INSECTICIDE SUSCEPTIBILITY OF THE DENGUE VECTOR, *AEDES AEGYPTI* (L.) IN METROPOLITAN BANGKOK

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Abstracts. Mosquito larvae were collected from the houses of dengue infected patients in Bangkok, Thailand from 55 sites (36 out of the 50 districts of Metropolitan Bangkok). *Aedes aegypti* larvae were tested against temephos using WHO bioassay techniques. Adult mosquitoes were tested for susceptibility to permethrin, deltamethrin, cyfluthrin, malathion and DDT using WHO diagnostic doses. Most of the larvae tested were susceptible to temephos. Only few specimens were resistant to temephos. Most adult mosquitoes were highly susceptible to malathion. Deltamethrin resistance was seen in 6 districts of Bangkok. Variable levels of susceptibility were seen with cyfluthrin. Most of the specimens showed resistance to permethrin and all specimens were resistant to DDT.

Keywords: *Aedes aegypti*, dengue vector, insecticide susceptibility bioassay technique, Bangkok, Thailand

INTRODUCTION

Dengue fever (DF), dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS) are important mosquito borne viral diseases. The first outbreak of DHF in Thailand to be reported was in 1958 (Nimmanitya, 1987). Since then it has been a major public health problem in Thailand. The disease has been increasing, with cyclic outbreaks every 2-3 years. Currently no effective vaccines or specific anti-viral treatments are available to treat DHF. Control of the disease relies mainly on control of the mosquito vector. The two main approaches used for control of *Aedes aegypti* mosquitoes are reduction of mosquito breeding sites and application of chemical insecticides. The larvicide temephos has been used for controlling mosquito larvae for over 50 years. Adult control by space spraying is usually carried out as an emergency measure for suppressing vector populations during an outbreak of DHF. At present, pyrethroids are the main insecticides used for controling disease-carrying vectors in Thailand.

DHF is one of the top ten diseases under surveillance in Metropolitan Bangkok. There were 5,392 cases of DHF resulting in 8 deaths in Bangkok in 2005 (Ministry of Public Health, Thailand, 2005). Temephos sand granules (1%) are the larvicide routinely used to control mosquito larvae. Deltacide™ (biollethrin

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0.09% w/w; deltamethrin 0.06% w/w and piperonyl butoxide 11.9%) is frequently used to control adult mosquitoes. During September-December 2005 a study of the density, vector species and key-containers at breeding sites was conducted by the staff of the Vector Control Subdivision, Health Department, Bangkok Metropolitan Administration (BMA). The collected mosquito larvae were sent to the Department of Medical Entomology, Faculty of Tropical Medicine, Mahidol University for species identification and insecticide susceptibility testing. Insecticides have been widely used to control mosquito vectors, but baseline data of vector susceptibilities in endemic areas is limited. The decentralized policy of the Thai government allows each local government to choose and purchase the insecticide to be used in that area. Improper use of insecticides can result in resistance among mosquitoes and thus failure to control the vector. The objective of this study was to determine the insecticide susceptibility of DF vectors in Metropolitan Bangkok providing baseline information to assist policy decision makers in vector control.

MATERIALS AND METHODS

Field-collected mosquitoes

Mosquito larvae were collected during September-December 2005 from the houses of patients with DF prior to control by thermal fogging of insecticide conducted by the staff of the Vector Control Subdivision, Health Department, Bangkok Metropolitan Administration (BMA). The larvae were collected from 55 sites in 36 out of 50 districts in Metropolitan Bangkok and identified. They were then raised at the insectarium of the Department of Medical Entomology, Faculty of Tropical Medicine, Mahidol University at 26°C, 70-80% relative humidity at 12 hours light, 12 hours dark photoperiod. Larvae were fed with guinea-pig food pellets. Adults were provided with 10% sucrose solution and blood meals from hamsters. Mosquito larvae in some locations were collected to monitor insecticide susceptibilities in the following years.

Insecticide susceptibility test

F_1 and F_2 progeny of field collected *Aedes* mosquito larvae were used for insecticide susceptibility testing. *Aedes aegypti* larvae were tested against serial concentrations of temephos using a WHO bioassay technique (WHO, 1996, 1998). Temephos at a concentration of 0.02 mg/l was also tested against mosquito larvae. Adult mosquitoes were tested for susceptibility to: 0.75% permethrin, 0.05% deltamethrin, 0.15% cyfluthrin, 5% malathion, and 4% DDT using a WHO test kit. At least 100 female mosquitoes were used for each insecticide tested. The baseline toxicity of temephos, permethrin, deltamethrin, cyfluthrin, malathion and DDT against *Aedes* mosquitoes was determined using a standard susceptible strain: *Aedes aegypti* Bora Bora.

Data analysis

Data were analyzed using probit analysis (Finney, 1971) to determine 50% lethal concentration values (LC_{50}) and 95% lethal concentration values (LC_{95}). Control mortality was determined using the Abbott formula (Abbott, 1925). Resistance ratios (RR) were calculated as the ratio of the LC_{50} or LC_{95} in the field strains divided by the LC_{50} or LC_{95} of the susceptible strain. The percent mortality of adult mosquitoes 24 hours after exposure to the insecticide was calculated. The number of knocked down mosquitoes 60 minutes after insecticide exposure was recorded and used to calculate the knock down

Table 1
Temephos susceptibility among *Aedes aegypti* larvae from various districts of Metropolitan Bangkok.

District	Location	Total treated	LC_{50} (95% CI)	LC_{95} (95% CI)	[a]RR_{50}	[a]RR_{95}	Slope	% Mortality at 0.02 mg/l
Phra Nakhon		2,050	0.0064 (0.0058-0.0070)	0.0127 (0.0104-0.0155)	2.6	2.6	5.6	100
Pom Prap Sattru Phai		1,400	0.0070 (0.0053-0.0093)	0.0132 (0.0069-0.0254)	2.8	2.7	5.9	98
Dusit		1,900	0.0062 (0.0060-0.0064)	0.0131 (0.0124-0.0141)	2.5	2.7	5.1	100
	Wat Chom Pai	1,600	0.0056 (0.0046-0.0068)	0.0101 (0.0069-0.0147	2.2	2.1	6.4	100
Pathum Wan	Soi Pra Jane	1,943	0.0064 (0.0063-0.0066)	0.0119 (0.0113-0.0127)	2.6	2.4	6.2	100
	Wat Duang Khae	600	0.0082 (0.0055-0.0122)	0.0181 (0.0059-0.0558)	3.3	3.7	4.7	98
Bang Rak	Khun Nawa	1,100	0.0066 (0.0063-0.0068)	0.0124 0.0116-0.0135)	2.6	2.5	5.9	100
	Hua Lum Phong	2,000	0.0069 (0.0067-0.0071)	0.0139 (0.0131-0.0150)	2.8	2.8	5.3	100
	Wat Kaew Jam Fa	300	0.0059 (0.0055-0.0064)	0.0116 (0.0103-0.0138)	2.4	2.4	5.7	100
Sathon	Ban Pan	1,500	0.0088 (0.0035-0.0228)	0.0185 (0.0009-0.3937)	3.5	3.8	5.1	99
	Soi Yen Argart	700	0.0101 (0.0097-0.0106)	0.0169 (0.0154-0.0192)	4.0	3.4	7.3	99
	Soi Kuson Raum Jai	1,600	0.0063 (0.0061-0.0065)	0.0109 (0.0105-0.0116)	2.5	2.2	6.8	100
	Wathana Sin	600	0.0094 (0.0057-0.0160)	0.0159 (0.0041-0.0756)	3.8	3.2	7.9	100
Watthana	Su Lao Sam In	1,650	0.0079 (0.0071-0.0088)	0.017 (0.0132-0.0220)	3.2	3.5	4.9	100
	Thong Lo	1,600	0.0061 (0.0052-0.0071)	0.0128 (0.0089-0.0187)	2.4	2.6	5.1	100
Ratchathewi		2,100	0.0066 (0.0064-0.0067)	0.0119 (0.0114-0.0126)	2.6	2.4	6.3	100
	Soi Suan Ngearn	1,500	0.007 (0.0067-0.0072)	0.0161 (0.0147-0.0182)	2.8	3.3	4.5	100
Chatuchak		2,000	0.0064 (0.0061-0.0066)	0.0168 (0.0156-0.0184)	2.6	3.4	3.9	99
Huai Khwang		1,500	0.0089 (0.0075-0.0106)	0.0192 (0.0131-0.0281)	3.6	3.9	5.0	97
	Pracha Niwet	1,500	0.0064 (0.0053-0.0077)	0.0128 (0.0085-0.0194)	2.6	2.6	5.4	100
Din Daeng	Suthisan	1,500	0.0054 (0.0047-0.0061)	0.0124 (0.0097-0.0161)	2.2	2.5	4.5	99
	Vichakarn	1,800	0.0069 (0.0067-0.0071)	0.0159 (0.0147-0.0175)	2.8	3.2	4.5	100

Table 1 (Continued).

District	Location	Total treated	LC_{50} (95% CI)	LC_{95} (95% CI)	aRR_{50}	aRR_{95}	Slope	% Mortality at 0.02 mg/l
Yan Nawa		800	0.0072 (0.0032-0.0159)	0.0114 (0.0023-0.0581)	2.9	2.3	8.1	100
Bang Kho Laem	Saphan Krungthep	1,200	0.0069 (0.0053-0.0091)	0.0138 (0.0071-0.0269)	2.8	2.8	5.5	99
	Lad Bua Khao	2,000	0.0068 (0.0066-0.0070)	0.0161 (0.0148-0.0177)	2.7	3.3	4.3	99
	Charoen Krung Hospital	2,400	0.0069 (0.0068-0.0071)	0.0139 (0.0132-0.0149)	2.8	2.8	5.5	99
Phra Khanong	Bang Chak	600	0.0076 (0.0028-0.0204)	0.0132 (0.0011-0.1585)	3.0	2.7	6.8	100
Khlong Toei	Wat Toei	1,950	0.0093 (0.0075-0.0115)	0.0197 (0.0125-0.0310)	3.7	4.0	5.1	96
	Wat Saphan	2,200	0.0067 (0.0058-0.0076)	0.0147 (0.0105-0.0208)	2.7	3.0	4.8	100
	Klong Samukkee	1,600	0.0083 (0.0068-0.0103)	0.0197 (0.0109-0.0360)	3.3	4.0	4.4	99
Bang Na		1,400	0.0051 (0.0049-0.0053)	0.0096 (0.0090-0.0103)	2.0	2.0	6.0	98
Khlong San	Mit Bhon	900	0.0071 (0.0044-0.0114)	0.0124 (0.0043-0.0408)	2.8	2.5	6.8	99
Bangkok Yai	Phet Khasem	2,133	0.0087 (0.0085-0.0090)	0.0167 (0.0158-0.0178)	3.5	3.4	5.8	99
Thon Buri	Wat Kuntarum	1,360	0.0073 (0.0065-0.0083)	0.0174 (0.0134-0.0228)	2.9	3.6	4.4	98
	Bang Sakae Nok	1,500	0.0085 (0.0068-0.0107)	0.0196 (0.0115-0.0338)	3.4	4.0	4.5	97
	Bang Sakae Nai	1,600	0.0076 (0.0066-0.0087)	0.0159 (0.0114-0.0228)	3.0	3.2	5.1	98
	Samukkee Thum	1,600	0.0048 (0.0041-0.0056)	0.0085 (0.0064-0.0112)	1.9	1.7	6.6	100
Phasi Charoen	Karn Rau	1,800	0.0074 (0.0068-0.0081)	0.0148 (0.0124-0.0179)	3.0	3.0	5.5	99
Rat Burana	Wat Noi	800	0.0084 (0.0060-0.0119)	0.0167 (0.0077-0.0366)	3.4	3.4	5.5	98
	Suk Sawat	1,500	0.0064 (0.0062-0.0066)	0.0122 (0.0114-0.0131)	2.6	2.5	5.9	100
Chom Thong		900	0.0074 (0.0072-0.0077)	0.0132 (0.0123-0.0144)	2.9	2.7	6.6	99
Bang Kapi		925	0.0053 (0.0052-0.0055)	0.0095 (0.0090-0.0099)	2.1	1.9	6.6	100
Suan Luang	Wat Tai	1,300	0.007 (0.0067-0.0072)	0.0142 (0.0132-0.0156)	2.8	2.9	5.3	99
Khan Na Yao		2,000	0.0065 (0.0063-0.0066)	0.0128 (0.0121-0.0137)	2.6	2.6	5.5	100
Saphan Sung	Wat Yai	1,900	0.0063 (0.0061-0.0065)	0.0136 (0.0128-0.0147)	2.5	2.8	4.9	100

Table 1 (Continued).

District	Location	Total treated	LC_{50} (95% CI)	LC_{95} (95% CI)	[a]RR_{50}	[a]RR_{95}	Slope	% Mortality at 0.02 mg/l
Nong Chok	Wat Lum Pak Chee	1,800	0.0058 (0.0052-0.0064)	0.0094 (0.0078-0.0115)	2.3	1.9	7.8	100
Khlong Sam Wa		1,200	0.0077 (0.0074-0.0080)	0.0169 (0.0152-0.0194)	3.1	3.4	4.8	100
Lat Krabang		1,200	0.006 (0.0035-0.0102)	0.0106 (0.0040-0.0298)	2.4	2.2	6.7	100
Prawet	On Nut	2,000	0.0046 (0.0045-0.0048)	0.0086 (0.0082-0.0091)	1.8	1.8	6.1	100
Nong Khaem		1,200	0.0063 (0.0056-0.0071)	0.0112 (0.0089-0.0143)	2.5	2.3	6.5	100
Bang Khae		2,000	0.0063 (0.0061-0.0064)	0.0127 (0.0120-0.0136)	2.5	2.6	5.3	100
Taling Chan		1,600	0.0062 (0.0050-0.0076)	0.0121 (0.0077-0.0190)	2.5	2.5	5.6	96
Thawi Watthana		1,800	0.0072 (0.0070-0.0074)	0.0134 (0.0126-0.0142)	2.9	2.7	6.2	99
Bang Khun Thian	Kheha Thonburi	1,800	0.0083 (0.0039-0.0177)	0.0171 (0.0016-0.1882)	3.3	3.5	5.2	97
Thung Khru		1,200	0.0084 (0.0045-0.0155)	0.0299 (0.0031-0.3020)	3.4	6.1	2.9	86
Bora Bora susceptible strain		1,000	0.0025 (0.0015-0.0047)	0.0049 (0.0016-0.0172)	1.0	1.0	5.8	100

[a]Resistance Ratio (RR_{50}, RR_{95}) is the ratio of LC_{50} or LC_{95} of the field strain divided by LC_{50} or LC_{95} of the susceptible strain.

rate (% KD). The Knock Down Times (KT_{50}, and KT_{95}) for the mosquitoes were also determined. The WHO recommendations for susceptibility testing are as followes: 98-100% mortality indicates susceptibility, 80-97% mortality suggests the possibility of resistance (incipient resistance) needing to be confirmed and <80% mortality suggests resistance.

RESULTS

Most F_1 mosquito larval populations from the 36 out of 50 districts of Metropolitan Bangkok were susceptible to Temephos. The larvae from 6 collection sites, Huai Kwang, Khlong Toei, Thon Buri, Taling Chan, Bang Khun Thian and Thung Kru, had incipient resistance at a temephos concentration of 0.02 mg/l (Table 1). This indicated a low level of resistance compared to the standard susceptible strain, with RR_{50} values ranging from 1.8 to 4.0. The LC_{50} and LC_{95} value for the larvae from the 55 collection sites were: 0.0046 mg/l to 0.0101 mg/l and 0.0085 mg/l to 0.0299 mg/l, respectively.

The operational criterion for resistance has usually been taken as the survival of ≥ 20% of the individuals tested at diagnostic doses using WHO test kits (WHO, 1992). Table 2 showed the KT_{50}, KT_{95} and KD rates 60 minutes after ex-

posure and percent mortality of female *Aedes aegypti* mosquitoes 24 hours after a 1 hour exposure to insecticide impregnated papers. Most of the tested colonies had high resistance (<80% mortality) to permethrin, with mortality rates ranging from 5 to 78%. Mosquitoes from Ratchathewi-Soi Soun Ngung had the highest resistance to permethrin with 5% mortality. The KT_{50} and KT_{95} for permethrin in the Bora Bora standard susceptible control strain were 7.6 minutes and 14 minutes, respectively, while the field mosquitoes had KT_{50} and KT_{95} values of 40 to 111 minutes and 60 to 318 minutes, respectively. Only mosquitoes from 2 collecting sites, Lat Krabang and Nong Khaem, were susceptible to permethrin (98% and 100% mortality) with KT_{50} values of 15 and 16 minutes, respectively. Deltamethrin resistance was detected in 6 districts, Pathum Wan-Wat Duang Khae, Huai Khwang, Klong San, Rat Burana- Wat Noi, Bang Kapi and Bang Khun Thian, with mortality rates of 27, 77, 78, 62, 70 and 53%, respectively. The percent knock down (%KD) rate at 60 minutes ranged from 33 to 96%. Most locations had incipient resistance. Mosquitoes from 17 out of 53 locations were susceptible to deltamethrin. The KT_{50} and KT_{95} for deltamethrin among susceptible colonies ranged from 15 to 35 minutes and 23 to 60 minutes, respectively. Cyfluthrin susceptibility was found in mosquitoes from 7 locations: Thon Buri, Phasi Charoen, Khan Na Yao, Lat Krabang, Prawet, and Nong Khaem. Mosquitoes from 28 out of 53 locations had incipient resistance; 17 of 53 locations had high levels of resistance to cyfluthrin with mortality rates ranging from 21 to 79%. *Aedes aegypti* mosquitoes at most study sites were susceptible to malathion; only a few locations (Pathum Wan-Wat Duang Khae, Bang Rak-Khun Nawa and Huai Khwang) showed incipient resistance with percentage mortality rates ranging from 89 to 97%. Complete resistance to DDT (0% mortality, data not shown) was seen in all tested insects.

Monitoring of insecticide susceptibility patterns was done in 2008, 2009 and 2010 at other locations in Bang Khae, Thung Khru and Taling Chan districts. The results showed increasing of pyrethroid resistance was present (Table 3).

DISCUSSION

Baseline data of insecticide susceptibility were obtained for *Aedes aegypti* larvae and adult mosquitoes from 55 locations in 36 out of 50 districts of Metropolitan Bangkok. Use of discriminating or diagnostic dose is the method of choice for routine monitoring of insecticide susceptibility/resistance status in mosquito vectors. Comparisons of susceptibility data from a single place over time are useful to indicate resistance trends. In adult mosquitoes, besides mortality rates to pyrethroids, knock down (KD) rates should also be obtained. A change in the KD rates among mosquitoes is a sensitive indicator of early pyrethroid resistance. Evidence of resistance to temephos and malathion among *Ae. aegypti* and *Culex quinquefasciatus* mosquitoes in some areas in Bangkok has been observed since 1986 (Chareonviriyahpap *et al,* 1999). Temephos resistance among *Ae. aegypti* mosquitoes has been reported from other provinces in Thailand (Ponlawat *et al,* 2005, Paeporn *et al,* 2006). However, our study showed *Ae. aegypti* larvae at most studied sites in Bangkok were susceptible to temephos. Both RR_{50} and RR_{95} were less than 10. About 65.5% of the collection sites had larvae with an approximate LC_{95} value of 0.01 mg/l, while the larvae in 34.5% of collection sites exhibited a higher LC_{95} value

Table 2
Susceptibility of *Aedes aegypti* mosquitoes from various districts of Metropolitan Bangkok to permethrin, deltamethrin, cyfluthrin, and malathion[a].

District	Location	0.75% Permethrin				0.05% Deltamethrin				0.15% Cyfluthrin				5% Malathion			
		KT_{50} (min)	KT_{95} (min)	%KD	% Mortality	KT_{50} (min)	KT_{95} (min)	%KD	% Mortality	KT_{50} (min)	KT_{95} (min)	%KD	% Mortality	KT_{50} (min)	KT_{95} (min)	%KD	% Mortality
Phra Nakhon		77	111	14	42[b]			100	99	30	54	96	81[c]	38	54	100	100
Pom Prap Sattru Phai		54	74	72	88[c]			100	95[c]	25	42	99	95[c]	37	54	100	100
Dusit		76	158	29	43[b]			91	89[c]	41	62	91	75[b]	39	57	100	100
	Wat Chom PraiNgang	68	124	39	61[b]			100	99	20	33	100	97[c]	25	52	100	100
Pathum Wan	Wat Dung Khae	78	136	20	26[b]	68	120	33	27[b]	59	86	54	21[b]	56	102	58	97[c]
	Soi Pra Jane	71	169	37	67[b]	26	48	99	95[c]	28	49	99	77[b]	34	58	97	100
Bang Rak	Khun Nawa	70	144	25	38[b]	45	71	87	81[c]	35	61	95	87[c]	36	58	97	89[c]
	Wat Kaew Jam Pha	62	98	48	46[b]			100	85[c]	23	32	100	93[c]	40	55	100	100
	Wat Hua Lum Pong	59	98	58	68[b]			88	90[c]	44	77	84	75[b]	42	59	94	100
Sathon	Ban Pan	80	185	30	78[b]			90	90[c]	30	51	98	87[c]	42	63	97	100
	Kuson Reom Jai	64	108	42	76[b]			99	96[c]	25	41	100	95[c]	40	64	88	100
Watthana	Thong Lo	40	190	66	82[c]			99	97[c]	15	34	100	93[c]	35	52	98	100
	Su Lao Sam In			11	47[b]			97	89[c]	38	58	96	84[c]	40	56	99	100
Ratchthewi	119/72	57	96	56	71[b]	42	70	88	84[c]	36	67	91	76[b]	38	54	81	100
	Soi Suan Ngearn			1	5[b]	42	89	85	83[c]	44	82	84	43[b]	43	92	79	100
Chatuchak		54	165	58	66[b]	30	56	99	93[c]	25	51	100	79[b]	31	46	100	100
Huai Khwang		111	289	14	19[b]	49	78	71	77[b]	48	85	78	75[b]	43	68	89	100
	Pracha Nivaj	60	79	50	55[b]	40	60	95	96[c]	34	62	99	95[c]	37	55	100	100
	Hatsawee	82	169	25	66[b]	46	73	86	97[c]	44	81	81	73[b]	40	62	100	90[c]
Din Daeng	Vichakarn	78	118	29	40[b]	28	44	99	93[c]	23	41	99	89[c]	33	53	100	100
Yan Nawa		73	104	29	52[b]	33	49	100	100	32	46	100	93[c]	31	41	100	100
Bang Kho Laem	33	68	124	36	59[b]	34	55	98	91[c]	30	61	95	76[b]	43	62	95	100
	Saphan Krungthep	60	84	44	56[b]	40	57	95	92[c]	28	44	99	76[b]	39	52	100	100
	Lad Boua Khao	83	134	14	22[b]	35	59	98	100	32	53	99	71[b]	42	62	93	100
Phra Khanong	Bang Chark			6	49[b]	27	48	100	95[c]			99	84[c]	29	55	100	100
Khlong Toei		56	82	59	85[c]	24	39	100	100	19	29	100	94[c]	25	51	100	100
	Wat Toei	62	110	47	80[c]	25	37	100	98	24	34	100	92[c]	28	51	100	100
	Klong Samukkee	69	119	37	49[b]	30	44	99	97[c]	25	43	100	91[c]	40	62	96	100
Bang Na		98	247	20	49[b]	27	53	99	100	32	61	97	87[c]	41	62	95	100

Khlong San	Mit Phon	89	147	10	33[b]	39	62	95	78[b]	38	63	89	75[b]	32	44	100	100
Bangkok Yai		100	318	32	89[c]	26	39	100	100	25	40	100	97[c]	24	35	100	100
Thon Buri	Bang Sakae Nok	55	110	62	63[b]	31	58	93	83[c]	31	59	96	77[b]	33	57	98	100
	Bang Sakae Nai	42	62	50	54[b]	28	52	98	98	29	47	99	96[c]	36	53	100	100
	Wat Kantaram	66	89	31	93[c]	40	54	100	100	40	54	100	100	45	54	100	100
	Samukkee Thum	85	141	13	31[b]	30	44	99	96[c]	22	33	100	98	32	45	100	100
Phasi Charoen		67	99	31	93[c]	45	60	98	100	40	54	100	99	46	57	100	100
Rat Burana	Wat Noi			4	48[b]	48	70	96	62[b]	49	71	91	48[b]	48	66	100	100
	Suk Sawat	50	60	86	85[c]	32	56	97	96[c]	35	61	98	88[c]	36	51	99	100
Chom Thong		47	66	57	74[b]	28	45	98	96[c]	28	45	99	85[c]	30	42	100	100
Bueng Kum		73	118	23	40[b]	40	62	98	91[c]					45	61	92	100
Bang Kapi		86	212	25	45[b]	53	106	62	70[b]	50	133	66	62[b]	51	73	78	100
Suan Luang	Wat Tai	57	83	56	77[b]	31	45	100	100	31	48	100	85[c]	43	67	95	100
Khan Na Yao		62	97	47	84[c]	26	37	100	99	25	45	100	98	31	48	100	100
Saphan Sung	Wat Yai	81	157	22	35[b]	33	48	99	97[c]	31	46	100	94[c]	39	59	99	100
Nong Chok	W Lum Pak Chee	73	125	28	56[b]	32	46	100	100	29	47	100	90[c]	41	62	99	100
Khlong Sam Wa		55	91	57	96[c]	28	42	100	93[c]	26	37	100	89[c]	32	43	100	100
Lat Krabang		15	27	99	98	15	24	100	97[c]	14	20	100	100	30	41	100	100
Prawet	Oon Nut	63	133	45	65[b]	26	38	100	100	26	37	100	100	33	61	100	100
Taling Chan		100	220	18	42[b]	41	72	86	82[c]	32	52	98	92[c]	39	71	97	99
Nong Khaem		16	28	100	100	15	23	100	100	14	21	100	99	27	42	100	100
Thawi Watthana		79	152	23	52[b]	32	55	93	95[c]	32	61	91	83[c]	27	38	100	100
Bang Khun Thian				4	8[b]	50	80	74	53[b]	47	73	78	57[b]	44	62	91	99
Thung Khru		75	133	29	58[b]	30	46	100	98	26	44	98	92[c]	29	44	100	100
	Bora Bora strain	7.6	14		100	8	15.7		100					26.4	39.4		100

[a]98-100% mortality indicates susceptible; 80-97% mortality suggests the possibility of resistance that needs to be confirmed ([c]incipient); <80% mortality suggests resistance ([b]resistance)

KT_{50} KT_{95} = time needed to knock down 50% and 95% of tested insects respectively; %KD (knock down rate) = percentage of tested insects knocked down at 60 minutes.

Table 3
Percent mortality of *Aedes aegypti* 24 hours after exposure to diagnostic doses of various insecticides during different years.

Province	District	Year	Mortality (%)							
			0.05% Deltamethrin	0.75% Permethrin	0.15% Cyfluthrin	5% Malathion	4% DDT	0.1% Propoxur	0.1% Bendiocarb	0.05% Lambda-cyhalothrin
Bangkok	Bang Khae	2008	66.27	16.96	-	99.88	1.08	-	-	-
		2009	47.15	3.65	42.1	99	0.25	6.35	27.35	19.45
	Thung Khru	2005	98	58	92	100	0	-	-	-
	Thung Khru[a]	2005	96.4	57.6	92	100	0.8	-	-	-
		2008	46	10	-	99	0	-	-	-
	Taling Chan	2005	82	42	92	99	0	-	-	-
	Taling Chan[a]	2005	82	57.6	92	99	0	-	-	-
		2010	56	19	55	100	0	8	56	38

[a]Another location in the same district.

(> 0.01 mg/l). Temephos, the principal larvicide used to control *Aedes* larvae in Thailand, can still be used effectively with proper dosing. *Ae. aegypti* mosquitoes were completely resistant to DDT. The tendency for cross resistance to pyrethroid insecticides may have occurred (Prasittisuk and Busvine 1977; Brengues *et al*, 2003; Limoce *et al*, 2006). Permethrin was inadequately effective in more than 77% of studies areas. Resistance to cyfluthrin is also increasing in many locations. Both deltamethrin and malathion are still useful for control of dengue vectors during outbreaks. However, there was a trend toward deltamethrin resistance among adult mosquitoes in more than half of larval collection sites (30 out of 53 locations). Data from monitoring susceptibilities over time confirms rapidly increasing resistance, especially against pyrethroids (Table 3). Therefore, periodic monitoring of resistance should be carried out in order to early detect insecticide resistance and develop appropriate management strategies.

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