REPORT OF THE EIGHTH MEETING OF THE
GLOBAL COLLABORATION FOR DEVELOPMENT
OF PESTICIDES FOR PUBLIC HEALTH

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World Health Organization
REPORT OF THE EIGHTH MEETING OF
THE GLOBAL COLLABORATION FOR
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1. INTRODUCTION

The eighth meeting of the Global Collaboration for Development of Pesticides for Public Health was held at the headquarters of the World Health Organization (WHO) in Geneva, Switzerland, on 20–21 February 2012. The theme of the meeting was surveillance and management of dengue vectors.

Dr Hiroki Nakatani, WHO Assistant Director-General, HIV/AIDS, Tuberculosis, Malaria and Neglected Tropical Diseases, opened the meeting by referring to neglected tropical diseases as medically diverse yet sharing common features because all are strongly associated with poverty, all flourish in impoverished environments and all thrive best in tropical areas, where they tend to co-exist. Control of neglected tropical diseases has become a show case for goodwill by offering health to the poorest of the poor in the many countries where these diseases are endemic and which collectively kill about half a million people every year. Neglected tropical diseases are a challenge to achieving United Nations Millennium Development Goal 6 (combating HIV/AIDS, malaria and other diseases) and are closely linked with goal 1 (eradicating extreme poverty and hunger) and other goals for universal education, empowerment of women and safe drinking-water. A meeting held in London, United Kingdom, on 30 January 2012, on uniting to combat neglected tropical diseases was inspired by the WHO roadmap on accelerating work to overcome these diseases.1 The world is now alerted to the importance of neglected tropical diseases, and donors are committed to accelerating work to eliminate or eventually eradicate them. WHO has produced overwhelming evidence to show that many of the 17 neglected tropical diseases in the roadmap, which affect more than 1 billion people worldwide, can be controlled and, in many cases, eliminated or even eradicated.

Dengue, one of the 17 diseases targeted in the roadmap, can be controlled provided that surveillance, data reporting, cross-border information exchange, case management and hospital

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care are significantly improved and sustainable vector control measures are implemented through principles of integrated vector and disease management.

The conclusions and recommendations of the meeting would be taken to the back-to-back WHO Consultation on dengue prevention and control (22–24 February 2012) in order to refine WHO’s strategy for dengue control. Prevention and control of the disease require long-term political and financial commitment and the full engagement of countries.

In his opening remarks, Dr Lorenzo Savioli, Director, WHO Department of Control of Neglected Tropical Diseases, referred to dengue control as one of the Organization’s priorities. Dengue affects millions of people worldwide and is endemic in more than 100 countries. In 2010, all six WHO regions recorded cases of the disease, and indigenous outbreaks were reported for the first time in the European Region. WHO estimates that more than 50 million cases of dengue occur annually.

Dr Morteza Zaim, Coordinator, WHO Vector Ecology and Management, introduced the objectives of the meeting as follows:

To review the evidence on effective dengue vector control interventions (both during outbreaks and as sustained control interventions in endemic countries).
To gather more evidence on innovative technologies in the pipeline.
To review the integrated vector management (IVM) approach to dengue management, including integrated vector and case surveillance.
To recognize the role of vector control in an integrated programme before and after the introduction of a dengue vaccine.
To identify and acknowledge the role of partners in dengue control.

The meeting was convened in plenary sessions (Annex 1) and attended by representatives of industry, national and government supported agencies and national programmes, the Bill & Melinda Gates Foundation, regional and international
organizations, universities and research institutions, WHO temporary advisers and members of the WHO Secretariat (Annex 2). Dr Ronald Rosenberg was appointed as the Chairman and Dr Paul Reiter as the Rapporteur of the meeting.

2. DENGUE AS AN EXPANDING PUBLIC HEALTH PROBLEM

Dr Ronald Rosenberg, Associate Director for Science, United States Centers for Disease Control and Prevention, gave the keynote speech of the meeting. About one billion people are at significant risk of dengue virus infection and more than 50 million people are infected annually. There is a sense that both the range and the intensity of transmission continue to increase, although verification is difficult. Conditions that favour transmission – urbanization, lack of adequate water supply and climate change – are increasing. The most common vectors of dengue (Aedes aegypti and Aedes albopictus) are widely distributed mosquitoes that have adapted to human domestication. The discovery, after 75 years, of persistent dengue transmission in Florida, suggests that areas of even developed countries can be at risk. During 2010, more than 20 000 dengue cases were confirmed in Puerto Rico – estimated as representing more than 100 000 unreported cases out of a population of just 4 million – as part of an apparent El Niño-related surge of cases in Asia and Latin America.

A confounding factor in dengue transmission – and a particular complication in vaccine development – is that the disease is caused by four closely related but distinct viruses, often referred to as serotypes 1–4. Immunity to one virus does not protect an individual or a population against epidemic infection with another virus, and reinfection increases the incidence of dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS), the most serious forms of the disease. Dengue haemorrhagic fever is now common in South America and the Caribbean, where it had been almost absent 50 years ago. Although most closely associated with South-East Asia and the western hemisphere, the occurrence of dengue in Africa, where it apparently originated, is often overlooked. In part this might be because dengue fever is masked by co-occurring febrile
illnesses, such as malaria. The recent experience of African peacekeepers in Somalia, in whom dengue incidence among those reporting with acute fever exceeded 50%, suggests more attention to dengue in Africa should be paid.

The main challenge is prevention and suppression of the disease. In the absence of a vaccine, vector control remains the only method for prevention. The most common method of vector control has been source reduction (that is, the removal of places where the mosquito can lay eggs). Although theoretically this method seems ideal, in practice its success has been difficult to maintain. Human compliance is essential, and human behaviour is difficult to modify. Tools that can compensate for community shortcomings have been limited to insecticides. This might now be changing. Several innovative methods for vector control are being tested, including several that exploit the vector genome, such as sterile insect release and the introduction of Wolbachia. An added value is that reduction of the population of Aedes reduces not only the risk of dengue but also that of other arboviruses, such as yellow fever and chikungunya.

The prospects for a vaccine are high. There are a number of vaccine prototypes in various stages of development, and several in clinical trials. A successful vaccine must be efficacious against all four dengue viruses, which has been a pharmaceutical challenge. Ideally, the vaccine should also have long-term efficacy and be initially administered as a single dose. At least 9 candidate vaccines are in development, including 5 already in or entering clinical trials. It will likely be some years until it is known how closely any of the vaccine candidates meet those ideals. The farthest advanced, from Sanofi-Pasteur, is expected to enter Phase III trials in 2012 but its optimum dosage will probably be three immunizations over 12 months. The characteristics of administration and price will greatly influence the acceptability of a vaccine to immunization programmes and possibly limit the implementation of a sufficiently immunogenic candidate. What does seem certain is that at least one vaccine will be available within the next 10 years.
It might be thought that the availability of a vaccine will supplant the need for vector control. The opposite will be true. Effective vaccine coverage is inevitably much less than hoped for. This is true even for highly immunogenic, long-lasting vaccines such as those for poliovirus and measles and is especially true for the zoonoses. The availability of the 17D yellow fever virus vaccine since 1937 has reduced the severity of epidemics but not stopped them, as recent events in Paraguay and Uganda show. Dengue, like yellow fever, has a monkey reservoir, but affects many more people in a much broader geographical area. It is not too early to examine how theoretically a vaccine could be used in concert with vector control to reduce – or even eliminate, where transmission is less intense – dengue in some areas. In general, the lower the basic reproduction rate ($R_0$) the greater the probability that the introduction of a vaccine will effectively eliminate transmission. Vector control will play a critical role in lowering transmission to a level that makes implementation of a vaccine successful; conversely, use of a vaccine will lower transmission levels to those where vector control will be more efficacious.

Vector control urgently needs both new methods and new ways of implementing existing methods if it is to take advantage of the opportunity vaccines offer. Better indices are needed to measure effect. There are still hardly any data on how vector control affects incidence of the disease, the only meaningful measure of efficacy. The usefulness of some widely used methods, such as ultra low volume fogging, in epidemic suppression remains debatable. Costs of sustainable vector control are a major hindrance to poorly financed ministries and the development of commercial products that appeal to the at-risk population, such as insecticide treated nets for malaria, which could expand the range of control, as would the potential of some relatively low-cost community-independent measures such as genetically modified *Aedes*.

The advent of vaccines should rejuvenate interest in vector control, and it is imperative that the vector control community prepare for a changed situation.
3. DENGUE PREVENTION AND CONTROL: CHALLENGES, OBSTACLES AND WAY FORWARD – NATIONAL PERSPECTIVES

Brazil
Dr Giovanini Evelim Coelho, Coordinator, National Programme for Control of Dengue, Ministry of Health, Brazil, informed the meeting that dengue fever is one of the most challenging public health problems in Brazil due to the complexity of urban areas, the changing epidemiology, the resistance of Aedes spp. to insecticides, and the difficulties of implementing prevention and control activities.

A National Sanitation Survey conducted in 2008 in 5564 municipalities showed a lack of basic sanitation infrastructure in several of them: two of the indicators highlighted favourable conditions for Ae. aegypti breeding sites from potable water rationing (23%) and daily waste collection (39%). These infrastructure problems contribute to the dispersion of the vector throughout the country (all 27 states). According to the entomological surveillance data collected by local health authorities, the number of municipalities infested with Ae. aegypti increased from 1753 to around 4000 during 1996–2009. Another determinant of the wide dispersion of the vector is the mosquito resistance to organophosphate insecticides. Routine monitoring of 100 municipalities in different areas of the country showed evidence for resistance and the need to replace insecticides in use with effective ones. These results were observed in the main metropolitan areas of the country, which account for a major part of the population.

The dengue burden in Brazil is escalating, with an increased number of severe cases being observed during the past decade. The predominating virus serotype varied from DEN-3 (2002–2007), DEN-2 (2007–2009) and DEN-1 (2009–2011). This shift in the serotypes led to large dengue outbreaks throughout this period. This shift was also followed by changes in the disease epidemiology, with an increase in severe cases (DEN-3), a shift in disease severity to children (DEN-2) and deaths associated with coinfection (DEN-1). More than 1 million probable cases were observed in 2010 and the number
of dengue deaths has remained higher than malaria deaths in the country since 2002.

In response to the trends observed in the epidemiology of the disease, the Ministry of Health initiated new activities to improve dengue prevention in the country. The National Dengue Control Programme is based on the need to improve the quality of field activities aimed at vector control and strengthening of epidemiological and entomological surveillance, focusing on early detection of outbreaks and identification of risk areas.

The diversity of geographical and environmental characteristics associated with differences in the local organization of the health system in Brazil pose another challenge for the implementation of strategies to improve the effectiveness of vector control activities. Due to these difficulties, the adoption of new technologies by the National Dengue Control Programme is based on evaluation of simplicity and large-scale reproducibility.

The Government of Brazil has supported different initiatives, some still in the evaluation phase, to determine their usefulness in routine dengue prevention activities. The use of adult mosquito traps and introduction of new insecticides or larvicides, including different delivery systems, are part of this effort.

**China**

Dr Qiyong Liu, Professor and Director of the Department of Vector Biology and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, briefed the meeting on dengue prevention and control activities in China, where dengue-like illness occurred as early as 992 AD. In 1871, dengue epidemics were recorded in Xiamen, a port city of Fujian province. The first confirmed dengue fever outbreak occurred in 1978 in Foshan, Guangdong province, and was caused by DEN-4 virus. From 1978 to 2010, 688,000 cases of dengue fever and 507 deaths were reported. All four serotypes have been reported from confirmed dengue cases. A serious risk for imported cases also exists, with the distribution of outbreak points in the southeast coast and the border areas of Yunnan. Outbreaks of dengue
fever are spreading further north, as evident by an outbreak in Zhejiang province in 2009. However, no sufficient evidence supports its endemcity in the country. Today, dengue is a Type B notifiable infectious disease according to the law of the People's Republic of China on prevention and control of communicable diseases.

Dengue virus is transmitted through the bite of *Aedes* mosquitoes, most commonly *Ae. albopictus*. Both *Ae. aegypti* and *Ae. albopictus* exist in China, while *Ae. albopictus* has a wider geographical distribution. *Ae. albopictus*, known as the Asian tiger mosquito, is the most important vector of dengue virus in China. Given its ability to withstand low temperatures, *Ae. albopictus* occupies a wider north–south geographical range than *Ae. aegypti*. Additionally, spatial expansion has been reported recently and is likely due to global climate change and a changing social-economic landscape. Many Chinese provinces are endemic for *Ae. albopictus*, mostly in areas south of 30 ° latitude. In 2010, the China CDC also reported distribution of *Ae. albopictus* in north-western China after collecting specimens in 33 urban and rural areas in NE provinces. Thus, a larger population is now threatened by dengue fever. Although most of the outbreaks in China can be traced to imported cases, concerns are increasing about whether dengue fever is endemic in some areas of China specifically, Guangdong province.

The systematic surveillance of dengue viruses and their vectors occurs throughout China. Based on these data, government agencies developed health education, mosquito control and other related interventions for dengue prevention and control. Compared to the 1980s and 1990s, the incidence rate was mitigated in 2000–2010. The incidence of dengue has remained stable in recent years. However, some large outbreaks were reported every four to six years. Recently, dengue outbreaks have also shifted to the more northern regions such as Cixi and Jinhua in Zhejiang province.

Unplanned urban growth, increasing urban construction, migrant populations, and deficiencies in water supply and urban cleaning favour proliferation of the vector mosquitoes, and generate major challenges in dengue prevention and control.
Globalization also leads to more international contact and travel. Exchange in population and goods increases the risk of imported dengue especially in coastal cities, thus increasing the domestic spread of the disease.

Unsustainable mosquito control, disease surveillance, diagnosis and control of dengue epidemics in places where epidemics are relatively new are of concern. For example, implementation of control programmes is reduced during non-epidemic periods. There are generally peak intervals of dengue prevalence every several years in Guangdong province. During the years with zero or few cases, vector control is often neglected. Halting or reduction of control programmes also occurs during the winter season, despite peak prevalence in the summer. With several years of little or no vector control, the density of mosquitoes can increase sharply and remain sustained at a high level. Thus, once imported cases of dengue are introduced, outbreaks of dengue fever are inevitable. Mosquito control during the winter could have a multiplying effect. Furthermore, specific operations should be implemented to inform public officials about dengue fever, to mobilize resources, and to enhance public awareness with the goal that these efforts and investments will control the vector, and ultimately control dengue fever.

The main goal of dengue control in China should be timely detection of epidemics, prevention and control of index and early cases to prevent large-scale outbreaks and to minimize the effects of epidemics. China has a sustainable dengue control strategy with close monitoring, which is in line with the WHO Global Strategic Framework for IVM published in 2004. Monitoring includes and is strengthened by control of mosquito vector density, high vigilance for imported dengue cases, improvement of diagnosis and case management, enhancing cooperation among different public health departments, and mobilizing social effort to combat epidemics. Other objectives include increasing capacity for early detection and early response to dengue outbreaks, and advanced prediction of future epidemics. To address these programmatic issues and gaps that require new or improved tools for effective dengue prevention and control, China has instituted community
participation, model development, social mobilization, health education, intersectoral coordination and legislative support.

The Government of China has carried out sustainable management around IVM, which aims to improve efficacy, cost effectiveness, ecological soundness and sustainability. China has a large land area. The Chinese government has drawn up a hierarchical risk control plan for different parts of the country; monitoring for early disease is the fundamental need throughout the country, followed by diagnosis and case management. In high-risk areas, however, monitoring of the disease, warning analysis and vector management should be carried out sustainably from epidemic season to non-epidemic season. In areas with moderate risk, both case-oriented vector control and vector surveillance in higher risk areas should be enforced. In low-risk endemic areas, only case-oriented vector control is needed. The last level is the absence of endemic risk areas, where only case management is necessary.

The implementation of top-down communication strategies with intersectoral collaboration is successful within the IVM framework. Communities, and related units, and even local people can participate in elimination of the vector.

Despite the growing threat from dengue, resources for its control have not increased. National support continues to fall short of the need, even though there are untapped resources at the national and regional levels. To mobilize additional resources, synchronized action is needed with support from partners and stakeholders. Prevention and control efforts will be successful only if they become everyone’s concern and responsibility. Sustained action is required at the individual, family and community levels. Prevention and control have to be supported by the local self-government and the national government through the involvement of the health and other relevant sectors. Communication and co-action with inter-ministerial leadership and support of WHO are needed. Only with the development of intersectoral collaborations in the delivery of dengue vector control will dengue prevention and control efforts be successful.
**Indonesia**

Dr Darmawali Handoko, Ministry of Health, Indonesia, informed the meeting that the Indonesian archipelago consists of 17 508 islands with 33 provinces and 447 districts or municipalities. The estimated population in 2011 was 237.6 million. Dengue was first reported in Indonesia in 1968 (Jakarta and Surabaya) with very high case fatality rate (CFR) of >41.3% (58 cases with 24 deaths). The first dengue epidemic outside of Java occurred in 1972 in Sumatra (West Sumatra and Lampung), in 1973 on Sulawesi (North Sulawesi) and Bali, and in 1974 on Kalimantan (South Kalimantan) and Nusa Tenggara; dengue has affected all provinces in Indonesia since 1997.

In 2011, there were 58 065 cases with 504 deaths. The morbidity (incidence) rate is 24.44/100 000 population (CFR 0.87%). The five provinces with the highest morbidity rate are Bali (81.08), DKI Jakarta (78.19), Aceh (53.66), Riau Islands (49.70) and Central Sulawesi (47.27). However, the highest CFR was reported in Gorontalo (4.55), Banten (2.70), East Nusa Tenggara (2.41), South Kalimantan (2.35) and Riau (2.28). The CFR was static during 2010 (0.87%) and 2011; however, the incidence rate has reduced significantly from 65.57 (2010) to 24.44 (2011). Most dengue cases are in people aged >15 years (55.1%); however, most deaths were among the age groups 10–14 years (26.1%) and >15 years (26.1%).

Dengue is one of the most important public health problems in Indonesia. The National Dengue Control Programme strategy is based on the WHO Global Strategy.¹ This includes integrated vector control through community participation; prompt case management and diagnosis; strengthening case and vector surveillance; outbreak preparedness and response; partnership empowerment; and capacity building, training and surveys or research.

Dr Handoka noted the increasing trend in cases and outbreaks. DHF has been reported from most provinces. Efforts to control

Dengue include community or intersectoral participation using integrated vector management, active surveillance, emergency preparedness, capacity building, trainings and operational research in vector control. An external evaluation of dengue control programme was made in 2002 and again in February 2011, which generated recommendations that have been implemented.

National dialogue on dengue was conducted by the ministries of health and internal affairs on 14 June 2011 and was attended by local government representatives, where the National Declaration for Dengue Prevention and Control was made.

The Ministry of Health in collaboration with WHO and the Association of Southeast Asian Nations (ASEAN) launched the first ASEAN Dengue Day in Jakarta on 15 June 2011, attended by ASEAN countries and WHO delegations, to promote the “Jakarta Call for Action” urging all ASEAN countries to combat dengue.

Despite the achievements in dengue prevention and control, challenges include: no specific drug and vaccine; low community participation; high CFR in several districts; inadequate surveillance; and limited budgeting/ funding support. In order to further reduce CFR and incidence rates, the national dengue control programme has formulated a 2-year plan for 2012–2013, which includes training on dengue programme management for district managers from high-incidence districts; training on dengue case management for physicians, paediatricians and interns from districts with high CFR; distributing rapid diagnostic test kits to local health centres and hospitals and improving surveillance; and virus mapping to strengthen the surveillance system.

**Saudi Arabia**

Professor Ziad A. Memish, Assistant Deputy Minister for Preventive Medicine, Ministry of Health, Riyadh, briefed the meeting on challenges and obstacles for prevention and control of dengue in Saudi Arabia. Dengue fever was reported in Jeddah in 1993 with a consequent epidemic in 1994, in which 289 confirmed cases were reported. As a result of this
outbreak, the Ministry of Health and all hospitals in the country were alerted and advised to report suspected cases of DHF.

There has been a rapid decrease in the number of reported cases for almost a decade. From 1995 to 2003, reported cases ranged between 0 and 36 cases per year. Dengue resurged in 2004 in Jeddah (291 cases) and in Makkah (222 confirmed cases). In 2006, another outbreak was reported in Jeddah and the number of cases reported continues to date. There were also cases detected in Jazan region in the south. In 2006, a total of 1544 confirmed dengue cases was reported: 1308 in Jeddah, 199 in Makkah, 29 in Jazan, 7 in Madinah and 1 in Najran.

In response to this situation, Royal Decree Number 36 was issued on 13 March 2006, whereby each ministry concerned (Ministry of Health, Ministry of Municipal and Rural Affairs, Ministry of Agriculture and Ministry of Finance) was assigned a role in dengue control and prevention. A comprehensive control plan was established by the concerned parties, consisting of disease surveillance and case management, vector inspection and control and health education. All sectors of the community were engaged in an intensively coordinated work to control and eradicate all possible breeding sites for dengue vector mosquitoes.

As a result of these measures, in 2007 the number of cases decreased to 490 (243 in Jeddah, 182 in Makkah, 61 in Jazan and 3 in Najran) but started to increase subsequently. According to the disease pattern in the kingdom, dengue cases begin to increase during February and March, and peak in Makkah and Jazan during April and May. In Jeddah, the number of cases peaks during May and June, and occasionally in July. Cases decrease at the end of July or sometimes in August.

There are many contributing factors to the resurgence of dengue fever, such as the presence of *Ae. aegypti* in high density, ineffective mosquito control efforts, rapid growth of cities leading to overcrowding, urban decay, and substandard sanitation; allowing more mosquitoes to live closer to more people with diverse cultures (of which some have poor habits of
collecting water in exposed containers that attracts a good environment to the vector), the potential spread of eggs of Ae. aegypti due to the presence of exposed solid waste collecting drums, old plastic water drums, tires, and public water storage tanks, increased air travel that gets people infected with dengue viruses which are then transferred easily from one city to another.

In response to the recent remarkable increase in the number of cases, a subcommittee to the Ministerial Committee was established in 2011, with the objective of following up the plan for the control of disease vectors and monitoring its execution. Although the control measures have been performed according to the plan, the epidemic pattern of the disease has shown variation in the number of cases reported weekly.

**Singapore**
Dr Lee Kim-Sung, Programme Head for Vector Borne Diseases, Environmental Health Institute of Singapore, explained the principles of dengue vector control in the national programme, which largely targets Ae. aegypti. The strategies are based on an understanding of the epidemiology of the target disease, the ecology and bionomics of its vector and technologies offered by disciplines such as informatics and molecular biology.

The urban and peridomestic habitats of Ae. aegypti offer an opportunity to suppress the vector population through careful environmental management and urban planning. In Singapore, the programme is supported by legislation that penalizes households and commercial entities found with mosquito breeding sites. A team of trained health officers performs regular house-to-house checks. The premise Aedes index was reduced from about 50% in the 1960s to less than 5% by the mid-1970s. Along with the plummeting premise index, the incidence rate of dengue decreased significantly. Transmission has resurged since the 1980s and an unprecedented outbreak in 2005 caused 14 006 cases. It has been postulated that the resurgence was due to factors such as an increase in human population and density, increase in international and local travel, and low herd immunity resulting from low transmission for more than a decade. In response to the 2005 outbreak, a thorough review of the system has revealed its failure to evolve
with the changing environment and society. Population in Singapore grew from 2.1 million in 1970 to 5 million by 2009, making the arduous house-to-house check unsustainable. In 2009, 18 million passengers arrived by air, a dramatic increase from the 1.7 million recorded in 1970. Locally, the construction of the first expressway was initiated in 1966 and the first operation of the mass rapid transport system in 1987. These developments favoured propagation of *Aedes* mosquitoes, frequent importation and rapid dispersal of dengue viruses within the country, all of which contribute to the increased human–vector contact.

Singapore’s mosquito control programme has been maintained as an integrated one that includes environmental management, source reduction of breeding areas, regular mosquito surveillance, routine larviciding in breeding areas that cannot be eliminated and adulticiding only when necessary. A preventive mosquito control programme is complemented with outbreak control measures. To address the increasing challenge of dengue, Singapore’s vector control programme has been enhanced since 2005. A novel feature is the incorporation of a decision support system that is built on four cornerstones – case-, viral- and entomological surveillance, and ecological information. Surveillance and ecological data are used for temporal and spatial risk stratification, which forms the core of the decision support system and facilitates optimal use of resources in time and space.

In the enhanced system, ambient temperature and circulating serotypes are monitored weekly for early warning of outbreaks or increased transmission. More intensive control measures are triggered by early warning signs (temperature and serotype switch). In 2007, an early warning provided by these surveillance data, 6 months ahead of an outbreak, likely contributed to the moderate size of the outbreak. Risk of transmission is also spatially stratified using geographical information system. Factors that are taken into consideration include the predominant virus serotype in circulation, previous exposures of the human population to the different serotypes, *Aedes* population, vegetation index (negatively correlated), age of buildings and population density.
Singapore has focused attention on vector control during annual inter-epidemic periods, to reduce the Aedes population and the human reservoir (number of cases) before the usual dengue season. The spatial and temporal risk assessment has allowed enhanced preventive vector control measures to be targeted before any onset of outbreaks.

The new strategies have effected a reduction in annual dengue cases; particularly noticeable is the suppression of the traditional high peaks, which usually occur during the warmer months (June–August). The Singapore situation shows that a strategy can become obsolete, superseded by changes in the environment and the demography; and that there is need for constant updating of disease epidemiology and technologies for an effective evidence-based control programme.

In Singapore, vector control function resides with the environment sector, rather than the health sector. Surveillance of vector-borne diseases is a part of the national disease surveillance programme at the Ministry of Health. Daily communication of surveillance data enables prompt vector control response from the National Environment Agency. Through a coordinated inter-agency task force, vector control has also become an important agenda of each government agency. Together with community involvement and a pest control industry that supports the national vector control effort, IVM in Singapore is aligned with the whole government effort in establishing public, private and people (3P) partnerships to develop innovative and sustainable environmental initiatives that promote environmental ownership among the local community. Through coordination between ground vector control and laboratory case and virus surveillance, the ground effort is guided by scientific evidence. There are many stakeholders for the control of vectors and the associated diseases, and communication among them with elements of feedback and data sharing is constantly being improved. Success in controlling chikungunya (transmitted by Ae. albopictus) and malaria (transmitted by Anopheles) demonstrates how a small modification of the same system according to the bionomics of various vectors can be adapted to control other mosquito-borne diseases.
The factors that contribute to Singapore's challenges in dengue control in past decades are increasing population and mobility. The cases or outbreak averted due to preventive measures reduce herd immunity and may increase susceptibility of the population to dengue outbreaks. It underscores the need for sustained and perhaps increasingly effective vector control efforts. Success would hinge on a global or regional concerted effort, to reduce the level of transmission in the region, which in turn could reduce the exchanges of viruses and further spread of the vectors. Unfortunately, today’s vector control approaches are labour intensive, monotonous and dependent on individuals’ competence. Constant advocacy and educational efforts that target all stakeholders are essential for a fruitful programme. The challenge of insecticide resistance, though not obvious currently, is also looming large.

High transmission of viruses leads to genetic diversity. It offers the virus ample opportunities to improve its fitness and to adapt, resulting in viruses with high epidemic potential. This phenomenon is evident in Singapore’s epidemiology, where a new clade of DEN2 has been found to have a shorter extrinsic incubation period in local Aedes species. Viruses and vectors continue to evolve, occasionally with formations of new partnerships and with increased fitness. Vector control will thus remain as a pursuit of solutions to the evolving epidemiology of pathogens. Breakthroughs are wanting, and the community must support the development of novel tools such as release of insects carrying a dominant lethal gene and Wolbachia-infected Aedes.

4. DISCUSSION

The meeting discussed the issues raised by the above-mentioned speakers and addressed the challenges and obstacles to dengue prevention and control. These included:

- While it is important to foster innovation in new tools and technologies, political commitment and international support are critical to the success of global efforts to halt the spread and outbreaks of dengue and to reduce its
burden. Development of a global dengue control strategy by WHO is timely and most welcome.

- A shift is needed from reactive programmes to long-term prevention strategies against dengue that are proactive and based on forward planning.

- Vector control will continue to play an important role in controlling transmission of dengue. Availability of vaccine in the near future will not replace the need for vector control as seen in the cases of yellow fever and Japanese encephalitis control using immunizations. Vector control will be essential to reduce dengue transmission and to contribute to the success of vaccine; similarly, use of a vaccine could lower transmission to such levels where vector control will potentially be more efficacious.

- Intersectoral collaboration is essential to ensure proper management of waste and provision of safe water. An integrated disease control approach, especially with malaria programmes, will ensure optimal use of resources.

- Estimating the true burden of dengue remains a major challenge. Metrics for monitoring performance and for surveillance and assessment need to be established. More reliable, practical and standardized methods for vector surveillance need to be developed.

- Strong action through the International Health Regulations is needed to halt the spread of dengue within and among countries.

- There is need for improved modeling of the interplay between acceptable levels of vector control and acceptable coverage of vaccine and to closely monitor the impact of immunity on the dynamics of viral transmission, disease outcomes and effectiveness of vector control.
- Inadequate advocacy and education across diverse sectors have created favourable conditions for proliferation of dengue vectors.

- Further studies are required on the biology and ecology of dengue vectors in different eco-epidemiological settings in order to better understand disease transmission, particularly the impact of climate change on dengue transmission.

- Efficacy and effectiveness of dengue vector control interventions on disease transmission, including those of community-based interventions and use of biological control agents, should be better documented. Entomological correlates of virus transmission (e.g., entomological inoculation rate) should be determined. Lack of correlation between vector control interventions and disease transmission may also be due to the challenge of lack of a suitable methodology to measure disease transmission and estimate the true burden of the disease.

- Operational research and routine monitoring and evaluation of vector control interventions should inform planning for dengue prevention and control. However, in most endemic countries, necessary capacity for these purposes is inadequate, which poses greater obstacles especially in the decentralised health systems.

- Risk assessment or stratification is a crucial component of integrated dengue surveillance. Timely detection of the risk and prompt response are critical to successful prevention and control of epidemics. There is a need to enhance capacity in countries for vector surveillance and monitoring of insecticide resistance.

5. CURRENT STATUS OF VECTOR CONTROL FOR DENGUE PREVENTION AND OUTBREAK CONTROL

Dr Philip McCall, Everett-Dutton Reader in Medical Entomology, Liverpool School of Tropical Medicine, presented a review of
dengue vector control interventions. Of the major vector-borne
diseases, dengue remains unique because its prevention
depends entirely on vector control. To date, the most widely
used method to prevent dengue outbreaks is attacking the
mosquito’s breeding sites, often called source reduction:
elimination of vector breeding sites where possible, and
larviciding of those that cannot be eliminated. Prevention is
usually carried out together with education, community
involvement and mass media campaigns. Such vector control
programmes are effective when they use an integrated vector
management approach,1 but deficiencies in capacity, standards,
budgets and community engagement are serious limitations.2
Thus outbreaks continue to occur, even in areas where such
prevention methods have been undertaken for many years,
though potentially at lower intensities and frequencies than in
the absence of any vector control.

The most common response to an outbreak is to space-spray
with insecticide, which is typically delivered outside houses on a
street-by-street basis. This intervention has limited, if any,
impact on dengue transmission.3,4 However, when carried out
indoors, it can reduce rapidly the adult vector population, as
well as providing some residual effect, protecting those in the
house over the following weeks. A major limitation is that
indoor house treatments are labour-intensive and, in most
locations, they are not a feasible rapid response to an outbreak.
With the global spread of dengue and the increase in the
numbers of cases reported annually showing no signs of

1 Erlanger TE et al. Effect of dengue vector control interventions on
entomological parameters in developing countries: systematic review
and meta-analysis. Medical and Veterinary Entomology, 2008,
22:203–221.
2 Horstick O et al. Dengue vector-control services: how do they work?
A systematic literature review and country case studies. Transactions
of the Royal Society of Tropical Medicine and Hygiene, 2009,
104:379–386.
3 Pilger D et al. Dengue outbreak response: documented effective
interventions and evidence gaps. Tropika Reviews, 2009
(www.tropika.net).
4 Esu E et al. Effectiveness of peridomestic space spraying with
insecticide on dengue transmission; systematic review. Tropical
slowing, the need for a suite of proven effective vector control strategies, suitable for the range of contexts in which dengue is transmitted, has never been greater, particularly for the vast urban communities where dengue outbreaks occur today.

Effective vector control exploits the vector’s natural history in a way that requires minimal behavioural change by disease-endemic communities while being highly acceptable to them, to deliver a low-risk, low-cost, sustainable impact on the vector population such that infection, morbidity and/or mortality rates are reduced in the human population. *Aedes aegypti* is a highly synanthropic vector that has proliferated within the man-made urban environment and, partly because it is diurnally active, has proven remarkably difficult to control. Effective methods that target the adult mosquito have the potential to impact on dengue transmission as well as vector population size, and are urgently needed.

A number of new approaches are being evaluated. These include the use of insecticide-treated materials (ITMs) and genetically modified mosquitoes (GM *Aedes*). ITMs are commonly used as insecticide-treated curtains hung in windows, doorways, corridors, cupboards, wardrobes or room dividers, or insecticide-treated water container or jar covers, fitted to large domestic water storage barrels. Early trials in Latin America indicated they could reduce dengue vector populations. More recently completed trials indicate that ITMs are well accepted by target communities and can impact significantly on vector populations, but only when local conditions (e.g. house structure, vector breeding sites, human behaviour) are favourable. ITMs offer a solution to the challenge of implementing indoor treatments in large populations, since their use is not dependent on vertical programmes. Whether they affect dengue transmission, when used alone or in combination with other approaches, has yet to be proven.

The first of the long-awaited approaches arising from molecular genetic studies of vectors is nearing fruition: the first field trials involving release of GM or *Wolbachia*-infected *Aedes aegypti* have taken place already. Larger trials are already under way or planned, although the design of controlled trials to measure
the efficacy of these types of interventions remains problematic. Initial results are promising, but in addition to the technical challenges and questions surrounding cost and sustainability, issues remain regarding the perceptions, understanding and confidence surrounding such releases, both in the scientific community and among the public, in target and donor countries.

While no individual approach offers a single, simple vector control solution, a number of these methods can impact on dengue vector populations when used in combination within integrated or community-based programmes. However, the magnitude of their impact on dengue cases or morbidity is unknown. Consequently, evaluation of the impact on dengue transmission or dengue infections by the most promising intervention tools remains a top priority.

Filling important knowledge gaps, such as more reliable indices for adult vector mosquito infestation or biting rates, and quantifying dengue virus infection rates in the vector, would increase the power and reliability of these studies. The development of tools to measure these indices and of affordable and reliable rapid diagnostic tests for dengue infections in the human population will enable the effectiveness of vector control to be measured accurately.

6. COST OF ROUTINE DENGUE VECTOR CONTROL

Dr Patrick Van der Stuyft\textsuperscript{1} of the Institute of Tropical Medicine, Antwerp, Belgium, made a comprehensive presentation on the cost of routine dengue vector control. Dengue inflicts significant health, economic and social burdens on the populations of endemic areas. The global annual disease burden is estimated at 750,000 disability-adjusted life-years (DALYs) lost. For Latin America and the Caribbean, estimates vary from 87 to 658 DALYs/year per million inhabitants and for South-East Asia from 243 to 732 DALYs/year per million inhabitants.

\textsuperscript{1} A presentation jointly prepared by V. Vanlerberghe\textsuperscript{1}, A. Baly\textsuperscript{1,2} and P. Van der Stuyft\textsuperscript{1} (\textsuperscript{1}Institute of Tropical Medicine, Department of Public Health, Antwerp, Belgium; \textsuperscript{2}Instituto de Medicina Tropical Pedro Kouri, La Habana, Cuba).
In the Americas, the total annual cost of dengue has been estimated (averaged over the period 2000–2007) at US$ 2.1 billion (range 1–4 billion) for case management (a cost per capita of at least US$ 2) and at US$ 331 and US$ 671 million for vector control, in 1996 and 1997, respectively (over US$ 0.7 per capita). In South-East Asia, estimates are only available for a few countries. Cambodia reported for case management and disease control a total annual cost of US$ 3.3 to 14.4 million (US$ 1.0 to 4.4 per capita) in 2008 and 2007 (an epidemic year) respectively, of which 15% and 3% respectively were for vector control. Thailand estimated in 2010 a total annual cost of US$ 158 million (US$ 3.55 per capita) of which 28% was for vector control.

During epidemics, the total cost, including case management and vector control, can be very high. For example, in Cuba in 1981 the cost of controlling an epidemic was US$ 103.2 million (about US$ 10 per capita), while in 2005 in Panama the cost was US$ 16.9 million (US$ 5.22 per capita), of which 42% and 38% respectively were for vector control.

Precise, reliable, comparable and detailed data on the total expenditure for dengue vector control are hard to find in the literature. Often, Aedes control programmes are integrated in general vector-borne disease control programmes (covering, for example, vectors of dengue, malaria, Chagas disease) and/or they operate only or mainly in response to real or perceived emergencies. Expenditure from nationally mobilized funds or from donations can then be very high, while few resources are made available for routine operations. Comparability is further compromised by variability in dengue epidemiology, considerable differences in control programme structure and activity mix, and huge differences in attained coverage. A few existing older reports on routine costs for dengue vector control at national level have only little relevance today. Efficacy studies are not useful to assess these costs, but various relatively recent ‘small area’ studies, often linked to interventions, permit a fair approximation.

The lowest expenses are reported in settings with only one intervention. Larviciding twice a year with temephos (attaining
91% coverage) in Cambodia cost US$ 0.20 per inhabitant per year; mesocyclops application through a community-based approach in Viet Nam cost 0.28–0.89 US$/inhabitant. Most cost studies conducted during the past decade have reported higher annual cost for routine Ae. aegypti control in programmes with a mix of activities. However, the reported figures are surprisingly similar: US$ 2.4/inhabitant per year in Panama in 2005 and between US$ 1.8 and US$ 2.4/inhabitant per year in a 2008 study in four countries in Latin America and four in Asia. But there are notable exceptions. In Mexico, costs were around US$ 6/inhabitant per year in 2008. In Cuba and Singapore, countries where dengue control is a political priority and in which routine programmes achieve extremely high coverage, spent US$ 24/inhabitant per year in 2000. Cost in Cuba further increased to US$ 38/inhabitant per year in 2004. To our knowledge, there is only one study that documents the incremental costs during an outbreak. In Guantanamo, dengue vector control costs were US$ 1.67/inhabitant per month in 2006 in the non-epidemic period, as opposed to US$ 1.89 during the outbreak. This increase is marginal, but the increase in total cost – from US$ 2.76 to US$ 6.05/inhabitant per month – was substantial.

Figures on the distribution of cost items for routine vector control are still harder to find than coverage figures. Analysed by inputs, 32% cost was spent on insecticides or larvicides and 28% for salaries in Thailand. Conversely, in the Bolivarian Republic of Venezuela 61% cost was attributed to salaries and 12% to insecticides or larvicides. Similar distributions were reported for Cuba and Panama. The difference in the relative share of the main cost drivers can be explained by different salary rates and the use of different insecticides. Studies that used a breakdown of costs by activity attributed 74% to source reduction and 24% to fumigation in Malaysia; the corresponding figures were 65% and 13% in Puerto Rico.

Dengue vector control involves various actors and not all costs are borne by the control programme or the ministry of health, but by other sectors including the community. Very few cost studies take a full social perspective. The effectiveness of routine vector control cannot be directly estimated. Estimates of the effectiveness of specific vector control activities stem from
intervention studies that compare the incremental effect of single (innovative) control measures on top of the existing (if any) routine programme. Most of these studies evaluate the effects on entomological indices and not on transmission or disease incidence. The latter outcomes are hard to measure (because of problems with diagnostic tools, operational challenges, dependence of transmission on account of herd-immunity and climate factors) and huge sample sizes are needed.

The routine vector control activities initiated in 1968 in Singapore resulted in house indices of around 2% and a low dengue incidence over a 15-year period; the vector control operations in Cuba brought the 1981 epidemic under control in 4 months and consistently interrupted dengue transmission (apart from some local outbreaks) up to the late 1990s.

Temephos application in Cambodia, compared with no intervention, was found to be cost effective in terms of DALYs gained (from a health sector perspective US$ 313/DALY saved and from a societal perspective US$ 37/DALY saved). Few reports in the literature link costs of control activities to effectiveness measures (absolute number of Aedes foci controlled through community-based environmental management in Cuba; reduction in the number of reported cases by community programmes using Mesocyclops in Viet Nam).

Most cost-effectiveness estimates of vector control activities arise from modelling exercises. A simulation-study using data from Puerto Rico concluded that larval control programmes that reduce dengue transmission by 50% and cost less than US$ 2.5 per person will be cost effective. The cost of dengue vector control (larval control and focal adulticiding) and case management during a short outbreak in a non-endemic area in Argentina was compared with a hypothetical situation without reactive vector control. If the attack rate would then reach more than 29/1000 inhabitants, the intervention would have a positive cost–benefit ratio. Finally, the study concluded from modelling that an intervention consisting of six high-efficacy insecticide applications for adult control is cost effective (defined as less than three times the national per capita gross domestic product).
and that it has an incremental cost-effectiveness ratio of US$ 1267/DALY saved. However, the assumptions used in the model have been questioned.

A preliminary modelling exercise using a paediatric dengue vaccine suggests that, under certain assumptions, the cost per DALY saved could be as low as US$ 50. Whether vector control is cost effective in comparison with dengue vaccination, or how they can best be combined from an economic perspective, is a question for which an answer is urgently needed. Along the same lines: what about the release of genetically modified Aedes mosquitoes or ‘infrastructure improvements’, taking into account their impact on several diseases?

Routine dengue vector control programmes are highly diverse, many are mainly reactive and few are intensive. Their cost depends on activity mix, intensity and coverage. Reported extremes range from US$ 0.2 to US$ 38.0/inhabitant per year, but the median cost lies around US$ 2.5/inhabitant per year. From the available estimates at country or regional levels, it seems that generally more is spent on case management than on vector control. Not much evidence exists on the cost-effectiveness of vector control activities, let alone routine control programmes. If a vaccine becomes available in the near future, the latter information will become crucial for making informed decisions on budget allocations for vector control and vaccination campaigns.

7. DISCUSSION

The meeting discussed vector control interventions and the cost of routine dengue vector control, and noted that:

- Public awareness and community participation in vector control interventions should be further promoted, inter alia, to improve coverage; integration of vertical and horizontal services should be better defined; and quality implementation of vector control interventions should be emphasized.
Vector control interventions are costly, but there are great opportunities for transformation of vector control interventions to make them more cost effective in terms of quality of application and coverage. Such cost by no means would be comparable to the cost of delivering a dengue vaccine, which could be much higher given the requirement of multiple doses over 12 months and the difficulty of delivering these through the routine expanded programme on immunization.

Objectives of vector control intervention(s) in each setting should be clearly defined and linked to disease transmission, and metrics should be determined for their monitoring and evaluation.

Improved models of dengue transmission that allow for long-term evolutionary and immunological effects of decreased dengue transmission and cost-effectiveness analysis of different interventions are needed.

Broader cost to economy has to be taken into consideration when estimating the cost of dengue prevention and control. This should include impact on gross domestic product, including economic activities such as tourism. Historical trends should also be taken into consideration, i.e. what would be the impact if no intervention was implemented. Challenges in estimating true burden of the disease can significantly change the outcome of cost analysis.

There is need to do cost-effectiveness analyses of vector control vis-à-vis other interventions.

8. ECO-BIO-SOCIAL DETERMINANTS OF DENGUE VECTOR BREEDING

Dr Johannes Sommerfeld, Scientist, Vector Control Interventions, WHO Special Programme for Research and Training in Tropical Diseases (WHO/TDR), presented the eco-bio-social determinants of dengue vector breeding. Dengue vector surveillance and management practices in line with the
principles of IVM should be evidence-based and relevant to local conditions. As dengue vector transmission in such specific local contexts is determined by a complex interaction of vector-related, biological and community factors, there is, consequently, a need for good operational and implementation research practices when conducting vector control needs assessments relevant to local vector ecologies and the community context in which vector transmission occurs.

Recent research initiatives in Asia, Latin America and the Caribbean, supported by a research partnership between WHO/TDR and the International Development Research Centre of Canada, are based on a systematic research framework for multidisciplinary research on ecological, biological and social ("eco-bio-social") aspects of vector-borne diseases.¹

He introduced the rationale, research framework, methodology and preliminary results of the two research initiatives, focusing on the just completed study in Asia. The research and capacity building programme in Asia was carried out between 2006 and 2011 in six countries of South Asia (India, Myanmar, Sri Lanka,) and Southeast Asia (Indonesia, Philippines, Thailand). The programme was set up to investigate, from a multidisciplinary perspective, the ecological, biological and social (i.e. "eco-bio-social") dimensions of dengue in urban and periurban areas in Asia and to develop, on the basis of a detailed local situation analysis, community-based intervention programmes aimed at reducing dengue vector breeding and viral transmission.

Multidisciplinary research teams from six leading Asian research institutions participated in the effort, forming a Community-of-Practice (CoP) for EcoHealth research on vector-borne diseases, with a focus on dengue in urban and periurban settings. Based on a common core protocol and standardized data collection instruments, all six sites undertook a situation analysis to characterize and map the urban ecosystem, vector

ecology in its relation to rainfall, the social context, including stakeholder environment, and community dynamics, including gender implications. Case studies on vector control investigated the health policy context, the organization, the human resources, budgets and current vector control practices in the study areas.

The situational analysis identified productive container types (i.e. those producing a large proportion of adult mosquito vectors), social and environmental risk factors favouring vector breeding, variation of vector ecology in the dry and wet seasons and in public and private spaces and made recommendations for locally adapted interventions. All six teams conducted a spatial analysis of randomly selected area-clusters (urban neighbourhoods) through grid sampling. In 20 (in three sites 12) clusters per site, standardized household surveys, cluster (neighbourhood) background surveys and entomological (pupal and larval) surveys in public and private spaces were carried out.

The most productive breeding sites of dengue vectors were outdoor water containers that had been unused for more than a week, uncovered and usually below vegetation, explaining why rainfall is associated with increased dengue incidence. Public spaces – except for schools and religious facilities – and commercial areas were much less important for pupal production than the peridomestic and intradomestic environment, particularly in densely populated neighbourhoods. The (non-significant) association between water supply and pupal counts was complex: irregular supply with piped water as well as the absence of piped water may lead to increased water storage and vector development. Lack of waste disposal was associated with vector abundance only in one site where, in the absence of large water containers, vectors breed in discarded containers (i.e. rubbish). Knowledge of dengue-transmitting mosquitoes was associated with reduced mosquito breeding and production, often due to increased self-protection with domestic insecticides. Vector control measures (mainly larviciding in one site) reduced substantially the larval/pupal indices and "pushed" mosquito breeding to alternative containers.
The comparative analysis of vector control services indicated that in spite of extensive dengue-related national and local guidelines and a significant formal organization of public services, most vector control interventions are limited to space spraying and selective larviciding in situations of local outbreaks and increased case incidence.

All sites conducted a participatory problem analysis, based on the situational analysis with important multisectoral stakeholder groups, aimed at building consensus on potential intervention approaches. This process led to the design of site-specific intervention packages using innovative biological, chemical, mechanical and/or environmental vector control technologies and/or a combination of these tools. The intervention tools ranged from mechanical lid covers for key productive water containers to chemical (e.g. pyriproxyfen, Bti) to biological methods (e.g. dragonfly nymphs, larvivorous fish and copepods). Several groups experimented with solid waste management, composting and recycling schemes, particularly in those sites where small discarded water containers were the most productive ones. Many of the intervention tools were locally produced and all tools were implemented through community partnership strategies. All sites prepared socially and culturally-appropriate health education materials. Various community groups (women's groups, students, new volunteer groups for environmental health) were mobilized and empowered at different levels. The teams applied the process indicator framework for assessing degrees and intensities of community participation to their interventions.¹

women in the intervention. Leadership by communities ranged widely, from 1 to 5.

The programmes had varying impact on vector densities and led to significant outcomes at community level, with the formation of community groups with broad environmental hygiene and sanitation interests. The findings have significance and relevance for defining efficient, effective and ecologically sound vector control needs based on local evidence, as proposed in the IVM approach. Within the IVM approach, "eco-bio-social research" can be considered an important research framework for the systematic assessment of vector control needs and the development of partnership strategies.

9. VECTOR SURVEILLANCE

Dr Francis Schaffner, Avia-GIS, Zoersel, Belgium, and Institute of Parasitology, University of Zürich, Switzerland, briefed the meeting on surveillance of dengue vectors on the European continent. Although mosquito-borne diseases generate a far higher burden in tropical regions, with a heavy impact on the countries’ opportunities for socioeconomic development, there have always been autochthonous mosquito-borne diseases in Europe, both endemically and epidemically. Dengue, for example, occurred in Europe until the early 20th century. Concern about mosquito-borne diseases is nowadays rising as both vectors and pathogens are increasingly being introduced into Europe by international travel and trade. Some of these diseases are emerging or are resurfacing after a long absence, others are spreading. Their occurrence is often associated with changes in ecosystems, human behaviour and climate. This is illustrated by the recently reported epidemics of chikungunya (Italy 2007, France 2010), dengue (Croatia 2010, France 2010), and West Nile (many Old World countries during recent years) viruses. Assessing and managing the risk of mosquito-borne diseases introduced into and established in Europe are now necessities and a priority, particularly in countries where the invasive Asian tiger mosquito, *Ae. albopictus* and/or other putative vector species are established.
The development of risk assessments and risk management plans for mosquito-borne diseases is first and foremost based on data related to the vectors. Thus, surveillance programmes are implemented in order to obtain solid and updated information on presence, abundance and bionomics of potential vector species. ‘Surveillance’ of mosquitoes refers to procedures developed with regard to a risk and conducted to support control action, whereas ‘monitoring’ of mosquitoes is implemented merely for temporary or continuous observation (e.g. evolution of species’ biology). Surveillance of mosquito vectors may be part of global plans for risk assessment and risk management of mosquito-borne diseases.

At country or provincial level, risk plans for mosquito-borne diseases may be implemented, as done in France (where a national plan for dengue and chikungunya has existed since 2006\(^1\)); or in Italy (Emilia-Romania regional plan, since 2008\(^2\)). Other countries develop or have developed temporary scientific programmes to investigate the mosquito fauna from the perspective of mosquito-borne disease risk as, for example, in Belgium (Mosquito vectors of disease: spatial biodiversity, drivers of change, and risk programme; MODIRISK; 2008–2010), Malta (Risk assessment for vector-borne diseases in Malta expert mission; ECDC, 2009) and Switzerland (Mosquitoes and related hazards in Switzerland in 2010, and Spatio-temporal diversity of mosquito fauna in Switzerland, 2011–2012). Field methodologies vary depending on the aim of surveillance and on the tools and funding available. However, a key issue may be to enforce the quality of surveillance and monitoring data sets, i.e. defining the experimental design of field studies in accordance with expected modelling outcomes, gaining advantage from technical support and quality control procedures, harmonizing data collection and analysis with new tools that are under development in a pan-European network (e.g. the VECMAP system\(^3\)).

\(^1\) Available at: http://www.sante.gouv.fr/la-dengue-les-documents-essentiels.html.
\(^3\) Available at: http://iap.esa.int/projects/health/vecmap).
In Europe, several initiatives address the topic of invasive mosquitoes and associated mosquito-borne disease. First, the European mosquito control association (EMCA) supports and promotes pan-European exchange of information and collaborations and has established a dedicated ‘Ae. albopictus and other invasive mosquitoes’ working group. Recently, EMCA in collaboration with the WHO Regional Office for Europe has launched an initiative to produce guidelines on the control of invasive mosquitoes and associated mosquito-borne disease, based on a pan-European consultation. A first strategic document will be available soon.

The strengthening of pan-European networking is also actively supported by ECDC. In 2008, a project (TigerMaps) was funded to develop Ae. albopictus risk maps, and since 2010 vectors and vector-borne diseases issues have been addressed by VBORNET, a European network of medical entomologists and public health experts (www.vbornet.eu). TigerMaps has developed precise distribution maps of Ae. albopictus in Europe and risk maps for establishing Ae. albopictus in Europe by considering different scenarios of climate change proposed by the Intergovernmental Panel on Climate Change. A major task of VBORNET is to create or maintain databases for vector surveillance. As result, European distribution maps of all invasive mosquito species are produced and updated every 3 months, and made available online. In addition, VBORNET provides ad-hoc technical support to ECDC by developing risk assessment documents and factsheets on vectors of public health importance and inventories of vector-borne disease and related public-health activities and expertise in Europe.

In an attempt to further harmonize surveillance procedures within Europe, ECDC has published guidelines for the surveillance of invasive mosquitoes, which aim to support the implementation of tailored surveillance for invasive mosquito species of public-health relevance. The guidelines provide evidence-based guidance and technical support for focused data collection in the field, taking into account cost-

effectiveness estimates and suggesting adaptations according to the evolution of the epidemiological situation. They also contribute to harmonizing surveillance methods and information records at the European Union level so that data from different countries or areas can be compared over time. The guidelines are intended to provide support to professionals involved in implementing surveillance or control of invasive mosquito species, but also to non-specialists of mosquito surveillance, stakeholders in public health, and decision- and policy makers.

The targeted mosquito species are all exotic, invasive *Aedes* species reported as having been introduced into Europe, including *Ae. aegypti*, *Ae. albopictus*, *Ae. atropalpus*, *Ae. japonicus*, *Ae. koreicus* and *Ae. triseriatus*. They share the common characteristics of being container-breeding species, invasive (proven or suspected), anthropophilic and showing significant vectorial capacity. Indeed, *Ae. aegypti* and *Ae. albopictus* are so far the only confirmed vectors of dengue and chikungunya in Europe. The suggested methods may be applicable in the whole geographical area of Europe (thus in all European Union Member States and European Economic Area or European Free Trade Association countries, including outermost regions) but not overseas associate territories.

The guidelines describe all procedures directly applied for the surveillance of invasive mosquito species. The first part addresses strategic issues and options to be considered by the stakeholders during the decision-making process, dependent on the aim and scope of the surveillance, its organization and management, and the surveillance strategy to be developed. Three basic scenarios are delineated, which may correspond more or less to the situations in a specific country. They are defined first and foremost according to the presence or absence of invasive mosquito species. Reports of the presence of mosquito-borne diseases possibly transmitted by invasive mosquito species (i.e. dengue and chikungunya) are considered for extending or strengthening surveillance activities: Scenario 1 – No invasive mosquito species known to be established (but introduction and establishment of invasive mosquito species estimated as likely); Scenario 2 – Locally established invasive mosquito species (with low risk of spreading into new areas); Scenario 3 – Widely established
invasive mosquito species (with high risk of spreading into new areas).

The second part of the guidelines addresses all operational issues and options to be implemented by professionals involved in the applied process, such as key procedures for field surveillance of invasive mosquito species, complementary procedures including field collection for population parameters, pathogen screening and environmental parameters. This part also recommends methods for the identification of invasive mosquito species and for data management and analysis, as well as strategies for data dissemination and mapping. Finally, a third part deals with the evaluation of the surveillance programme, by providing guidance for cost estimation of the envisaged programme and for the evaluation of the applied surveillance process.

10. DISCUSSION

The meeting discussed the issues raised by the above-mentioned speakers and noted that:

- Community-based dengue prevention is critical to the success of dengue prevention and control. It should be a social learning process, implying a transfer of power and responsibilities to local people. Communities should be enrolled into partnerships with broader socio-development objectives than a single disease or vector control target, which can bring them together with broader services, e.g. water and waste management, and provide them with realistic expectations that will lead to improved social and living conditions. Political support can help effectively implement interventions.

- Capacity for entomological surveillance should be developed to identify areas of high-density infestation or periods of vector population increase. In areas where the vector is no longer present, entomological surveillance is critical in order to detect new introductions rapidly before they become widespread and difficult to eliminate. Capacity should also be built
Dengue is posing a major threat in the European region, especially around the Mediterranean. There is a need to link information from various institutions in Europe.

11. INSECTICIDE RESISTANCE PREVENTION AND MANAGEMENT

Professor Hilary Ranson of the Liverpool School of Tropical Medicine addressed the challenges of monitoring, prevention and management of insecticide resistance. She reiterated that mosquito control is currently the only available means to prevent dengue transmission. As vector control relies primarily on insecticides, and the classes of insecticides available are severely limited, the development of insecticide resistance in dengue vectors is a serious threat to sustainable control. Pyrethroids and organophosphates are the most important classes of insecticide used in dengue control. During the past decade, the use of pyrethroids has gradually increased as a proportion of the total insecticides used for dengue control. However, organophosphates are still widely used, and usage patterns will likely be affected by increasing concerns over pyrethroid resistance. Mexico, for example, has reintroduced space spraying with organophosphates in some states, in response to high levels of pyrethroid resistance in local vectors.

Both organophosphates and pyrethroids are used in space spraying, and residual spraying with carbamates plays a minor role in adult mosquito control. Organophosphates, bacterial larvicides and insect growth regulators are used in larviciding. Pyrethroids are the only class of insecticides currently available for use in insecticide treated materials (curtains, jar covers, nets, screens, etc.) and importantly, in terms of resistance management strategies, are used in consumer products in volumes that dwarf their use in vertical dengue control programmes.
Resistance to pyrethroids and, to a lesser extent, organophosphates, is widespread in the primary dengue vector, *Aedes aegypti*. There have been fewer studies on *Ae. albopictus* and so comparisons are difficult to make, but available data suggest that resistance is less prevalent in this species. The vast majority of studies on resistance rely on bioassays, but as a wide range of techniques are used, reliable comparisons between studies are difficult. Standard methods for detection and reporting of resistance must be agreed to facilitate resistance management. Furthermore, very few studies actually measure the impact of resistance. Susceptibility test results, while an essential component of resistance management programmes, are not sufficient to make evidence-based decisions on insecticide use. Further investment needs to be made in testing the impact of resistance in local vectors against interventions in use, or under consideration. The methodology is very straightforward and can be adapted to local control practices but it should be embedded within all insecticide based control programmes.

A clearer understanding of patterns of cross-resistance between and within insecticide classes is also urgently needed. Incorrect interpretation of data from bioassays can lead to inappropriate selection of insecticides, with potentially damaging results. A greater understanding of molecular mechanisms of resistance would be helpful in this regard.

Data on the susceptibility status of the local vector populations is only one part of the equation. For a resistance management strategy to be effective, control programmes must be able to act proactively to prevent resistance from compromising control. Alternative insecticides may have higher costs, or be less welcomed by communities, and procurement issues can also affect the availability of such products. All of these factors need to be addressed at the programmatic level to ensure that local control programmes can, ideally, implement an effective resistance management strategy to avoid resistance compromising control or, as is usually the reality, respond to the emergence of resistance.

Given the logistic challenges associated with resistance management, there is a need for tools to measure the
effectiveness of these strategies. As there are a very limited number of insecticide classes available, and it will be many years before new active ingredients are approved, an effective resistance management strategy must aim to maintain or restore susceptibility to all major insecticide classes. This is usually attempted by the use of mixtures or rotations of insecticides with different modes of action. But what should be the trigger for changing insecticide? In reality, it is often reports of control failure but by this stage, the resistance alleles are likely present at very high frequency in the population and very hard to remove. Molecular tools that can provide an early warning of resistance would aid planning of effective resistance management programmes and would also provide the means to measure their impact: if resistance management is successful, the frequency of insecticide resistance alleles in a mosquito population should rapidly decrease once the selection pressure is removed.

In conclusion, if we are to ensure the effectiveness of current insecticide classes for dengue control in the coming decades, resistance management strategies must take higher priority in dengue control programmes. Such strategies should be built on the principles of integrated vector management and involve non-insecticidal methods to minimize selection pressure for resistance.

12. INNOVATIVE VECTOR CONTROL TECHNOLOGIES AND PRODUCTS IN THE PIPELINE

Dr Tom McLean, Chief Operating Officer of the Innovative Vector Control Consortium, Liverpool School of Tropical Medicine, United Kingdom, presented an overview of activities and technologies or products in the Consortium’s pipeline. Epidemic dengue fever and dengue hemorrhagic fever are major public-health problems in Asia, Latin America and the Caribbean, and the disease is rapidly spreading, driven in part by expansion of the range of the Aedes vectors and increasing urbanization of at-risk populations. Control measures are heavily predicated upon operational effectiveness of pyrethroid insecticides delivered by outdoor fogging or as larvicides. Recent information suggests that these application techniques
are only effective in the most favourable environmental and socioeconomic conditions. Resistance to pyrethroids has emerged in *Ae. aegypti* in most endemic countries and is spreading and increasing in intensity.

While there is a choice of larvicides, the number of adulticides available for control of dengue, malaria and other NTDs is severely limited. All current public health pesticides were initially developed for the agrochemical market. In the 1980s, the shift of the agrochemical target product profile – from broad spectrum contact insecticides to stomach poisons delivered systemically via the plant – decimated the number of new agrochemicals that could be repurposed for public health. Consequently, no new public health adulticide has been developed since that time. The same is true for the application paradigm by which insecticides are delivered.

The Consortium works with the pesticide industry and research partners using funds raised from donors to reduce the risk in the early stages of product development to a level at which it can become viable for the companies to develop products. It publishes target product profiles creating an open call for proposals from companies and institutions with the capability to develop such products. The development projects are managed as a portfolio against agreed milestones.

Three areas of product development are of particular relevance to dengue control: new formulations and active ingredients for insecticides; information systems and tools for monitoring and evaluation of dengue fever interventions; and new paradigms for vector control. The Consortium has created an unprecedented pipeline of vector control products. Already in 2010, several of its projects have successfully completed field trials and entered the regulatory phase. These products, with a relatively longer lasting residual action, will enable insecticides to be sprayed only once in each transmission season, dramatically reducing application cost and increasing acceptability to the inhabitants. In the longer term, the Consortium is targeting the creation of completely new active ingredients for use in vector control, and screening programmes initiated by several major industrial partners have already revealed candidates for these novel products. However, their
effective use will require a system of insecticide resistance management of considerable sophistication.

Significant progress is being made towards area-wide interventions for dengue vector control; these lie outside the Consortium’s portfolio but include genetically modified mosquitoes refractory to dengue, Wolbachia-infected mosquitoes refractory to dengue and sterilizing techniques by release of mosquitoes with a dominant lethal gene.

Information systems and tools to support vector control interventions are an essential element of the proposed insecticide resistance management process. The Consortium supports the development of information systems such as the Dengue Decision Support System, which is a suite of software tools and information-gathering protocols. The system integrates existing monitoring and evaluation systems with local dengue control campaigns to collect and disseminate key data to enable evidence-based decision-making about disease control strategies.

Novel paradigms for vector control encompassing different epidemiological modes of action such as repellency or different delivery paradigms such as treated curtains or wall hangings will form an essential part of the future of vector control. Historically, it has taken many years and much controversial effort to achieve widespread acceptance and policy adoption of new paradigms. The Consortium, in conjunction with a wide range of disease control stakeholders, has prepared a framework for validation of new paradigms, which will streamline the process of acceptance and adoption. Projects using this framework are under way.

13. DISCUSSION

The meeting discussed the issues raised by the above-mentioned speakers and noted that:

- Insecticide resistance is widespread and is compromising dengue vector control in many countries. Yet, no baseline information is available in many
geographical areas. Resistance management strategies need to be urgently implemented, following the principles of integrated vector management including judicious use of insecticides, and promotion of non-chemical vector control interventions. Such action must be immediate and pre-emptive and not reactive. Close collaboration with national pesticide regulatory authorities and industry is required to ensure regulation of counterfeit and substandard products as well as rational and effective use of quality pesticides, including household insecticide products.

- Availability of limited number of tools, especially as it relates to adulticides, calls for urgent investment into development of improved and innovative tools and technologies. Better documentation of epidemiological impact of existing dengue vector control paradigms, e.g. space spraying, or establishment of epidemiological impact for new paradigms can facilitate investment into alternative insecticides for dengue vector control. New paradigms may include re-purposing existing insecticides for use in lethal ovitraps, sugar-baited traps, etc. Establishment of a body for timely and independent review and assessment of new paradigms and technologies for dengue vector control is required. There is urgent need to develop guidance to measure the burden of dengue that can be used in experimental studies, in testing and evaluation of new products, as well as in national control programmes.

- Methods and criteria for detection of insecticide resistance of dengue vectors should be further improved and standardized. In addition, patterns of cross-resistance between and within insecticide classes should be further studied.

- Impact of resistance on dengue transmission and control programmes should be assessed and documented. It is not clear, how often, reported failures in control programmes are due to insecticide resistance or poor quality operations. In addition, establishment of a global
data base to monitor insecticide susceptibility of dengue vectors is necessary.

- It is important to critically monitor interventions that national programmes are implementing. There is a need to develop an operational framework for a district level use for vector control and resistance management.

14. MECHANISMS FOR PARTNERSHIP

Dr Kathryn Aultman, Senior Programme Officer, Infectious Diseases, Bill & Melinda Gates Foundation, presented the case for partnership in dengue control, with focus on product development. A list of potential stakeholders and their functions or roles was provided. Stakeholders include industry, academia, national programmes and WHO.

The complexity of dengue on one hand and the momentum that is created by developing a Global strategy for dengue and prevention by WHO on the other, will be used to strengthen effective and sustainable collaboration and partnership among all stakeholders, for implementation of the strategy. This should include regional collaboration for coordination, information exchange and capacity strengthening, and attract the existing Associations, networks/partnerships, e.g. ACTMalaria (Asian Collaborative Training Network for Malaria) and Asia-Pacific Dengue Partnership. The partnership should align and integrate action, avoid duplication of effort and fill gaps, thereby making more efficient use of limited resources in an austere financial climate. The partnership should support development of evidence to inform policy and decisions; development of new tools (including insecticides and technologies, norms and standards, and guidelines); information exchange; advocacy and resource mobilization; and capacity building. An informal but effective global partnership, with strong engagement of key stakeholders, was the preferred mechanism suggested by the meeting. Specific details of such a partnership should be further developed.

The WHO Department of Control of Neglected Disease plans to review its collaboration with WHO Collaborating Centres and
their terms of reference and to expand and strengthen this network to support the implementation of the Global Strategy. The WHO dengue web page will be revised to improve information exchange.

15. STRATEGIC AND POLICY DIRECTIONS FOR EFFECTIVE DENGUE VECTOR CONTROL INTERVENTIONS – REGIONAL PERSPECTIVES

WHO Region of the Americas/Pan American Health Organization

The regional perspective on strategic and policy directions for effective dengue vector control interventions was made on behalf of Dr José Luis San Martín Martinez, WHO Regional Adviser for Dengue in the WHO Regional Office for the Americas, presented. The situation of dengue in the Americas during the past 28 years has shown an upward trend, with recurring epidemic peaks every 3–5 years, with each epidemic peak regularly higher than its predecessor. Dengue has been on the political agenda of the Pan American Health Organization (PAHO) for decades and this attention has increased in recent years.

Reformulated PAHO regional guidelines for the prevention and control of dengue in Resolution CD43.R4 of the Directing Council in 2001\(^1\) and in the year 2003, during the 44th Directing Council of PAHO/WHO, adopted Resolution CD44.R9,\(^2\) that guided the strategy to follow and endorsed the political will of the region to face this complex problem. The resolution contained new recommendations on ways and methods that should be applied to the Organization’s technical cooperation and introduced the model of Integrated Dengue Management

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EGI-dengue in Spanish). It also created a technical working
group in the region (Grupo Tecnico Dengue or GT Dengue) and
indicated the need for a global response to the problem and not
just by the health sector.

The EGI-dengue integrates areas of action and key
components that have the greatest responsibility in planning
and implementing prevention and control. These key areas
include social communication, surveillance, laboratory services,
patient care, integrated vector management and environment
management. To date, 21 countries have developed and
implemented the integrated management strategies for the
prevention and control of dengue. These countries account for
about 95% of dengue reported annually in the Americas.

One of the main components of EGI-dengue is IVM. The PAHO
campaigns to eradicate *Ae. aegypti* were highly successful in
the 1950s and 1960s and by 1972 it was reported that the
programme had eradicated the vector in 21 countries in the
region. The programme declined in the 1980s and 1990s with
the introduction of the yellow fever vaccine and the loss of
priority to control *Ae. aegypti*. This loss of responsiveness to
prevent and control dengue vectors by the national
programmes is an important determinant of the spread of
dengue in the Americas.

In the EGI-dengue response model, IVM against *Ae. aegypti* is
a high priority because of its effectiveness in interrupting the
transmission of other vector-borne diseases. The region is
working on new tools and methodologies to promote and
improve existing ones. This includes strengthening

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1. EGI-dengue: an Integrated Management Strategy for the prevention
   and control of dengue in the Region of the Americas. José Luis San
2. Rodríguez Cruz R. Strategies for control of dengue and *Aedes
3. Delivery issues related to vector control operations: a special focus
   on the Americas. Jose Luis San Martin, Olivia Brathwaite (available at
   http://www.tropika.net/svc/review/061001-
   Dengue_Delivery_issues?pf=y).
entomological surveillance and promoting monitoring of insecticide resistance to achieve more rational use of insecticides.

Conversely, increasing emphasis is being placed on promoting public policies that could impact the health determinants of the presence of the vector, such as the supply and proper storage of water and proper disposal of rubbish and tires. These are major challenges for sustainable dengue control because the most common and productive sources of \textit{Ae. aegypti} in this region are the poorly covered water tanks and water that accumulates in the rubbish and tires.

Progress can be seen with the collaboration of private industry and ministries of the environment in the control of determinants of dengue transmission, such as the presence of used tires, which are common, productive breeding sites of \textit{Ae. aegypti}.

Efforts are under way to forge collaboration with the private pesticide industry to fund a project for the monitoring of \textit{Ae. aegypti} resistance with the health ministries and academia. This project will enhance preservation and protection of available pesticide active ingredients for a more rational use of insecticides in control activities. It may also include systematic and continuous training to improve techniques for applying insecticides and the certification of pesticide applicators.

In 2012, the process of implementing EGI-Dengue will be reviewed during the 45th Pan American Sanitary Conference of PAHO’s Executive Committee. The programme will work closely with the immunization programme to prioritize environmental control actions for when the dengue vaccine becomes available and the EGI-dengue strategy, whose components will be adapted to meet the new demands that might arise.

\textbf{WHO South-East Asia Region}

The South-East Asia Region faces an upsurge in reported cases of dengue in all Member countries except the Democratic People’s Republic of Korea. In 2008, the South-East Asia Region and the Western Pacific Region developed a bi-regional dengue strategic plan (2008–2015), which was endorsed by the
61st Session of the Regional Committee Meeting. The strategy has six components with IVM as an important one.

Dengue vector control interventions involve entomological surveillance, identification of potential breeding sites, elimination of mosquito larvae, destruction of adult mosquitoes with space spraying, and legal enforcement for mosquito prevention and control, where applicable. Because dengue is everyone's concern, key messages are developed for the target groups and communities are involved in vector control operations. Environmental management and source reduction are important interventions in many situations.

Improper collection and disposal of solid waste, illegal dumping of rubbish, poor inter-ministerial cooperation in controlling dengue, urbanization, human migration and use of non-biodegradable products are some of the constraints of dengue vector control in the region.

A programme managers meeting on dengue control was held in Chiangrai, Thailand, in June 2010. All endemic countries reported progress in implementing the Asia-Pacific strategy for dengue control and agreed to scale up vector control using IVM. A guideline for prevention and control of dengue and DHF was prepared in 2011, with detailed strategic and policy directions on dengue vector control. The meeting was followed by a regional workshop on IVM in Chiangmai, Thailand in September 2010 with participation of WHO/NTD staff. A regional training course on IVM was organized in October 2011 at the Vector Control Research Centre in Pondicherry, India. There is a high level political commitment in many countries for control of dengue.

**WHO Western Pacific Region**

Dengue has emerged as a serious public health problem in the Western Pacific Region. In 2010, almost the same number of cases was reported as for the last major pandemic in 1998; the worst affected countries were Malaysia, the Philippines and Viet Nam. Dengue is a priority programme in the region and in most of the countries incidence exceeds that of malaria. Overall, case management has improved through capacity building, leading to a decrease in case fatality rates to 0.35% in 2011.
Dengue has also spread throughout the Pacific Island countries and areas. Historically, dengue has been reported predominantly among urban and periurban populations where high population density facilitates transmission. *Aedes aegypti* is the main vector and *Ae. albopictus* plays a role in some of the countries; other potential vectors are *Ae. polynesiensis*, *Ae. pseudoscutellaris*, *Ae. scutellaris*, *Ae. henselli*, *Ae. marshallensis* and *Ae. cooki*.

Implementing the Bi-regional Dengue Strategy for Asia and the Pacific (2008–2015) is a priority following its endorsement by the 2008 resolution WPR/RC59.R6 of the WHO Regional Committee for the Western Pacific. The draft IVM strategy was discussed in regional programme managers meetings for dengue and malaria but has yet to be implemented by Member countries. A regional workshop on IVM was held in 2010 and further country level training took place in Malaysia in 2011. A regional consultation on the sound management of public health pesticides held also in Malaysia in 2011 included the development of a framework for action.

Strategies for dengue prevention include routine vector surveillance, source reduction, enforcement of legislation, health education, school-based activities, biological control, preemptive larviciding, environmental sanitation and use of jar lids and net covers for water storing containers and drums respectively. Outbreak response includes space spraying, larviciding and community mobilization. A majority of countries do not have a dengue control programme and respond to outbreaks with the support of WHO. The region maintains a stockpile of insecticides in Fiji for outbreak response in the Pacific.

A project – Strengthen control of vector-borne diseases to lessen the impact of climate change in the Western Pacific Region – is in progress in Cambodia, Mongolia and Papua New Guinea. Another project using guppy fishes in drinking-water has yielded positive results with a significant decrease in vector density and high community acceptance. Efforts are under way to build a network for monitoring insecticide resistance in dengue vectors with capacity building.
The Association of South East Asian nations observed 15 June as ASEAN dengue day with active participation from regional and country offices. This event highlights the political commitment and prioritization of dengue in 11 ASEAN Member countries.

Strategic and policy direction studies in the region include documenting the evidences for IVM, developing a monitoring and evaluation framework for dengue interventions, and evaluating and refining the COMBI approach. Entomological capacity development and resource mobilization remain a major challenge for the region.

16. DISCUSSION

- Need for a shift from reactive programmes and build/strengthen capacity for sustainable integrated surveillance and vector control was discussed.

- Vector control should be based on integrated vector management (IVM), a rational decision-making process to optimize use of resources for vector control. IVM aims to improve efficacy, cost effectiveness, ecological soundness and sustainability of vector control interventions. WHO has recently published the following guidance documents that should be of use in implementing the principles of IVM: Guidance on policy-making for integrated vector management; Handbook for integrated vector management; and Core structure for training curricula on integrated vector management.

- Build capacity and develop plans for introduction of vaccine and carry out health economics studies to determine the complementary role of vector control and

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1 Available at http://whqlibdoc.who.int/publications/2012/9789241502795_eng.pdf.
2 Available at http://whqlibdoc.who.int/publications/2012/9789241502801_eng.pdf.
3 Available at http://whqlibdoc.who.int/publications/2012/9789241502788_eng.pdf.
dengue vaccine and their potential public-health impact for informed decision-making. It was important to make an economic case in endemic or at risk countries to emphasize the need to allocate adequate resources.

- Dengue control strategies and interventions should be adapted to local vector ecology, epidemiology and resources, guided by operational research and subject to routine monitoring and evaluation. Guidance documents should be developed to assist WHO Member States in this effort.

- In partnership with major global players, WHO should organize global advocacy and coordinate with its regional offices for mobilizing resources for implementation of the Global Strategy.

17. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the presentations made and the discussions held during its eighth meeting, the Global Collaboration for Development of Pesticides for Public Health concluded that dengue has attained global public-health importance. Estimating the true burden of the disease, however, remains a major challenge. Metrics for monitoring performance and for surveillance and assessment are not well established. Risk assessment is a crucial component of integrated dengue surveillance and a change in the dengue virus "serotype" is an important indicator of possible outbreaks.

Vector control will continue to play an important role in controlling transmission of dengue and will complement the effectiveness of a potential dengue vaccine, when it becomes available. There are, however, operational challenges to implementing and sustaining current vector control interventions that need to be addressed. Insecticide resistance has also emerged as a major challenge to effective control and this must be urgently addressed. Improved tools for entomological monitoring should also be developed and validated.
The capacity of national programmes for evidence-based planning, implementation, monitoring and evaluation of dengue prevention and control is generally inadequate. In decentralized health systems, lack of such capacity poses greater operational challenges for disease prevention and control. There is a need to institutionalize intersectoral collaboration for prevention and control of the disease at the national level. Likewise, there is a need for improved collaboration and coordination among global players and stakeholders.

**Recommendations**

**Dengue epidemiology**

- Improve methods for risk assessment and response; and
- Investigate the interface with and complementary role of vector control and dengue vaccine in different epidemiological settings.

**Metrics for surveillance and assessment:**

- Select well-characterized field sites where metrics for efficiency and progress can be appropriately defined;
- Develop epidemiological metrics and methods for their estimation (e.g. vector thresholds, virus prevalence and/or incidence); and
- Establish goals for suppression of dengue and its vectors.

**Entomological and epidemiological surveillance:**

- Establish reliable, practical and standardized methods for vector surveillance;
- Determine entomological correlates of virus transmission (e.g. entomological inoculation rate for dengue);
- Develop rapid, sensitive, specific and inexpensive diagnostics;
- Ascertain the burden of disease and measure the risk factors in various eco-epidemiological settings.
Vector control:

- Critically assess vector control interventions and tools in different eco-epidemiological settings;
- Establish methods for assessing the impact of vector control interventions on dengue transmission; and
- Foster innovation of alternative vector control tools and technologies.

Monitor and manage insecticide resistance:

- Standardize methods and criteria for detection of resistance;
- Assess the impact of resistance on dengue prevention programmes; and
- Develop and promote resistance management strategies for dengue vector control.

Capacity strengthening:

- Develop capacity for evidence-based decision-making, planning and implementation at different levels in programme hierarchy.

Partnership and coordination:

- Promote intersectoral collaboration within countries and regional or international networking and information exchange; and
- Promote collaboration or coordination among global players and stakeholders for successful implementation of the Global Strategy.
ANNEX 1. AGENDA

Monday, 20 February 2012

09:00–09:30 Opening of the meeting and welcoming remarks
   Dr Lorenzo Savioli, Director, WHO Department of
   Control of Neglected Tropical Diseases
   Dr Hiroki Nakatani, Assistant Director-General,
   HIV/AIDS, Tuberculosis, Malaria and Neglected
   Tropical Diseases

09:30–09:40 Appointment of chairperson and rapporteurs
   Introduction of meeting procedure, working
   arrangements and housekeeping matters
   Dr Morteza Zaim, Coordinator, WHO Vector
   Ecology and Management unit

09:40–10:00 Dengue as an expanding public health problem
   Dr Ron Rosenberg, Centers for Disease Control
   and Prevention, USA

10:30–11:20 Dengue prevention and control: challenges,
   obstacles and way forward – national perspectives
   Brazil – Dr Giovanini E. Coelho, Ministry of Health
   China – Dr Qiyong Liu, Center for Disease
   Control and Prevention
   Indonesia – Dr Darmawali Handoko, Ministry of
   Health
   Saudi Arabia – Dr Zaid Memish, Ministry of
   Health
   Singapore – Dr David Lee, Environmental Health
   Institute

11:20–12:30 Discussion
14:00–14:20  Current status of vector control for dengue prevention and outbreak control
Dr Philip McCall, London School of Hygiene and Tropical Medicine

14:20–14:40  The cost of routine dengue vector control
Dr Patrick Van der Stuyft, Institute of Tropical Medicine, Antwerp

14:40–15:30  Discussion

16:00–16:20  Eco-bio-social determinants of dengue vector breeding
Dr Johannes Sommerfeld, WHO Special Programme for Research and Training in Tropical Diseases

16:20–16:40  Vector surveillance
Dr Francis Schaffner, Institute of Parasitology, University of Zurich

16:40–17:30  Discussion

Tuesday, 21 February 2012

09:00–09:20  Insecticide resistance prevention and management
Professor Hilary Ranson, Liverpool School of Tropical Medicine

09:20–09:40  Innovative vector control technologies or products in the pipeline
Dr Tom McLean, Innovative Vector Control Consortium

09:40–10:15  Discussion
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<th>Time</th>
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<tr>
<td>10:45–12:30</td>
<td>Mechanisms for partnership Discussion</td>
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<tr>
<td>14:00–14:45</td>
<td>Strategic and policy directions for effective dengue vector control interventions – regional perspectives</td>
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<td>WHO South-East Asia Region – Dr A.P. Dash</td>
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<td>WHO Western Pacific Region – Dr E.M. Christophel</td>
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<td>WHO Region of the Americas – Dr José Luis San Martin</td>
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<td>14:45–15:30</td>
<td>Discussion</td>
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<td>Strategic and policy directions, including the role of vector control in an integrated programme before and after the introduction of a dengue vaccine</td>
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<td>16:00–17:00</td>
<td>Conclusions and recommendations</td>
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<td>17:00–17:10</td>
<td>Closure</td>
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REPORT OF THE EIGHTH MEETING OF THE
GLOBAL COLLABORATION FOR DEVELOPMENT
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