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United States Department of Agriculture
Agricultural Research Service EFFECTIVENESS OF REPELLENTS AGAINST
CULICINE MOSQUITOES^{1/}By B. V. Travis,^{2/} F. A. Morton,^{3/} and W. W. Yates^{4/}

A large number of repellents were tested in the laboratory and field against several culicine mosquitoes from 1942 to 1946. The principal test species were Aedes taeniorhynchus (Wied.), sollicitans (Wlkr.), and a mixed population of Mansonia in Florida. A few tests were made against mountain Aedes and Culiseta in Oregon, Aedes (Aedes) sp. in New Guinea, and several arctic species in Canada and Alaska. Field tests were made against mosquitoes in general in a number of States. Most of the materials included in this report had been found to be outstanding in laboratory tests against Aedes aegypti (L.) (Morton et al. ^{1/}, Travis et al. ^{3/}), but a few were tested only in the field.

The primary objective of these tests was to find chemicals or formulations that would protect troops from mosquito bites much longer than the standard repellents--dimethyl phthalate, ethyl hexanediol, Indalone, and a 6-2-2 mixture of these respective materials. Many of the preparations were tested only a few times, and then dropped from consideration because they did not give protection at least as long as the better standard materials. The more promising repellents were tested extensively.

A manuscript covering this work was prepared in 1947 but could not be completed for publication at that time. Since then much additional work has been done on repellents for salt-marsh and subarctic Aedes, and reports on these tests have been published (Travis and Smith ^{4/}, Smith et al. ^{2/}). The previous work, however, contains considerable information that may be of interest to other workers, particularly the results with creams and other formulations. All the tests were made in Florida unless otherwise indicated.

^{1/} This work was conducted at the Orlando, Fla., laboratory of the former Bureau of Entomology and Plant Quarantine under funds allotted by the former Office of Scientific Research and Development and the Department of the Army. E. F. Knipling, J. H. Cochran, J. H. Robinson, and other members of the laboratory assisted in making the tests, and Lyda Robertson in keeping the records and assembling the data. This laboratory is now a part of the Entomology Research Branch.

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Methods

The materials were applied to the arms (1/4 teaspoonful elbow to wrist) and the legs (3/8 teaspoonful knee to ankle) of the test subjects. The treated subjects exposed themselves to mosquitoes in the field to determine how long the materials would prevent bites. The time from treatment to the first bite was called the repellent time. Most of the exposures were continued until more than one bite had been received. With some preparations paired tests were made--concurrently on both arms or legs of the same subject. The routine procedure was to apply each material to several subjects to learn as much as possible of the variation to expect on different individuals. No tests were conducted against salt-marsh Aedes unless the biting rate was in excess of 20 bites on an untreated leg in half a minute. The biting rates for the mountain Aedes were 5 to 12 per half-minute, for Culiseta 0 to 5, and for Mansonia 5 to 10.

Most of the test materials were liquids, applied undiluted. Some of the most effective ones were later diluted with alcohol or used in other formulations. In some a thickener such as ethyl cellulose or a powder such as bentonite was added to the liquid. In others a pyrethrum insecticide was included, or two or more repellent materials were mixed.

Results

The results of these tests are presented separately for each mosquito species. Some of the tables include repellent ratios, calculated by dividing the average repellent time of a test material by that of a standard material in concurrent tests and then multiplying by 100. The effectiveness of a chemical could often be compared best by means of this ratio, as the repellent time of any given material varied considerably in different test periods.

Occasionally it was necessary to terminate a test before bites were received. Where the repellent time for such a test exceeded the average for the completed tests with that material, it was included in the average. Such averages are marked in the tables with a plus sign.

Aedes taeniorhynchus

Of the 129 undiluted repellents listed in table 1, 21 gave longer protection against taeniorhynchus than the standard material. The following materials were 1 1/2 to 2 1/2 times as effective as the standard: 2-(x-chloro-y-ethylphenyl)ethanol; N-butyl-4-cyclohexene-1,2-dicarboximide; N-isopentylacetanilide; 1,2,3, 4-tetrahydro-2-naphthol; 2,5,7-trimethyl-3-octyne-2,5-diol; and the propyl ester of N,N-diethylsuccinamic acid.

The last material has been cleared in pharmacological tests for use on the skin. Such tests with 2,5,7-trimethyl-3-octyne-2,5-diol were inconclusive, and the other four compounds were rejected because of toxicity or skin irritation.

The repellent times obtained with the standards during different field trips are shown in table 2. Ethyl hexanediol and mixture 6-2-2 were about equally effective and superior to dimethyl phthalate and Indalone, which were about equally effective. In only one field trip, on July 11-14, 1944, was ethyl hexanediol greatly superior to mixture 6-2-2; however, only two tests were made with ethyl hexanediol. If the range of the average repellent times is compared, mixture 6-2-2 is superior to the other standards, with a range of 326 to 161 minutes, giving a ratio of 2.02 as compared with 3.82 for ethyl hexanediol, 5.24 for dimethyl phthalate, and 7.24 for Indalone.

When pyrethrins or N-isobutylundecenamide or both were added to Indalone, ethyl hexanediol, or the ethylene glycol ether of pinene, they had practically no repellent value (table 3). Although 1 percent of pyrethrins in Indalone and 0.5 percent in the ethylene glycol ether of pinene gave higher repellent times than the repellents without the pyrethrins, the differences were not statistically significant. The addition of N-isobutylundecenamide, either alone or with the pyrethrins, reduced the average repellent time.

Most of the mixtures of repellents that were tested in the field were superior to the standard (table 4). Only three mixtures had repellent ratios less than 90--dimethyl phthalate plus ethyl hexanediol; 2-phenylcyclohexanol plus 3,4-diethoxybenzaldehyde; and cyclohexyl benzoate plus anisyl alcohol.

The addition of such thickeners as cellulose acetate, ethyl cellulose, methyl cellulose, nitrocellulose, colloidal silica, magnesium, zinc and calcium stearates, a synthetic gum, and the ethyl ester of o-benzoylbenzoic acid failed to increase the repellent time consistently.

In a series of paired tests with various creams and liquids containing volatile solvents and either dimethyl phthalate or a mixture of 2-phenylcyclohexanol and 1,2,3,4-tetrahydro-2-naphthol, the creams were found to be superior to the liquid preparations (table 5). All the preparations containing 2-phenylcyclohexanol and 1,2,3,4-tetrahydro-2-naphthol were superior to those containing dimethyl phthalate. Dimethyl phthalate was more effective in a zinc oxide paste cream than in a cream containing bentonite and calcium stearate; however, this cream was less effective than a vanishing cream containing the same repellent.

Some of the more promising powder-base creams tested in the laboratory against aegypti (Travis et al. 3) were tested in the field against taeniorhynchus (table 6). Those prepared with pyrophyllite or tricalcium phosphate were considerably less effective than the standard repellent. This was also true of creams prepared with bentonite except the one

containing ethyl hexanediol, dimethyl phthalate, and Indalone. With ethyl hexanediol, dimethyl phthalate, and calamine the average repellent time was more than twice that obtained in concurrent tests with undiluted ethyl hexanediol. In two series of tests, one with dimethyl phthalate and one with the mixture 6-2-2, the addition of calcium stearate as a thickener to creams containing bentonite extended the repellent time. The solid repellents butyl sulfone, N-ethylacetanilide, and N-propylacetanilide gave considerably longer repellent times than the standard.

Cold creams and vanishing creams containing 30 percent of the repellents 2-(2-cyclohexyloxyethoxy)ethanol; 3-(2-cyclohexyloxy-1-methylethoxy)-2-propanol; ethyl hexanediol; and 2- $\sqrt{2}$ -(3,3,5-trimethylcyclohexyloxy)ethoxy/ethanol were found less effective than the undiluted repellents.

The repellent time of a number of the better repellents was reduced by the addition of a volatile solvent, but the reduction was not in proportion to the dilution (table 7). N-Ethylacetanilide was the only solid material that gave more than 100 minutes' protection.

When the repellents were mixed with nonvolatile solvents, the repellent time was also reduced. Occasionally a few tests with such materials would give a long repellent time. However, the results were not consistent; so only screening-type tests were made with these materials.

Some tests were made with materials added to dimethyl phthalate. The addition of 2 percent of camphene, 10 percent of a crude alkaloid of Haplophyton, 5 percent of aluminum chloride, or 10 percent of calcium chloride caused little or no increase in repellent time. The last two compounds are said to reduce sweating.

A number of preparations containing ethyl hexanediol, dimethyl phthalate, or Indalone, and some unidentified aromatic substances in powder, petroleum, or beeswax base sent by various agencies were tested in the field. Only the powder-base creams and a beeswax-base cream containing ethyl hexanediol or a mixture of this repellent and dimethyl phthalate gave repellent times that compared favorably with the undiluted repellents. A proprietary product containing 50 percent of the acetate of 2-(2-butoxyethoxy)ethanol was found to be only slightly less effective than this compound undiluted.

Aedes sollicitans

Of the 12 materials tested against sollicitans, 2- $\sqrt{2}$ -(2-ethylhexyloxy)ethoxy/ethanol, 2- $\sqrt{2}$ -(alpha-methylbenzyloxy)ethoxy/ethanol, and dl-dibutyl malate were effective for more than 5 hours (table 8). Dimethyl phthalate and Indalone were equally effective against sollicitans as against taeniorhynchus. A proprietary material containing 50 percent of 2-(2-butoxyethoxy)ethyl acetate was found in 5 tests to be equally as effective as the undiluted material.

Miscellaneous Aedes species and Culiseta incidens

The various standard repellents were tested both in the laboratory and in the field against several species of Aedes and C. incidens in Oregon. Table 9 shows that ethyl hexanediol and the mixture 6-2-2 were generally superior to Indalone or dimethyl phthalate. In four other tests against A. dorsalis the average protection time was 376 minutes with 2-(2-butoxyethoxy)ethyl acetate, 277 minutes with benzyl benzoate, and 75 minutes with butyl phthalate.

Tests with other compounds against the mixed population containing Aedes sticticus and vexans are summarized in table 10. In addition 6 tests with an 80:20 mixture of dimethyl phthalate and ethyl hexanediol gave an average repellent time of 368+ minutes, and 4 tests with a powder-paste cream containing 69 percent of dimethyl phthalate, 151 minutes. Conclusive data were not obtained with many of the repellents, as it was frequently necessary to terminate the tests before a bite was received. The data show that these mountain Aedes are rather easily repelled.

The repellent times against Culiseta incidens are considerably longer than for the various Aedes species (table 9), probably because of the low biting rate prevailing during the test.

Mansonia perturbans (Wlkr.) and titillans (Wlkr.)

In tests with some of the more promising repellents against a mixed population of these species in Florida, it was found that they are easily repelled and that the standard repellents give good protection (table 11).

Aedes spp.

In 1945 W. V. King and Army coworkers made tests in New Guinea against a mosquito population containing more than 99 percent of a species of Aedes subgenus Aedes near similis (Theob.) and the remainder of Culex halifaxii Theob. and Armigeres sp. (table 12). The biting rates averaged 9.5 on arms and 13 on legs in 5 minutes. The skin was moderately wet with sweat during the tests. Phenethyl ester of 2-methylactic acid was found to be the best material.

In 1943 H. H. Stage, of the Bureau of Entomology and Plant Quarantine and Terris Moore, of the Office of the Quartermaster General, U. S. Army, made a number of field tests with the standard repellents in Churchill, Canada (table 13). The mosquito population was predominantly Aedes nearcticus Dyar with some cataphylla Dyar. The repellents were applied to the arms and legs by the standard procedure. Mixture 6-2-2 was found to be more effective than any one of its ingredients. A paste made of ethyl hexanediol and bentonite (not included in table) gave an average of only 26 minutes' protection in 9 tests.

In 1944 Mr. Stage conducted similar tests in Alaska against several species of Aedes (table 13). At Nome powder pastes containing dimethyl phthalate were the most effective repellents against a mixed population of nearcticus and riparius D. and K., and mixture 6-2-2 was superior to any one of its ingredients. In tests near Anchorage with flavescens (Mull.) and species of the stimulans group, he found ethyl hexanediol and dimethyl phthalate to be of equal effectiveness and mixture 6-2-2 to be superior to any one of its ingredients. Powder pastes with dimethyl phthalate and mixture 1-1-1 were much superior to the liquid repellents. In tests near Fairbanks with four repellent creams against mixed populations of cinereus and excrucians (Wlkr.), the one containing N-sec-butylphthalimide was the most effective.

C. R. Twinn, of the Canadian Department of Agriculture, made a number of field tests against woodland Aedes in Canada with the four standard repellents. He reported the following repellent times (in minutes): Dimethyl phthalate 267, ethyl hexanediol 329, Indalone 106, mixture 6-2-2 360.

Miscellaneous Species

In response to a request from the Bureau's Division of Plant Disease Control, one of the more promising materials, 2-phenylcyclohexanol, was sent to its field employees in 20 States, who compared it with the repellent they were using, which was presumed to contain dimethyl phthalate. When all the reports were summarized, 571 tests with 2-phenylcyclohexanol gave an average repellent time of 114 minutes and 475 tests with the standard gave 106 minutes. Both these figures are lower than those obtained by the research group at Orlando, Fla., but the data seem to be in line with what might be expected from practical tests.

Summary

From 1942 to 1946 a large number of compounds and formulations were tested in the field against several species of culicine mosquitoes in an effort to find some that would protect troops from mosquito bites longer than the standard repellents.

Against Aedes taeniorhynchus (Wied.) the best materials were 2-(x-chloro-y-ethylphenyl)ethanol; N-butyl-4-cyclohexene-1,2-dicarboximide; N-isopentylacetanilide; 1,2,3,4-tetrahydro-2-naphthol; 2,5,7-trimethyl-3-octyne-2,5-diol; and the propyl ester of N,N-diethylsuccinamic acid. Only the last one has been cleared in pharmacological tests for use on the skin.

Tests with the four standard repellents--dimethyl phthalate, ethyl hexanediol, Indalone, and mixture 6-2-2--showed that the mixture gave the most consistent results and Indalone the least consistent.

The addition of pyrethrins or N-isobutylundecenamide failed to increase the repellent time of Indalone, ethyl hexanediol, or ethylene glycol ether of pinene. In most tests mixtures of the better repellents were more effective than the standard ethyl hexanediol.

The addition of thickeners failed to increase the protection time of repellents, but generally powder-base creams to which thickeners had been added were more effective than the liquid repellents. Likewise, repellents formulated with a vanishing or cold cream were not effective.

The repellent times were much longer with the mountain Aedes, Culiseta, and Mansonia than with the salt-marsh Aedes, but this may have been due to the low biting rates prevailing during the tests.

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Table 1.--Effectiveness of repellents against Aedes taeniorhynchus.

Material	Orlando No.	Tests	Average repellent		Repellent ratio
			Number	Minutes	
Acetamide, 2-butoxy- <u>N</u> -pentyl-	925	8	312	125	
2-butoxy- <u>N</u> -cyclohexyl-	614	18	362	145	
<u>N</u> -cyclohexyl-2-(2-methylallyloxy)-	1881	3	217	80	
Acetanilide, 2-butoxy-	1714	5	175	65	
<u>N</u> -butyl-	2484	10	359	115	
<u>N</u> -isopentyl-	5528	11	290	254	
Acetoacetic acid, cyclohexyl ester	6230	4	102	89	
Acetophenone, 3',4'-dichloro-	479	3	110	31	
4'-ethoxy-	1029	2	82	48	
4'-methoxy-	227	4	84	50	
Adipic acid, diethyl ester	342	13	96	32	
Anisole, <u>o</u> -phenyl-	236	4	5	1	
Anisyl alcohol	1170	20	93	50	
Benzaldehyde, <u>p</u> -propoxy-	5518	7	110	96	
Benzamide, <u>N,N</u> -diethyl-	1197	1	437	--	
Benzyl alcohol, <u>alpha</u> -ethoxymethyl-	338	7	69	20	
Benzyl benzoate	523	2	61	36	
Benzyl ether	2269	8	91	24	
Bicyclo[2.2.1]hept-5-ene-2,3-dicarboximide, <u>N</u> (mixed)amyl-	1492	4	203	120	
Bicyclo[2.2.1]hept-5-ene-2,3-dicarboxylic acid, diethyl ester	4132	8	115	101	
<u>cis</u> -, dimethyl ester (dimethyl carbate)	3916	23	208	62	
2-Biphenylamine	67	2	116	69	
<u>gamma</u> -Cadinene	209	10	82	23	
Cinnamaldehyde, <u>alpha</u> -pentyl-	658	4	83	49	
Cinnamic acid, isopropyl ester	2026	33	172+	55	
• methyl ester	579	2	91	54	
propyl ester	2024	22	287	91	
Citric acid, tributyl ester	394	6	55	16	
<u>d</u> -Citronellol	204	3	133	38	
acetate	205	4	148	42	
Cyclohexanecarboxylic acid, <u>alpha</u> -cyano-, ethyl ester	4999	8	76	67	
Cyclohexanecarboxylic acid, 1-hydroxy-, cyclopentyl ester	6133	8	155	136	
1,2-Cyclohexanedicarboxylic acid, diethyl ester	5567	10	96	84	
Cyclohexane-2-hexenoic acid, methyl ester	2000	2	100	59	
Cyclohexanol, 2-cyclohexyl-	1023	21	159	67	
4-(1,1-dimethylpropyl)-	431	19	147	51	
2,4-dipentyl-	421	5	51	14	
2-phenyl-	2133	73	252+	94	
3-Cyclohexene-1-carbonitrile, 5,5-dimethyl-2- (1-methylpropenyl)-	1651	6	61	22	
4-Cyclohexene-1,2-dicarboximide, <u>N</u> -butyl-	4145	12	181	159	
<u>m</u> -Dioxane, 4-(<u>p</u> -methoxyphenyl)-5-methyl-	5533	8	62	54	
5-methyl-5-nitro-2-propyl-	7102	8	37	32	
Diphenylamine, <u>N</u> -pentyl-	55	4	13	3	
Elemol	210	8	157	48	
Ethanol, 2-(benzyloxy)-	1040	4	185	43	
2-[bis(1,1-dimethylpropyl)phenoxy]-	447	9	62	18	
2-(2-butoxyethoxy)-, acetate	170	74	126	47	

Table 1.--Continued

Material	Orlando No.	Tests	Average repellent time	Repellent ratio
		Number	Minutes	
Ethanol, 2-(p-tert-butylphenoxy)-	33	2	53	31
2-(x-chloro-y-ethylphenyl)-	2103	8	421	170
2-(2-cyclohexyloxyethoxy)-	373	15	310	88
2-N-ethylanilino-	1463	13	303	135
2-(alpha-methylbenzyloxy)-	164	14	153	43
2- $\sqrt{2}$ -(alpha-methylbenzyloxy)ethoxy/-	166	16	205	58
2-(3-methyl-2-norcamphanylmethoxy)-	773	7	234	94
2- $\sqrt{2}$ -(3-methyl-2-norcamphanylmethoxy)ethoxy/-	774	6	334	134
2-phenoxy-, acetate	2145	8	100	88
2,2'-thiodi-, diacetate	5542	8	57	50
2- $\sqrt{2}$ -(3,3,5-trimethylcyclohexyloxy)ethoxy/-	376	23	300	83
Ether, p-(1,1-dimethylpropyl)phenyl pentyl	423	4	32	9
pentyl phenyl	441	4	29	8
pentyl xylyl	438	4	70	20
butyl phenyl	446	4	22	6
Ethylene glycol, alkyl benzyl ethers	4723	8	41	36
2-Furoic acid, cyclohexyl ester	1487	2	161	95
Geraniol	206	8	92	26
1,3-Hexanediol, 2-ethyl- (standard)	375	166	265	--
Hydracrylic acid, 3-phenyl-, ethyl ester	6216	11	86	75
Hydrocinnamic acid, alpha,beta-epoxy-beta-methyl-, ethyl ester	2947	9	100	88
Indalone	9	162	162	60
Isobutyl sulfone	5529	8	121	106
Lactic acid, butyl ester	397	1	14	4
ethyl ester	395	1	60	17
2-methyl-, benzyl ester	1654	7	117	44
bornyl ester	1653	6	102	39
phenethyl ester	1650	4	153	58
Lauric acid, pentyl ester	425	1	8	2
2 $\sqrt{p}$ -(1,1-dimethylpropyl)phenoxy/ethyl ester	422	5	47	13
isopropyl ester, crude	1094	4	56	22
Maleic acid, dipentyl ester	418	9	74	21
Malic acid, dl-, dibutyl ester	337	41	272	101
Mandelic acid, butyl ester	1789	8	275	102
ethyl ester	1643	17	210	90
isopropyl ester	1788	4	233	86
methyl ester	1787	6	89	53
Myristic acid, isopropyl ester, crude	1095	3	36	14
Naphthalene, 2-pentyloxy-	445	4	18	5
2-Naphthol, 1,2,3,4-tetrahydro-	5563	17	211	185
Octanal	3961	8	106	--
3-Octyne-2,5-diol, 2,5,7-trimethyl-	7139	8	232	204
Oils, bay	463	4	108	31
camphor, ethereal	466	4	23	6
citronella	159	20	70	25
eucalyptus	464	4	59	17
juniper berry	469	3	29	8
lemon	465	4	14	4
orange	468	4	46	13
pennyroyal, European	472	4	32	9

Table 1.--Continued

Material	Orlando No.	Tests	Average repellent time	Repellent ratio
		Number	Minutes	
Oleic acid, pentyl ester	417	6	56	16
Oxalic acid, dipentyl ester	419	8	94	27
2-Pentanol, 4-(3-hydroxypropoxy)-2-methyl-	169	3	91	26
Phenethyl alcohol, <u>p</u> -chloro-	2719	2	231	53
<u>p</u> -isopropyl-	1774	18	207	77
Phenol, <u>p</u> -(1,1-dimethylpropyl-, acetate	420	13	108	31
Phosphoric acid, tributyl ester	399	2	149	42
Phthalic acid, diethyl ester	329	4	116	46
dimethyl ester (standard)	262	233	161	58
Phthalimide, <u>N</u> - <u>sec</u> -butyl-	2419	10	77	68
Pinene, ether with ethylene glycol	558	34	229+	92
Propanediol, <u>x</u> -(2-ethylbutoxy)-	1442	6	315	117
1,2-Propanediol, 3-isopentyloxy-	3554	4	422	98
Propionic acid, 2-benxyloxy-2-methyl-, benzyl ester	1910	7	75	28
ethyl ester	1911	10	74	27
Propanol, butoxypolypropyleneoxy-	163	6	298	85
2-Propanol, 3-(2-cyclohexyloxy-1-methylethoxy)-	374	28	310	100
1- <u>[2</u> -(3,3,5-trimethylcyclohexyloxy)propoxy]-	1123	20	255	102
Propionic acid, diester with 1,5-pentanediol	6154	8	95	83
Ricinoleic acid, acetyl-, butyl ester	400	1	27	8
Salicylic acid, pentyl ester	334	8	56	16
isopentyl ester	378	7	67	19
Sebacic acid, dibutyl ester	393	2	52	15
Stearic acid, pentyl ester	430	11	64	18
butyl ester	398	5	39	11
Succinamic acid, <u>N,N</u> -diethyl-, propyl ester	6168	10	182	160
<u>N,N</u> -dipropyl-, ethyl ester	6252	10	158	138
Succinic acid, 2-cyano-3-methyl-, diethyl ester	5611	8	20	18
Tartaric acid, dibutyl ester	396	4	69	20
diisopropyl ester	3572	13	70	25
Toluenesulfonamide, <u>N,N</u> -dibutyl-	424	3	21	6
Undecanoic acid, hydroxy-, lactone	751	2	189	43
Undecyl alcohol	330	3	36	10

Table 2.--Average repellent times obtained with several standard repellents against Aedes taeniorhynchus in different field trips.

Date of tests	Ethyl hexanediol		Dimethyl phthalate		Indalone		Mixture 6-2-2	
	Tests	Repellent time	Tests	Repellent time	Tests	Repellent time	Tests	Repellent time
	Number	Minutes	Number	Minutes	Number	Minutes	Number	Minutes
<u>1942</u>								
June 29-30	23	351	24	209	23	246	---	---
Sept. 17-22	12	260	11	121	17	170	---	---
Oct. 15-23	28	249	12	170	44	140	---	---
<u>1943</u>								
June 10-19	34	270	35	214	39	206	14	270
July 12-13	12	148	25	50	10	70	--	--
16-17	4	200	7	71	7	110	5	194
22	1	201	9	98	1	180	--	--
Aug. 23	2	169	10	80	2	101	--	--
Sept. 10	4	345	5	213	--	--	--	--
<u>1944</u>								
June 2-6	5	251	13	262	--	--	19	271
21-23	12	267	21	200	4	60	8	205
July 11-14	2	436	6	246	6	193	18	300
19-21	5	337	7	156	--	--	6	326
26-28	6	431	12	248	--	--	--	--
Aug. 3-5	4	250	6	69	--	--	--	--
16-18	--	--	4	212	--	--	--	--
<u>1945</u>								
July 1-Aug. 31	8	114	22	83	9	334	14	175
<u>1946</u>								
Sept. 10	4	181	4	206	--	--	4	161
Total or average	166	265	233	161	162	162	88	250

Table 3.--Effect of adding pyrethrins and/or N-isobutylundecenamide on the repellent time of repellents against Aedes taeniorhynchus.

Repellent	Pyrethrins	<u>N</u> -Isobutyl-undecenamide	Tests	Average repellent time
	<u>Percent</u>	<u>Percent</u>	<u>Number</u>	<u>Minutes</u>
Ethylene glycol ether of pinene	--	--	4	218
	--	2	3	167
	5	--	7	192
	1	--	15	211
	0.5	--	12	281
	1	2	3	167
Ethyl hexanediol	--	--	12	316
	--	2	4	152
	1	--	4	256
	1	2	3	167
Indalone	--	--	12	191
	--	2	4	171
	1	--	4	218
	1	2	4	176
Pyrethrins check ^{1/}	5	--	4	33

^{1/} From a 20-percent pyrethrum concentrate in equal parts of white petroleum oil and the sodium salt of bis(2-ethylhexyl) sulfosuccinate.

Table 4.--Effectiveness of mixtures of repellents against Aedes taeniorhynchus.

Repellent mixture (figures after ingredients indicate percent)	Tests	Average repellent time	Repellent ratio
	<u>Number</u>	<u>Minutes</u>	
Cyclohexyl benzoate plus--			
Anisyl alcohol 50	1	133	31
Isopropyl cinnamate 50	9	107	94
Dimethyl phthalate plus--			
Coumarin 40	8	281	113
Ethyl hexanediol 20	28	258	78
Ethylhexanediol and Indalone			
33.3 each	29	313	109
25 each	6	360	107
20 each	89	250	92
10 each	26	253	93
Ethyl hexanediol plus--			
Butyl sulfone 25	11	175	153
Indalone 75	5	293	116
50	4	251	100
25	11	254	101
Indalone plus--			
Butyl sulfone 25	12	124	109
Coumarin, saturated	7	351	141
2-Phenylcyclohexanol plus--			
Cyclohexyl benzoate 50	12	171	150
2-Cyclohexylcyclohexanol 30	12	173	96
3,4-Diethoxybenzaldehyde 50	10	180	42
Isopropyl cinnamate 50	12	132	116
Methyl anthranilate 50	8	158	138
<u>alpha</u> -Pentylcinnamaldehyde 50	12	185	162
1,2,3,4-Tetrahydro-2-naphthol 30	12	220	198

Table 5.--Results of paired tests with liquid and cream formulations of repellents against *Aedes taeniorhynchus*.

Composition of repellent (figures after ingredients indicate percent)	Form	Tests	Average repellent time
		Number	Minutes
2-Phenylcyclohexanol 70 + 1,2,3,4-tetrahydro-2-naphthol 30	Liquid	10	191
Dimethyl phthalate 65 + bentonite 33 + calcium stearate 2	Cream	10	142
2-Phenylcyclohexanol 35 + 1,2,3,4-tetrahydro-2-naphthol 15 plus--			
1-Hexanol 50	Liquid	16	148
Zinc oxide 50	Cream	16	307
1-Hexanol 50	Liquid	19	310
Dimethyl phthalate 65 + bentonite 33 + calcium stearate 2	Cream	19	182
2-Phenylcyclohexanol 42 + 1,2,3,4-tetrahydro-2-naphthol 18 plus--			
1-Hexanol 40	Liquid	8	145
Tegin 25 + Tween 60 5 + water 10 Sample 1	Cream	8	183
Sample 2	Cream	8	183
Dimethyl phthalate 65 + bentonite 33 + calcium stearate 2	Cream	8	122
Dimethyl phthalate 50 plus--			
1 Hexanol 50	Liquid	10	90
Zinc oxide 50 Sample 1	Cream	10	183
Sample 2	Cream	19	206
Dimethyl phthalate 65 + bentonite 33 + calcium stearate	Cream	19	174
Dimethyl phthalate 60 plus--			
1-Hexanol 40	Liquid	9	88
Tegin 10 + Tween 60 5 + water 25 Sample 1	Cream	9	138
Sample 2	Cream	9	149
Dimethyl phthalate 65 + bentonite 33 + calcium stearate 2	Cream	99	191

Table 6.--Effectiveness of powder-base repellent creams against *Aedes taeniorhynchus*.

Composition of cream (figures after ingredients indicate percent)			Tests	Average repellent time	Repellent ratio
Repellent	Powder	Thickener			
			Number	Minutes	
1-Benzylcyclohexanol 34 ^{1/}	Bentonite 33	Olive oil 33	6	50	44
Butyl sulfone 31-35 ^{1/}	32-33	33-36	11	206	181
2-(2-Cyclohexyloxyethoxy)ethanol 58	Pyrophyllite 42	--	4	76	22
17	83	--	7	94	27
3-(2-Cyclohexyloxy-1-methylethoxy)-2-propanol 58	Tricalcium phosphate 42	--	7	45	13
Dimethyl phthalate 69	Hyflo Super-Cel 21	Vaseline 10	15	140	53
67	Bentonite 33	--	4	124	46
64-66	32-33	Calcium stearate 2-3	52	171	71
N-Ethylacetanilide 32 ^{1/}	31	Olive oil 37	10	148	130
2-Ethyl-1,3-hexanediol--					
9 + dimethyl phthalate 35	Calamine 56	--	21	258	226
9-14 + dimethyl phthalate 35-56	Bentonite 28-33	Calcium stearate 2	57	307	90
9 + dimethyl phthalate 36	Zinc oxide 52	3	39	270	82
21 + dimethyl phthalate 21 + Indalone 21	Bentonite 34	3	6	319	73
12 + dimethyl phthalate 22 + Indalone 22	34	--	7	299	111
Mixture 6-2-2 67	33	Calcium stearate 3	10	251	90
		--	6	172	64
N-Propylacetanilide 34 ^{1/}	33	Olive oil 33	10	223	196
2,2,2-Trichloro-N-(2-chloroethyl)-acetamide 34 ^{1/}	34	32	8	93	82
2-[2-(3,3,5-Trimethylcyclohexyloxy)-ethoxy]ethanol 17	Pyrophyllite 83	--	9	55	16

^{1/} Solid materials.

Table 7.--Effectiveness of repellents in volatile solvents against Aedes taeniorhynchus.

Repellent	Volatile solvent ^{1/}	Tests	Average repellent time
	Percent	Number	Minutes
1-Benzylcyclohexanol ^{2/}	68 ^{3/}	3	63
Butyl sulfone ^{2/}	75 ^{4/}	1	18
2-(2-Cyclohexyloxyethoxy)ethanol	0	11	298
	50	4	221
	70	3	178
2-(2-Cyclohexyloxypropoxy)-1-propanol	0	4	419
	50	4	229
	70	4	210
Dimethyl phthalate	0	35	214
	80	4	85
Dimethyl phthalate 75% + ethyl hexanediol 9%	16	4	217
<u>N</u> -Ethylacetanilide ^{2/}	61 ^{5/}	2	176
	68 ^{3/}	2	86
Ethyl hexanediol	0	12	316
	10	4	175
	25	9	257
	50	10	185
Indalone	0	61	142
	10	24	113
	25	2	52
	50	15	92
	75	11	63
2- <u>2</u> -(3-Methyl-2-norcamphanylmethoxy)-ethoxy/ethanol	0	6	334
	75	4	302
<u>N</u> -Propylacetanilide ^{2/}	68	3	70

^{1/} Ethanol unless otherwise indicated.

^{2/} Solid material.

^{3/} Benzyl acetate.

^{4/} 1-Hexanol.

^{5/} Acetone.

Table 8.--Effectiveness of repellents against Aedes sollicitans.

Repellent	Orlando No.	Tests	Average repellent time
			<u>Number</u> <u>Minutes</u>
Adipic acid, diethyl ester	342	3	143
Ethanol, 2-(2-butoxyethoxy)-, acetate	170	32	107
2- <u>[2-(2-ethylhexyloxy)ethoxy]</u> -	300	6	308
2-(2-hexyloxyethoxy)-	301	3	217
2-(<u>alpha</u> -methylbenzyloxy)-	164	27	159
2-(<u>alpha</u> -methylbenzyloxy)-, acetate	165	4	261
2- <u>[2-(<u>alpha</u>-methylbenzyloxy)ethoxy]</u> -	166	2	344
Indalone	9	38	157+
Malic acid, <u>dl</u> -dibutyl ester	337	11	348+
Phthalic acid, dibutyl ester	283	3	14
dimethyl ester	262	14	182
2-Propanol, 1-(tetrahydro-2,6-dimethyl-3-pyranylmethoxy)-	299	15	259

Table 9.--Effectiveness of standard repellents against several species of Aedes and Culiseta incidents, Oregon, 1942-44.

Species (figures indicate percent)	Tests	Average repellent time			
		Ethyl hexanediol	Dimethyl phthalate	Indalone	Mixture 6-2-2
	Number	Minutes	Minutes	Minutes	Minutes
<u>Aedes sticticus</u> (Meig.)	4	480+	355	220	471
<u>sticticus</u> 85 and <u>inreptitus</u> Dyar and <u>vexans</u> 15	8-10	372	353	111	421
<u>fitchii</u> (F. and Y.) 58, <u>cinereus</u> Meig. 27, and <u>hexodontus</u> Dyar and <u>communis</u> (Deg.) 15	12-13	232	189	96	266
<u>lateralis</u> (Meig.) 68 and <u>vexans</u> 32	10-12	463	286	176	450
<u>nigromaculis</u> (Ludl.)	10-13	356	161	156	348
<u>varipalpus</u> (Coq.) ^{1/}	4-5	398	468	481	396
<u>Culiseta incidens</u> (Thoms.)	3-7	485	462	380	480+

^{1/} Cage tests.

Table 10.--Protection obtained with repellents against a population containing 68 percent of Aedes sticticus and 32 percent of vexans, Oregon 1942-44.

Repellent	Orlando No.	Tests	Average repellent time
		Number	Minutes
Acetoacetic acid, cyclohexyl ester	6230	3	152
Anisyl alcohol	1170	2	388+
Anthranilic acid, propyl ester	2576	3	330
Benzaldehyde, 3,4-diethoxy-	2069	2	323+
o-ethoxy-	1358	4	116
Benzoic acid, cyclohexyl ester	2126	2	255
tetrahydrofurfuryl ester	4567	4	179
Benzyl alcohol, o-methoxy-	5521	4	180
Benzyl benzoate	523	4	324
Benzyl ether	2269	4	83
Bicyclo[2.2.1]hept-5-ene-2,3-dicarboxylic acid, diethyl ester	4132	5	262
cis-, dimethyl ester (dimethyl carbate)	3916	4	228
Cyclohexaneacetic acid, alpha-cyano-, ethyl ester	4999	3	127
Cyclohexanecarboxylic acid, 1-hydroxy-, cyclopentyl ester	6133	3	293+
1,2-Cyclohexanedicarboxylic acid, diethyl ester	5567	3	292
Cyclohexanol, 2-phenyl-	2133	2	355
4-Cyclohexane-1,2-dicarboximide, N-butyl-	4145	3	355+
m-Dioxane, 4-(p-methoxyphenyl)-5-methyl-	5533	4	164
5-methyl-5-nitro-2-propyl-	7102	3	143
5-m-Dioxanol, 2-hexyl-	5024	4	349+
1,4-Dioxaspiro[5.5]undecan-3-ol, 7-methyl-	5032	4	258
1,3-Dioxolane, 2-hexyl-4-(methoxymethyl)-	5027	3	290+
Ethanol, 2-(2-butoxyethoxy)-, acetate	170	7	256
2-phenoxy-, acetate	2145	3	168
2,2'-thiodi-, diacetate	5542	3	185
Ethylene glycol, alkyl benzyl ethers	4723	3	267
Hydracrylic acid, 3-phenyl-, ethyl ester	6216	3	355+
Hydrocinnamic acid, alpha,beta-epoxy-beta-methyl-, ethyl ester	2947	3	273+
Isobutyl sulfone	5529	3	168
Lactic acid, 2-methyl-, phenethyl ester	1650	4	289+
Malic acid, dl-, dibutyl ester	337	4	264+
2-Naphthol, 1,2,3,4-tetrahydro-	5563	3	365+
3-Octyne-2,5-diol, 2,5,7-trimethyl-	7139	3	372+
Phenethyl alcohol, p-isopropyl-	1774	4	260
Phthalic acid, diallyl ester	2574	4	55
dibutyl ester	283	8	46
Phthalimide, N-sec-butyl-	2419	3	42
1,2-Propanediol, 3-(1,3-dimethylbutoxy)-	4562	4	269
2-Propanol, 3-(2-cyclohexyloxy-1-methylethoxy)-	374	3	266+
Propionic acid, diester with 1,5-pentanediol	6154	4	214
Succinamic acid, N,N-diethyl-, propyl ester	6168	3	363+
N,N-dipropyl-, ethyl ester	6252	3	362+
Succinic acid, 2-cyano-3-methyl-, diethyl ester	5611	3	42
Undecenoic acid	2065	2	388+

Table 11.--Protection obtained with repellents against a mixed population of Mansonia perturbans and titillans, 1945.

Repellent (figures after ingredients indicate percent)	Tests	Average repellent time
	<u>Number</u>	<u>Minutes</u>
Dimethyl phthalate	12	243
Dimethyl phthalate plus--		
Bentonite 30 and calcium stearate 20	8	288
Calcium stearate 35	8	182
Ethyl hexanediol 13, bentonite 33, and calcium stearate 2	12	308
Ethyl hexanediol 9, zinc oxide 52, and calcium stearate 3	4	289
Ethyl hexanediol 8, zinc oxide 58, and calcium stearate 3	10	259
Zinc oxide 50	6	267
Zinc stearate 30	8	201
Ethyl hexanediol	10	406
Mixture 6-2-2	11	336
2-Phenylcyclohexanol	12	328
2-Phenylcyclohexanol plus--		
Bentonite 32 and calcium stearate 3	8	295
Bentonite 6 and calcium stearate 31	8	313

Table 12.--Effectiveness of repellents against a population consisting mainly of Aedes (Aedes) sp., New Guinea, 1945.

Repellent	Orlando No.	Tests	Average repellent time to--	
			First bite	Second bite
			Number	Minutes
Benzyl ether	2269	2	120	157
Cinnamic acid, isopropyl ester	2026	1	47	60
(cream)	2026	2	150	165
Cyclohexanol, 2-phenyl-	2133	5	150	165
Lactic acid, 2-methyl-, phenethyl ester	1650	2	187+	202+
Malic acid, <u>dl</u> -, dibutyl ester	337	2	135	135
Phthalimide, <u>N</u> - <u>sec</u> -butyl-	2419	2	120	150
Succinimide, <u>N</u> -pentyl-	2971	2	150+	180+
Mixture 6-2-2	M-1473	6	135	190

Table 13.--Results with repellents against mixed populations of arctic and subarctic Aedes spp., Canada 1943, Alaska 1944.

Repellent (figures after ingredients indicate percent)	Tests	Average repellent time
	<u>Number</u>	<u>Minutes</u>
Tests at Churchill, Canada		
Dimethyl phthalate	17	94
Ethyl hexanediol	17	108
Indalone	17	78
Mixture 6-2-2	10	130
Tests at Nome, Alaska		
Dimethyl phthalate	16	131
Dimethyl phthalate 65, bentonite 33, and calcium stearate 2	17	240
Dimethyl phthalate 49, zinc oxide 49, and bentonite 2	17	238
Ethyl hexanediol	17	119
Indalone	17	97
Mixture 1-1-1	16	131
Mixture 6-2-2	16	137
2-Phenylcyclohexanol	16	128
Tests at Anchorage, Alaska		
Dimethyl phthalate	36	126
Dimethyl phthalate 67, bentonite 31, and calcium stearate 2	15	229
Dimethyl phthalate 49, zinc oxide 49, and bentonite 2	15	233
Ethyl hexanediol	36	121
Indalone	15	87
Isopropyl cinnamate	21	117
Mixture 1-1-1	36	129
Mixture 1-1-1 64, bentonite 33, and calcium stearate 3	21	223
Mixture 1-1-1 43, zinc oxide 51, and bentonite 6	21	214
Mixture 6-2-2	36	134+
2-Phenylcyclohexanol	35	123
Tests at Fairbanks, Alaska		
<u>N</u> -sec-Butylphthalimide	15	186
Ethyl hexanediol 50 and soft soap 50	15	119
Isopropyl cinnamate	15	157
Propyl cinnamate	15	156

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