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AQUATIC STUDIES WITH SILICONE ANTITRANSPIRANT

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INTRODUCTION

The principal aim of this investigation was to determine the effect of silicone antitranspirant on insect drift. This chemical inhibits the transpiration rate of green plants by reducing gaseous exchange within the stomatal openings. It retards respiration by the same mechanism. The potential use of this chemical is to increase soil moisture storage and stream flow of forested watersheds by aerial spraying of an area immediately after peak runoff. The field study occurred between 6 and 10 June 1974, when silicone antitranspirant was applied to a small drainage in North Idaho.

Investigators have shown that the application of toxicants to an aquatic ecosystem could cause pronounced increases in insect drift. Such an increase immediately after introduction of a toxicant would suggest acute stress and possible toxic effects to other organisms of the ecosystem. Drift net samples have effectively been used by Gibson and Chapman (1972) and Brusven and MacPhee (1974) to evaluate *in situ* the effects of selective toxicants on nontarget species. Therefore, this approach was selected for part of the study.

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The diet of stream fish contains mostly aquatic insects. Therefore, any harmful effects of silicone emulsion on stream insects could indirectly affect the production of trout and transfer of energy from one trophic level to another.

Prior to the field study, the maximum concentrations of silicone antitranspirant (Dow Corning XEF-4-3561) that representative fish and insects could tolerate were determined in static bioassays. Tests were also made to determine the toxicity of a surfactant mixture (Ref. No. E-2055-100) without silicone antitranspirant. The silicone antitranspirant used in the field and laboratory studies is a series of dimethylsiloxane polymers developed by Dow Corning Research Laboratory, Midland, Mich.

METHODS

Field Procedures

Two small tributaries of Benton Creek, a tributary of lower Priest River, were selected for control and test streams. About 375 liters per hectare (40 gallons per acre) of 5 percent solution of silicone emulsion were applied by helicopter to the plants in the 26-hectare watershed of the test creek. None was applied to the 20-hectare watershed of the control.

The experimental plan was to determine pre-treatment and post-treatment numbers of insects captured in control and test drift nets. The emulsion was applied between 0800 and 1500 of 8 June.

An insect drift net (mesh size, 1 mm) was placed at the outlet of each channel of 2 water gauging stations. Station No. 4 was on the test creek and Station No. 5 on the control creek, the numbers of these stations being the same as those used in a master plan involving concurrent research. The drift nets were large enough to contain the total discharge and capture all drifting organisms in the streams (Fig. 1).

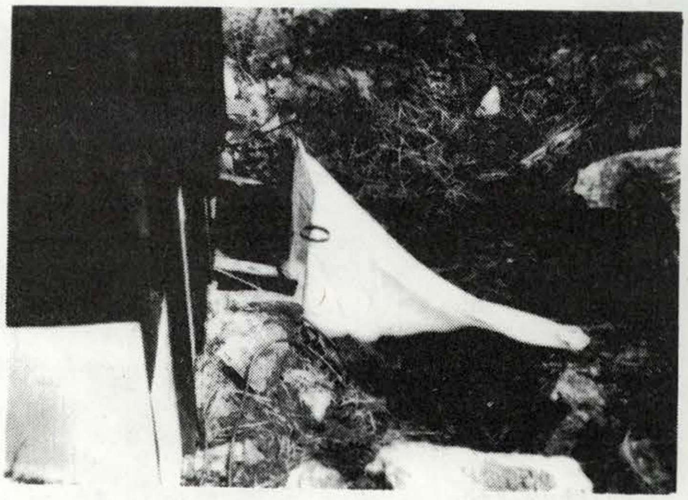

Fig. 1. Insect drift net established below the watergauging station of the test creek (Station No. 4).

Drift net samples were continuously taken for 96 hours except for 3 1-hour periods per day when the nets were emptied and washed. The nets were emptied of their contents at 1300, 2100 and 0500 each 24-hour period.

Sampling began at 1300 of 6 June and ended at 0500 of 10 June. Samples were preserved for later enumeration and identification of organisms in the laboratory. Diel water temperatures varied between 5 and 6 C.

A goodness of fit test was used to determine if statistical independence existed between treated and control drift samples for major animal groups. The 2-day pre-treatment and 2-day post-treatment samples formed units of data. Observed and empirically determined expected values were compared in a 2 x 2 contingency table using chi-square to test for independence. No statistical dependence due to treatment with the silicone emulsion was deemed to exist for populations which had chi-square values smaller than 3.841, $P(\alpha) < 0.05$, 1 d.f.

<u>Bioassay Facilities and Procedures:</u>

The silicone antitranspirant used in the bioassays was composed of 50 percent polydimethylsiloxane, 3.5 percent surfactant used as an emulsifier, and 46.5 percent water.

Fish assays were made with University artesian well water. On 17 August 1972, the chemistry of the University artesian well water was as follows: methyl orange alkalinity, 164 ppm; pH, 812; total hardness, 180 ppm; and total dissolved solids, 150 ppm.

Juvenile chinook salmon (*Oncorhynchus tshawytscha*), 40 mm in fish length, were obtained from a state fish hatchery at Rapid River, Ida.; rainbow trout (*Salmo gairdneri*), 31 mm in fork length, from Dworshak National Fish Hatchery; pumpkinseed sunfish (*Lepomis gibbosus*), 85 mm in fork length, were collected by seine nets from local farm ponds. Stonefly (*Arcynopteryx* sp.) and caddis fly (*Limnephilus* sp.) nymphs, 23 mm and 26 mm in body length, respectively, were collected with a fine-meshed dip net from the Palouse River near Laird Park, Ida. in March and April of 1974.

On arrival at the laboratory, fish and aquatic insects were acclimated at least overnight in large temperature controlled tanks or troughs equipped with aerators. They were not fed. Each species was graded for uniformity in size and placed in aerated, plastic bioassay aquaria for one day prior to the addition of chemical. Different amounts of water were used in assays: 60 liters for pumpkinseed sunfish; 20 liters for chinook salmon; 10 liters for trout; and 5 liters for caddis fly and stonefly nymphs which were assayed together. To avoid excessive handling of fish and insects prior to testing, exact loads were not determined until bioassays were completed. Thus, the loads varied from 0.07 to

2.20 g of fish or insects per liter of water. Ideally not more than 1 g of biomass per liter of water was to be used.

Rainbow trout, chinook salmon and insects tested with silicone antitranspirant were acclimated and assayed at temperatures of 10, 14, and 20 C (± 1 C) simultaneously in 3 separated temperature controlled laboratory rooms. Rainbow trout were acclimated and assayed at 15 C for the surfactant assays. Due to technical problems, these temperatures were not always maintained, but for any set of assays, water temperatures were relatively uniform.

The numbers of test organisms and different concentrations of chemicals used in bioassays varied (Table 1). Observations were made at the time indicated in Tables 2 and 3. The times of death were noted and fish or insects were removed from aquaria as they succumbed.

Table 1. Summary of the number of animals and concentrations of chemicals tested in bioassays

Species	Number of animals per aquarium	Total number of test animals	Number of test concentrations
Rainbow trout	4 or 5	230	9
Chinook salmon	20	600	9
Pumpkinseed sunfish	10	270	9
Stonefly nymph	15	270	6
Caddis fly nymph	20	360	6

Table 2. Approximate LC_0, LC_{50}, and LC_{100} in parts per thousand of silicone antitranspirant obtained in 12-, 24-, and 96-hour bioassays with two species of fish and two species of immature aquatic insects. The concentrations in parentheses were derived graphically using semi-logarithmic paper.

Species	Temperature	12-hour			24-hour			96-hour		
		LC_0	LC_{50}	LC_{100}	LC_0	LC_{50}	LC_{100}	LC_0	LC_{50}	LC_{100}
Chinook salmon	10	50	(70)	200	50	(70)	200	5	(7)	20
	15	20	(45)	100	20	(45)	100	5	(9)	20
	20	20	(30)	50	20	(30)	50	5	(7)	10
Pumpkinseed sunfish	10	200	...	...	100	(140)	200	10	(20)	50
	15	200	...	...	50	(70)	100	20	(30)	50
	20	50	(70)	100	20	(30)	50	10	(20)	50
Stonefly nymph	10	500	(700)	1000	500	(400)	1000	500	(700)	1000
	15	500	(700)	1000	500	(400)	1000	100	(670)	1000
	20	500	(700)	1000	200	(700)	1000	100	(670)	1000
Caddis fly nymph	10	500	(850)	*	500	(700)	1000	500	(700)	1000
	15	500	1000	*	500	(700)	1000	500	(700)	1000
	20	500	(850)	*	500	(700)	1000	500	(700)	1000

* A LC_{100} was not attainable with undiluted stock solution of silicone antitranspirant.

Table 3. Approximate LC_0, LC_{50}, and LC_{100} in parts per thousand of antitranspirant surfactant mixture obtained in bioassays with rainbow trout. The concentrations in parentheses were derived graphically using semilogarithmic paper.

Hour	Temperature, centigrade	LC_0	LC_{50}	LC_{100}
2	15	2.0	(3.2)	5.0
6	15	0.5	(1.0)	2.0
12	15	0.2	(0.3)	0.5
24	15	...	0.2	0.5
36	15	...	...	0.2

RESULTS AND DISCUSSION

A total of 1,082 aquatic insects was obtained from both creeks in 96 hours. Of these, 857 were netted in the test stream and 225 in the control stream. The only other important invertebrate group was the leech. Thirty-two leeches were captured in the test stream and 22 in the control streams.

In spite of generally small sample sizes, the observed number of organisms counted during the 48-hour post-treatment period as compared with the calculated expected number, ranged a maximum of only 5 percent for the four most numerous *taxa* (Table 4). In addition to the numbers of mayfly, caddis fly and crane fly, the total of insects included 17 stoneflies, 25 midges and 2 Elmidae. The sample sizes of these 3 last mentioned groups were too small to warrant a separate chi-square analysis (Table 5). However, they were included together with other groups of insects in Class Insecta.

The chi-square values that are indicated in Table 4 for leeches, insects, mayflies and crane flies are less than the tabled value of 3.841, $P(\alpha) < 0.05$, 1 d.f. Therefore, the observed number of organisms was not significantly different from the expected number and thus we deem that these invertebrate groups were not affected by the silicone emulsion.

Drift-net analysis provided a useful means for evaluating the short-term effects of silicone antitranspirant on benthos. If benthos was adversely affected by the chemical, large increases in drift would have been expected; such was not the case. Therefore, we conclude that

Table 4. Percentage change in drift net counts following treatment relative to expected values calculated for the test station and chi-square intepretation of significance ($p(\alpha)<0.05$) for a 4-day period

	Number of organisms[a]	Percentage of organisms following treatment[b]	Chi-square value	Statistical interpretation
Class Hirundinia	54	94	0.569	Not significant
Class Insecta (all species)	1082	103	2.726	Not significant
Order Ephemeropetera (two species)	349	98	0.557	Not significant
Order Trichoptera (five species)	491	103	3.048	Not significant
Order Diptera Family Tipulidae	198	100	0.001	Not significant

[a] Total organisms of all samples (24) from 2 stations for 4 days.

[b] Observed divided by expected number of organisms x 100.

Table 5. An example of a chi-square analysis and the components of the 2 x 2 contingency table for leeches

	Numbers of leeches	
	Pre-treatment	Post-treatment
Test creek (station 4)	10	9
Control creek (station 5)	22	13

Chi-square analysis:				
Observed values	10	9	22	13
Expected values (e)	11.3	7.7	20.7	14.3
Deviation (d)	- 1.3	1.3	1.3	- 1.3
d^2	1.69	1.69	1.69	1.69
d^2/e	0.150	0.219	0.082	0.118
X^2=sum of d^2/e=0.569				

a 5 percent solution of silicone emulsion applied at 375 liters per hectare has little or no acute effect on drift of aquatic insects or leeches present in this study.

Approximate LC_0, LC_{50}, and LC_{100} for the 4 species of fish and insects that were exposed to silicone antitranspirant in bioassays are summarized in Table 2. Concentrations in parentheses were obtained from regression lines graphically depicting the relationship between percentage mortality and the log of the concentration. The data show that the experimental fish and aquatic insects can resist relatively high concentrations of the emulsion. Inspection of the LC_{50} data in Table 2 indicates that the test species varied in their tolerance to silicone antitranspirant as follows: chinook salmon, pumpkinseed sunfish, stonefly nymph, and caddis fly nymph--the chinook salmon being the least and caddis fly nymph the most tolerant to silicone antitranspirant.

Approximate LC_0, LC_{50}, and LC_{100} for rainbow trout with surfactant are summarized in Table 3. The results show that the surfactant is more toxic than the antitranspirant to the fish tested.

The laboratory bioassays indicate that the silicone antitranspirant will not kill the test organism at recommended field doses and likely will not kill other associated species.

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