Journal of the American Mosquito Control Association, 17(1):28–32, 2001

INDOOR THERMAL FOGGING APPLICATION OF PESGUARD® FG 161, A MIXTURE OF *d*-TETRAMETHRIN AND CYPHENOTHRIN, USING PORTABLE SPRAYER AGAINST VECTOR MOSQUITOES IN THE TROPICAL ENVIRONMENT

H. H. YAP, Y. W. LEE, J. ZAIRI, K. JAHANGIR AND C. R. ADANAN

Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia

ABSTRACT. Indoor bioefficacy of the thermal fogging application of Pesguard® FG 161, a formulation containing both knockdown and killing agents (active ingredient [AI]: *d*-tetramethrin 4% [w/w] and cyphenothrin 12% [w/w]) was compared with Resigen® (AI: *s*-bioallethrin 0.8% [w/w], permethrin [25/75] 18.7% [w/w], and piperonyl butoxide 16.8% [w/w]), another pyrethroid formulation, as larvicides and adulticides against *Aedes aegypti, Aedes albopictus, Anopheles sinensis,* and *Culex quinquefasciatus* using a portable Agrofog® AF35 sprayer indoors in houses on Penang Island, Malaysia. Pesguard FG 161 at the concentrations tested was effective against all 4 mosquito species tested. The water-based Pesguard FG 161 performed far better as a larvicide than the diesel-based formulation. Resigen was also effective as a larvicide and adulticide against all 4 mosquito species tested. Larvae of *Ae. aegypti* were most susceptible to water-based Pesguard FG 161, followed by *Cx. quinquefasciatus, An. sinensis,* and *Ae. albopictus.* Even at the lowest concentrations tested, Pesguard FG 161 showed adequate adulticidal properties. At higher dosages, water-based Pesguard FG 161 proved effective as a larvicide against all 4 mosquito species.

KEY WORDS Thermal fogging, pyrethroid formulations, *Aedes aegypti, Aedes albopictus, Culex quinquefasciatus, Anopheles sinensis*

INTRODUCTION

The most common vector mosquitoes in urban and suburban environments in many tropical areas are *Aedes aegypti* (L.), *Aedes albopictus* (Skuse), and *Culex quinquefasciatus* (Say) (WHO 1989), whereas *Anopheles sinensis* (Wied.) is widely distributed in rural areas in Southeast Asia (WHO 1989). Over the last 5 decades, dengue fever (DF) and dengue hemorrhagic fever (DHF) have increased steadily in both incidence and distribution globally. As of 1996, 2,500–3,000 million people in the tropical and subtropical region worldwide live in areas that are at potential risk of dengue virus transmission (WHO 1997). *Aedes aegypti* and *Ae. albopictus* are important vectors of DF and DHF. The common night-biting *Cx. quinquefasciatus,* which is cosmotropical in distribution and a vector of parasites causing bancroftian or urban filariasis, is also a public health problem. About 106 million people in the tropical areas of Africa, India, Southeast Asia, the Pacific Islands, and south and Central America are affected by the bancroftian parasite (*Wuchereria bancrofti*) (WHO 1995b). In addition to being a vector, *Cx. quinquefasciatus* is also a major household nuisance (Abu Hassan and Yap 1999). Meanwhile, the *Anopheles* mosquito is a vector of malaria as well as filariasis and arboviral diseases (Abu Hassan and Yap 1999). Every year, more than 100 million people are infected and more than 1 million people die because of malaria (WHO 1999).

In Malaysia and other neighboring Southeast Asian countries, vector-borne disease control follows WHO guidelines. House-to-house indoor thermal fogging sprays using diesel-based malathion (Cythion®) and vehicle-mounted ultra-low volume (ULV) outdoor sprays are carried out when there are outbreaks of DF or DHF (Yap 1984; WHO 1995a, 1997; Yap and Zairi 1999; Yap et al. 2000).

The use of space spray applications for the control of vector mosquitoes was reviewed recently (Yap et al. 1994, WHO 1996, Chavasse and Yap 1997, Gary 1998). Field evaluations of a few thermal fogging and ULV insecticide formulations against mosquitoes have been carried out in Malaysia (Yap et al. 1983, 1988, 1996, 1997, 1999; Lam and Tham 1988; Lim and Lee 1991) as well as in other tropical countries (Fox 1980, Itoh et al. 1988, Shono et al. 1991, Newton and Reiter 1992, Castle et al. 1999). Sometimes conflicting results have been obtained from such sprays because of different environment conditions and discrepancies in the implementation of spray programs. The objective of this study was to investigate the adulticidal and larvicidal efficacy of water- and diesel-based Pesguard® FG 161 in comparison with water-based Resigen® against *Ae. aegypti, Ae. albopictus, Cx. quinquefasciatus,* and *An. sinensis* using portable thermal fogging sprayer in living premises on Penang Island, Malaysia.

MATERIALS AND METHODS

Mosquitoes: Laboratory-cultured, sucrose-fed, female mosquitoes aged 3–5 days old and late 3rd- to early 4th-stage larvae of all 4 mosquito species (*Ae. aegypti, Ae. albopictus, Cx. quinquefasciatus,* and *An. sinensis*) from the Vector Control Research

Unit, Universiti Sains Malaysia, were used in this study. Assessment of adulticidal efficacy for each of the species were carried out with 20 adult mosquitoes placed in cylindrical fine-mesh cages with wire frame supports (10-cm diameter × 15-cm height). For larvicidal assessments, a similar number of larvae was placed in a cylindrical paper cup (top diameter 8 cm and height 10 cm) filled with 200 ml of seasoned tap water. Two checkpoints, one in the living room and the other in the kitchen, were set for each tested house.

Insecticide formulations and equipment used: A microemulsion pyrethroid formulation recommended for both ULV and thermal fogging purposes, namely Pesguard FG 161 (active ingredient [AI]: *d*-tetramethrin 4% [w/w] and cyphenothrin 12% [w/w]) supplied by Sumitomo Chemical Enviro-Agro Asia Pacific Sdn. Bhd. (Sumitomo Seremban Negeri Sembilan Darul Khusus, Malaysia) and Resigen® (AI: *s*-bioallethrin 0.8% [w/w], permethrin [25/75] 18.7% [w/w], and piperonyl butoxide 16.8% [w/w]) obtained from Aventis Environmental Science, formerly known as AgrEvo Environmental Health (M) Sdn. Bhd. (Kuala Lumpur, Malaysia), were used for the tests. Two portable thermal foggers, the Agrofog® (model AF 35) from Agro Technic Pte. Ltd. (Singapore) were used for spraying purposes. The discharge rates of the machines with 0.8 nozzle size were set at 230 ml/min. All spraying activities were conducted between 1800 and 1930 h.

Fogging operations: The trials were carried out in single-story terrace residential houses in an urban settlement on Penang Island, Malaysia. We compared the performance of water-based and diesel-based Pesguard FG 161 at dilution rates of 1:159, 1:99, and 1:49 with water-based Resigen at 1:99. A minimum of 10 similar-sized double-story concrete houses (5 with cages and cups) at alternate positions (with 1 house in between) from a single lane were chosen for the spraying of each of the formulations. The test site consisted of more than 20 lanes of residential terrace houses. Different lanes at least 50 m apart were chosen for the spraying of each formulation. Each of the selected houses was sprayed for a period of 40 ± 5 sec covering an area of 120 m^2.

Knockdown of adult mosquitoes was observed at 5, 10, 20, 30, and 60 min after spraying in the sprayed premises. After field exposure, the adult mosquitoes were brought back to the laboratory and transferred into clean polyethylene cups with 10% sucrose pads. Mortality of adult mosquitoes was recorded at 24 h after treatment. For larvicidal assessment, the larvae were brought back to the laboratory after the 1-h exposure and kept in clean paper cups. Mortality of larvae was recorded at 24 h after treatment. Percentages of knockdown and mortality values were subjected to an arcsine transformation followed by a comparison of means with

Table 1. Fogging time, discharge rate, and mean insecticide volume used per house for different insecticide formulations using Agrofog® thermal-fog machine (Model AF35, with nozzle size 0.8) at residential houses on Penang Island, Malaysia.

	Formulation[1]						
	R 100	FGW 160	FGW 100	FGW 50	FGO 160	FGO 100	FGO 50
Mean fogging time (sec) per houses	41 ± 0.2	42 ± 0.4	41 ± 0.1	42 ± 0.3	40 ± 0.5	41 ± 0.2	41 ± 0.1
Discharge rate (ml/min)—fixed	230	230	230	230	230	230	230
Mean volume of formulation sprayed (ml)/house	157 ± 0.8	161 ± 1.5	157 ± 0.4	161 ± 1.2	153 ± 2.0	157 ± 0.8	157 ± 0.4
House area measuring (m^2)—standard	120	120	120	120	120	120	120
Mean insecticide sprayed (ml/ha)	131 ± 0.3	84 ± 0.8	131 ± 0.3	268 ± 2.0	80 ± 1.1	131 ± 0.7	262 ± 1.0

[1] R 100, Resigen® (1:99) water-based; FGW 160, Pesguard® FG 161 (1:159) water-based; FGW 100, Pesguard FG 161 (1:99) water-based; FGW 50, Pesguard FG 161 (1:49) water-based; FGO 160, Pesguard FG 161 (1:159) diesel-based; FGO 100, Pesguard FG 161 (1:99) diesel-based; FGO 50, Pesguard FG 161 (1:49) diesel-based.

Table 2. Mean percentage knockdown and mortality of tested mosquito species from 5 premises at residential houses on Penang Island, Malaysia, at different posttreatment time after thermal-fog spraying with different insecticide formulations.[1]

	Percentage of adult knockdown					Percentage of adult mortality	Percentage of larval mortality
Formulation	5 min	10 min	20 min	30 min	60 min	1,440 min	1,440 min
Aedes aegypti							
Resigen®, water (1:99)	93 ± 5.9^{a}	99 ± 0.2^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	72 ± 2.2^{b}
Pesguard®, FG 161 water (1:49)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
Pesguard FG 161, water (1:99)	99 ± 1.3^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	97 ± 2.2^{a}
Pesguard FG 161, water (1:159)	85 ± 1.7^{b}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	77 ± 4.1^{b}
Pesguard FG 161, diesel (1:49)	100 ± 0.0^{a}	99 ± 0.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	4 ± 0.2^{c}
Pesguard FG 161, diesel (1:99)	99 ± 0.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	3 ± 0.0^{c}
Pesguard FG 161, diesel (1:159)	79 ± 4.3^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	2 ± 0.0^{c}
Aedes albopictus							
Resigen, water (1:99)	86 ± 1.8^{b}	98 ± 1.4^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	74 ± 1.9^{b}
Pesguard FG 161, water (1:49)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	94 ± 2.3^{a}
Pesguard FG 161, water (1:99)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	72 ± 3.2^{b}
Pesguard FG 161, water (1:159)	87 ± 0.1^{b}	96 ± 2.2^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	18 ± 0.0^{c}
Pesguard FG 161, diesel (1:49)	97 ± 1.7^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	2 ± 0.0^{d}
Pesguard FG 161, diesel (1:99)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	1 ± 0.0^{d}
Pesguard FG 161, diesel (1:159)	65 ± 3.5^{c}	99 ± 0.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	2 ± 0.0^{d}
Culex quinquefasciatus							
Resigen, water (1:99)	58 ± 4.2^{c}	91 ± 2.1^{b}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	79 ± 2.3^{b}
Pesguard FG 161, water (1:49)	98 ± 0.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
Pesguard FG 161, water (1:99)	96 ± 2.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	96 ± 3.1^{a}
Pesguard FG 161, water (1:159)	57 ± 3.6^{c}	80 ± 1.2^{c}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	99 ± 1.1^{a}	75 ± 2.1^{b}
Pesguard FG 161, diesel (1:49)	91 ± 3.2^{a}	98 ± 2.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	15 ± 1.0^{c}
Pesguard FG 161, diesel (1:99)	88 ± 4.1^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	98 ± 2.1^{a}	4 ± 0.0^{d}
Pesguard FG 161, diesel (1:159)	77 ± 1.1^{b}	97 ± 2.3^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	99 ± 1.0^{a}	14 ± 0.0^{c}
Anopheles sinensis							
Resigen, water (1:99)	88 ± 3.1^{b}	98 ± 2.3^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	79 ± 3.1^{b}
Pesguard FG 161, water (1:49)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	93 ± 0.0^{a}
Pesguard FG 161, water (1:99)	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	69 ± 4.6^{b}
Pesguard FG 161, water (1:159)	93 ± 2.1^{b}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	50 ± 3.8^{c}
Pesguard FG 161, diesel (1:49)	98 ± 0.8^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	26 ± 3.0^{d}
Pesguard FG 161, diesel (1:99)	97 ± 1.4^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	15 ± 2.5^{d}
Pesguard FG 161, diesel (1:159)	80 ± 3.1^{b}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	23 ± 3.2^{d}

[1] Mean percentages followed by the same letters within the same columns are not significantly different ($P < 0.05$, Duncan's multiple range test).

the Duncan multiple range test (SAS Institute 1985).

RESULTS AND DISCUSSION

The final volumes of water-based Pesguard FG 161 sprayed at dilution ratios of 1:159, 1:99, and 1:49 were 84 ± 0.8, 131 ± 0.3, and 268 ± 2.0 ml/ha, respectively. Volumes of diesel-based Pesguard FG 161 sprayed at dilution ratios of 1:159, 1:99, and 1:49 were 80 ± 1.1, 131 ± 0.7, and 262 ± 1.0 ml/ha and that of water-based Resigen sprayed at a dilution ratio of 1:99 was 131 ± 0.3 ml/ha (Table 1). Analysis of results indicated that all 4 adult mosquito species tested (*Ae. aegypti, Ae. albopictus, Cx. quinquefasciatus,* and *An. sinensis*) showed more than 98% mortality for both formulations tested at all dilution rates (Table 2). The dilution of water- and diesel-based Pesguard FG 161 tested seemed to possess good adulticidal properties. Resigen, another pyrethroid formulation, was effective as a larvicidal and adulticidal agent against all 4 mosquitoes species tested, with 100% mortality at 24 h after spraying (Table 2).

Even at the lowest concentrations tested, Pesguard FG 161 formulations (84 ± 0.8 ml/ha in water-based and 80 ± 1.1 ml/ha in diesel-based formulation) showed good adulticidal properties. All the formulations with their dilutions tested showed good knockdown properties, with 100% knockdown within 30 min. No significant differences ($P < 0.05$) were found in knockdown or mortality among all of the formulations tested against all 4 adult mosquito species 10 min after spraying.

Water-based Pesguard FG 161 at 268 ml/ha showed 100% larval mortality at 24 h after spraying against *Ae. aegypti* and *Cx. quinquefasciatus,* and even at lower dosages, it still provided adequate larvicidal control. However, diesel-based Pesguard FG 161 showed no larvicidal effect. Among the Pesguard series of formulations, Pesguard PS 102 (containing *d*-allethrin and *d*-phenothrin) at 625 ml/ha showed adulticidal properties only (Yap et al. 1999). The present study indicates that the use of Pesguard FG161 containing *d*-tetramethrin (a knockdown agent) and cyphenothrin (a killing agent) at proper dosages achieves sufficient larvicidal effect in indoor thermal fogging sprays. This is comparable to Resigen, which has been registered and sold in Malaysia and other Southeast Asia countries since the early 1990s for the control of dengue vectors. Resigen provides both adulticidal and larvicidal properties in a single spray (Yap et al. 1988, WHO 1995a). The control of larval- and adult-staged *Aedes* vectors in space spray may be essential for the disruption of DF and DHF transmission because of the possibility of transovarial transmission of dengue virus in both *Ae. aegypti* and *Ae. albopictus.* In this study, the water-based thermal fogging formulation of Pesguard FG 161 seemed to achieve significantly better larvicidal effect than diesel-based spray ($P < 0.05$). This could be due to better settlement of the spraying droplets of formulation mixture on exposed water surfaces in a water-based spray when compared with diesel-based spray.

Larvae of *Ae. aegypti* were most susceptible to water-based Pesguard FG 161 used at lower dosages (131 ± 0.3 and 84 ± 0.8 ml/ha), followed by *Cx. quinquefasciatus, An. sinensis,* and lastly by *Ae. albopictus.* As a larvicidal agent, water-based Pesguard FG 161 at higher dosages (131 ± 0.3 and 268 ± 2.0 ml/ha) was effective against all four mosquito species.

ACKNOWLEDGMENTS

We would like to thank the Coordinator of Vector Control Research Unit (VCRU), School of Biological Sciences, Universiti Sains Malaysia, for the use of laboratory and transport facilities; Sumitomo Chemical Enviro-Agro Asia Pacific Sdn. Bhd. (Malaysia) and Aventis Environmental Science, formerly known as AgrEvo Environmental Health (M) Sdn. Bhd. for Pesguard FG 161 and Resigen formulations, respectively; the staff of VCRU especially R. Rahim, Y. Abdul Malik, and B. Rohaizat, for technical assistance; and Agro Technic, Singapore, for supplying machinery.

REFERENCES CITED

Abu Hassan A, Yap HH. 1999. Mosquitoes. In: Lee CY, Yap HH, Chong NL, Jaal Z, eds. *Urban pest control, a Malaysian perspective* Penang, Malaysia: Universiti Sains Malaysia. p 26–38.

Castle T, Amador M, Rawlins S, Figueroa JP, Reiter P. 1999. Absence of impact of aerial malathion treatment on *Aedes aegypti* during a dengue outbreak in Kingston, Jamaica. *Rev Panam Salud Publica Pan Am J Public Health* 5:100–105.

Chavasse DC, HH Yap, eds. 1997. *Chemical methods for the control of vector and pests of public health importance* WHO/CTD/WHOPES/97.2. Geneva, Switzerland: World Health Organization.

Fox I. 1980. Evaluation of ultra-low volume aerial and ground applications of malathion against natural populations of *Aedes aegypti* in Puerto Rico. *Mosq News* 40: 280–283.

Gary AM. 1998. A critical review of ultralow-volume aerosols of insecticide applied with vehicle-mounted generators for adult mosquito control. *J Am Mosq Control Assoc* 14:305–334.

Itoh T, Marijani JH, Keto AJ, Matsushita T. 1988. Control of *Anopheles* mosquitoes by ultra-low-volume applications of *d*-allethrin and *d*-phenothrin in combination with larvicidings of fenitrothion in Tanzania. *J Am Mosq Control Assoc* 4:563–564.

Lam WK, Tham AS. 1988. A field evaluation of the effectiveness of ULV application of malathion 96% technical grade and sumithion L-40S against *Aedes aegypti* and *Aedes albopictus* in Ipoh Municipality, Perak, Malaysia. *Trop Biomed* 5:81–88.

Lim JL, Lee KF. 1991. Efficacy and relative potency of lambda-cyhalothrin and cypermethrin applied as a group-based ULV aerosol for the control of houseflies and mosquitoes. *Trop Biomed* 8:157–162.

Newton EA, Reiter P. 1992. A model of the transmission of dengue fever with an evaluation of the impact of ultra-low volume (ULV) insecticide applications on dengue epidemics. *Am J Trop Med Hyg* 47:709–720.

SAS Institute. 1985. *SAS™ user's guide: statistics, version 5 ed* Cary, NC: SAS Institute, Inc.

Shono Y, Jean-Francois V, Jean YS, Itoh T. 1991. Field evaluation of ultra-low volume applications with a mixture of *d*-allethrin and *d*-phenothrin for control of *Anopheles albimanus* in Haiti. *J Am Mosq Control Assoc* 7:494–495.

WHO [World Health Organization]. 1989. *Geographical distribution of arthropod-borne diseases and their principal vector* WHO/VBC/89.967. Geneva, Switzerland: World Health Organization.

WHO [World Health Organization]. 1995a. *Guidelines for dengue surveillance and mosquito control* WHO/WPRO. Geneva, Switzerland: World Health Organization.

WHO [World Health Organization]. 1995b. *Tropical disease research* Twelfth programme report of the UNDP/World Bank/WHO special programme for research and training in tropical diseases (TDR). Geneva, Switzerland: World Health Organization.

WHO [World Health Organization]. 1996. *Operational manual on the application of insecticides for control of the mosquito vector of malaria and other diseases* WHO/CTD/VBC/96.1000. Geneva, Switzerland: World Health Organization.

WHO [World Health Organization]. 1997. *Dengue haemorrhagic fever, diagnosis, treatment, prevention and control* 2nd ed. Geneva, Switzerland: World Health Organization.

WHO [World Health Organization]. 1999. Tropical disease research—progress 1997–98. Fourteenth Programme Report. In: *TDR news*. TDR/PR 14/99.1. p 64.

Yap HH. 1984. Vector control in Malaysia—present status and future prospects. *J Malaysian Soc Health* 4:7–12.

Yap HH, Chong ASC, Adanan CR, Abdul Malik Y, Chong NL, Lim SY, Rohaizat B. 1996. Field efficacy of a pyrethroid microemulsion (Pesguard PS 102®) as ULV ground aerosols against three urban mosquito species. *Trop Biomed* 13:59–63.

Yap HH, Chong ASC, Adanan CR, Chong NL, Rohaizat B, Abdul Malik Y, Lim SY. 1997. Performance of ULV formulations (Pesguard® PS102®/Vectobac 12AS®) against three mosquito species. *J Am Mosq Control Assoc* 13:384–388.

Yap HH, Chong NL, Foo AES, Lee CY. 1994. Dengue vector control: present status and future prospects. *J Med Sci Kaohsiung* 10:102–108.

Yap HH, Zairi J. 1999. Mosquito control. In: Lee CY, Yap HH, Chong NL, Jaal Z, eds. *Urban pest control, a Malaysian perspective* Penang, Malaysia: Universiti Sains Malaysia. p 39–49.

Yap HH, Khoo TC, Chee CS, Cheong WH. 1983. Comparative adulticidal and larvicidal effects of thermal fogging formulations of Dursban, malathion, and bioresmethrin against *Aedes aegypti* (Linnaeus) and *Culex quinquefasciatus* (Say) on Penang Island, Malaysia. In: Pang T, Pathmanathan, eds. *Dengue/dengue haemorrhagic fever* Proceedings of the International Conference. 1983 September 1–3; University of Malaya, Kuala Lumpur, Malaysia. p 231–246.

Yap HH, Khoo TC, Tan HT, Chung KK, Abdul Malik Y, Narayanan VS. 1988. Comparative adulticidal and larvicidal effects of thermal fogging formulations of Resigen® and malathion against *Aedes aegypti* (Linnaeus) and *Culex quinquefasciatus* Say in urban areas, Malaysia. *Trop Biomed* 5:125–130.

Yap HH, Lee YW, Chong ASC, Zairi J. 1999. Bioefficacy of pyrethroid formulation (PESGURD® PS 102) in thermal fogging application against urban mosquito species of public health importance. *Trop Biomed* 16:17–22.

Yap HH, Lee YW, Zairi J. 2000. Chemical control of mosquitoes. In: Ng FSP, Yong YS, eds. *Mosquito and mosquito-borne diseases: biology, surveillance, control, personal and public protection measures.* Kuala Lumpur, Malaysia: Academy of Sciences Malaysia. p 197–210.