

SOME OBSERVATIONS ON MOSQUITO REPELLENTS¹

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Space sprays are widely used in Maryland for the control of adult mosquitoes. These sprays are generally effective. Initially, chlorinated hydrocarbons such as BHC and DDT were in general use and applied as emulsions. In addition to the immediate kill, these sprays left residues that often functioned to kill mosquitoes that invaded the treated area. Residents who lived in many of the communities that received these area sprays expressed the belief that odors from sprays, particularly BHC, tended to produce a barrier that repelled mosquitoes from the treated area. This belief is prevalent in tidewater communities where the salt-marsh mosquito, *Aedes sollicitans* (Walker) is common.

Because of the possibility of milk and vegetable contamination, chlorinated hydrocarbon sprays have been eliminated from space spray operations in Maryland. They have been replaced by quick acting, rapidly dissipating organic phosphorus insecticides. Evaluation studies have established that from the standpoint of original kill, these sprays are equally or more effective than the formerly used

chlorinated hydrocarbons. However, residents in a number of communities reported that the malathion and naled sprays did not give the same degree of protection as the more orderiferous BHC sprays.

Maryland workers tended to feel that the "barrier concept" as it related to odor was largely psychological and that freedom of sprayed areas from mosquito annoyance was the result of kill from residual deposits. On the other hand, Maryland mosquito control workers had given considerable attention to deodorants for masking spray odors, particularly BHC (Mallack, Joseph and Foster 1961). A commercial material, sold under the name Deodall, had proven quite satisfactory for this purpose. Many communities continued to use this deodorant with the malathion and naled sprays. These areas seldom reported unsatisfactory results.

The idea of using repellents to reduce mosquito annoyance is very old. The burning of old rags with sulphur and the use of essential oils such as citronella have long been used. Lopp and Buchanan (1959) and Horsfall (1959) reported that area repellency resulted from relatively light applications of kerosene type solvents on vermiculite granules. *Aedes* mosqui-

¹ Maryland State Board of Agriculture Contribution Number 6,

toes were repelled from treated areas for as long as one week. Currently, there are several chemicals being marketed that are quite efficient mosquito repellents for short periods. The above facts led to evaluation studies to determine whether there was opportunity for using repellents in area sprays for protection against adult mosquitoes.

Berry, Joseph and Langford (1965) reported that some of the materials used in the Maryland spray program repelled while others attracted mosquitoes. BHC emulsions proved to be repellent while malathion emulsions were attractive. The naled spray was generally neutral and the deodorant Deodall had considerable repellency.

During the summer of 1965 a preliminary study was made on the use of area mosquito repellents. The results obtained indicated opportunities for possible use of area repellents in space sprays for mosquito control. For example, 2 ethyl 1, 3 hexanediol a commonly used mosquito repellent, was effective for reducing mosquito populations in an open field when emulsified and used as a space spray. Outstanding results were obtained from a chemical 2, 2, 4-trimethyl-1, 3-pentanediol. This chemical was evaluated under a grant in aid from Eastman Chemical Products, Inc., Kingsport, Tennessee. It will be referred to in this paper as TMPD. Eastman's application for registration for use in personal insect repellents is currently being reviewed by the United States Department of Agriculture.

METHODS AND MATERIALS. Repellency or attractiveness in all tests was measured by mosquito landing counts before and after treatment. Three or more observers participated in each test and an equal number of counts were made with each chemical. All studies were performed in the tidewater communities of Crisfield and Monie, both in Somerset County, Maryland. These tests areas were selected because of abundant populations of *Aedes sollicitans* and *A. taeniorhynchus* (Wiedemann). Repellency values for each test repellent were obtained by wetting a 2-

foot by 2-foot cheesecloth square and holding it near, but not against, one's trousers, while counting the number of mosquitoes landing in thirty seconds. Twenty such counts were made for each chemical and untreated cheesecloth was used to make the control counts. Only mosquitoes landing below the waist were counted and each observer moved a short distance between counts. Another method of evaluation consisted of treating the cloth trousers worn by the observer and making 10 landing counts of 30 seconds each. A clean pair of trousers was utilized for each chemical or dilution. The test sites were on large lawns. Chemicals applied to test plots were evaluated by 20 landing counts, 30 seconds duration each count.

Area repellent tests were made with emulsions of 2 ethyl 1, 3 hexanediol, TMPD, and a TMPD granular formulation. The emulsifiable materials were applied by an orchard gun to the smaller plots and as mist sprays on larger plots.

RESULTS. Table 1 shows the relative attractiveness or repellency of malathion, naled, BHC waste isomers, and Deodall along with several other materials under observation. Malathion was attractive, naled virtually neutral and Deodall repellent. As would be anticipated, 2 ethyl 1, 3 hexanediol (612) and diethyl-metaltoluamide (12.75%—Off) gave excellent repellency. Equally effective were results from the chemical TMPD. Hallcomid M-8-10 revealed excellent repellent action, the highest percent reduction of any material evaluated by the cheesecloth method. This material is n,n, dimethyl caprylamide-capramide² a product of the C. P. Hall Company, Chicago, Illinois.

Table 1 also shows that the addition of Deodall to malathion mixtures changed attractiveness to repellency. Landing rate counts using treated trousers moistened with malathion showed that 43 percent more mosquitoes landed as compared to

² Composition—N,N-dimethyl Caproamide 5 percent, N,N-dimethyl Caprylamide 50 percent, N,N-dimethyl Lauramide 5 percent, N,N-dimethyl Capramide 40 percent.

TABLE 1.—Comparison of the effectiveness of some mosquito repellents, insecticides and combinations of the two as determined by mosquito landing counts.

Material (undiluted)	Cheese Cloth Tests		
	Total mosquitoes landing 20 counts—30 seconds each		Percent reduction
	Check cloth	Treated cloth	
BHC waste isomers 1 lb./gal. xylene (E.C.)	63	43	32
Sinpinc (100%)**	63	22	65
TMPD (2,2,4-trimethyl 1,3 pentanediol 50% E.C.)	63	10	84
	493	64	87
	493	47	90
	148	10	93
612 (2-ethyl-1,3 hexanediol 100%)	63	15	76
	148	14	90
Off (N,N-diethyl meta-toluamide 12.75% other isomers 2.25%)	148	21	90
Hallcomid M-8-10	493	36	86
	148	3	98
Material (2 ml. of conc. in 98 ml. H ₂ O)	Trousers Tests*		
	Total mosquitoes landing 10 counts—30 seconds each		Percent reduction
	Check	Treated	
Deodall 100%**	198	109	45
Malathion 57% E.C.	103	147	+43 attracted
Malathion + Deodall	103	97	6
Naled 26%	103	115	+12 attracted
Naled + Deodall	103	97	6
BHC waste isomers (1 lb./gal. xylene)	198	168	15
TMPD 50%	198	91	54
Hallcomid M-8-10	103	20	81

* An average of 27 ml. of emulsion used in each trouser treatment.

** Deodall and Sinpinc are marketed by the Sindar Corp., New York, as deodorants. Formulas are secret. They consist principally of various terpenes, terpene alcohols, and terpene oxide. Deodall has a longer residual effect than Sinpinc.

untreated trousers. The addition of Deodall resulted in 6 percent fewer mosquitoes landing than on untreated trousers. Two percent solutions of TMPD and Hallcomid M-8-10 revealed 54 percent and 81 percent reductions respectively in the number of mosquitoes landing.

Landing counts were made using both the cheesecloth and trouser treatment methods to evaluate various dilutions of TMPD emulsion. Table 2 gives these results. Emulsions of this material in water indicated some excellent results. The 2.5 percent emulsion by the cheesecloth method repelled 69 percent of the mosquitoes, while the 5 percent repelled 85 percent. This was under conditions where the landing rate count was 350 mosquitoes for 20 counts of 30 seconds each.

Field tests for area repellency were made with sprays prepared from a 50 percent TMPD E.C., 80 percent 2 ethyl 1, 3 hexanediol E.C. and a 67 percent TMPD granular formulation.

Table 3 shows the results obtained with the emulsions. Spray solutions prepared from TMPD and 2 ethyl 1, 3 hexanediol emulsifiable concentrates were applied with an orchard gun at 400 P.S.I. to plots of 10,000 square feet. There was an initial reduction in mosquitoes for all tests and for both chemicals. The reduction one hour after treatment was undoubtedly influenced by killing as well as repellent action as the sprays had oily characteristics, especially TMPD at the higher dosages. The dosages of actual TMPD applied per 1,000 square feet were 2 lbs., 1 lb., and 1/2 lb. and in each appli-

TABLE 2.—The relationship of TMPD concentration to repellent action.

Cheese Cloth Tests		
Test Material	Total mosquitoes landing 20 counts—30 seconds each	Percent reduction
TMPD 2.5%	107	69
TMPD 5%	52	85
TMPD 12.5%	48	86
TMPD 25%	36	89
TMPD 50% (concentrate— 4 lbs. A/gallon)	17	95
Control	350	

Trousers Tests		
Test Material	Total mosquitoes landing 10 counts—30 seconds each	Percent reduction
TMPD 2.5%	68	34
TMPD 5%	22	79
TMPD 10%	11	89
Control	103	

cation the reduction one hour after treatment was 99 percent—100 percent. Only the treatment of 2 lbs. TMPD per 1,000 square feet maintained a satisfactory repellent effect for two weeks. This dosage level caused extensive foliage injury to grass and shrubs. It is not known what physical effect, if any, this foliage damage had on repelling mosquitoes from the treated plot. The two lighter dosages of TMPD emulsion revealed fair repellent action one day after treatment, but there were no indications of repellency after 8 days. Foliage injury was greatly reduced at the two lighter dosages.

Like TMPD, the 2 ethyl 1, 3 hexanediol emulsion at a dosage of .36 lb./1,000 square feet showed excellent results, 86 percent at the end of one hour. However, in this plot the mosquitoes returned more rapidly than in the TMPD plots. Heavy mosquito populations were encountered 24 hours after treatment.

Mist applications of 2.5 percent and 5 percent TMPD emulsion, by volume in water, made to 10 acre test plots showed reductions of 40 percent and 46 percent respectively in the number of mosquitoes

landing one hour after treatment. High mosquito populations one day after treatment revealed little evidence of repellent action in either of these mist-sprayed plots. The calculated dosages of actual TMPD applied, based on a 200 feet swath were .2 lb. per acre with the 2.5 percent emulsion and .4 lb. per acre with the 5 percent emulsion. The tests using emulsions were unreplicated.

Granular TMPD, Table 4, applied with a hand seeder at the rate of 2 lbs. of actual TMPD per 1,000 square feet of lawn showed good repellency under conditions of very heavy mosquito populations. Population reductions were from 50.9 percent to 92.3 percent one hour after treatment. Results after 18 and 24 hours indicated that mosquitoes had returned to the treated area.

SUMMARY. Studies were made with several known mosquito repellents and experimental chemicals to find materials which might have promise as area mosquito repellents. Tests were made with cheesecloth squares and with treated trousers to evaluate repellency. Hallcomid M-8-10 and TMPD showed excellent repellency in the cheesecloth tests. Deodall added to malathion and naled sprays changed their attractiveness to repellency in the trouser tests.

TMPD and 2-ethyl-1, 3 hexanediol were tested under field conditions as area repellents. TMPD emulsion as a spray and applied at the rate of 2 lbs. of actual chemical to 1,000 sq. ft., showed promise, but it caused extensive foliage injury at that dosage. Applied at 1 lb. and ½ lb. of actual chemical to 1,000 sq. ft. it showed repellent action for one day. Mist sprays of TMPD emulsions at .2 lb. and .4 lb. to the acre, on 10 acre plots, showed a reduction in mosquitoes after one hour. Granular TMPD, at 2 lbs. of actual chemical to 1,000 sq. ft. resulted in reductions after one hour that ranged from 50.9 percent to 92.3 percent. Emulsified 2-ethyl-1, 3 hexanediol sprayed on a 10,000 sq. ft. plot (total actual chemical 3.6 lbs.) showed excellent repellency after one hour. Mos-

TABLE 3.—The results of applications of TMPD and ethyl hexanedioi emulsions as revealed by landing counts.

Date	Actual material per 10,000 sq. ft.	Before treatment	1 hr.	Total mosquitoes landing—20 counts—30 seconds each after treatment					14 days
				1 day	3 days	4 days	8 days	14 days	
8/12/65	3.6 lbs. ethyl hexanedioi	336	48	152	...	123	...	...	52
8/12/65	20 lbs. TMPD *	267	0	1	...	5	...	...	3
8/12/65	Check	...	294	43	...	12	...	...	47
9/9/65	10 lbs. TMPD *	631	3	99	...	...	...	170	...
9/9/65	5 lbs. TMPD *	571	4	102	...	...	...	413	...
9/9/65	Check	355	...	410	...	...	...	157	...
Emulsions applied from power sprayer with hand gun									
Total mosquitoes landing—30 counts—30 seconds each									
Actual material per 10 acre plot									
10/10/65	4 lbs. TMPD (5% emulsion)	259	140	233	232	...	...	...	...
10/10/65	2 lbs. TMPD (2.5% emulsion)	354	210	382	349	...	...	...	...
10/10/65	Check	306	272	648	414	...	...	...	...
Total mosquitoes landing—30 counts—30 seconds each TMPD emulsion—applied from mist blower **									

* Amount in 30 gallons of water.

** TMPD emulsion—Delivery rate 100 gallons per hour. 400 P.S.I. Swath width 200 feet.

TABLE 4.—The results of applications of 67% TMPD granular, 2 lbs. actual/1000 sq. ft. as revealed by landing counts.

Date	Dosage	Plot size	Before treatment	Total mosquitoes landing— 20 counts—30 seconds each after treatment			
				1 hr.	18 hrs.	24 hrs.	4 days
8/12/65	30 lbs.	10,000 sq. ft.	212	22	..	133	30
8/12/65	30 lbs.	10,000 sq. ft.	165	81	..	124	43
8/12/65	30 lbs.	10,000 sq. ft.	...	119	..	191	46
8/26/65	30 lbs.	10,000 sq. ft.	61	18	54	...	..
8/26/65	Check	10,000 sq. ft.	71	62	82	...	..
8/26/65	60 lbs.	20,000 sq. ft.	52	4	33	...	..
8/26/65	Check	20,000 sq. ft.	71	80	83	...	..

quitoes had returned when checked the following day.

Acknowledgment is made to E. Elwood Lynch, J. Milton Hall, and James H. Harris who, from time to time, assisted the authors in performing tests and making mosquito landing counts.

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