and the Department of Radiotherapy, University of Maryland for providing x-ray facilities. This investigation was supported by NIH Grant No. AI-07807-02.

References

BHALLA, S. C. 1968. White eye, a new sex-linked mutant of *Aedes aegypti*. Mosq. News. 28:380–385.

BHALLA, S. C., and CRAIG, G. B., JR. 1967. Bronze, a female-sterile mutant of *Aedes aegypti*. J. Med. Ent. 4:467–476.

BHALLA, S. C., and CRAIG, G. B., JR. 1970. Linkage analysis of chromosome I of *Aedes aegypti*. Canad. J. Genet. (in press)

BURNHAM, C. R. 1962. Discussions in Cytogenetics. Burgess, Minneapolis, 375 pp.

HICKEY, W. A., and CRAIG, G. B., JR. 1966. Distortion of sex ratio in populations of *Aedes aegypti*. Canad. J. Genet. 8:260–278.

LAVEN, H. 1969. Eradicating mosquitoes using translocations. Nature 221:958–959.

RAI, K. S. 1967. Manipulation of cytogenetic mechanisms for genetic control of vectors. Wld. Hlth. Org. Mimeographed Report. SC/VG/67.

RAI, K. S. 1967. Techniques for the study of cytogenetics and genetics of vectors: Genetics of Insect Vectors of Disease. J. W. Wright and R. Pal, Ed. Elsevier Amsterdam, 794 pp.

RAI, K. S., and ASMAN, SR. M. 1968. Possible application of a reciprocal translocation for genetic control of the mosquito, *Aedes aegypti*. Proc. XII Int. Congr. Genet. 1:164.

SEREBROVSKII, A. S. 1940. On the possibility of a new method for the control of insect pests. Zoologichcskii Zhurnal. 19:618–630.

SERRA, J. A. 1965. Modern Genetics 2. Academic Press, N. Y. 616 pp.

STURTEVANT, A. H., and BEADLE, G. W. 1936. The relations of inversions in the X chromosome of *Drosophila melanogaster* to crossing-over and disjunction. Genetics. 21:554–604.

WHO Scientific Group. 1968. Cytogenetics of Vectors of Disease of Man. Wld. Hlth. Org. Techn. Rep. Ser. No. 398, 41 pp.

MOSQUITO CONTROL IN SEWAGE OXIDATION PONDS WITH DRIP AND POUR-IN LARVICIDES[1]

M. S. MULLA,[2] H. A. DARWAZEH[2] AND D. R. PETERS[3]

The Cucamonga sewage water ponds operated by the Cucamonga Water District, Cucamonga, California are located 5 miles east of Ontario and 6 miles south of Cucamonga. Raw sewage flows southward from the City of Cucamonga in a pipeline underground into the ponds at an average rate of one million gallons per day. The effluent from the initial two stabilization ponds or lagoons which are connected in series, subsequently passes into four percolation ponds connected in parallel. The four percolation ponds were periodically rotated. All ponds were found to be an ideal breeding source for several species of mosquitoes. During a 2-year period (December 1967–November 1969) larvae of four species were recovered and identified. They were: *Culex peus* Speiser, *C. quinquefasciatus* Say, *C. tarsalis* Coquillett, and *Culiseta inornata* (Williston), all biting man or pestiferous to man and domestic animals at times.

High, dense vegetation growth around the edges of the ponds, where mosquito larvae are found, hinders mosquito control operations from the levees. Mosquito larvicidal sprays failed to penetrate the heavy vegetation to yield adequate control. Weed control programs could reduce the intensity of the mosquito problem in the ponds, but the cost of material, equipment and labor is somewhat high. In order to achieve satisfactory control of mosquito breeding in this type of habitat at a low

[1] These studies were partially supported by the Cucamonga County Water District. The assistance and cooperation of R. D. Sjogren, manager of the Northwest Mosquito Abatement District, during the course of these studies is appreciated.

[2] Department of Entomology, University of California, Riverside, California.

[3] Cucamonga County Water District, Cucamonga, California.

cost, and for the longest time possible, new techniques for insecticide application had to be explored and developed.

Lancaster (1964), Sjogren and Mulla (1968), and Mulla *et al.* (1969) achieved excellent control with emulsifiable concentrates of mosquito larvicides applied by a continuous drip method in rice fields, irrigated pastures, and slow-flowing water in ditches. The efficacy of the drip application method was found to be highly promising, which led to the use of the same technique in the evaluation of the commonly used, and newly developed mosquito larvicides in the following studies.

METHODS AND MATERIALS. Emulsifiable concentrate insecticides evaluated were: Abate® (*O,O,O′,O*-tetramethyl *O,O′*-thiodi-*p*-phenylene phosphorothioate), Akton® (*O*, [2-chloro-1-(2,5-dichlorophenyl) vinyl] *O,O*-diethyl phosphorothioate), Dursban® (*O,O*-diethyl *O*-(3,5,6,-trichloro-2-pyridyl) phosphorothioate), Ciba-9491 (*O,O*-dimethyl-*O*, 2,5-dichloro-4-iodophenyl thiophosphate), fenthion (*O, O*-dimethyl *O*-[4-(methyl-thio)-*m*-tolyl] phosphorothioate), GS–13005 or Supracide® (*O,O*,-dimethyl-*S*-[5-methoxy-1, 3, 4-thiadiazol-2-(3H)-on-3yl-methyl]-dithiophosphate), and Bay 77488 (*O,O*-diethyl thiophosphoryl *O*-a-cyanobenzaldoxime). One or 2 gallons of emulsifiable concentrate containing 25–50 percent of active ingredients were applied at an average dosage rate of 0.3–0.4 lb. per acre. Dosage rate was determined by the area of ponds flooded at the time of application.

Each chemical was applied either by the drip method or by a direct pouring into the main sewage water effluent, in a manhole, before entering the oxidation ponds. The drip application method as described in previous studies by Mulla *et al.* (1969) was used. The chemicals were applied either through a constant head metering assembly within 24 hours, or poured into the flowing water over a period of 5 minutes. Effectiveness and longevity of the larvicides employed were determined by inspecting the ponds for mosquito larvae by taking 10 dips per pond before and after treatment. After each test, weekly inspections of the ponds were continued until noticeable build-up of mosquito larvae was observed.

RESULTS AND DISCUSSION. Abate in the first test yielded complete control of mosquitoes in all the ponds for a period of more than 28 days during December 1967–January 1968 (Table 1). During the period of February–March 1968, Abate also gave good control of mosquitoes for a period of 4 weeks or more in most of the ponds except pond Number 6, where some breeding of mosquitoes took place. Since this was the farthest pond, it is possible that this pond was closed off early during the treatment, thus making it receive a low level of the insecticide from water flowing from the stabilization lagoons.

Supracide® or GS–13005, gave mediocre level of control during the spring and fall months. Level of control, however, was poor when this material was poured into the sewage stream in the summer (June 1969). It seems that Supracide does not perform well under highly septic conditions.

Fenthion gave good control when applied early in the season during May–June 1968. It controlled mosquito breeding for a period of 3 weeks. Duration of control, however, was shorter (only 1 week) during the summertime (June–August 1968).

Ciba 9491 at the rate of 0.3 lb./acre produced mediocre control of mosquitoes. The suppression lasted for only 1 week. This material does not hold promise for mosquito control under highly septic conditions.

Akton® at the rates of 0.3 and 0.4 lb./acre yielded mosquito control for about 2 weeks. In the test conducted in the summer, heavy breeding of mosquitoes occurred 3 weeks after treatment.

Dursban®, a recently registered mosquito larvicide, was applied at the rates of 0.3 and 0.4 lb./acre both by the drip and "pour-in" methods. This material gave complete control of mosquito breed-

TABLE 1.—Introduction of various mosquito larvicides as emulsifiable concentrates into flowing sewage stream for mosquito control in sewage oxidation ponds.

Material and formulation	Duration of Experiment	Rate lb./a	Avg. no. larvae/dip days after treatment					Mosquito species[a] breeding
			Pre-treat	7	14	21	28	
Abate EC4[c]	Dec. '67–Jan. '68	0.3	13	0	0	0	0	*Culex tarsalis* *Culiseta inornata*
	Feb.–March '68	0.4	9	0	5[b]	1[b]	0	*Culex peus*
Supracide EC2	April–May '68	0.4	6	0	0	1	4	*C. peus* *Culex quinquefasciatus*
	June '69	0.4	32	45	..	..	..	*C. tarsalis*
	Sept.–Oct. '69	0.4	27	0	2	18	..	*C. tarsalis*
Fenthion EC4[c]	May–June '68	0.4	4	0	0	0	17	*C. tarsalis*
	June–Aug. '68	0.4	17	0	4	..	..	*C. tarsalis*
Ciba-9491 EC3	Aug.–Sept. '68	0.3	7	0	20	..	..	*C. peus*
	June–July '69	0.3	72	15[d]	0	5	4	*C. peus*
Akton EC2	Nov.–Dec. '68	0.3	18	0	0	..	..	*C. peus* *C. quinquefasciatus*
Akton EC2	June '69	0.4	18	8[d]	0	80	..	*C. peus* *C. tarsalis*

[a] At the time of the treatment.
[b] Breeding occurred in pond #6, the farthest from point of insecticide introduction.
[c] Dripped into the flowing sewage stream over a period of 24 hours. All others poured in.
[d] Ponds infested with larvae were retreated by adding one quart of the concentrate of these materials to each pond.

ing during the summer and fall months for a period of 77 days or longer (Table 2). In 1969 tests, complete control was achieved up to 42 days after treatment. No heavy breeding occurred until 63 days after treatment. From these three tests it can be concluded that Dursban is very effective and quite residual under highly septic conditions. In highly polluted water, Dursban was found to control mosquitoes for longer periods elsewhere (McNeill *et al.* 1968).

Bay 77488 was also tested in the sewage oxidation ponds by the "pour-in" method. No control was obtained by using this material at the rate of 0.4 lb./acre.

During the course of these studies, adult mosquito populations in the neighboring area of the ponds were much lower than during the period prior to the initiation of the treatments. Prior to the treatments, the average number of mosquitoes caught in a light trap per week over a 3-month period was about 2000 mosquitoes (Table 3). The average adult mosquito catch per trap-week during a 14-month period during the treatment was about 35.

There is no doubt that the drip and "pour-in" application methods provide the most effective and economical control of mosquito breeding in sewage oxidation

TABLE 2.—Dursban (EC[2]) application for the control of mosquito larvae in sewage oxidation ponds.

Pond no.	Avg. no. of larvae/dip, days after treatment					
	Pre-treat.	7	42	49	56	63
			Rate 0.4 lb./acre (June–Aug. 1968)[a]			
1	11	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	dry	.	..	..	..	..
6	7	0	0	0	0	0
Total Av.	18	0	0	0	0	0
			Rate 0.3 lb./acre (Sept.–Nov. 1968)[b]			
1	41	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	1	0	0	0	0	0
5	75	0	0	0	0	0
6	5	0	0	0	0	0
Total Av.	122	0	0	0	0	0
			Rate 0.3 lb./acre (July–Sept. 1969)[c]			
1	7	0	0	0	3.5	8.5
2	125	0	0	1.5	2.3	5.9
3	6	0	0	0.8	0	0.9
4	26	0	0	0	0	4.3
5	40	0	0	0	0	0.0
6	55	0	0	0.9	0.5	11.0
Total Av.	259	0	0	3.2	6.3	30.6

[a] Population consisted of *Culex peus* and *Culex tarsalis*. Material dripped in for 24 hours. Counts taken every week but was 0/dip for weeks not shown. No breeding 70 and 77 days after treatment.

[b] Population consisted of *Culex peus* and the chemical poured into the main flow of sewage for 5 minutes. No breeding 70 and 77 days after treatment.

[c] Population consisted of *Culex peus* and *Culex tarsalis*. Chemical poured into the main flow of sewage for 5 minutes.

TABLE 3.—Mosquito population trends as determined by New Jersey light trap at Brusso's residence located 1 mile east of Cucamonga sewage oxidation ponds.

Month & year	Avg. weekly collection of mosquitoes[a]				
	Culex peus	*Culex tarsalis*	*Culex quinqs.*	*Culiseta inornata*	Total
August 1967	2976	352	0	0	3328
September	1636	110	54	4	1804
October	992	56	32	40	1120
Treatment of the ponds started in December 1967					
April 1968	3	0	4	1	8
May	9	0	2	0	11
June	78	1	2	0	81
July	67	1	1	0	69
August	80	2	0	0	82
September	127	2	0	1	130
October	2	0	0	0	2
April 1969	0	0	0	0	0
May	0	0	0	0	0
June	7	1	0	0	8
July	70	4	0	0	74
August	31	1	0	0	32
September	32	2	0	0	34

[a] Trap is only operated from April to the end of September or mid-October of each year.

ponds. The frequency of treatment will depend on the climatic conditions, material used and possibly the volume of effluent. Mosquito species breeding may also influence the efficacy of a given treatment. From the conduct and results of these studies it was found that the "pour-in" technique is more practical than the drip technique for mosquito control in sewage oxidation ponds. The "pour-in" technique is very simple and requires no equipment or tools whatsoever. Treatment of the total facilities should take but only a few minutes; therefore, savings from labor and equipment are substantial.

The ponds farthest from the inlet pose some minor problem as to the uniform distribution of larvicides applied in the drip or "pour-in" methods. It is likely that at times only sublethal amounts of the chemical reach these ponds. This problem can be overcome by applying a small amount of the concentrate (1 pint to 1 quart) into the inlets of each pond. In this manner the larvicidal material will be uniformly distributed in all the ponds.

SUMMARY. Emulsifiable concentrates of several organophosphorus mosquito larvicides were either dripped or poured into a sewage effluent for the control of mosquito larvae. The rate of application of the active ingredients ranged from 0.3–0.4 lb./acre.

Among all the materials employed, Dursban yielded the best control of mosquitoes. The next material with some residual activity was Abate. The remaining materials (fenthion, Supracide, and others) gave initial control, but their residual effectiveness was quite short-lived.

References Cited

MCNEILL, J. C., IV, MILLER, W. O., and C. M. WLECZYK. 1968. Evaluation of Dursban as a larvicide in septic ditches. Mosq. News 28(2): 160–1.

LANCASTER, J. L., JR. 1964. Results of the evaluation of a volunteer mosquito control program. Ark. Farm Res. 13(5):4.

MULLA, M. S., DARWAZEH, H. A., GEIB, A. F. and E. W. WESTLAKE. 1969. Control of pasture *Aedes* mosquitoes by dripping larvicides into flowing water, with notes on residues in a pasture habitat. J. Econ. Entomol. 62(2):365–70.

SJOGREN, R. D., and M. S. MULLA. 1968. Drip application of three organophosphorus insecticides for mosquito control. Mosq. News 28(2):172–7.