

Delivery Issues Related To Vector Control Operations: A Special Focus On The Americas

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Introduction

Vector control is an essential part of the control of vector-borne diseases and effective preventive measures to reduce or interrupt their transmission. It also plays a critical role in the prevention and containment of epidemics. With the gradual abandonment of programmes for the eradication of malaria and *Aedes aegypti* in the 1960s and 1970s and the decentralization of most vector control programmes, capacity has diminished dramatically in many countries, although expenditure associated with vector control is still responsible for a large share of the budget of vector-borne disease control programmes [26].

While vaccines have been developed for other flaviviruses, such as yellow fever and Japanese encephalitis, the development of vaccines for dengue is complicated by the need to incorporate all four virus serotypes into a single preparation. An approved vaccine is not likely to be available for 5 to 7 years; the only way to prevent dengue transmission, therefore, is to reduce the population of its principal vector, *Ae. aegypti* [19].

In many countries, health-sector reform poses new challenges for programme delivery, including decentralization and issues of selection, purchase, procurement, and use and monitoring of insecticide application. Moreover, a limited number of new, cost-effective chemical pesticides suitable for public-health use have been developed in recent years. This problem is particularly acute with regard to larvicides suitable for use in stored water for domestic consumption [19]. For these reasons, better strategies for programme delivery are needed.

Background

Dengue has been successfully prevented via vector control in at least three instances. The first was the highly successful, vertically-structured paramilitary hemispheric eradication campaign directed by the Pan American Sanitary Board [19]. Campaigns to eradicate *Ae. aegypti* were successful between 1948 and 1972, when complete vector eradication was achieved in 21 countries of the Americas [26]. The second was also a rigorous, top-down, military-like vector control operation in Cuba that was based on intensive insecticidal treatment followed by reduction of available larval habitats (source reduction) in 1981 [12]. The third successful programme was in Singapore. However, none of these programmes was sustainable, with consequent reinfestation and a loss of the progress made in previous years [19].

Since the early 1970s, the World Health Organization (WHO) has been actively involved in developing and promoting strategies for the treatment and control of dengue. In resolution WHA46.31, the Forty-sixth World Health Assembly in 1993 confirmed that dengue prevention and control should be among the priorities of WHO. In 1995, the WHO Global Strategy for Prevention and Control of Dengue Fever and Dengue Haemorrhagic Fever was developed [35]. It comprises five major components: selective integrated vector control, with community and intersectoral participation; active disease surveillance based on a strong health information system; emergency preparedness, capacity building and training; and vector control research [35]. Global and regional strategies emphasizing the need for effective prevention, active surveillance and outbreak preparedness have since been developed in the Regions of the Americas, Western Pacific and South-East Asia.

The Pan American Health Organization (PAHO) developed regional guidelines for dengue prevention in 1994 [23] and, during the meeting of its Directing Council in 2001, adopted Resolution CD43.R4, which is a political declaration concerning the alarming situation and regarding support for a new generation of dengue programming [20]. The new generation of programmes for the prevention and control of dengue aims to strengthen prevention and control through community participation and health education [22]. In 2003, the 44th Directing Council of PAHO/WHO approved Resolution CD44.R9, promoting the adoption of the Integrated Management Strategy for Dengue Prevention and Control [21].

The WHO Regional Office for South-East Asia developed a regional strategy for the prevention and control of dengue fever/dengue haemorrhagic fever in 1995, revising it in July 2001. Different countries formulated control programmes according to their own priorities, infrastructure capacity, and resources (e.g. Thailand, Indonesia, Myanmar, Sri Lanka). The countries of this region have developed various models of community-based control programmes-based source reduction, which have met with varying degrees of success [40].

Dengue fever is also a growing problem in the WHO Region of the Western Pacific; more than 160 000 cases of dengue and dengue haemorrhagic fever were reported in this region in 2004. Despite the significance of dengue, activities for the prevention and control of dengue are under-funded in many countries of this region [38].

Programme Delivery: The traditional model of eradication versus control

Control and eradication are two different strategies, with different methodologies and targets. The eradication strategy implies universal coverage of every breeding site of the mosquito in every house of every locality infested in the entire country, for the total elimination of the vector and subsequent permanent surveillance to detect reinfestation. The up-front cost of this strategy is high, but once the mosquito is eliminated, the cost of surveillance to detect reinfestation is much smaller and the transmission of dengue and urban yellow fever is totally prevented [26].

The first eradication campaigns had great success in the 1950s and 1960s primarily because there was great political will for the implementation of the strategy, which was reflected in internal and external financing for personnel, insecticides and equipment. Great emphasis was placed on the reduction of sources of vector breeding; development and implementation of policies for adequate use of insecticides, including residual insecticides; and management through vertical, centralized and well-organized programmes based on strict discipline.

However, from the 1970s onwards, these results were not maintained and receded notably; the programme lost political importance and priority in the majority of the countries that had achieved eradication. Once reinfestation was detected, government response was very late; high costs were associated with providing materials, equipment, salaries and benefits for the workers that were not kept in their positions, and reinfestation was concomitant with the appearance in *Ae. aegypti* of resistance to organochlorated insecticides and the fast and rampant growth of suburban centres. Currently, few countries in the world maintain a strategy of eradication, for example, in the WHO Region of the Americas only Cuba maintains these principles of work [26].

A control strategy is based on preventing or reducing dengue epidemics and deaths caused by severe dengue; a secondary focus is on the prevention of urban yellow fever. This strategy identifies areas at greater risk and concentrates efforts on these areas in order to reduce, but not eradicate, the vector [26]. The cost of the control strategy is less than the cost of the attack phase of the eradication strategy, but higher than the maintenance phase of the eradication strategy (surveillance against vector reinfestation).

An intermediate strategy between control and eradication, especially when there are insufficient resources for universal coverage, would be the total elimination of the vector in limited high-risk areas, with a progressive expansion of these areas as funds permit, and with surveillance against reinfestation [26].

National programmes, especially in the Americas, have been predominantly vertically structured; however, there is a growing trend in recent years towards decentralization of dengue control programmes. Unfortunately, this decentralization has often been applied indiscriminately and with little decentralization of financial and human resources, with a consequent loss of control capacity.

Current status of vector control programmes

Currently dengue is presented as a health problem whose magnitude exceeds the borders of the health sector; the prevention and control of dengue is the responsibility of not only the health sector but also of other government sectors.

There are several barriers to addressing the shortcomings of dengue programmes. These obstacles are very similar to those encountered in the past, but current working models are not sufficiently comprehensive and participatory to address service delivery problems in all its magnitude and dimensions. We highlight some elements that make this relevant:

Macrofactors related to dengue—environmental, socioeconomic, political and social factors have a strong impact on dengue, and are associated with the re-emergence of dengue as a serious issue. Climate change and ecosystem alterations have provided ideal conditions for expanding the geographical distribution of pathogens and vectors, and increases in migration and international traffic favour the spread of the vector and the disease.

Unprecedented population growth—the world's population has tripled in the last 70 years—is also contributing to increasing the number of vector breeding sites. Also, *the presence of dengue in large urban centres, and especially in 'megacities'* (e.g. Rio de Janeiro, São Paulo, and Caracas), associated with urbanization that is neither planned nor controlled and poverty, with the absence of basic services (electricity, running water, sewer systems, refuse collection), poses new challenges and requirements for prevention activities and control. Such activities are expensive and require great coordination and synchronization, and the incorporation of extrasectorial actors, such as the tyre industry.

The *local health services*, now politically and administratively responsible for disease prevention and control programmes, are generally not sufficiently prepared for the management of dengue control programmes, and resources are usually insufficient. The lack of human resources to cover the large number of houses reduces the quality of work, programme managers do not know how to prioritize areas of high complexity, and the work is converted into a routine household inspection with standard container-control messages offered to homeowners and businesses. The sustainability and continuity of control actions are always given a lower priority than other health demands and policy, with which they compete.

Elements such as employment instability of the *workers* (i.e. vector control inspectors), training methods that continue to employ curricula content that does not lead to participatory models for vector control, and use of old control/eradication models in which the vector control inspector carries out control actions during his household visit prevent the transfer of responsibilities and creation of abilities to prevent and control *Aedes* breeding in the household and surrounding areas.

In general, ministries have very few *external partners* and little ability to negotiate partnerships. There exists little communication, collaboration or integration between key components within ministries of health, (epidemiology, entomology, environment, health promotion, laboratory, etc.), as well as with other ministries, and governmental, nongovernmental and community agencies. Establishment of partnerships, traditional and non-traditional, may help to address the problem in all its magnitude and dimensions.

Countries carry out *vector control primarily using insecticides*. Frequently, larvicides are applied to containers that could be destroyed or better managed; there is excessive use of ultra-low-volume application of adulticides in areas where there is no transmission of dengue. This method is useful as a support for the suppression of epidemics, but not for routine control [26].

Participation of the community in the prevention and control of dengue- the community has transferred the responsibility for *Ae. aegypti* control to the health sector as a result of the long-standing traditional vertical model [27]. It is limited to response to official demands and control actions, and is not viewed as an empowerment process for the community. The work dynamic of the vector control inspectors and their interactions with families can be paternalistic; their focus is the destruction of the containers in which mosquitoes breed, with little ability to motivate residents towards ongoing environmental management of their premises. There is an evident need for matching the interests of residents and health-care providers in order to attain a significant social mobilization [27].

Incorporation of the *Communication-for-Behavioural-Impact (COMBI)*¹ planning methodology is opening new roads; in contrast to intensified routine control activities, a community-based intervention approach promises to be sustainable [16,27]. There is still a need for monitoring and impact assessment of this planning instrument, and we cannot say that has been introduced and generalized in all programmes in the Americas.

Water-supply and waste-management systems are limited in many high-risk areas; this facilitates vector proliferation and persistence. We point out that the high presence of plastic containers that can contain water and that are not biodegradable also facilitates vector persistence, because these containers remain for long periods in the environment and must be eliminated properly by man.

¹ COMBI: <http://www.paho.org/english/ad/dpc/cd/den-step-by-step.htm>

Operational research on new approaches and control strategies has not been sufficient to investigate and monitor its impact.

The role of the vector control inspectors: what do we expect from them?

Any strategy or programme plan that is adopted may need the presence of field inspectors, employed either by the public or the community. The household visit is important as a preliminary and basic prevention activity for health promotion. These visits are a great opportunity (particularly in countries at risk of dengue, where large groups of the population have a low level of education), to review and determine the application of control actions.

However, the function of vector control personnel should be analysed seriously; traditional programmes do not have a sufficient impact in disease control owing to severe and ongoing reductions in personnel. A significant programmatic change is needed, and health services must have personnel who are able to interact with residents and who can assume a greater role as health promoters and evaluators, without losing the point of entomological surveillance and vector control. These personnel should be part of epidemiological surveillance teams and the actions that they recommend or take should not be routine, but should be based on an analysis of the situation.

The great challenge is to provide these field staff with good communication skills, thus training is very important. Given that residents must also assume some responsibility and capacity for self-care, it is hoped that having better relationships with householders will improve the development of practical prevention actions, taking into account that the residents may need not only increased knowledge related to health, but also skill-building to carry out the recommended behaviour. Changing the current passive nature of the house visits by emphasizing communication and interpersonal contact can help transmit more appropriate messages that may modify behaviours related to breeding sites of *Ae. aegypti*. For this, the system has to provide adequate tools and materials for the inspectors that respond to this objective.

Dengue prevention and control programmes need to work with the community, women, young people and children directly; using organized networks that exist in the community is one way to achieve this. This may be a means to create comprehensive control with co-responsibility that is led jointly by the residents and municipalities; the programmes will have to change from the traditional model toward a participatory model, giving a comprehensive nature to the control measures. To achieve this end-point, models of mass interactive community–institution communication may need to be developed and tested.

Strategic partnerships for vector control

Strategic partnerships for dengue prevention and control have been identified as an important source of support for vector control programmes. These partnerships can promote the coordination of actions among the government, health sector and other social and economic sectors, volunteer and nongovernmental organizations, churches, local authorities, industry and mass media. Furthermore, the importance of adapting the programmes to the realities and local needs is recognized, taking into account social, cultural and economic differences.

State–industry–community partnership

Environmental management that promotes the elimination of vector breeding sites should be a priority in control programmes. Programmes that involve the creation of strategic partnerships should include intersectoral participation of public and private corporations with a strong component of community participation, as well as participation of different ministries and institutions with a greater direct relationship to the various components that lead to continued dengue transmission (e.g. ministry of health, of protection of the environment, of finance, of construction, of transportation, of sports), universities, nongovernmental organizations, importers of tyres, tyre repair shops, municipal government, among others. There could also be partnerships between the ministries of health and education, promoting dengue prevention during the teaching process among elementary-school students.

These partnerships can be promoted by the state, through the promulgation and implementation of laws that serve as a framework. For example, Puerto Rico, the United States of America, Spain, Costa Rica, Israel and Brazil have established decrees or laws for the adequate control and management of used tyres—the habitual breeding site of the vector in many countries and for which few or no adequate mechanisms exist for final disposal. Experience gained in Brazil is a positive example. In Brazil, the tyre-recycling industry employs more than 20 000 people directly, and involves nearly 15 companies and 21 factories. To date, 18 municipalities in 8 states are promoting tyre recycling. Other models of application of this have been observed such as the creation of artificial reefs (Colombia, Malaysia, Thailand, the Philippines), use of tyres in the cement industry (Brazil, Barbados), and use of tyres in construction, lamination and for exportation. Used tyres also have uses in the construction of athletic fields, as roofing materials, vibration insulation and carpets, among others.

Ecoclubs

Ecoclubs are democratic organizations, with more than 15 000 volunteers distributed in 600 networks around the world (International Network of Ecoclubs, INE²). These networks link actions to various institutions of the community, visualizing an improvement of the quality of life. Ecoclubs promote actions in the health–environment axis, such as strategies for the rational use of water, dengue prevention, and waste management, among other topics. With sensitization campaigns coordinated with other institutions and communities, Ecoclubs involve neighbours via the use of participatory strategies and actions in the implementation of programmes that are characterized by their sustainability and that can be evaluated practically.

These experiences have demonstrated that large budgets are not necessarily needed to implement community programmes for the prevention and control of dengue; it is this philosophy, including different social actors for a common cause that Ecoclubs promote. But management guidance is needed and this is a role that should be played by health workers. However, there still are large gaps in information on the overall impact of the work of these associations.

Other perspectives and new tools for vector control

Integrated vector management

Vector control has mainly relied on the use of chemical insecticides and has not been very successful owing to human, technical, operational, ecological, and economic factors. Problems of insecticide resistance, costs and environmental concerns have resulted in a reduced reliance on insecticides, and an emphasis on the need for other vector control measures involving environmental management,

² Ecoclubs International: <http://www.ecoclubes.org/DENGUE/ingles/dengue.asp>

biological control and personal protection. In addition, the Stockholm Convention on Persistent Organic Pollutants (POPs) adopted in 2001 [32] requires a reduced reliance on, with a goal to eliminate, the use of DDT and other intentionally produced POPs and the promotion of research and development of safe alternative products, methods and strategies. The WHO Global Strategic Framework for Integrated Vector Management provides a basis for strengthening vector control in a manner that is compatible with national health systems [35].

The integrated vector management (IVM) process aims to be effective and efficient. It uses indicators of impact on vector populations and disease transmission, and employs approaches compatible with local health systems. It is also robust enough to allow for effective planning and decision-making to take place at the lowest possible administrative levels (e.g. community level). It encourages a multi-disease and multi-strategy control approach whenever possible, and efficient integration with other disease control measures as well as the application of a range of interventions. Such a commitment requires an approach that effectively integrates the roles of the various sectors, including health, within a strategic management framework. Finally, IVM can also strengthen the rational use of insecticides, increasing their efficiency and impact and for the achievement of the Millennium Goals [37].

IVM has been effectively applied in several regions and steps towards its implementation have been taken in the WHO South-East Asia, Western Pacific, Americas, Eastern Mediterranean and African Regions [37-39]. Good examples of its application have been provided by researchers in Viet Nam [11,34] and in Africa [17]. IVM is based on the premise that effective control is not the sole preserve of the health sector but requires the collaboration of various public and private agencies, and community participation. The engagement of communities is a key factor in assuring sustainability, but further operational research is required to develop surveillance systems that are practical, affordable, effective and acceptable so that community-based IVM can be implemented [33].

Ecohealth approach for dengue control and prevention

The aim of the Ecosystem Approach to Human Health (Ecohealth)³ is to improve community health through a holistic approach to the management of complex socio-ecological ecosystems. The International Development Research Centre (IDRC) of Canada has made an emphasis on assessing the potential of the Ecohealth approach to contribute to the prevention of vector-borne diseases, and more specifically with dengue (Lebel, 2003)

The Ecohealth approach is being supported by the Special Programme for Research and Training in Tropical Diseases (TDR), an independent collaborative programme financed jointly by the United Nations Development Programme (UNDP), the United Nations Children's Fund (UNICEF), World Bank and WHO. With support from IDRC, TDR is applying the Ecohealth approach in two research programmes in South America. Furthermore, the Pan American Health Organization (PAHO) provides support for the implementation of this approach in two projects on dengue in Central America and the Caribbean. These projects are also supported by the United Nations Environment Programme (UNEP). In Guatemala, researchers are developing a 'Community strategy for the reduction of dengue and diarrhoeal diseases in urban ecosystems'; on the border of Guatemala and Mexico the 'Development and validation of a community strategy for the reduction of the risk of dengue and diarrhoea in urban ecosystems' is being carried out; and in the City of Havana, Cuba, a 'model for sustainable development and healthy municipal environments in an approach to ecosystem in human health for the prevention of dengue at the local level' is being tested [13]. In these large agglomerations, many

³ Ecohealth: http://www.idrc.ca/in_focus_health/

groups with diverse interests interact: the private sector, civil society, municipal authorities, different ethnic groups, castes, and social classes, men and women. All play a role in the management of the urban ecosystem.

Integrated Management Strategy for Dengue Prevention and Control (EGI-Dengue)

The Integrated Management Strategy for Dengue Prevention and Control in the Americas (EGI-Dengue) addresses the issue of how to achieve effective programmatic integration of prevention and control actions. This introduces a new form of technical cooperation between PAHO and member countries through the 'dengue task force' (known by its Spanish abbreviation 'GT-Dengue International'). The GT-Dengue task force is a group of technical experts from across the region who, starting with a regional analysis, works with the dengue technical teams in each country to develop a national strategy for integrated operations. From these initial work plans, efforts are made in consultation with other countries to change existing programme practices and implement the new integrated strategy for dengue prevention and control. The new integrated management strategy is horizontal, intersectoral, inter-programmatic, and seeks changes in behaviour at all levels to reduce the risk factors for dengue.

The purpose of this strategy is to achieve a sustainable national strategy that allows a functional integration of actions among its key components (social communication, epidemiological surveillance, entomology, patient care, laboratory and environment), designed by the country with technical cooperation from the GT-Dengue, using a multisectoral, intersectoral, and interdisciplinary (integrated) approach, based on new practices that permit the evaluation and continuity of the activities, with national resources [[21](#)].

The Integrated Management Strategy for Dengue Prevention and Control demands research on new indicators that better measure the risk of transmission, and environmental and behaviour indicators in order to know what the behavioural impact has been. Indicators are also needed to investigate new or modified existing practices both for surveillance (e.g. MosquiTrap, LIRAA), control (e.g. impregnated curtains, dabbed bleach), and management and integration processes that each country prepares using a log-frame matrix (EGI-Dengue).

Communication for Behavioural Impact (COMBI)

COMBI is a novel approach in the design and implementation of behaviourally focused social mobilization and communication actions for the control of communicable diseases. It is a planning methodology for programme managers to prepare, implement and evaluate the social mobilization and communication interventions developed as part of the integrated plans [[16](#)].

The general strategy for preventing and controlling dengue and dengue haemorrhagic fever is based on promoting behaviour changes that lead to involving the community as a partner in controlling the disease, particularly the vector. In order to achieve this, dengue communication programmes should have two primary aims: converting information into practice and working with the community to adopt and maintain appropriate and relevant prevention and control measures. The new generation of programmes should be designed taking into account the local sanitation structure (water distribution and waste disposal) as well as information on community organizations and the roles of different family members. Furthermore, new vector control models should incorporate all ten components of an integrated programme [[22](#)]: epidemiological surveillance, intersectoral actions, community participation, managing the environment and basic services, patient care, case reporting, education, rational use of insecticides and vector control, training, and preparing for emergencies. Communication

should be aimed at supporting positive mosquito-control behaviours among individuals and the community, and their empowerment to identify and carry out community-relevant prevention and control measures.

Geographic information systems

While investigating the spatial patterning of health events and disease outcomes has a long history, the development of geographic information systems (GIS) has facilitated the inclusion of a spatial component in epidemiological and entomological studies. GIS is a computer system that allows the collection, storage, integration, analysis, and display of spatially referenced data. In the field of health, GIS has been widely used for disease mapping of different pathologies, in analysis of space and space-time distributions of disease data, in identifying risk factors, and in mapping risk areas. In most studies, each patient or person exposed to a disease is located at the residential address, and these locations are integrated into GIS for mapping and analysis. Because GIS allows epidemiologists to map environmental factors associated with disease vectors, it has become especially relevant for the surveillance of infectious and vector-borne diseases such as dengue and malaria [[18,30](#)].

Examples of the use of this technology include the geographic analysis conducted for the 2001–2002 outbreak of dengue fever in the state of Hawaii [[30](#)]. In another study, a GIS spatial/temporal analysis depicting the spread of the disease and a spatial dengue threat model (DTM) were created. In addition, GIS case-clustering and mean/median distance comparison analysis of homes in rural and semi-urban areas was conducted. This model may be adapted for use as a predictor in other arbovirus (arthropod-borne virus) outbreaks in various geographic locals.

Rapid Survey Index for *Ae. aegypti* for estimating the Breteau and house indices (LIRAA)

Simpler methods for sampling have been proposed, with the objective of facilitating the acquisition of information that contributes to the evaluation of health-services programmes through the conduct of systematic and periodic research. There are simplified methods to estimate entomological indices, associated with acceptable errors of margin that are also rapid and economical. Such is the example of the Rapid Survey Index for *Ae. aegypti* for estimating Breteau and house indices developed in Brazil (LIRAA in Portuguese). The implementation of this system permits the dengue programme manager to target control measures to the areas of highest risk, thereby permitting better use of human resources and of available materials not only during routine control activities but also in critical periods with higher numbers of cases that might indicate an outbreak. The National Program for the Control of Dengue (PNCD) of Brazil, launched in July 2002 by the Ministry of Health, uses this methodology as a component of epidemiological surveillance [[14](#)].

MosquiTRAP

MosquiTRAP is a novel, simple, easy-to-use, low-cost, and efficient trap developed to catch *Aedes* mosquitoes. It relies on visual cues and synthetic oviposition attractants (AtrAedes), based on volatile substances identified from grass infusions. Compared with ovitraps, the MosquiTRAP allows the identification of mosquito species in the field, thus saving time and avoiding laboratory routines such as counting eggs and larval identification. Trapped mosquitoes can also be used for virus diagnosis. New entomological indices are: (a) the positive MosquiTRAP index (PMI), which is the percentage of positive traps; and (b) the adult density index for *Ae. aegypti* and *Ae. albopictus*. Field data can be collected using hand-held PDAs (personal digital assistants) and then loaded directly into a GIS program, for an efficient determination of local entomological indices. At the moment, a national monitoring programme in Brazil using this technology is being established [[6](#)].

The new technology for the monitoring and generation of indices for entomological surveillance, composed of MosquiTRAP, AtrAedes for oviposition, and a system of computerized monitoring is promising and should be considered for possible future use as results on efficacy and efficiency are published in the literature.

Research and development: observations

Efforts based solely on chemical vector control have been insufficient in modern times. Moreover, evidence demonstrates that educational measures do not modify the behaviours or habits of the population (Texeira et al, 2005). Thus, as a vaccine is not available, further dengue control depends on potential results from basic interdisciplinary research and intervention studies, integrating environmental change, community participation and education, epidemiological and virological surveillance, and strategic technological innovations aimed at stopping transmission. Some examples of these research efforts are:

- The Innovative Vector Control Consortium (IVVC) will address the market for new insecticides by developing a portfolio of chemical and technological tools that will be directly and immediately accessible to populations in the developing world [9].
- Searching for new bioactive, environmentally friendly and biodegradable natural insecticides and repellents, particularly from botanical sources in Thailand, China, Libya, Burkina Fasso, India and other countries [1,2,4,10,25,31].
- *Ae. aegypti* population replacement: A proposed strategy to aid in controlling the growing burden of vector-borne disease is population replacement, in which a natural vector population is replaced by a population with a reduced capacity for disease transmission. Endosymbiotic *Wolbachia* bacteria are potential transgene drivers. Stable infections of wAlbB *Wolbachia* were established in *Ae. aegypti* and caused high rates of cytoplasmic incompatibility (that is, elimination of egg hatching). Laboratory cage tests demonstrated the ability of wAlbB to spread into an *Ae. aegypti* population after seeding of an uninfected population with infected females, reaching infection fixation within seven generations [42].
- A web-based multimedia spatial information system was used to support a study of the re-invasion of *Ae. aegypti* in the deserts of the south-west United States/north-west Mexico. The system was developed by applying open geospatial consortium and worldwide web consortium open specifications and using open source software. The system creates a sensory-rich environment, one that allows users to interact with the system to explore connections among data (maps, remotely sensed images, text, graphs, 360 degree panoramas and photos), visualize information, formulate their own interpretations, generate hypotheses and reach their own conclusions [15].
- Evaluating the practicality of a survey method based on the rationale that certain water containers are particularly productive of the dengue vector, *Ae. aegypti* and whether this can consistently identify and classify particularly productive classes of container, and so provides guidance on the development of targeted control strategies. This was done as study involving nine Latin American, Asian, and African countries [7].

The time has come to restore vector control to its key position in the prevention of disease transmission, albeit with an increased emphasis on multiple measures, which may include use of pesticides and environmental modification, and with a strengthened managerial and operational capacity [29]. Today, prevention and control of dengue require consideration of a wider perspective than simply tropical disease. Many of the affected countries are also some of the poorest. Approaches that are realistic for limited infrastructures need to be urgently developed. A systematic approach and a clear international research agenda can quickly bring forward the frontiers of knowledge. Better

understanding of the above will not only feed into operational policies for dengue control, but also provide fertile terrain for vaccine application strategies in the future. Accelerating the research programme, with emphasis on mechanisms of transmission dynamics, validation and improvement of existing or new vector control methods and their application, partnership building, and formulation of guidelines for research will help in these strategic areas [8].

Based upon and guided by scientific knowledge and operational research, and subject to routine monitoring and evaluation of control activities, the strategies and interventions need to be adapted to local vector ecology, epidemiology and resources. Well-targeted operational research is urgently needed to make progress in dengue prevention and control.

Priority research recommendations for the next five years (2007–2011)

- Assessment of the impact of dengue prevention and control activities that have incorporated the use of new methodological instruments, strategies, technologies etc.
- Investigate potential indicators for risk of transmission with greater sensitivity than the current entomological indicators.
- Development of mathematical prognostic models, geographic or others, which consider different levels of risk of transmission.
- Studies of cost-effectiveness of the new tools, strategies, and instruments being developed and incorporated into programmes.

Conclusions

In this document we have summarized current approaches and the status of recent ideas and technologies that are being tested, in particular in the Americas, in response to the broader question of how dengue prevention and control interventions are currently being delivered and/or developed. Nevertheless, some questions still do not have a conclusive answer:

- What do we expect from vector control services, particularly from vector control inspectors during household visits? Should they continue these visits or does this component need to be changed? Do we need to seek other associations in order to transfer the responsibilities of what they currently do to a more appropriate group locally?
- Can we change the current control services in other ways? How can we work with the population to change attitudes toward control strategies?
- Which are the most cost-effective strategies, comparing traditional vector control with new tools and managerial and organizational strategies? If the new tools are effective, (COMBI, LIRAA, GIS, among others) can they be generalized? What operational research is needed to strengthen vector control service delivery?

We look forward to a rich scientific exchange that will contribute new ideas and knowledge to these issues.

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