

still not possible to offer reasons for such behaviour, particularly for the striking reversals in polarity of movement occurring at different field strengths. Further experiments employing pulsed currents would be valuable as it is possible that higher voltages could thereby be used to enhance directional movement producing paralysis. A further advantage of using pulsed currents would be reduction in

the bulk and weight of power supplies which would facilitate field experiments in congregating or collecting native populations.

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AZIRIDINYLPHOSPHINE OXIDES AND SULFIDES AS CHEMOSTERILANTS IN MALE PUPAE OF *ANOPHELES ALBIMANUS* WIEDEMANN¹

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ABSTRACT. When 19 aziridinylphosphine oxides and sulfides were evaluated as sterilants for pupae of *Anopheles albimanus* Wiedemann, the methyl, ethyl, and propyl alkylamino derivatives of phosphine sulfide were effective: The SC90 concentrations ranged from 0.016 to 0.093 percent. Also, the toxicity of these compounds was rela-

tively low since the safety factors (margin of safety between lethal and sterilizing concentrations—LC15:SC90) ranged from about 5 to 8. A comparison of the homologous series of PS and PO compounds showed that the PS compounds were much more effective sterilants, probably because of greater absorption through the pupal cuticle.

Patterson *et al.* (1971) reviewed the literature concerning sterilization of mosquitoes, investigated methods of sterilizing large numbers as pupae, and concluded that thiotepa administered by the method of White (1966) was a promising procedure for sterilizing *Culex pipiens quinquefasciatus* Say. Also, in our preliminary tests with *Anopheles albimanus* Wiedemann, we found that thiotepa was an effective sterilant; however, the difference between toxic and sterilizing concentrations of the compound was not large enough to insure sterility without exces-

sive mortality. We, therefore, evaluated a series of related bis(1-aziridinyl)phosphine oxides and sulfides in attempts to find compounds that would be less toxic to the mosquitoes. The results are reported here.

METHODS. The procedure used for the test was a modification of that reported by White (1966). Thus, about 200 pupae were removed from water with a small cloth strainer, blotted dry on a paper towel, and transferred from the strainer to filter paper (9 cm, Whatman No. 2) in 9-cm plastic petri dishes. Then 10 ml of aqueous solutions (buffered to pH 9) of the various concentrations of the test chemicals were pipetted over the pupae and filter paper. The petri dish was partly covered with the lid to retard evaporation yet permit emerging males to escape when the dish and pupae were placed in an aluminum screen cage (15.2 x 25.4 x 25.4 cm).

¹ This paper reports the results of research only. Mention of an insecticide in this paper does not constitute recommendation of this product by the U.S. Department of Agriculture.

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A 10 percent sugar-water solution on cotton was provided for food. Mortality counts of pupae and adults that did not complete emergence were made after 48 hours.

The adults that did emerge were separated in a cold room ($1-2^{\circ}\text{C}$) within 24 hours of emergence and mated in lots of 25 males and 50 virgin, untreated females. The females were blooded 4 days later on a guinea pig and 2 days later were placed individually in 5-dr plastic vials or 3-oz paper cups. Then, a few milliliters of a water infusion of larval diet (1:1:1 ratio of dried brewer's yeast, liver powder, and a hog supplement) were added to each vial or cup to induce oviposition. The resulting eggs were held for 4 days in the vial before hatch was determined. All egg clutches with less than 5 percent hatch were considered sterile. This procedure may not be as precise as detailed categorizations of the egg hatches of each egg clutch, but we believe the data are just as informative. Also, the method greatly facilitated classification and tabulation of the data. The data for each of the 19 test

compounds were subjected to probit analysis, and the concentrations required to sterilize 50 (SC_{50}) or 90 percent (SC_{90}) or to kill 15 (LC_{15}) or 50 percent (LC_{50}) were calculated. Also, we compared the relative toxicities of the sterilants by computing a safety factor for each chemical. This factor consisted of the ratio of the LC_{15} to the SC_{90} .

RESULTS AND DISCUSSION. The toxic and sterilizing effects of the test compounds are summarized in Table 1.

Because the compounds represented two distinct categories, phosphine oxides (1-11) and phosphine sulfides (12-19), it might seem helpful to compare activities in homologous series and also in the corresponding PO-PS pairs. However, the usefulness of such comparisons is limited because mosquito pupae exposed to equal concentrations of two compounds do not always absorb the same quantities of the two compounds; therefore, the lethal or sterilizing concentrations are not always proportional to the lethal or sterilizing doses. For example, Seawright *et al.* (1971) treated pupae of *C. p. quinque-*

Table 1.—Toxicity and sterilizing activity of aziridinyl phosphorus compounds in male pupae of *A. albimanus*.

No.	ENT No.	X " $(\square\text{N})_2\text{P-Y}$		Lethal concn. (%)		Sterilizing concn. (%)		Safety factor
		X	Y	LC_{15}	LC_{50}	SC_{50}	SC_{90}	
1	61586	0	C_2H_5	>1.0	..	1.06	11.17	>0.1
2	51254	0	NHCH_3	0.40	>1.0	0.20	0.45	.9
3	50787	0	NHC_2H_5	>1.0	..	.27	.49	>2.0
4	50990	0	$\text{N}(\text{CH}_3)_2$	>1.0	..	.28	.79	>1.4
5	51253	0	$\text{NH}(\text{CH}_2)_2\text{CH}_3$	>.25	..	.066	1.22	>0.2
6	51256	0	$\text{NHCH}(\text{CH}_2)_2$	.30	>1.0	.39	1.69	.2
7	51028	0	$\text{NH}(\text{CH}_2)_3\text{CH}_3$	.58	1.26	.12	.55	1.0
8	61342	0	OCH_3	>1.0	..	.78	2.22	>.5
9	50761	0	OC_2H_5	>1.0	..	.35	1.01	>1.0
10	61355	0	$\text{OCH}(\text{CH}_3)_2$	>.50	..	.032	.24	>2.0
11	61354	0	$\text{O}(\text{CH}_2)_3\text{CH}_3$	.35	2.28	.44	1.68	.2
12	61587	S	C_2H_5	.022	0.046	.015	.025	.9
13	61969	S	NH_2	.25	1.16	.049	.16	1.6
14	61585	S	NHCH_3	.093	.16	.007	.012	7.8
15	24916	S	$\text{N}\square$	.17	.50	.028	.049	3.5
16	61581	S	NHC_2H_5	.072	.18	.008	.014	5.1
17	61580	S	$\text{NH}(\text{CH}_2)_2\text{CH}_3$	.027	.056	.004	.005	5.4
18	50044	S	$\text{O}(\text{CH}_2)_2\text{CH}_3$	.016	.033	.027	.045	.3
19	61584	S	SC_2H_5	.020	.045	.011	.021	1.0

fasciatus with solutions containing equal concentrations of tepa and thiotepa and found that the PS compound thiotepa was absorbed by the pupae 5-10 times faster than the PO compound tepa. Then, since the sterilizing doses of both compounds were about equal, any given concentration of thiotepa induced a much higher degree of sterility than the same concentration of tepa.

In our test, as Table 1 shows, a similar relationship existed between effective concentrations of analogous PO and PS compounds. For example, the SC_{50} of the PO compound 1 was 1.06 percent, but the SC_{50} of its PS analog 12 was 0.015 percent. We have not determined the uptake of the test compounds in *A. albimanus*, but a quantitative study of similar compounds in the male house fly, *Musca domestica* L., indicated that the sterilizing doses of analogous PO and PS compounds are usually equal (Chang *et al.*, 1970); therefore, the apparent superior activity of the PS compounds in *A. albimanus* appears to be a consequence of the rapid uptake of these compounds by the pupae.

Similar considerations apply to the structure-activity correlations within each homologous series in Table 1, i.e., for the alkylamino compounds 2-7 and 13-17 and the alkoxy compounds 8-11. The evidence in our test, though tenuous, indicates an increase in activity with increasing size of the alkyl group. (In theory, however, such an increase would not be surprising because the lipophilic properties of homologous compounds also increase with the size of the alkyl group.) Also, Madhukar *et al.* (1971) had similar results when they studied the effects of similar compounds in pupae of *Aedes*

aegypti (L); they could detect no consistent relationship within any homologous series, but the alkylamino compounds were active at lower concentrations than the alkoxy compounds.

Because the toxicity and the sterilizing activity of a chemosterilant are mutually independent, sterilizing activity alone is not a sufficient indicator of a compound's practical potential. A more useful indicator, the safety factor (Bořkovec 1966), is a combination of the two parameters. Thus, in Table 1, the safety factor is taken as a ratio ($LC_{15}:SC_{90}$) that should be larger than 1 for any compound deserving practical consideration. Several of our test compounds met this criterion, but the alkylamino derivatives 14-17 are clearly outstanding; they deserve further intensive study and possibly field testing.

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