succeed, the lack of such research should not restrain the more widespread use of guppies when there is a reasonable chance that they will exert control. This is especially true in tropical regions where *C. p. fatigans* is largely produced in polluted ground pools and similar sources. These polluted breeding sites seldom harbour indigenous species of fish that would be endangered by the introduction of guppies, although the possibility must be taken into consideration in some areas where polluted waste water drains into natural watersheds. More often, however, it appears that when guppies enter these drainage systems they do not survive or thrive because of the indigenous piscivorous fishes that are present. This was the case in Rangoon, a short distance from where the *kutchas*, well populated with guppies, entered the Pazundaung Creek near Tamwe. Similar observations were made by Johnson & Soong (1963) in Malaysia.

Where guppies are readily available, or can be reared, for mosquito control in tropical areas their use in the types of habitat discussed here should be encouraged. It is likely, however, that in most areas, for one or more of the reasons described, guppies will become established in only a small proportion of *C. p. fatigans* breeding sites.

The contribution of guppies to mosquito control where they succeed, however, can well compensate for the many introductions that fail.

ACKNOWLEDGEMENTS

We thank Mr S. Y. Liu for the use of his data concerning guppy introductions in Taipei, and members of the Taiwan Provincial Malaria Research Institute who were responsible for gathering these data.

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A field trial of Abate larvicide for the control of *Aedes aegypti* in Bangkok, Thailand*

Y. H. BANG [1] & C. P. PANT [2]

Abate [3] has been shown to have a low toxicity for mammals (Laws et al., 1969) combined with a long-term effectiveness against *Aedes aegypti* larvae in various types of water container. Schoof (1967) reviewed the work on the development of 1% sand granules, which can be added to water containers to give a concentration of 1 ppm, and the US Public Health Service approved the use of Abate to control *Ae. aegypti*. Bang et al. (unpublished report to WHO) have shown that a single mass treatment with 1% sand granules at a level of 1 ppm gave good control of *Ae. aegypti* for periods of 6–24 weeks, depending on the nature of the surrounding areas, which appears to influence the recovery of the adult density. It has also been shown that Abate was liberated rapidly from sand granules, but the prolonged toxicity of the formulation in water jars, which is commonly found in Thailand, was due to a strong affinity of the larvicide for the walls of the container. Thus, in contrast to the earlier belief, the 1% sand granules did not act as a slow-release formulation but the containers themselves seemed to play a vital role in retaining the insecticide and releasing it gradually over a prolonged period. Regulation of the dosage in water containers is easier when sand granules rather than another formulation are used, since expensive equipment is not required; furthermore, since the granules are visible, supervision of the operators is facilitated.

Larviciding provides longer lasting control than does the use of fogs or aerosols against adults, but is

* This study was supported by Public Health Service research grant No. CC 00261 from the Center for Disease Control, Atlanta, Ga., USA.

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[3] *0,0,0',0'*-tetramethyl *0,0'*-thiodi-*p*-phenylene phosphorothioate, manufactured by the American Cyanamid Company.

difficult because of the very large number and variety of larval habitats, many of which cannot easily be found. Thus training and supervision of control crews in finding and treating all existing breeding sources appears to be one of the main factors in a successful control programme. Bang et al. (unpublished report to WHO) also compared the effectiveness and economics of two different control procedures and concluded that a method combining cyclic mass treatment at 3-monthly intervals with the simultaneous treatment of new habitats between mass treatments gave the best control. A very limited number of data are available on the economics of larviciding as a control measure against *Ae. aegypti.* The expense involved in a control operation using Abate varies with the area to be treated, the quality of the personnel and the amount of training they have received, and the method of treatment.

During 1969–70, the WHO *Aedes* Research Unit carried out a field trial in Bangkok to provide some basic information on the effectiveness of larviciding, the degree of control obtained, the personnel required, and administration and management practices appropriate to a large-scale control programme.

Description of the area

The trial area was located in Sutisan in the northern section of Bangkok (Fig. 1). The area comprised 173 ha and was cut by Sutisan Street into 2 unequal parts, a southern part of 65.7 ha and a northern part of 106.8 ha. On the northern side the area is bordered by a canal 15 m wide with many coconut palms on both sides; in the southern part are open fields while the highway to Don Muang airport runs along the eastern boundary. Along stretches of the western boundary (1 306 m long) of the trial area that bordered untreated areas a barrier zone was established to reduce the infiltration of mosquitos into the trial area. The shortest distance between the edges of the trial and untreated areas was about 60 m. A block of 160 houses lying about 2 km north of the trial area served as the check area.

Materials and methods

Treatment. Abate in a 1% sand-granule formulation [1] was used to treat all larval habitats other than ant traps and smaller containers. The target dosage was 1 ppm in all habitats whether full of water or empty (i.e., 15 g of the granules per container of 150 litres). Although the size of the water containers varied considerably, they were all classified into one of four groups (water jars, ant traps, tin cans, and miscellaneous containers) and treated with the required quantity of granules (Bang et al., unpublished report to WHO). Ant traps and other temporary smaller containers that did not contain potable water were treated at a dosage level of 1–10 ppm. Minor habitats were cleaned up, destroyed, or treated. All treated containers were marked with a spot of paint to differentiate them from untreated or new containers placed after treatment. The treatment was carried out by a team of 12 mosquito scouts and 3 supervisors and a WHO staff member. The area was divided into 6 zones (Fig. 1) and each team of 2 scouts always worked in the same zone in order to increase the efficiency of the operations. The actual treatment involved larviciding and recording. In each zone, larvicide was applied from a plastic bucket containing the sand-granule formulation by a scout using plastic spoons holding 5 and 10 g. This scout also marked treated receptacles with paint. The other scout recorded the house number, the number of each type of container treated, and other information required. The second and fourth (final) treatments were applied by one man in each zone without recording the containers treated.

Houses that were locked at the time of the initial visit (amounting to 15–20%) were treated during subsequent visits by the same control team. A supervisor recorded the man-hours needed for the operation and the quantity of granules applied. The initial mass treatment began on 16 June 1969 and ended about 2 weeks later. The second, third, and fourth treatments were applied in September, December, and April 1970, respectively. At each of the successive treatments, the containers were marked again with paint of a different colour.

The barrier zone, which contained 189 houses in two streets (Fig. 1), was treated in the same way as the other zones.

Larval inspection between mass treatments. Monthly examination of larval habitats started on the first day of the month following each mass treatment and ended before the next treatment. The examination following the final mass treatment was completed after 6 months. An inspection was made in every other house during the first 2 weeks and the rest of the houses were examined during the second half of the month. A search for larval breeding sites included not only the treated containers but also new ones and those that had been overlooked by the control team. All the newly found receptacles without a paint

[1] Formulated and produced by the American Cyanamid Company.

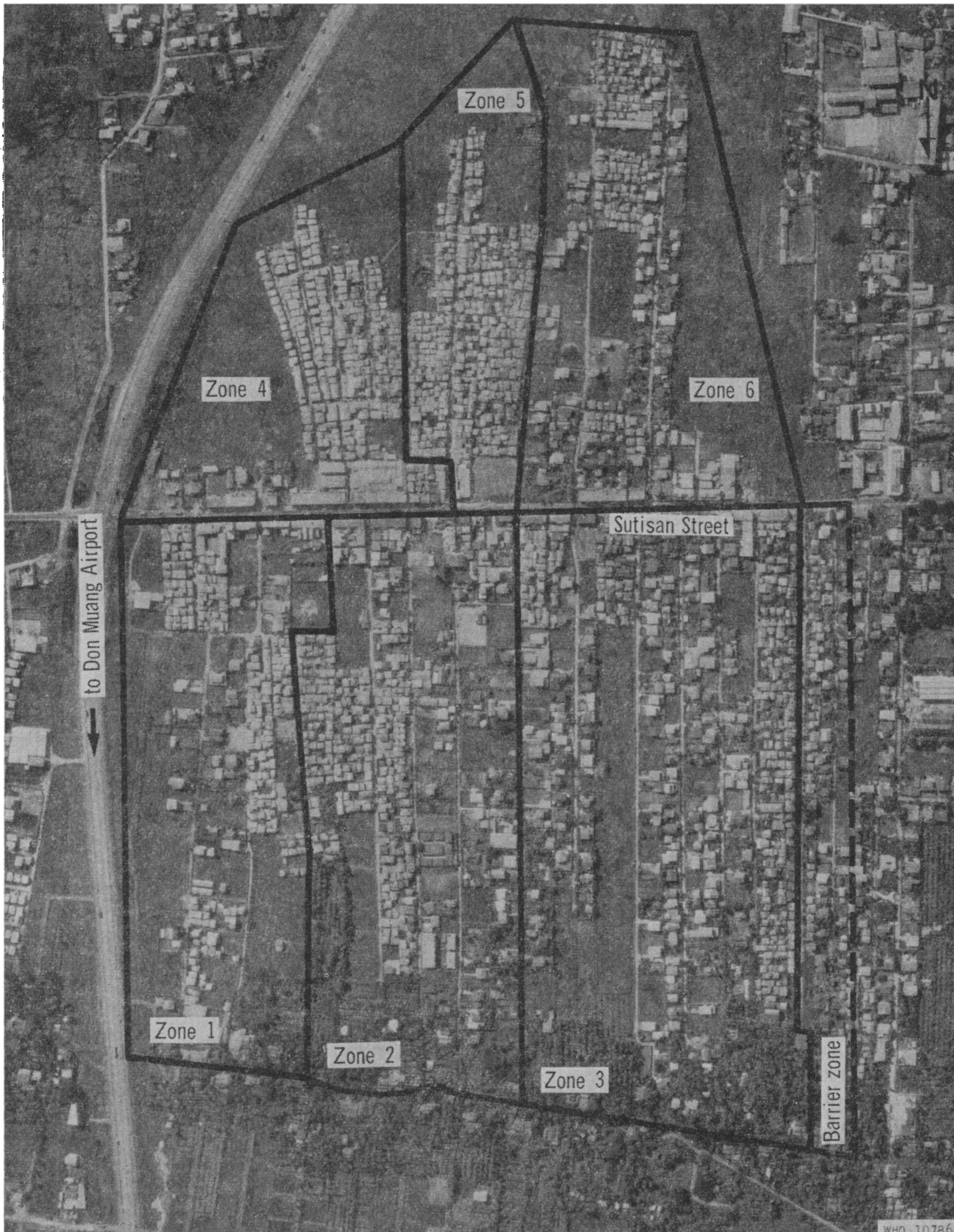

Fig. 1. The Sutisan trial area, Bangkok.

spot were treated in addition to those found to be positive for larval breeding. This inspection and treatment was carried out simultaneously in the six zones by six scouts under two supervisors. Cross-inspections were carried out for 2 days at the end of the monthly inspection when the supervisors exchanged duties.

In the check area, visual larval surveys were conducted each month in 150 reference houses. The larval habitats were classified into three categories as larger water containers, ant traps, and smaller temporary containers. A similar survey was carried out twice weekly in 25 houses selected at random in each of the three sections in the barrier zone, in one section of the untreated area and in the adjoining side of the trial area (Fig. 1).

Adult density. Mosquitos landing on human bait or resting on different surfaces were collected twice monthly in 18 permanent stations in each zone by one scout for three mornings between 08.00 and 11.00 hours, 20 min being spent at each station. The collectors were rotated twice monthly, except in the check area. Adult collections began 4 weeks before the larvicidal treatment, during which time three catches were made, and continued until the adult density was well on the way to recovery and approaching the original population level after the final larvicidal treatment. A similar collection was conducted in the barrier zone to determine adult population levels in the vicinity of the treated area. Six stations were selected at random in each of the five sections; the mosquito scouts were rotated as in the treated area.

Results

Treatment. An average of 3 434 houses per treatment were treated four times with 1% Abate sand granules at a target dosage of 1 ppm at intervals ranging from 2.5 to 4 months (Table 1). The number of houses treated increased from 3 337 in the first

Table 1. Requirements of insecticide and labour during the four mass treatments

Treatment	Visit	No. of houses treated	No. of containers per house	Total amount of Abate used (kg)	Amount of Abate applied per house (g)	Man-hours needed [a]	Time required per house (min)
first (15 June 1969)	initial	2 824	11.1	317.8	112.5	676	14.4
	subsequent	513	3.5	16.0	31.2	142	16.6
	total	3 337	10.3	333.8	100.0	818	14.7
second [b] (8 Sept. 1969)	initial	2 841	—	279.9	98.5	258	5.5
	subsequent	502	—	37.7	75.1	142	17.0
	total	3 343	—	317.6	95.0	400	7.2
third (8 Dec. 1969)	initial	2 757	8.9	283.9	103.0	504	11.0
	subsequent	700	7.1	44.6	63.7	184	15.8
	total	3 457	8.6	328.5	95.0	688	11.9
fourth [b] (14 April 1970)	initial	2 919	—	301.6	103.3	266	5.5
	subsequent	679	—	42.1	62.0	169	14.9
	total	3 598	—	343.7	95.5	435	7.3
total	initial	11 341		1 183.2	104.3	1 704	9.0
	subsequent	2 394		140.4	58.6	637	16.3
	total	13 735		1 323.6	96.4	2 341	10.3

[a] Man-hours of supervision are excluded.
[b] Treatments were made by one-man control teams without the number of containers treated being recorded.

mass treatment to 3 598 in the final treatment. At the first two mass treatments approximately 15% of the total houses were found to be locked and this percentage increased slightly at the third and fourth treatments. During the first three applications, treatment was refused in less than 2% of the total houses visited but the number increased to 4% during the final treatment. However, most of these houses were treated by a Thai medical officer at subsequent visits.

The average amount of Abate used per house ranged from 98.5 g in the second mass treatment to 112.5 g in the first treatment. However, the difference in the amount of Abate used per house for the four treatments was not statistically significant ($F=0.54$). The average quantity of granules used for the houses treated during the initial visits was 417 g per house per year, which is 45% higher than the average for locked houses treated at subsequent visits. Generally, locked houses belonged to single labourers who left for work early in the morning, and these houses had fewer containers. The annual average for the Sutisan treatment was 385.6 g of granules per house, which is in general agreement with that estimated in a previous study.

The quantity of Abate used per house varied at the initial visit (Table 2), ranging from 84 g in zone 4 to 127 g in zone 3. This variation was statistically correlated with the number of larger containers treated per house ($r=0.862$; $P<0.01$). The quantity of granules used per house changed during the four treatments, since the number of containers per house varied. The average number of containers treated per house was 2 smaller during the third treatment (December 1969) than during the first treatment (July 1968). The amount of Abate used during this period fell by about 10 g per house (Table 1). The number of containers decreased during the cool dry season in all the zones except zone 5, which comprises slum houses. Miscellaneous containers showed the greatest decrease, followed by water jars, ant traps, and tin cans, in that order.

The average time required for larviciding during the initial visit was about 13 min per house for the first and third treatments (Table 1). When treatments were made by one man (second and fourth treatments) the time was reduced by about 60%. However, the reduction was smaller if the average time is calculated on the basis of the combined number of houses treated at both the initial and subsequent visits (Table 2). The time varied from zone to zone but was not statistically correlated with the number of containers per house ($r = 0.52$), indicating that the time per house did not depend on the number of containers. The actual number of houses treated by a control team varied with the zone ($F = 3.812$; $P<0.05$), ranging from 7 to 11 per half working

Table 2. Quantity of 1 % Abate sand granules used and labour needed for larvicidal treatments in relation to the distribution of larval habitats

Zone	No. of containers per house [a]			Amount of Abate per house (g) [b]			Time per house (min) [c]		No. of houses treated per half-day (2 hours)
	larger	smaller	total	initial visit	subsequent visit	average	two-man team	one man	
1	5.51	8.65	14.16	106	56	95	13.6	7.7	21.2
2	4.83	4.87	9.70	104	57	97	11.7	6.8	25.4
3	5.54	7.76	13.30	127	74	118	15.8	8.1	19.7
4	4.14	5.70	9.84	84	50	77	11.9	6.3	24.8
5	5.06	4.74	9.80	103	47	93	12.0	6.4	22.9
6	4.47	5.29	9.77	92	59	85	13.9	7.1	23.0
barrier	4.32	4.68	9.00	116	88	112	13.4	9.2	19.6
average [d]	4.93	6.13	11.06	104	59	96	13.2	7.3	22.4

[a] Based on the first mass treatment; larger containers included water jars and metal drums, others are considered as smaller containers.
[b] Average for the four mass treatments.
[c] Time required for mass larvicidal treatment.
[d] Average for four different mass treatments made at the initial visit.

day of 2 working hours. Analysis of variance indicates that the number of houses treated by one man was not significantly different from that treated by 2-man teams ($F = 1.078$; $P<0.05$). This is because only one man applied the treatment in both cases. The number of houses treated appears to be related to their income class rather than to the distribution of larval habitats within them.

Larval infestation. The Breteau index (number of infested containers per 100 houses inspected) of 330 before larvicidal treatment was reduced to 3.9 by the first application (Table 3), a reduction of 98.8%. The proportion of treated containers positive for larval breeding increased gradually after each of the four mass treatments. The Breteau index rose from 1.9 to 67.8 during the 6 months following the fourth mass treatment. The smallest reduction was about 80%, which occurred during the sixth month after the last treatment. With the exception of the third treatment, a new treatment was always started when the Breteau index reached about 10.

The water jar was the type of container most susceptible to reinfestation among the larval habitats inspected; these jars represented about 80% of the treated containers infested with larvae. Approximately 9.7% of the initially treated water jars became positive for larval breeding during the year of treatment; tin cans (8.9%) were next in order.

The number of new or untreated containers found during routine inspection varied with the month (Table 3), but averaged 0.06 per house, i.e., approximately 0.58% of the containers treated at the initial treatment. Thus there was less than one new container per man-hour of larval inspection except during the first month after the initial treatment. More than 30% of the new containers treated during routine larval inspections were water jars.

The time needed for routine larval inspections ranged from 3.7 to 7.1 min per house, with an average of 5.26 min (Table 3). The average time devoted to inspection at each house was slightly less than that required for the larvicidal treatment. More time was spent during the hot season (February, March, and May). The number of houses inspected by one scout varied from 20 to 26 during 2 actual working hours.

Table 3. Number of larval habitats treated, time taken, and insecticide used during the routine larval inspections

After mass treatment	Month	No. of houses inspected	New or previously untreated containers		Treated containers infested with larvae			Time required per house (min)	Amount of Abate per container (g)
			No. treated	No./100 houses	No. treated	No./100 houses	Percentage reduction [a]		
first	July 1969	3 590	901	25.1	141	3.9	98.8	4.9	9.8
	August 1969	4 173	324	7.8	395	9.5	97.1	4.8	9.0
second	October 1969	2 954	73	2.5	22	0.7	99.8	5.8	21.0
	November 1969	4 531	131	2.9	177	3.9	98.8	4.7	30.0
third	January 1970	2 103	68	3.2	28	1.3	99.6	5.6	26.0
	February 1970	2 468	45	1.8	57	2.3	99.3	6.8	24.0
	March 1970	2 135	85	4.0	226	10.6	96.8	6.2	19.0
fourth	May 1970	2 384	113	4.7	44	1.9	99.4	7.1	18.0
	June 1970	3 439	116	3.4	189	5.5	98.3	5.9	13.0
	July 1970	4 424	74	1.7	416	9.2	97.2	5.1	11.9
	August 1970	1 986	70	3.5	672	33.8	89.2	3.8	—
	September 1970	1 838	73	4.0	843	45.9	86.1	4.0	—
	October 1970	779	43	5.5	528	67.8	79.5	3.7	—

[a] On the basis of the Breteau index (330 containers per 100 houses) determined before the initial treatment.

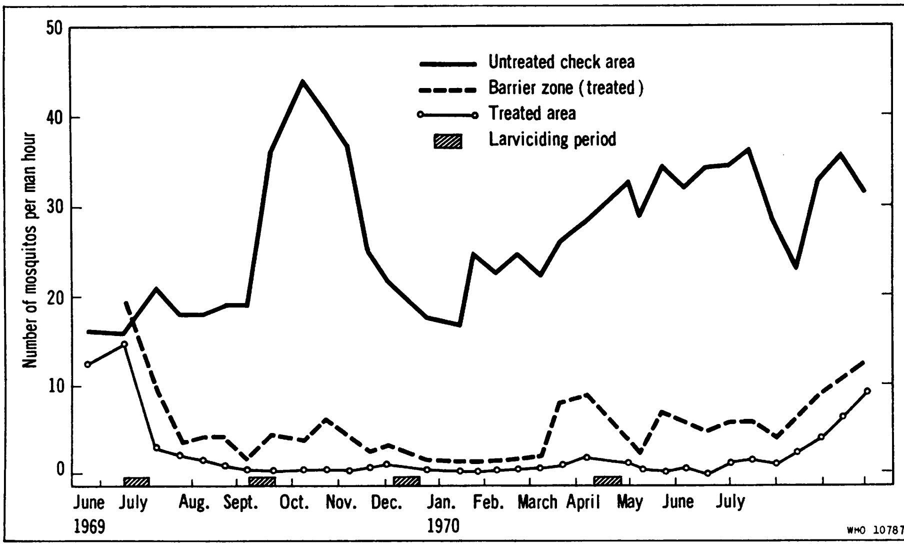

Fig. 2. Comparison of adult densities of *Aedes aegypti* in three experimental areas.

In the untreated check area of Sutisan, a considerable seasonal variation was observed, not only in Breteau index values but also in container index values. There were some fluctuations in the average number of containers per house and in the proportion of houses with infested containers, but the differences were not statistically significant. The mean number of infested containers per house during the cool season (November–January) was about 1.5 smaller than in the rainy season (July–September). The house index appeared to fluctuate less than the Breteau index and the container index.

Adult density. For the entire control period of 13 months starting in July 1969, the monthly average number of mosquitos caught in the treated area ranged from 0.2 to 2.1 (average, 1.04) per man-hour (Fig. 2). The mean number of adult mosquitos collected after the initial mass treatment was 2.4 per man-hour, approximately 3 times that observed after the four successive larvicidal treatments. The average number for the 4 months ending in December 1969 was the lowest, being about 0.7 mosquitos per man-hour. The number collected in the treated area fell by approximately 95.4 % during the 13-month period. The percentage reduction was slightly smaller when a comparison was made with the data for pretreatment populations. This difference can perhaps be attributed to lower adult densities before the first larvicidal treatment. After the monthly inspection of larval habitats ceased at the end of July 1970, the adult density increased gradually but had not returned to pretreatment levels 6 months later. The rate of recovery of the adult population is generally in agreement with that determined in the isolated village of Bang Sue, where a single application of the larvicide was made (Bang, Gratz & Pant, unpublished report to WHO).

There were no significant differences in adult mosquito activity for the six treated zones or the four different mass treatments. However, the average number of mosquitos collected in zone 5 was noticeably higher than in the other zones. This was probably because this zone comprises slum houses in which many types of container are widely dispersed.

In the untreated check area, adult counts fluctuated in a manner similar to the Breteau index (Table 4). The mean monthly catches gradually increased from September to October 1969 and then decreased until January 1970. A slow increase occurred again in April 1970 and continued up to October. The seasonal variation in the adult density was not significantly correlated with the container index (r=0.52), the house index, or the Breteau index.

Barrier zone. The adult density in the nearest section of the barrier zone to the trial area was less than 1.0 mosquitos per man-hour, which was not

Table 4. Breteau index determined in the barrier zones and in the untreated check area

After mass treatment	Month	Treated area	Barrier zones			Untreated	Check area
		Puhirun [a] East	Puhirun West	Porntip East	Porntip [b] West	Pongsichan East	Untreated
first	July 1969	0	0	7	12	573	425
	August 1969	24	28	36	140	576	506
second	September 1969	0	8	0	—	328	495
	October 1969	0	12	0	48	508	437
	November 1969	4	24	28	56	532	358
third	December 1969	0	0	2	51	309	336
	January 1970	0	0	0	9	320	364
	February 1970	0	0	8	48	460	396
	March 1970	24	4	32	48	440	347
	April 1970	76	32	92	180	228	400
ourth	May 1970	0	8	4	20	216	402
	June 1970	4	12	4	16	188	421
	July 1970	12	8	0	96	240	—
	August 1970	42	144	8	64	232	—
	September 1970	192	108	148	110	126	—
Average, July 1969 to July 1970		11.1	10.5	16.4	56.3	378.3	407.3

[a] The peripheral street of the trial area.
[b] This section borders the untreated street Pongsichan East.

significantly higher than the average for the trial areas (Table 5). The density increased gradually with the distance from the trial area. The number of adults collected in the two barrier sections was at least 4–5 times that found in Puhirun West. The catching rate increased markedly in the section of the barrier zone that was immediately adjacent to the untreated area, but the density was still only about 50% of that in the latter area. The difference between the treated barrier zone and the untreated area was of the order of 5–10 mosquitos per man-hour. The average adult catch in the untreated area after the third mass treatment (December–March) was only 40% of the density determined after the initial treatment (July and August). The density had not returned to the initial level even 6 months after the fourth treatment.

A direct relationship between population density and proximity to untreated areas was also observed for larvae (Table 4); the Breteau index always declined after each treatment, corresponding to a lower density of adults. This decline was also noticed in the untreated zone. The annual average for the Breteau index in the three treated sections of barrier zone was only 7.3% of the average for the untreated neighbourhood. The Breteau index in untreated sections decreased gradually after the second application, being only 200 after the final treatment (35% of the original index). The container index after the fourth treatment was 35%, and thus it too showed a decrease.

Discussion

In countries of South-East Asia in general, and particularly in Thailand, the practice of storing water for drinking and for household use in earthenware and cement jars in and around the house is widespread. These containers are the main breeding sites for *Ae. aegypti*, the vector of haemorrhagic fever in

Table 5. Adult density of *Aedes aegypti* (number caught per man-hour) determined in five sections of the periphery of the Sutisan study area. The densities are averages for six stations sampled twice a month

After mass treatment	Month	Puhirun East (treated area)	Puhirun West (barrier zone)	Porntip East (barrier zone)	Porntip West (barrier zone)	Pongsichan (untreated)
first	July 1969	1.8	2.4	5.8	10.9	22.6
	August 1969	2.0	1.3	4.3	7.0	20.0
second	September 1969	1.5	1.3	0.5	7.5	20.3
	October 1969	2.3	1.8	1.5	12.5	17.0
	November 1969	3.3	1.8	6.0	3.8	14.0
third	December 1969	0.3	1.0	4.5	3.3	8.3
	January 1970	0.0	0.0	1.3	1.3	9.3
	February 1970	0.3	0.3	3.0	1.3	6.0
	March 1970	0.8	0.5	8.0	6.0	10.5
	April 1970	0.5	0.3	8.8	9.3	12.5
fourth	May 1970	0.0	0.5	5.8	7.8	16.3
	June 1970	1.0	1.0	6.0	7.5	15.5
	July 1970	4.0	1.0	6.0	10.8	12.8
	August 1970	11.0	7.0	5.0	2.0	12.5
	September 1970	13.8	8.0	12.0	12.5	17.5
Average for July 1969–July 1970		1.4	1.0	4.7	6.8	14.2

Thailand. In the absence of a safe and effective vaccine against dengue haemorrhagic fever, vector control is the only way to prevent the spread of this disease at present. The low toxicity of Abate for mammals, combined with its long residual effectiveness against *Aedes* larvae at the low concentration of 1 ppm and the fact that the active ingredient is released from the 1% sand-granule formulation and retained by the walls of water containers, makes it feasible to use this formulation for long-term control of *Ae. aegypti.*

During a field trial of Abate in Bangkok when four treatments were applied in an area with about 3 500 houses, it was observed that the first treatment was less persistent than the subsequent treatments, and effective control was maintained for 2, 2.5, and 3 months after the first, second, and third treatments, respectively. The amount of Abate used at the target dosage of 1 ppm varied with the number of containers per house and was approximately 10 g per container per treatment under the local conditions. Roughly 10 containers were treated in each house. It was shown that keeping records of containers treated has no particular advantage. One man could treat 40–50 houses per day, the number of houses treated per day depending on the distribution of the houses rather than on the number of containers per house.

Retreatment is necessary when the Breteau index rises above 10 or when the adult density determined by the collection of resting and landing mosquitos of both sexes is greater than 1 mosquito per man-hour. The collection of adults is the most sensitive method for checking the effectiveness of larvicidal treatments and for detecting failures in control. The number of collecting stations should be at least 1% of the total number of houses treated.

For intensive control, routine larval inspections may be needed to detect and treat positive containers. Since this requires a large control team it is not recommended as a method for determining control failures. It is estimated that one inspector can visit and examine 40–60 houses per day. A barrier zone about 50 m wide is adequate for protecting treated areas against serious infiltration of adult mosquitos from untreated areas.

During the trial described here, four treatments were applied during the year; however, as a preventive method for controlling the vector of dengue haemorrhagic fever, larviciding with a 1% Abate sand-granule formulation can be carried out just before the rainy season and repeated within 2 months. Since the rainy season seems to be the peak period for transmission of dengue haemorrhagic fever, and the recovery of the adult mosquito population during the cool season is slow, two treatments during the year may be sufficient.

ACKNOWLEDGEMENTS

The authors thank the following persons, without whose help this work would not have been possible: Dr Prakorb Tuchinda, Director-General, Department of Medical Sciences, and Dr Sujarti Jatanasen, Division of Communicable Diseases Control, Ministry of Public Health, Thailand, who provided staff and laboratory facilities; Dr Raphiphat Kasemsook and the Municipality of Bangkok for providing a field office and assistance with public relations during the trial; Dr Poonluan Punthumchinda for helping with the treatments and public relations; and Mr Ongart Chareonsook, Mr Anek Ruangsri, and Mr Poonyos Rielrengboonya, who supervised the control and evaluation operations.

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