DENGUE VECTOR CONTROL: PRESENT STATUS AND FUTURE PROSPECTS

H. H. Yap, N. L. Chong, A. E. S. Foo* and C. Y. Lee

Dengue Fever (DF) and Dengue Haemorrhagic Fever (DHF) have been the most common urban diseases in Southeast Asia since the 1950s. More recently, the diseases have spread to Central and South America and are now considered as worldwide diseases. Both *Aedes aegypti* and *Aedes albopictus* are involved in the transmission of DF/DHF in Southeast Asian region. The paper discusses the present status and future prospects of *Aedes* control with reference to the Malaysian experience. Vector control approaches which include source reduction and environmental management, larviciding with the use of chemicals (synthetic insecticides and insect growth regulators and microbial insecticide), and adulticiding which include personal protection measures (household insecticide products and repellents) for long-term control and space spray (both thermal fogging and ultra low volume sprays) as short-term epidemic measures are discussed. The potential incorporation of IGRs and *Bacillus thuringiensis*-14 (*Bti*) as larvicides in addition to insecticides (temephos) is discussed. The advantages of using water-based spray over the oil-based (diesel) spray and the use of spray formulation which provide both larvicidal and adulticidal effects that would consequently have greater impact on the overall vector and disease control in DF/DHF are highlighted.

Key words: *Aedes aegypti*, *Aedes albopictus*, dengue fever/dengue haemorrhagic fever vector control

(*Kaohsiung J Med Sci* **10**: S102—S108, 1994)

Dengue fever (DF) and dengue haemorrhagic fever (DHF) have been the most common mosquito-borne diseases in the urban areas in Southeast Asia since the mid-1950s[1,2]. Dengue fever or classical dengue fever (DF) has en reported to be widespread and endemic in tropical Southeast Asia and the Pacific Islands since the nineteenth century. On the other hand, dengue haemorrhagic fever (DHF), with a tendency to develop into dengue shock syndrome (DSS), is a relatively new form of the disease which was first reported in Southeast Asia urban centers in the 1950s. Since then, both DF and DHF have spread to Central and South America and are now considered as worldwide diseases[3].

Major vectors for DF and DHF in Southeast Asia are those of the container breeding *Aedes aegypti* and *Aedes albopictus*[1,2]. Being an endemic species in Asia, *Ae. albopictus* has been associated with the transmission of DF in Southeast Asia since the nineteenth century[4,5]. Dengue viruses have been reported to be isolated from naturally infected *Ae. albopictus*[6–10]. Reports of major outbreaks of DF/DHF in Southeast Asia appear to show correlations between the two *Aedes* species and the DF/DHF cases. In general, the occurrence of DF cases appeared to match *Ae. albopictus* distribution, while *Ae. aegypti* distribution appeared to correlate with cases of DHF[8,11,12].

At present, there is no effective drug for the treatment of DF and DHF except those for symptomatic treatments. Hence, *Aedes* control remains the most practical and attainable approach for the prevention and control of DF and DHF. In the following discussion of *Aedes* control approaches, considerable experience is drawn from the Malaysian situation, both in terms of operational control and research activities[13,14].

In principle, *Aedes* control with the ulti-

Vector Control Research Unit, School of Biological Sciences, University Sains Malaysia, 11800 Minden, Penang, Malaysia, *Vector Borne Diseases Control Programme, Ministry of Health, c/o Polyclinic, Perak Road, 11600 Penang, Malaysia.

mate aim of DF/DHF disease management can be divided into two stages, the control of immature and of adult mosquitoes. The control of adults especially in DF/DHF epidemic situation is aimed at the killing of the infective mosquitoes. However, the control of *Aedes* immatures is targeted towards the overall reduction of the mosquito population as a means of lowering the incidence and occurrence of DF/DHF. In the actual operational control context, control of both stages may be carried out simultaneously or individually depending on the situation.

Ae. aeygpti and *Ae. albopictus* are both container-breeders. Both species prefer to breed in relatively unpolluted water. In general, *Ae. aegypti* breeds predominantly in man-made artificial containers[15] and *Ae. albopictus* more abundantly in natural habitats such as leave axils and tree holes[4,16]. Hence, container management should be the best approach to adopt for the source reduction of *Aedes* breeding. In container management, house-holders' perspectives on whether the containers are deemed "useful" and "essential" (eg. earthen jars, rainwater drums and ornamental plant containers) or "useless" and "non-essential" (eg. discarded tires, abandoned domestic containers, agricultural crop remains) should be taken into consideration. For useful containers, the control strategy will lie in the prevention of *Aedes* breeding. In contrast, the useless containers should be removed and destroyed. Source reduction should also include the elimination of breeding in natural habitats that accumulate water to prevent *Aedes* breeding (eg. tree holes, leaf axils, bamboo stumps).

Water storage containers in various shapes and sizes are essential in the daily lives of the population especially in areas where reliable piped water supply is not available. Such containers should be properly covered when not in use. For containers that remain open due to frequent usage, replacement of the water or proper larviciding (biological or chemical agents) should be carried out. For container management, public education and cooperation is essential for the success of the programme.

Chemical larviciding including the use of organic synthetic insecticides (temephos) and insect growth regulators (IGRs) which include juvenile hormone mimics (eg. methoprene, pyriproxyfen) and chitin synthesis inhibitors (eg. diflubenzuron, triflumuron) have been shown to be effective for the control of *Aedes* immatures and have the necessary residual effects[17-20]. However, temephos in the formulation of sand granules (Abate, 1% w/w) has been used in Southeast Asia including Malaysia since the early 1960s. After more than 30 years of usage, Abate has been shown to have decreased in its effectiveness with suspected resistance being developed by the *Aedes* mosquitoes[21]. Although a few IGRs are effective against *Aedes* mosquitoes, their slow action is not favorably perceived by the consumers. In addition, the use of juvenile hormone mimics (JHs) which interfere with the later stages of insect metamorphosis (pupal stages and adult emergence) can be ndered in countries such as Malaysia and ngapore where government legislation is against the breeding of *Aedes* immatures in occupied premises[22,23].

Information concerning the use of bio-control agents for mosquitoes has been reviewed before[24-26]. At present, there are only two bio-control agents, namely, *Bacillus thuringiensis* H-14 (*Bti*) and *Bacillus sphaericus* which are in operational use for mosquito control[24,27,28]. Due to its high specificity, *Bti* has been found to be more effective against mosquitoes which breed in relatively unpolluted water including those of the *Aedes* species[29,30]. *Bti* has an exceedingly low mammalian toxicity with LD50 values for both acute oral and dermal toxicity of more than 30,000 mg/kg[26,31]. Hence, its proper use in drinking water should not cause any problems.

For the control of adult mosquitoes, p sonal protection measures including the use of household insecticide products, repellents and insecticide impregnated nets or curtains have been very much a part of active and sustainable community participation in the overall control of nuisance and disease-carrying mosquitoes including *Aedes* vectors. In the prevention and control of DF/DHF outbreaks, the use of chemical insecticidal adulticides in the form of space spray formulations, both thermal fogging and ultra low volume (ULV) sprays, is routinely carried out[13] against *Aedes* vectors.

Among personal protection measures, the use of household insecticide products should be considered as the most active form of community participation. The householders incur personal expenses for protection against mosquito bites. The use of household insecticide products including aerosols, mosquito coils, electric mats and more recently, electric liquid vaporizers has been on the increase throughout the world, especially in the developing countries. Industrial sources indicated that the annual consumption of aerosols, mosquito coils and electric fumigation mats was around 0.81, 12.50 and 3.65 billion units (pieces or cans), respectively as of 1989[32,33].

Among the household insecticide products, industrial sources indicated that the mosquito coil is the most commonly used household insecticide product in the world, in particular in the greater Southeast Asian region. Laboratory efficacy studies of mosquito coils against major genera of vector mosquitoes indicated that the *Culex* species was more tolerant to synthetic pyrethroid-based mosquito coils than those species in the genera *Aedes, Anopheles* and *Mansonia*[34], Field efficacy trials conducted in occupied premises indicated that coils provided more than a 70% reduction in man-mosquito contact with indoor man-biting mosquitoes[35]. In addition, field trials in open swampy areas in Northern Malaysia using cattle-bait nets ($2.8 \times 2.8 \times 1.8$ m^3) also showed a 70% reduction of mosquites trapped in the net when coils were burnt. The mosquitoes attracted to the cattle-bait nets included *Anopheles, Culex, Mansonia* and *Aedes* species[36].

In addition to household insecticide products, repellents (common active ingredient DEET) in the form of an application on the exposed skin or impregnated clothing have been shown to be effective[37-39]. However, due to cultural practice, the use of exposed skin repellent formulations has not been very well accepted by the general public living in tropical regions. With the support of the World Health Organization, insecticide impregnated bed nets have been field-tested in the malaria endemic regions against nocturnal *Anopheles* mosquitoes [40,41]. Nevertheless, their use for day-time biting *Aedes* vectors would be limited.

In addition to personal protection measures, the use of space spray formulations including termal fogging[42,43] and ultra low volume (ULV) sprays[44,45] is routinely carried out by government authorities to control *Aedes* vectors of endemic diseases through out the world. However, mixed results have been obtained from such sprays due to discrepancies in the implementation of the spray programmes[46-48]. In the Malaysian situation, vehicle-mounted ULV outdoor sprays using premium grade malathion (Cythion) are carried out when the *Aedes* population indexes indicate the potential for triggering a DF/DHF outbreak. In an epidemic situation, both the above outdoor ULV sprays and indoor house-to-house sprays using diesel-based malathion in thermal fogging sprays would be carried out[13]. Although existing thermal fogging sprays using malathion are still effective against *Aedes* vectors in Malaysia, public apathy towards such sprays is widespread in operational control due to inherent smell, thick smoke and oily deposit of the sprays. In contrast, a newer water-based thermal fogging formulation with pyrethroids as active ingredients appeares to be a better alternative with both larvicidal and adulticidal properties against *Aedes* vectors in indoor house-to-house spray. More recently, ULV spray using a combination of permethrin and microbial agent *Bti. also achieved both larvicidal* and adulticidal control against *Ae. aegypti* in the Dominican Republic[49].

As in any mosquito-borne disease control programme, the cooperation and participation of the community is vital to the success of any program for the control of DF/DHF and other vector-borne diseases. Depending on the socio-economic and political situation in a particular community, different approaches can be used to educate and mobilize the community concerning their role in the success of DF/DHF control in their locality. Public Health Officials must be innovative and bold in their search for the most effective form of community participation and not slavishly adopt patterns which have been shown to be successful elsewhere. Where necessary in view of the peculiarities of the local situation, modifications must be made to any pre-existing approaches or other recommended approaches. Detailed information concerning community education and participation with reference to the control of *Aedes* vectors will be covered in other sections of this conference. Hence, it will not be discussed.

In Malaysia, vector-borne disease control is under the management of the National Vector-Borne Diseases Control Programme within the Ministry of Health. Under the DF/DHF control programme, vector and disease surveillance vector control including all aspects mentioned in this paper, and enforcement with proper legislation, as well as epidemic measures, have been carried out routinely in the country since the first major outbreak of DF/DHF in 1973/1974[13,50]. In spite of the efforts, DF/DHF appears to have been on the increase since the mid -1980s (Fig. 1). Hence, improved strategies are necessary in order to contain the DF/DHF epidemic.

In conclusion, *Aedes* vector control with the ultimate aim of reducing or disrupting the transmission of DF/DHF will encompass the following approaches to be implemented in an integraed manner:

1. For the control of *Aedes* immatures, elimination or reduction of breeding habitats (source reduction) appears to be the best approach for the container-breeding *Aedes* species. However, major infrastructural improvements (availability and reliable delivery of clean water, good drainage and proper sewage disposal) and active, diligent community participation are essential for the success of this control.
2. In the use of control agents for *Aedes* immatures, microbial agents (*Bacillus thuringiensis* H-14) and IGRs are acceptable alternatives to the existing synthetic insecticides. In situations when larvicidal application is required, special consideration should be given concerning the environmental impact of the larvicides used. Such consideration includes the toxicity to non-target organisms and the effects on water quality (eg. drinking water). The ease of use of such a larvicide in order to promote public acceptance and cooperation concerning its use is also essential for the successful implementation of a larvicidal programme. In the case of IGRs, formulation of anti-insect legislation should take into consideration the mode of action of IGRs so as to facilitate their usage.
3. For the control of the adult *Aedes* mosquito personal protection through the use of household insecticide products can be considered as the most active form of community participation in mosquito control including *Aedes* vectors. Hence, it should be integrated into the overall *Aedes* vector control programme.
4. The use of space spray formulations, thermal fogging and ULV spray included, should be employed in situations of emergency *Aedes* control to suppress an ongoing dengue epidemic or to prevent an imminent dengue

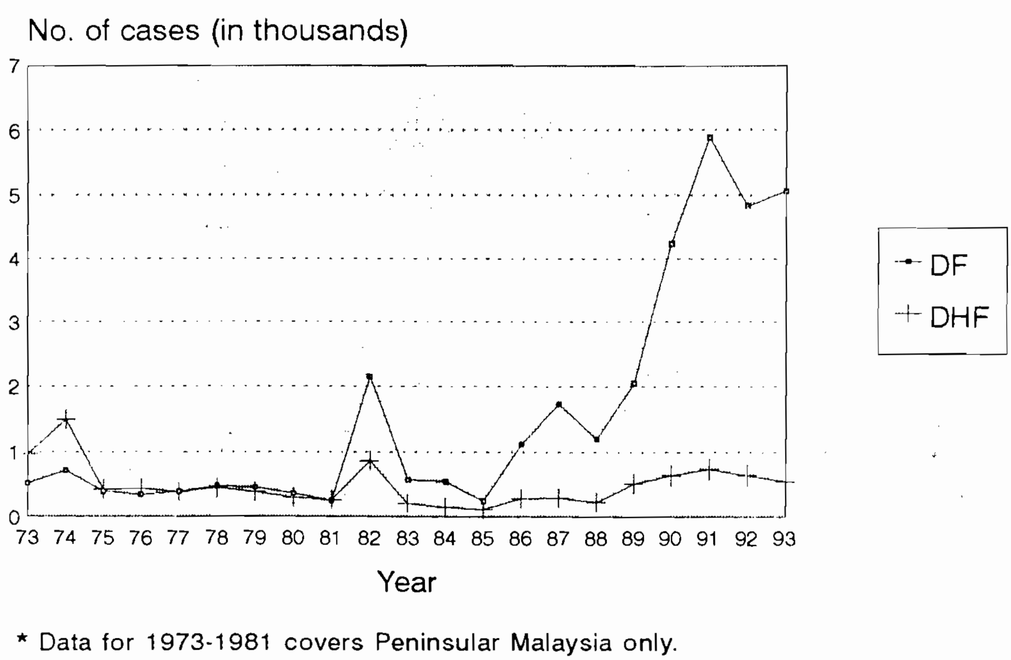

Fig. 1. Cases of dengue/dengue haemorrhagic fever in peninsular Malaysia (1973-1993)

outbreak from occurring.

5. In the choice of space spray insecticide formulations for *Aedes* control, the newer formulations which are both larvicidal and adulticidal against the *Aedes* mosquitoes should provide better control of *Aedes* populations than the existing adulticidal formulation. In addition, the use of water-based formulations, which have less environmental impact and are more acceptable by the community should be the trend for future space spray formulations.
6. Community participation is the key to the success of any aspect of vector control whether it is source-reduction or the use of control agents for *Aedes* control. Community education, awareness and eventual active participation should be an integral part of an overall programme for DF/DHF disease control.

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登革熱病媒防治：現況及展望

H. H. Yap, N. L. Chong, A. E. S. Foo and C. Y. Lee
徐爾烈 譯

自1950年代以來，登革熱及出血性登革熱是東南亞都市內最常見的傳染病。最近，這種傳染病已遠播至中南美洲，迄今已被公認是世界性的傳染病。在東南亞地區，埃及斑蚊及白線斑蚊都傳播登革熱及出血性登革熱。本篇報告主要是以馬來西亞之經驗爲例，討論斑蚊防治之現況及未來之展望。病媒防治包含了孳生源清除及環境管理，殺幼蟲劑（合成殺蟲劑，昆蟲生長調節劑及微生物殺蟲劑），長期防治用的殺成蟲劑及個人防護劑（家用殺蟲劑及忌避劑），短期緊急防止流行病的空間噴灑劑（熱煙霧劑及超低容量劑）。昆蟲生長調節劑，蘇力菌以色列品系，及有機磷殺幼蟲劑亞培松等綜合討論。使用水性空間噴灑劑較使用油性劑的優點，施用同時殺成蟲及幼蟲的〝雙殺〞的噴灑劑型在整體防治病媒及登革熱／出血性登革熱，亦予以強調。

（高雄醫誌 **10**: S102—S108, 1994）

馬來西亞檳城理科大學