PILOT STUDIES OF ABATE AS A LARVICIDE FOR CONTROL OF *AEDES AEGYPTI* IN BANGKOK, THAILAND

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INTRODUCTION

Aedes aegypti (L) is the principal vector of acute haemorrhagic fever in many areas of Southeast Asia and the Western Pacific (Rudnick, 1967). Adequate preventive or curative measures are not available to halt the spread of this disease and therefore vector control is, for the present, the sole means of control. The habits of man regarding water storage and discarded containers in his habitations are reflected in the abundance of the mosquitoes. Abatement of mosquitoes by eliminating or protecting the artificial containers from infestation would provide a longer-lasting control.

Abate (0, 0, 0', 0'-tetramethyl 0, 0'-thiodi-*p*-phenylene phosphorothioate; OMS-786) has been shown as an excellent larvicide against *A. aegypti* in potable water jars and it has a low mammalian toxicity (Laws *et al.*, 1968). Because of the success of these trials the WHO Aedes Research Unit (ARU) in Bangkok undertook a pilot control project using 1% Abate sand granules in March 1968. The objectives of this study were to compare the efficacy of two different procedures of control : (a) the mass treatment of all habitats followed by re-treatment only after 1% of the total number of water jars have become positive (cyclic treatment); (b) the mass treatment of all habitats followed by re-treatment of individual receptacles only when they become positive (positive source treatment), The evaluation methods employed were weekly collection of adult mosquitoes landing on human bait, inspection of larval habitats and egg collection by means of ovitraps.

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DESCRIPTION OF AREA

The test site selected was located in Makkasan (Fig. 1), an area of government houses occupied by railroad personnel in Bangkok, covering 7.3 hectares and divided into four unequal parts by a highway intersection. The north side is bordered by a street, a small canal, railroad tracks, and an open field. The west side has a small pond (1.4 hectares), and the south and east sides face canals, buildings and numerous slum dwellings. There are 614 houses in the area. The majority are two-storey wooden apartment structures consisting of eight family-house-units. The average family consisted of about 3.5 adults (16 years or older) and 3.5 young schoolchildren (15 years or younger). There is usually a water tap inside or outside the house, and the floor of the lower storey is cemented with a bathroom and kitchen, There is a cement floored patio in the back or in the front of the house where water jars are located. Open and closed drains may be found in front, in back, and inside of the houses. Several one-family unit dwellings inhabited by railroad officials are also located along the small lake. There are sand-gravel alleys or sidewalks between dwellings. The area was divided into two zones (Fig. 1) each with an equal number of houses for the evaluation of the two control methods.

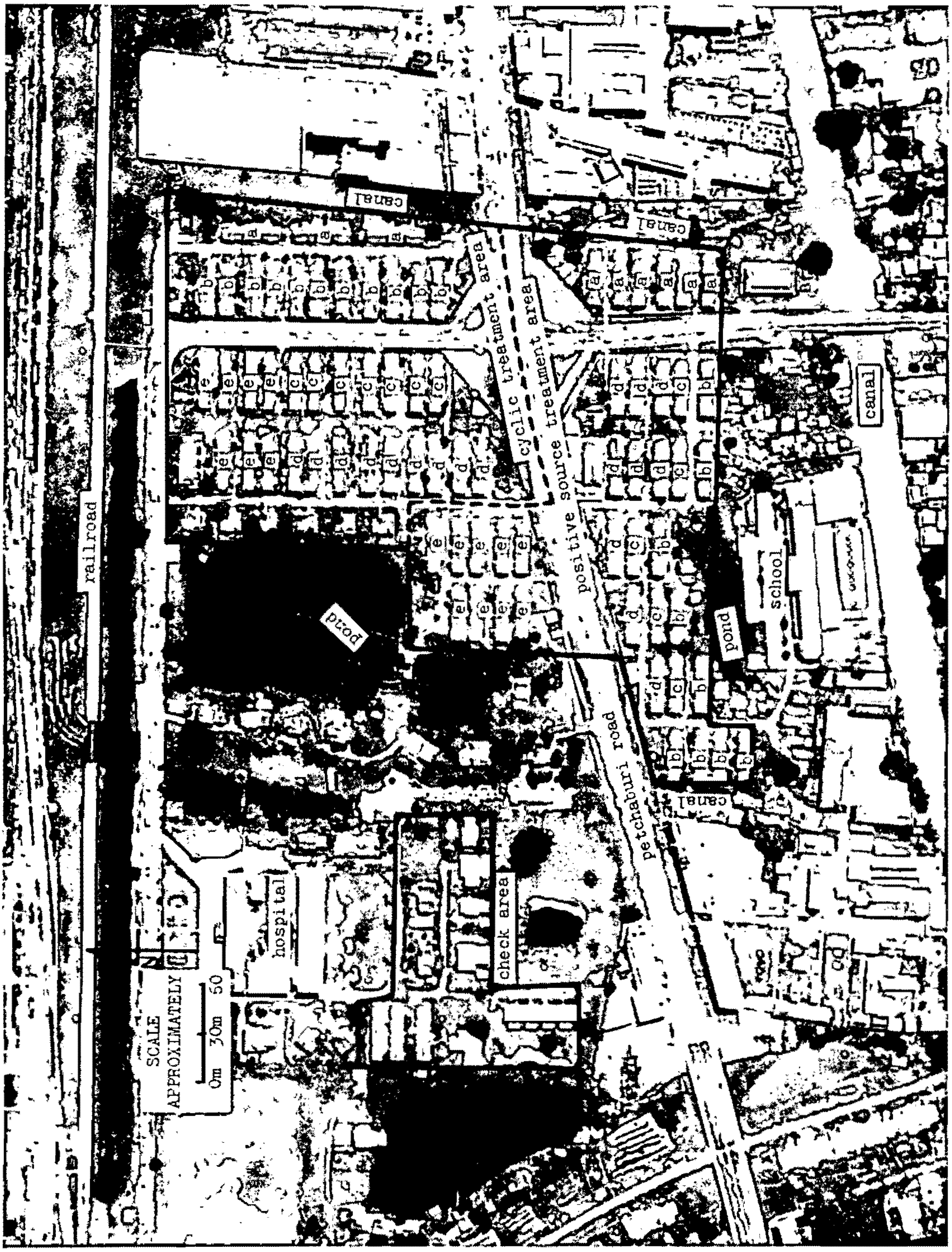

Fig. 1—Aerial view of the Makkasan pilot control area, Bangkok.

The check area consisting of similar housing was located behind the railroad hospital about 200 metres west of the treated area.

A larval survey was conducted in 600 houses to determine the relative prevalence of water jars and other breeding habitats in the two treated and the check areas and about 85% of the houses were found to be positive for *Ae. aegypti* larvae. There were an average of 8.2 major potential larval habitats per house. Water jars were the chief potential habitats and consisted of about 68% of the total number of containers. Ant traps comprised approximately 22% of these habitats and 55% of them were positive for *Aedes* breeding. More than 60% of the houses in the two treated areas had three to seven water jars per house. Very few houses possessed less than three or more than ten water jars.

MATERIALS AND METHODS

Treatment

All potential larval habitats whether full of water or empty (other than ant traps and smaller containers) were treated with 1% Abate sand granules at a target dosage of 1 ppm. Containers were classified by size into one of four different groups and treated with a pre-weighed amount of the larvicide as follows :

Group	Estimated size of containers (litres)	Amount Abate granules (grams)
1	under 100	10
2	100 - 150	15
3	150 - 200	20
4	Over 200	25

Ant traps and other temporary smaller containers not holding potable water were treated at 1 to 10 ppm. Some minor habitats such as discarded water jars or glass bottles were either cleaned up, destroyed or treated. In the commercially made ant traps in common use, both the inner and outer channels were treated. The initial treatment was started on 25 March and completed on 3 April 1968. About 15% of the houses were locked on the first visit and 4% at the second visit. All receptacles were marked with a paint spot at the time of treatment.

Larval inspection and re-treatment

The larval habitats were examined every 2 weeks in both of the treated areas. This routine bi-weekly inspection covered 80% of the houses treated in the cyclic treatment area and 95% in the positive source treatment area. The search included the treated containers and newly-made receptacles or containers missed by the control team. Any containers found without a paint spot were treated as in the mass treatment. The second, third and fourth mass treatments in the cyclic treatment area were made in the middle of June, in September and at the end of December 1968, respectively. At each successive treatment, the containers were marked again using a different colour paint. In the positive source treatment area, only the positive larval habitats were treated as discovered by the bi-weekly inspection. Records were kept of the sources receiving re-treatment, the manhour needed and the amount of granules applied. In the check area a visual larval survey was performed as in the treated area.

Adult collections

The mosquitoes biting and landing on human bait were collected weekly in 12 permanent stations in each area by two mosquito scouts (20 minutes per station) from 0900-1200 hours. The collection programme began three weeks before the initial mass treatment.

Additional adult collections were conducted to determine population levels on the periphery of the treated areas. Each treatment area was divided into 5 zones with 10 stations selected at random in each zone (Fig. 1). Catches here included mosquitoes landing on human bait as well as those resting on hanging clothes and other items Collections were made at least once a month by 5 collectors who were assigned at random on each collection day. The catching period was 10 minutes per station in the morning hours.

Egg collection

Eight ovitraps (Fay and Perry, 1965) were set up weekly inside each of 8 houses selected in the check area and 8 in the positive source treatment area while 12 traps were set up in the cyclic treatment area. The same number of ovitraps were also used outside the houses. Each ovitrap jar was filled weekly with 100 ml of clean water and the paddle was secured with a paper clip; the smooth side of the paddle was placed towards the inner wall of the jar. After two day's exposure each paddle was returned to the laboratory and examined with a microscope for eggs. The egg collection programme commenced at the same time as the adult collection.

RESULTS

Larval reinfestation

The results of the cyclic treatment (Fig. 2) showed that the container index rose above 1 % after 2.5 months had elapsed following the application. Thereafter the second application was made at this time, and the container

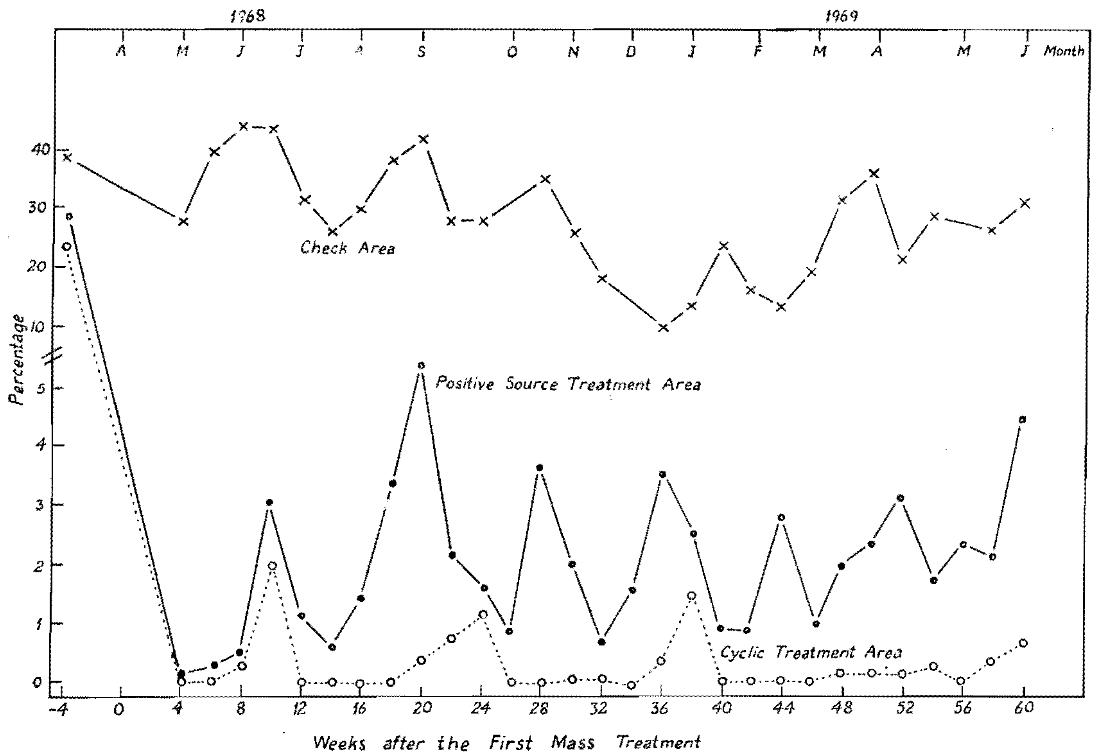

Fig. 2—Per cent positive water jar found in 3 experimental sites in the pilot control areas, Bangkok.

index decreased below 1% for 3 months. The third application resulted in a 3.5 months protection period, and the 4th and final application showed an effectiveness lasting to at least 5 months. In the positive source treatment area, peaks appeared of both positive water jars and ant traps every 8 or 10 weeks. The occurrence of reinfestation was somewhat slower in ant traps than in water jars. Approximately 50% of the total number of water jars were re-treated during the year. A preliminary survey indicated that the sand granules were still present in 60% of the water jars that had become reinfested. The complete history of each container reinfested shows that the rate of reinfestation of the treated water jars did not significantly vary with differences in their type, size, location, water usage practice, presence of organic debris or direct sun exposure. The house index and percentage of positive water jars and ant traps fell to zero for only a 2 to 4-week period immediately following either type of treatment. In the positive source treatment area, the percentage of positive water jars or ant traps never reached one-tenth of the pretreatment level. The protection of water jars afforded by the cyclic treatment method was even higher than the positive source treatment.

Adult collections

The reduction of adult mosquito density in the two treated areas, based on comparison with that of the check area (Fig. 3), was approximately 85%. For the post treatment, the mean number of mosquitoes caught in the cyclic and positive source treatment areas were only 2.07 and 2.21 per man hour respectively, and there was no significant difference in reduction of adult catches between the two treated areas. The number of males caught in both areas was slightly higher (1.2 per man hour) than that of females (0.9 per man hour). This is perhaps due to the fact that males are

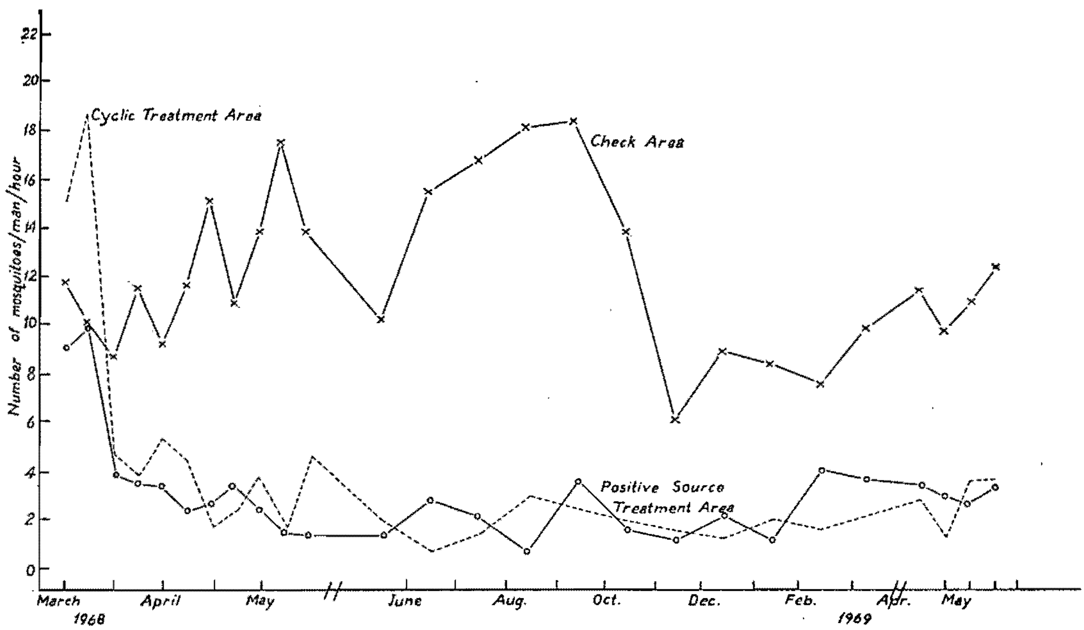

Fig. 3—Average number of mosquitoes landing on human bait caught per manhour at 3 experimental sites in the Makkasan pilot control areas, Bangkok.

more active than females (Sheppard *et al.*, 1969). The data show that the male population decreased faster than the female. A peak of the *Aedes* population was shown in the positive source treatment area every three months. However, these peaks did not coincide with those of the positive larval habitats discovered by the larval inspection.

Oviposition

The mean monthly percentage of the positive ovitraps in the cyclic and positive source treatment areas was 8.8 and 9.5% respectively, approximately 55% less than that of the check area (Table 1).

Table 1

Monthly average of per cent positive ovitraps with *Aedes aegypti* eggs at 3 evaluation sites.

Month	Check Area	Cyclic Treatment	Positive Treatment
March 1968	21.3	64.8	52.1
April*	25.0	8.8	5.2
May	22.4	7.3	8.5
June	25.0	2.5**	12.5
July	14.0	3.2	6.3
August	17.2	7.3	7.9
September	22.2	8.4**	13.5
October	12.5	12.4	6.3
November	40.6	12.2	10.4
December	12.7	14.7	17.9
January 1969	10.1	15.6**	11.2
February	12.8	19.8	7.3
March	11.2	8.4	3.2
April	22.5	15.9	16.3
May	29.7	16.7	28.1
Average	19.6	9.1	8.2

* The initial mass treatments were completed in the middle of the month.

** The cyclic mass treatments were given.

The percentage of positive paddles in the positive source treatment area declined sharply from 68% to nil after the initial treatment. The sharp decrease first occurred in the indoor ovitraps and later in the outdoor ovitraps. In the cyclic treatment area, however, the same result was observed in only the first treatment. The second and succeeding mass treatments did not reduce the number of the positive paddles as in the initial treatment. The per cent positive paddles varied with month, but the monthly average for the positive larval habitats and the occurrence of active oviposition sites did not coincide. There was no significant difference between the outdoor and the indoor traps in the positive paddles.

Infiltration

The average numbers of landing or resting mosquitoes remaining in each treatment area (Fig. 3) show that the annual average in the positive source treatment area was about 33% higher than in the cyclic treatment area. Where a collection zone was immediately connected to an untreated adjacent area, the catching rate increased markedly (Table 2). The highest rate was observed in zone A in the cyclic, and zones A and B in the positive source area. These 3 zones were especially open to adult infiltration from surrounding areas. The numbers of mosquitoes caught in zone C in the positive source treatment area was at least twice those caught in the central zones, while the stations in zone C were about 20 metres from zone B which was close to the untreated area. The relationship found between adult density and closeness to peripheries was not demonstrated in the percentages of positive larval habitats (Table 2). In general, the average of per cent positive water jars and ant traps in the cyclic treatment was much less than in the positive source treatment.

Expenditure

The amount of granules used in the positive source treatment area was 45.4 kg, as compared with 130.2 kg for the cyclic treatment area; these amounts equal to annual expenditure of 149 and 424 grams per house respectively. In the cyclic treatment area about 10,520 larval habitats in 1230 houses were treated during the year while only 3990 habitats in 1,044 houses were treated in the

Table 2
Adult density and positive larval habitats in relation to periphery of the treated area.
(Average of 12 months)

Treat Area	Zone*	Average number of mosquitoes caught (No./manhour)			% Positive Water Jar	% Positive Ant trap
		Female	Male	Total		
	A	3.6	4.3	7.8	16.4	0.0
Cyclic	B	0.6	0.8	1.4	4.6	1.0
Treatment	C	1.1	1.7	2.8	7.8	0.0
Area	D	1.2	0.9	2.1	4.8	1.2
	E	0.7	1.2	1.9	2.9	8.6
	Ave.	1.4	1.8	3.2	7.3	2.2
	A	3.5	3.6	7.1	56.2	68.9
Positive	B	3.7	4.6	8.2	55.7	31.3
Source	C	2.5	1.9	4.4	54.6	59.0
Treatment	D	1.0	1.0	2.0	38.8	41.2
Area	E	1.0	1.0	2.0	53.3	20.1
	Ave.	2.3	2.4	4.8	51.7	44.1

* See Fig. 1.

positive source treatment area. The average amount of granules used per receptacle was 13 grams. In the cyclic treatment area 1.36 man hours were expended per house per year but 5.01 were required in the positive source treatment area.

DISCUSSION

The breeding habits of *Ae. aegypti* in Southeast Asia and Western Pacific countries differ considerably from those of the sylvatic habitats in African forest and are almost entirely found in artificial containers. In the pilot control project area in Bangkok, water jars and ant traps appear to be the primary sources of breeding, representing 68 % and 22 % respectively of the total number of larval habitats. The other containers such as metal drums, tin cans, tires, flower pots, concrete baths, foot baths and bottles constitute the remaining 10% of breeding places. There is considerable indication that temporary container habitats such as tin cans, tires, bowls, bottles, buckets, etc., increase as the city takes on a denser, more urban form.

Abate sand granules safely protect containers from larval infestation. Approximately three times more larvicide was used in the cyclic treatment area than in the positive source treatment area, but the man hours of labour involved were 3.7 times greater. Choice of the control procedure will depend upon available manpower and larvicide; a method combining cyclic treatment every 3 months with additional positive source treatment at prescribed intervals would appear to be ideal where intensive control is required. The slowness of the reduction in the population of adult females is a disadvantage of the larvicide treatment if it is only method used in emergency control of an epidemic of dengue haemorrhagic fever.

The limited range of dispersal of *Ae. aegypti* is of prime importance to the success of larvicidal control operations (Schoof, 1967). Morlan and Hayes (1958) made collections of *Ae. aegypti* by using carbon-dioxide traps at distances up to 185 metres. In these studies, 93 of the recaptured *Ae. aegypti* were within 23 metres of the point of release during the first 24 hours and only 1 % in the range of 54 to 87 metres. The results derived from the study of mosquito movement in the periphery (Table 2) suggest that most of the population emanating from the untreated adjacent neighbourhoods appeared to be limited to one or two marginal apartment dwellings of the treated area. Devey and Lightbody (1965) recommend that houses within 60 yards of an individual infected with the *Ae. aegypti* transmitted virus should be sprayed with insecticides. However, Sheppard *et al.*, (1969) suggest that not less than 50 % of virus-infected mosquitoes might escape destruction if an area of radius of only 60 yards were sprayed. The distance remains to be established for the optimum size of a barrier zone in an operational programme of larval control and for the area to be sprayed when outbreak of dengue-haemorrhagic fever occurs.

Seasonal variation (Fig. 4) was observed in the check area for not only positive larval habitats ($P<0.01$) but also adult populations ($P<0.01$). Mean monthly adult catches during the rainy season were triple those of the dry-cool season. Of the 5 environmental factors analysed (the lowest and the highest temperature, relative humidity, number of rainy days, amount of rainfall) rainfall was the only factor that was positively correlated

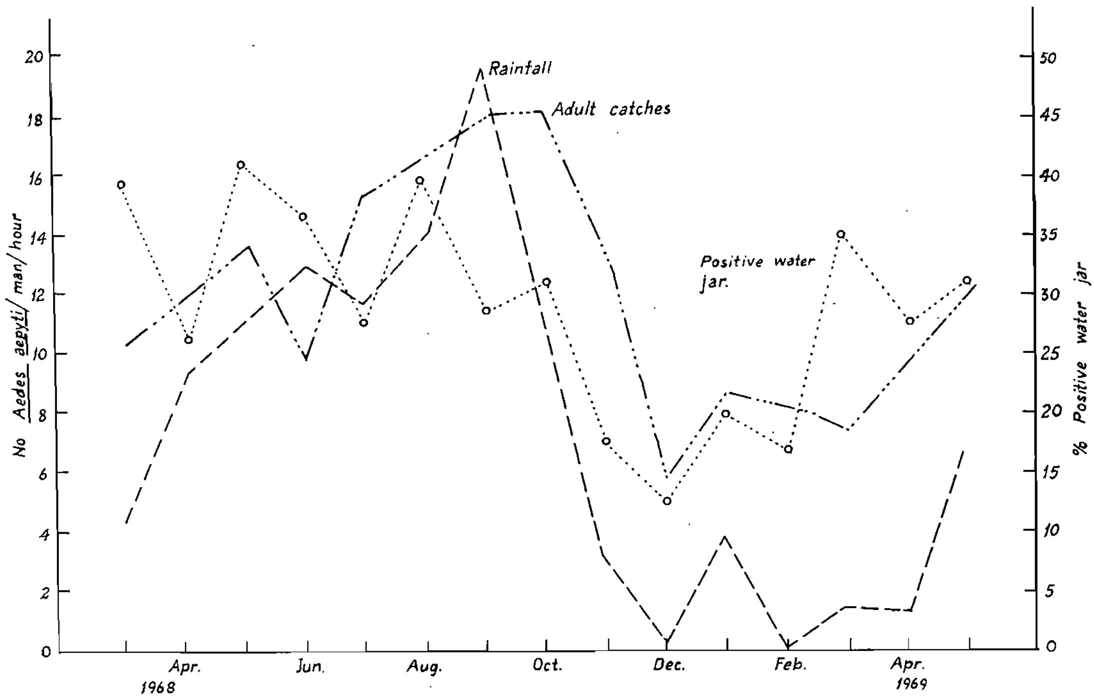

Fig. 4—Per cent positive water jar and adult density in the check area in relation to rainfall.

with seasonal fluctuation of adult population ($r = 0.74$, $P < 0.01$). The seasonal changes in the positive water jars generally agree with Tonn *et al.*, (1969) who found that the chief increase of positive larval habitats being between the cool and the warm seasons and the chief decrease from the wet to the cool season. There is a positive correlation between the positive water jar and mean of the lowest monthly temperature ($r = 0.61$, $P < 0.05$). The house index and number and percentage of positive and traps were not influenced by climate, consequently there was no tendency for them to indicate seasonal variation. A marked increase of adult density and positive water jars has been reported chiefly in the wet season and a marked reduction in the cool and hot seasons. The seasonal changes in the landing mosquitoes on human bait (Fig. 4) were in agreement with those of biting rates found in the Wat Samphaya (Yasuno and Tonn, 1970).

It is interesting to note that in the check area there was a great variation in number of adult catches between stations within the same block as well as between blocks. It some cases, there was a 26-fold difference between two collecting stations.

The oviposition trap technique failed to show any quantitative indication of adult activity in the treated area. However, the ovitrap method provides an economic and rapid means of detection of the presence of adult females.

SUMMARY

For a 12-month pilot control project in Bangkok, the effectiveness of one per cent Abate sand granules were assessed against *Ae. aegypti* in an area of 614 houses inhabitated by 4100 persons. The economics and efficacy of two different methods of control procedures were compared : (a) cyclic mass treatment of the all larval habitats with re-treatment only when 1% of the total habitats had become positive again and (b) one mass treatment followed by re-treatment of individual containers as they became positive. The former method required a greater amount of the larvicide while the latter needed a greater number of man hours. The difference between the two methods, either amount of the larvicide or number of man hours, was approximately three-fold.

A very high degree of control was achieved in 4000 larval habitats within an area of 7.3 hectares, with a concomitant reduction in adult density. The effective control period was 2.5 to 5 months with an average of 3 months. A combined method of cyclic mass treatment at 3-month intervals with simultaneous treatment of new habitats between the mass treatments would give better control.

There was about 85% in adult reduction by using Abate as a larvicide but decline was gradual, taking approximately 10 days to reach a very low level. Adult reinvasion from the surrounding neighbourhoods limited control slightly in the periphery of the treated areas. The catching technique of adult mosquitos landing on human bait revealed not only the efficacy of treatment but also seasonal variations of mosquito populations. The oviposition trap method did not quantitatively show the adult density in the treated areas but did indicate the presence of female mosquitoes.

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