sufficient funds, it can be predicted that the private sector will be able to provide effective control of *Aedes aegypti*. Pilot-scale projects are needed to test the ability of the private sector to control *Aedes aegypti* with and without the public sector.

**Discussion**

The difficulty of improving collective efforts to control dengue raises important questions:

*Why control dengue?* Dengue is a major disease problem with a moderate death toll. The 1993 World Bank’s World Development Report ranked dengue control as a low priority health programme for two reasons: (1) Annual deaths due to dengue are 1000-fold lower than such diseases as diarrhoea and malaria; and (2) Dengue control methods are both unproven and expensive (24). Recent efforts to re-calculate the cost of dengue place the dollar burden in the same league as hepatitis B and C or the tropical disease cluster (trypanosomiasis, schistosomiasis, filariasis, leishmaniasis and onchocerciasis) (25). These diseases command considerably more investment in research, control and prevention worldwide than does dengue. In calculating DALYs, the authors made a decimal error in estimating DHF/DSS deaths. From reliable annual country reports to WHO for the period 1996-1999, deaths due to dengue average 2584 per year worldwide, not 25,000. While admitting under-reporting in some countries, it is clear that the reported figure is not wrong by 900%! I suspect the real cost of dengue/DHF is much higher than the global high-end estimate of 1289 DALY’s/million population (malaria median – 6020 DALY’s). Measurement of the cost of dengue requires a different scale. Dengue conveys a sense of disorder not measured in dollars. It is the health equivalent of street crime or grafitti. These disorders create visually and emotionally contaminated environments in which people feel unsafe and lose their enjoyment of life. Dengue, as a house-borne disease, makes many people feel unsafe. Millions of parents in dengue endemic countries lose sleep worrying about the safety of their children. This is the conclusion emphasized by Sornmani and colleagues in their unique study on the social and economic impact of DHF in Thailand (26). Fear and worry are the enormous and largely unmeasured burdens of dengue.

*Why not use a vaccine and forget mosquito control?* Dengue vaccine development has proven a formidable challenge. Yet, there can be no doubt that a successful tetravalent dengue vaccine can and will be developed. But, many scientific and legal complexities will accompany the administration of dengue vaccines. Also, it is important to remember that dengue viruses are maintained in African and tropical Asian sub-human primates. This means that under the best of circumstances, dengue vaccines may not eradicate dengue viruses. While it is not certain that monkey-adapted dengue viruses will infect humans, it is negligent to base public policy on the probability that dengue viruses may not emerge from sylvatic to urban cycles. *Aedes aegypti* also transmits two other viruses of pandemic potential, yellow fever and chikungunya. No matter what vaccine choices become available, public health policy must also commit to the long-term control of *Aedes aegypti*. Mosquito control is a societal responsibility, similar to providing safe drinking water or waste management.

*Can a competent mosquito control programme have unexpected results?* Some countries have provided excellent *Aedes aegypti* control services. But, paradoxically, a sustained period of successful control has resulted in high levels of susceptibility leading to disease in adults. In settings in which the importation of dengue viruses continue, limited vector populations may persist and small outbreaks may occur. Large numbers of adults, who for the first time are susceptible to both primary and secondary dengue infections, become clinically ill. In Singapore, a few thousand dengue infections may have sent a few thousand adults to their doctors’ offices with dengue (26). With an excellent reporting system, in societies with low tolerance for sickness, these small outbreaks have had a big impact. In Cuba, reduced transmission uncovered another paradox; at long intervals from first to second infections, classical DHF/DSS occurred in adults with higher case-fatality rates than the
disease at short intervals\textsuperscript{(27,28)}. Without global eradication of dengue, those countries that make a strong effort to control \textit{aegypti}, will remain permanently at risk.

\textit{How can we build partnerships for dengue control?} For partnerships to succeed, we should try to identify the vested interests or benefits that the prospective partners will derive from working toward a common goal. It is particularly important to try to find financial incentives for working in partnerships, or, financial liabilities for failing to do so. An excellent partner may be the local and global tourist industry. Dengue is among the leading diseases of tourists. In some parts of the world, hotels themselves provide breeding sources for \textit{Aedes aegypti} and are sites of dengue transmission.

\textbf{Let’s get started}

1. Agitate! Move the dengue problem from the health to the political sector.

2. Teach! Help decision-makers to learn more about dengue.

3. Build a global alliance for dengue control that includes agencies or organizations representing the sectors identified above. This might include: WHO and other health-oriented UN agencies, Global Forum of Mayors, UN and global environmental agencies, international urban planners, international associations of lawyers and legal scholars, UNESCO, international education and universities associations, international research administrators, foundations and international development agencies. The purposes of this meeting are to raise awareness, raise funds, enlist the support of partners to work on a set of mutually established goals and prepare for partnership formation on the national level.

4. Promote country-level public/private vector control partnerships. Build the leadership required to forge partnerships.

5. Design interventions for public/private vector control partnerships and find the funds to support demonstration projects.

6. Fund a dynamic and innovative programme of social science research/capacity-building on dengue control.

7. Fund a dynamic and innovative programme of vector control research and capacity-building.

8. Encourage, support and reward innovation. Why not give Prizes for good ideas and accomplishment?

Dengue is working its way to the top of the health priority list. When it arrives, we must be prepared.

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