RESIDUAL ACTIVITY OF SELECTED INSECTICIDES AGAINST *ANOPHELES QUADRIMACULATUS*: DEGREE OF TOXICITY WITH SHORT EXPOSURE[1]

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ABSTRACT. Forty-five insecticides were tested in the laboratory against *Anopheles quadrimaculatus* Say to determine the minimum exposure to residues required to cause knockdown within 60 minutes and mortality within 24 hours. All were effective, and 25 produced mortality in 24 hours after an exposure of 10 minutes or less. Only three compounds, DDT, resmethrin, and tetramethrin, were considerably less effective against a DDT-resistant strain than against a susceptible strain.

The application of residual insecticides to buildings or other natural resting sites of mosquitoes is a highly effective method of mosquito control. The procedure is still the method of choice in malaria control programs and is useful in reducing annoyance by pest mosquitoes around human habitations. Therefore, since World War II, large numbers of compounds have been evaluated as residual insecticides by industry and by various governments and international agencies such as the World Health Organization.

However, insecticides applied for residual effect to mosquito resting surfaces may be less effective than anticipated if the mosquitoes do not remain on the treated surfaces, either because of natural behavior patterns or because they are irritated by the residue. The time of exposure of mosquitoes to residual deposits may thus be extremely variable, and residues do differ in speed of knockdown or kill. This factor, among many others, is important in the selection of a residual insecticide, but we know of no research study designed to compare the minimum exposure time required for knockdown or kill of the many effective and promising residual insecticides that are now available or under consideration. Forty-five insecticides were therefore selected for test including some already in use and some that have shown promise in laboratory or field trials. Then the minimum exposure required to knockdown or kill mosquitoes was determined and used as a criterion of the effectiveness of the insecticides. The present paper reports the results of the comparisons made in the laboratory with laboratory-reared mosquitoes.

METHODS AND MATERIALS. *Insecticides.* Two strains of *Anopheles quadrimaculatus* Say were used; one was our regular laboratory strain, which is susceptible to all insecticides; the other was the Hartwell Dam strain,[2] which is highly resistant to DDT and methoxychlor (Wilson et al. 1972). For each test, acetone solutions of insecticides were sprayed on plywood panels at the rate of 1 g/m^2 and aged for 1 week. Then twenty 1- to 2-day-old female mosquitoes were exposed to the panels by confining them under half sections of petri dishes on the panels for 1, 5, 15, 30 or 60 minutes. After the exposure, they were transferred to cylindrical screen cages, provided with a sugar-water solution in pads of absorbent cotton, and held for the 24-hour mortality counts. We calculated or estimated the time to 70 and 95 percent knockdown when the mosquitoes were removed from exposure

[1] This paper reflects the results of research only. Mention of a pesticide in this paper does not constitute a recommendation of this product by the U.S. Department of Agriculture.

[2] The Hartwell Dam colony was received several years ago from Dr. H. F. Schoof of the Technical Development Laboratory, CDC, Savannah, Georgia.

and then again at 30 and 60 minutes after removal from exposure. We also calculated the LT_{70} and LT_{95} at 24 hours after exposure. All tests were duplicated.

The list in Table 1 identifies by ENT number, company name or number, and chemical name those test compounds that do not have accepted common names.

TABLE 1.—Identification of chemicals used.

ENT number	Company number or trade name	Chemical name
	Chevron Chemical Co.	
27039	RE-5305	*m-sec*-Butylphenyl methylcarbamate
	CIBA Agrochemical Co.	
27564	C-9643	*o*-(4-Methyl-1,3-dioxolan-2-yl)phenyl methylcarbamate
27410	C-10015	*o*-(4,5-Dimethyl-1,3-dioxolan-2-yl)phenyl methylcarbamate
27569	C-11044	*O*-(2,5-Dichloro-4-iodophenyl) *O*-ethyl *O*-methyl phosphorothioate
	Geigy Chemical Corp.	
27193	GS-13005	*O,O*-Dimethyl phosphorodithioate *S*-ester with 4-(mercaptomethyl)-2-methoxy-Δ^2-1,3,4-thiadiazolin-5-one
	Hercules Corp.	
25911	9326	5-*tert*-Butyl-2-chlorophenyl methylcarbamate
27454	9418	m-Cumenyl methyl(trichloroacetyl)carbamate
25810	9699	*o*-(2-Propynyloxy)phenyl methylcarbamate
27405	13462	*O,O*-Dimethyl phosphorodithioate *S*-ester with *N*-(1-mercaptoethyl)succinimide
27348	14469	*m*-Cumenyl (mercaptoacetyl)methylcarbamate *S*-ester with *O,O*-dimethyl phosphorodithioate
	Hooker Chemical Corp.	
25780	HRS-1422	3, 5-Diisopropylphenyl methylcarbamate
	Mobil Chemical Co.	
27041	Mobam®	Benzo[*b*]thien-4-yl methylcarbamate
	Montecatini Edison S.p.A.	
27386	L-561	Ethyl mercaptophenylacetate *S*-ester with *O,O*-dimethyl phosphorodithioate
	Sandoz-Wander	
27754	52114	1-Ethyl-1-methyl-2-propynyl 3-hydroxycrotonate dimethyl phosphate
	Stauffer Chemical Co.	
25754	N-2230	*O*-(2-Chloro-4-nitrophenyl) *O*-ethyl ethylphosphonothioate
25755	N-2404	*O*-(2-Chloro-4-nitrophenyl) *O*-isopropyl ethylphosphonothiaote
27508	R-14493	*O,O*-Diethyl phosphorothioate *O*-ester with *p*-hydroxybenzaldehyde *O*-(butylcarbamoyl)oxime
27509	R-15552	Mercaptoacetic acid 2,2-dimethylhydrazide *O*-ethyl ethyl phosphonodithioate (ester)
	Shell Development Co.	
27018	SD-8211	2-Chloro-1-(2,5-dichlorophenyl)vinyl dimethyl phosphate
25818	SD-8280	2-Chloro-1-(2,4-dichlorophenyl)vinyl dimethyl phosphate
27464	SD-15963	*O*-(7-Chloro-4-benzofurazanyl) *O*-isopropyl *O*-dimethyl phosphorothioate
27102	SD-9098	*O*-[2-chloro-1-(2,5-dichlorophenyl)vinyl] *O,O*-diethyl phosphorothioate
25843	SD-8530	3,4,5-Trimethylphenyl methylcarbamate
	Upjohn Co.	
27350	U-18120	*o*-Isopropoxyphenyl (methoxyacetyl)methylcarbamate
	Vero Beach Laboratories, Inc.	
27213	Bay 38799	*o*-Cyclopentylphenyl methylcarbamate
27324	Bay 62863	2,3-Dihydro-2-methyl-7-benzofuranyl methylcarbamate

TABLE 2.—Length of exposure to insecticidal residues required for 70 (KDT-70) and 95 percent knockdown (KDT-95) and 24-hr. mortality of 70 (LT_{70}) and 95 percent (LT_{95}) of adult *Anopheles quadrimaculatus* from the Gainesville regular (R) and Hartwell Dam (H) strains. (Chemicals applied to plywood panels at a rate of 1 g/m².)

Chemical			Knockdown						Mortality after 24 hr.	
			At removal		After 30 min.		After 60 min.			
Code no. ENT-	Name or company designation	Mosquito strain	KDT-70	KDT-95	KDT-70	KDT-95	KDT-70	KDT-95	LT-70	LT-95
25671	Propoxur	R	<5	<5	1.7	3.1	<1	<1	<1	<1
		H	3.2	8	<1	<1	<1	<1	<1	<1
27039	Chevron RE-5305	R	6	10	<1	4	<1	1.9	<1	<1
		H	6	10	<1	1.7	<1	1.4	<1	1.2
19507	Diazinon	R	28	42	8	18	2	4.6	<1	<1
		H	33	46	11	28	3.7	9	<1	<1
27474	Resmethrin	R	30	<60	8	34	2.8	11	<1	<1
		H	50	<60	38	<60	30	<60	13	40
25736	Carbonolate	R	26	50	9	29	3.7	13	<1	<1
		H	21	41	8	26	1.3	7	<1	<1
25715	Folithion	R	<60	>60	27	41	14	23	<1	2.1
		H	>60	<60	33	46	15	24	1.1	2.6
16225	Dieldrin	R	>60	>60	>60	>60	33	>60	<1	<1
		H	>60	>60	>60	>60	36	>60	<1	17
25540	Fenthion	R	>60	>60	>60	>60	37	59	<1	<1
		H	>60	>60	>60	>60	36	58	<1	<1
27350	Upjohn U-18120	R	<15	<15	1.9	6	1.1	2.8	<1	1.8
		H	9	12	<1	2.7	<1	<1	<1	<1
25843	Landrin	R	33	>60	15	31	4.1	10	<1	2.4
		H	25	>60	8	19	3.1	9	<1	<1
27300	Promecarb	R	12	20	4.2	16	2.5	12	1.1	2.8
		H	12	19	2.4	8	1.8	7	<1	1.8
27324	Bay 62863	R	8	11	1.8	3.2	1.1	2.6	1.2	2.7
		H	18	24	2.4	7	1.5	2.7	1.2	2.7
27311	Chlorpyrifos	R	37	>60	14	>60	13	>60	1.3	3.9
		H	25	41	6	17	5	14	<1	7
27448	Phoxim	R	36	48	22	52	4.4	9	1.4	2.8
		H	40	50	15	45	16	28	1.6	3
27754	Sandoz-Wander 52114	R	>60	>60	35	48	21	28	1.4	2.8
		H	>60	>60	40	51	33	47	1.1	2.6
25754	Stauffer N-2230	R	>60	>60	35	48	21	28	1.4	2.8
		H	>60	>60	40	51	33	47	1.1	2.6

TABLE 2.—Continued

Chemical		Mosquito strain	Knockdown						Mortality after 24 hr.	
			At removal		After 30 min.		After 60 min.			
Code no. ENT-	Name or company designation		KDT-70	KDT-95	KDT-70	KDT-95	KDT-70	KDT-95	LT-70	LT-95
27464	Shell SD-15963	R	>60	>60	31	>60	20	38	1.4	2.9
		H	>60	>60	38	60	23	41	<1	<1
25911	Hercules 9326	R	34	>60	10	30	3.4	8	1.4	3.0
		H	20	37	4.1	15	2.3	7	<1	1.6
27508	Stauffer R-14493	R	>60	>60	41	51	26	41	1.9	3.3
		H	>60	>60	44	55	25	40	1.6	3.1
27213	Bay 38799	R	38	>60	18	60	10	33	1.9	4.6
		H	21	40	11	34	7	25	1.7	8
27348	Hercules 14469	R	18	26	7	17	4.1	11	3.2	7
		H	16	27	3.7	16	3.6	15	2.7	10
25715	Sumithion	R	>60	>60	>60	>60	31	49	3.4	4.9
		H	22	37	50	>60	20	38	2.1	3.6
17035	Dicapthion	R	>60	>60	46	>60	29	47	3.5	10
		H	>60	>60	58	>60	41	60	12	36
27193	Geigy GS-13005	R	>60	>60	18	24	10	18	3.6	8
		H	<60	60	21	26	14	21	3.5	8
27386	Cidial	R	53	>60	30	43	15	24	7	8
		H	>60	>60	29	42	19	25	4.2	9
17034	Malathion	R	40	50	>60	>60	15	23	5	12
		H	31	42	35	>60	12	21	4.4	9
27102	Shell SD-9098	R	>60	>60	>60	>60	>60	>60	6	11
		H	>60	>60	>60	>60	>60	>60	4.6	10
17449	Chlorphoxim	R	>60	>60	>60	>60	>60	>60	6	21
		H	>60	>60	>60	>60	>60	>60	5	15
25818	Shell SD-8280	R	>60	>60	39	>60	26	52	8	14
		H	36	52	26	45	17	29	4.3	12
25755	Stauffer N-2404	R	>60	>60	>60	>60	>60	>60	9	18
		H	>60	>60	>60	>60	>60	>60	4.2	12
25810	Hercules 9699	R	40	>60	30	>60	24	>60	9	19
		H	22	60	17	42	13	40	7	22
27341	Methomyl	R	>60	>60	29	>60	27	>60	7	42
		H	48	>60	35	>60	15	58	10	37
1506	DDT	R	55	>60	>60	>60	33	>60	10	35
		H	>60	>60	>60	>60	>60	>60	>60	>60

TABLE 2.—Continued

Chemical		Mosquito strain	Knockdown						Mortality after 24 hr.	
			At removal		After 30 min.		After 60 min.			
Code no. ENT-	Name or company designation		KDT-70	KDT-95	KDT-70	KDT-95	KDT-70	KDT-95	LT-70	LT-95
27405	Hercules 13462	R	>60	>60	>60	>60	52	>60	11	37
		H	>60	>60	>60	>60	50	>60	7	26
27569	CIBA 11044	R	>60	>60	>60	>60	>60	>60	15	24
		H	>60	>60	>60	>60	>60	>60	15	24
27041	Mobam	R	>60	>60	57	>60	42	>60	17	58
		H	>60	>60	38	>60	25	51	12	58
27410	CIBA C-10015	R	32	49	23	40	20	36	18	38
		H	41	>60	19	>60	13	39	9	27
27339	Tetramethrin	R	36	>60	20	40	18	39	20	47
		H	>60	>60	>60	>60	>60	>60	>60	>60
23979	Endosulfan	R	>60	>60	>60	>60	>60	>60	21	47
		H	>60	>60	>60	>60	>60	>60	26	>60
27018	Shell SD-8211	R	>60	>60	>60	>60	>60	>60	22	42
		H	>60	>60	>60	>60	>60	>60	20	46
27509	Stauffer R-15552	R	>60	>60	>60	>60	>60	>60	23	49
		H	>60	>60	>60	>60	>60	>60	37	>60
25780	Hooker HRS-1422	R	>60	>60	>60	>60	57	>60	25	59
		H	>60	>60	52	>60	44	>60	22	43
24717	Crotoxyphos	R	>60	>60	>60	>60	>60	>60	40	58
		H	>60	>60	>60	>60	>60	>60	36	57
23969	Carbaryl	R	>60	>60	>60	>60	>60	>60	37	>60
		H	>60	>60	>60	>60	>60	>60	50	>60
27564	CIBA C-9643	R	>60	>60	>60	>60	>60	>60	>60	>60
		H	>60	>60	>60	>60	>60	>60	>60	>60

RESULTS. The residual activities of the 45 compounds against the adult female *A. quadrimaculatus* are given in Table 2. The large number of compounds, exposure periods, and speed of action of some of the compounds made it impossible to obtain sufficient points for a probit analysis of the data.

All the insecticidal residues except those left by CIBA C-9643 and carbaryl caused at least 95 percent mortality of adults of the susceptible strain in 24 hours after a 60-minute exposure. Three, propoxur, diazinon, and carbanolate, killed both strains in 24 hours after only a 1-minute exposure (data not in Table 2).

Twenty-five compounds were highly effective in producing mortality in the susceptible strain after a very short exposure: 7 caused 95 percent mortality after 24 hours when the exposure was less than 1 minute; 14 when it was between 1 and 5 minutes; and 4 when it was between 5 and 10 minutes. Moreover, the high kill in 24 hours after short exposure did not appear to be restricted to a given type of chemical insecticide—i.e., pyrethroid, organophosphorus, carbamate or chlorinated hydrocarbon—since representatives of each of these types differed in the time required for high mortality. For example, dieldrin caused 95 percent mortality in 24 hours after an exposure of less than 1 minute: DDT required a 35-minute exposure; also, resmethrin required an exposure of less than 1 minute; tetramethrin required an exposure of 47 minutes.

Some compounds such as propoxur and Chevron RE-5305 were extremely effective in causing both rapid knockdown and high mortality in 24 hours. Others such as dieldrin, fenthion, and folithion caused high levels of mortality in 24 hours after very short exposure but did not show such rapid knockdown of mosquitoes. Many effective compounds were intermediate in speed of knockdown. Others had slower knockdown and required longer exposure for high levels of mortality after 24 hours.

Most compounds tested against the DDT-resistant Hartwell Dam strain of *A. quadrimaculatus* gave results similar to those obtained against the susceptible strain though some variations indicated slight differences in tolerance or susceptibility. However, the data were not such that we could compare these small differences statistically. Though DDT was not effective against the resistant strain as anticipated, the results obtained with resmethrin and tetramethrin are of interest. With both compounds, the exposure required for 70 or 90 percent knockdown or kill were much greater for the resistant strain than the susceptible strain. For example, with resmethrin, the time required for 95 percent mortality after 24 hours was 40 minutes for the resistant strain compared to <1 minute for the susceptible strain.

Literature Cited

Wilson, H. G., Labrecque, G. C., Weidhaas, D. E. and Gahan, J. B. 1972. Comparison of susceptible and DDT-resistant mosquito colonies. Mosq. News 32(2):215–218.