over 75 microns, damage to those surfaces could be expected. Little or no damage was observed with dosages at 4 oz./acre or below, when the MMD of particles was 50 microns or below.

References

YEOMANS, A. H. 1949. Directions for determining particle size of aerosols and fine sprays. U.S.D.A., Bureau of Entomology and Plant Quarantine ET-267.

RESIDUAL EFFECTIVENESS OF SOME NEW INSECTICIDES AGAINST *ANOPHELES QUADRIMACULATUS*[1]

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Residues of DDT and dieldrin have been used extensively throughout the world in control programs against anopheline mosquitoes. However, some species have already developed resistance to these insecticides, so there is a need for substitute materials. Therefore, the Entomology Research Division has maintained a continuing program at Orlando, or Gainesville, Florida to evaluate new insecticides for use as residual treatments against mosquitoes for the past 26 years. The latest results are published periodically.

Since the last report by Gahan *et al.* (1967) on the results of these laboratory tests, we have screened 186 compounds. This paper discusses the 29 that produced better than 70 percent mortality in 24 hours for at least 8 weeks. All were obtained for testing from commercial sources. The company designation, chemical name, and acute LD_{50} in rats (based on information received from the manufacturer) are given in the accompanying list.

METHODS AND MATERIALS. Acetone solutions, water suspensions, or emulsions of the compounds were sprayed on plywood panels at the rate of 1 gram per square meter, and enough panels were sprayed with each insecticide to avoid the necessity of using any surface twice. The panels were tested one week after treatment, again after 4 weeks, and then every 4 weeks thereafter for 24 weeks or until they became ineffective. In each test, twenty 1- to 2-day-old female *Anopheles quadrimaculatus* Say were exposed on the treated surfaces under each of two half sections of petri dishes for 60 minutes; then they were transferred to cylindrical screen cages, provided with a sugar-water solution in pads of absorbent cotton, and held for 24-hour mortality counts. Also, knockdown counts were taken after exposures of 30 and 60 minutes during the one-week test. Panels were considered ineffective when they failed to produce at least 70 percent mortality in 2 consecutive tests. Those compounds that remained effective for at least 6 months were scheduled for field tests against natural populations of *A. quadrimaculatus* in small buildings near rice fields in the vicinity of Stuttgart, Arkansas.

RESULTS. Thirteen compounds (six carbamates, five organic phosphorus compounds, one thioacetimidate, and one cyclopropanecarboxylate) killed all mosquitoes for the entire 6 months. Five carbamates (Bay 62862, CIBA C-9643,

[1] Mention of a pesticide in this paper does not constitute a recommendation of this product by the USDA.

CIBA C-10015, Hercules 9007, Upjohn U-18120), the thioacetimidate (Bay 78389), and the cyclopropanecarboxylate (NRDC-104) caused 100 percent knockdown within 30 minutes at the initial exposure. (NRDC-104 was applied both in acetone and as a wettable powder.) The other carbamate (Niagara NIA-10559), and the five phosphates (Bay 34042, Hercules 13462, Shell SD-15963, Stauffer N-2230, and Stauffer N-2404) produced no knockdown in 30 minutes.

Company Designation	Chemical Name	Acute oral LD_{50} (mg/kg) in rats [or mice]
Bay 33051	ethyl mercaptophenylacetate *S*-ester with *O,O*-dimethyl-phosphorodithioate	>1000
Bay 34042	*O*-ethyl *O*-[4-(methylthio)-*m*-tolyl] methylphosphoramidothioate	5–10
Bay 62862	3-*sec*-butyl-*p*-tolyl methylcarbamate	25
Bay 78389	ethyl *N*-[(methylcarbamoyl)oxy]thioacetimidate	25
Bay 78537	2,3-dihydro-2,2-dimethyl-7-benzofuranyl acetylmethylcarbamate	100–250
Bay 85032	1,1-dimethyl-4-indanyl methylcarbamate	500
CELA K-159	*O*-(4-bromo-2,5-dichlorophenyl) *O*-propyl methylphosphonothioate	23
Chevron RE-5305	*m*-*sec*-butylphenyl methylcarbamate	10
Chevron RE-5353	*m*-(1-methylbutyl)phenyl methylcarbamate	50
CIBA C-9491	*O*-(2,5-dichloro-4-iodophenyl) *O,O*-dimethyl phosphorothioate	2000
CIBA C-9643	*o*-(4-methyl-1,3-dioxolan-2-yl)phenyl methylcarbamate	110
CIBA C-10015	*o*-(4,5-dimethyl-1,3-dioxolan-2-yl)phenyl methylcarbamate	67
CIBA C-11044	*O*-(2,5-dichloro-4-iodophenyl) *O*-ethyl *O*-methyl phosphorothioate	330
Crotoxyphos		125
Dowco® 217	dimethyl 3,5,6-trichloro-2-pyridyl phosphate	820
Endosulfan		18–43
Hercules 9007	*m*-cumenyl (chloroacetyl)methylcarbamate	>400
Hercules 13462	*O,O*-dimethyl phosphorodithioate *S*-ester with *N*-(1-mercaptoethyl)succinimide	11.6
Hercules 14469	*m*-cumenyl (mercaptoacetyl)methylcarbamate *S*-ester with *O,O*-dimethyl phosphorodithioate	432
Montecatini L-561	ethyl mercaptophenylacetate *S*-ester with *O,O*-dimethyl phosphorodithioate	>1000
National Research Development Corp. NRDC-104	(5-benzyl-3-furyl)methyl 2,2-dimethyl-3-(2-methylpropenyl)cyclopropanecarboxylate	600–800
Niagara NIA-10559	4-chloro-2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate	964
Shell SD-8436	2-chloro-1-(2,4-dibromophenyl)vinyl dimethyl phosphate	964 [mice]
Shell SD-9098	*O*-[2-chloro-1-(2,5-dichlorophenyl)vinyl] *O,O*-diethyl phosphorothioate	109–286 [mice]
Shell SD-15135	*O*-1,2,3-benzothiadiazol-6-yl *O,O*-dimethyl phosphorothioate	1200 [mice]
Shell SD-15963	*O*-7-chloro-4-benzofurazanyl *O*-isopropyl *O*-methyl phosphorothioate	25
Stauffer N-2230	*O*-(2-chloro-4-nitrophenyl) *O*-ethyl ethyl phosphonothioate	23
Stauffer N-2404	*O*-(2-chloro-4-nitrophenyl) *O*-isopropyl ethylphosphonothioate	32
Stauffer R-7240	*O,O*-dimethyl phosphorodithioate *S*-ester with 3-(mercaptomethyl)-2,4-thiazolidinedione	68
Upjohn U-18120	*o*-isopropoxyphenyl (methoxyacetyl) methylcarbamate	70

TABLE 1.—Relative toxicity to *Anopheles quadrimaculatus* of insecticides that caused less than 100 percent mortality on one or more occasions.

Insecticide	Initial Knock-down in 30 minutes (%)	Percentage Kill in 24 Hours After Aging for indicated number of weeks						
		1	4	8	12	16	20	24
Acetone Solution								
Montecatini L-561	0	100	100	100	100	100	100	80
Shell SD-9098	0	100	100	100	100	70	100	100
Chevron RE-5353	100	100	100	100	...	98	100	0
Chevron RE-5305	100	100	100	100	100	100	78	73
Hercules 14469	50	100	100	100	100	100	78	85
CIBA C-11044	3	100	88	73	100	100	100	100
Crotoxyphos	0	100	98	95	100	100	100	100
CIBA C-9491	0	100	100	88	98	100	100	98
Dowco® 217	100	100	100	100	100	83	68	53
Bay 33051	0	100	100	100	100	100	13	48
Endosulfan	0	86	97	93	90	88	95	70
CELA K-159	0	100	100	93	100	78	75	3
Shell SD-8436	0	63	100	80	88	73	75	75
Stauffer R-7240	0	90	100	78	48	98	65	75
Bay 78537	100	100	100	100	90	98	53	68
Shell SD-15135	0	100	100	83	100	53	53	...
Bay 85032	90	100	100	100	3	0	...	...
Wettable Powders								
Montecatini L-561	0	100	100	100	100	100	55	100
CIBA C-9491	3	100	100	100	100	83	100	70
Hercules 14469	100	100	100	100	100	10	0	...
Emulsion Concentrate								
CIBA C-11044	0	100	100	100	90	100	88	73
CIBA C-9491	0	100	100	100	90	25	10	...

The 17 compounds that caused less than 100 percent mortality on one or more occasions but better than 70 percent mortality for at least 8 weeks are listed in Table 1 in descending order of residual effectiveness. Montecatini L-561 and Shell SD-9098 killed all the mosquitoes in 24 hours during every exposure period except one but produced no knockdown at 30 minutes. Montecatini L-561 was about equally effective when applied as an acetone solution or a wettable powder. Chevron RE-5353 killed 98–100 percent of the mosquitoes for 20 weeks and none the 24th week. Chevron RE-5305, Hercules 14469 (applied in acetone), CIBA C-11044, crotoxyphos, and CIBA C-9491 (applied in acetone and as a wettable powder) consistently killed 70 percent or more mosquitoes, but the mortality was below 100 percent on two or three occasions. The Hercules 14469 wettable powder and the CIBA C-9491 emulsion were 90–100 percent effective for 12 weeks and almost nontoxic the 16th and 20th weeks. Bay 33051 (which was the same compound as Montecatini L-561) and Dowco 217 killed all insects for 12–16 weeks and were relatively ineffective by the 20th and 24th weeks. Endosulfan, CELA K-159, Shell SD-8436, and Stauffer R-7240 caused less than complete mortality on many occasions, and all except endosulfan caused less than 70 percent on one or two occasions. The remaining compounds killed more than 70 percent of the mosquitoes for only 8 to 16 weeks. Hercules 14469, CIBA C-9491, and CIBA C-11044 appeared more effective when applied as acetone solutions than as wettable powders or water emulsions.

Since toxicity to warm blooded animals

is a very important consideration, the most promising materials appeared to be CIBA C-9643, Hercules 9007, Niagara NIA-10559, National Research Development Corp. NRDC-104, and possibly Montecatini L-561, CIBA C-9491, CIBA C-11044, crotoxyphos, and Shell SD-9098, all of which have an LD_{50} to rats at least as high as 100 milligrams per kilogram of body weight. CIBA C-9491, Montecatini L-561, and NRDC-104 appear to be particularly safe.

Bay 33051, Hercules 14469, and Montecatini L-561 had strong distinctive odors when they were being sprayed, but after aging on plywood panels for a few days, most of the odor dissipated. None of the compounds had any lasting, objectionable odor, and endosulfan was the only compound that caused any appreciable staining of the plywood surface. The National Research Development Corp. NRDC-104 caused the legs of the mosquitoes to break off.

SUMMARY. A series of tests was made to evaluate a group of insecticides as residual sprays against adult *Anopheles quadrimaculatus* Say exposed for 1 hour on plywood boards treated at 1 gram per square meter and then removed and held for 24-hour mortality counts.

Six carbamates, five organic phosphorus compounds, one thioacetimidate, and one cyclopropanecarboxylate killed all mosquitoes for 6 months. Bay 62862, CIBA C-9643, CIBA C-10015, Hercules 9007, Upjohn U-18120, Niagara NIA-10559, Bay 34042, Hercules 13462, Shell SD-15963, Stauffer N-2230, Stauffer N-2404, Bay 78389, and National Research Development Corp. NRDC-104.

Because of their low toxicity to warm blooded animals, CIBA C-9643, Hercules 9007, National Research Development Corp. NRDC-104, and Niagara NIA-10559 were considered the most promising for use in buildings naturally infested with *Anopheles quadrimaculatus* mosquitoes.

Literature Cited

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