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Effects of Four Agricultural Pesticides on *Daphnia pulex, Lemna minor,* and *Potamogeton pectinatus*

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In a previous study (Hartman and Martin 1984), we demonstrated that the presence of suspended sediment in water significantly increased the acute toxicity of the agricultural herbicide Roundup® (glyphosate) to Daphnia pulex and decreased its toxicity to Lemna minor. As a follow-up to that study, we conducted acute toxicity tests with two additional herbicides (alachlor and atrazine) and one insecticide (carbofuran) employing the same species and experimental design as in the earlier study. In addition to this we also evaluated the effects of the four pesticides (glyphosate included) on the sprouting and early growth of tubers of sago pondweed (Potamogeton pectinatus).

Selection of these four pesticides was based on the fact that each represents a different chemical "family," has a different mode of transport in a field runoff situation (Committee of Scientists of the Agricultural Research Service USDA 1975), is in widespread use in the northern cornbelt region of the United States (Eichers et al. 1978) and are all readily soluble in water (>30mg/L). The organisms were selected because they are naturally occurring components of wetland and lake ecosystems.

MATERIAL AND METHODS

Commercial liquid formulations of the four pesticides, Atrazine 4L (40.8% atrazine), Furadan 4 (40.6% carbofuran), Lasso (45.1% alachlor), and Roundup (41% glyphosate) were purchased locally in April 1979 and stored at room temperature. Acute toxicity tests with D. pulex and L. minor were conducted with and without suspended sediment in exactly the same manner as described by Hartman and Martin (1984). Test organisms were taken from the same laboratory cultures used in the previous study.

Tubers of P. pectinatus were obtained from a private nursery in Oshkosh, WI, and were kept refrigerated until testing began. They were rinsed with well water and allowed to air dry on paper toweling for 2 h and then weighed to the nearest 0.01 mg. Ten tubers were placed in 4 L wide-mouth glass jars containing silica sand approximately 1 cm deep and then covered with 2 cm of the sand to

prevent them from floating to the surface during the test. Pesticide-treated and control jars were filled with the same medium used in the Lemna studies (Miller et al. 1978) and placed in an environmental chamber under continuous illumination (2000 lux [±10%] and 22°C). At the end of 14 days, the tubers or plants were removed from the jar, rinsed with well water and allowed to air dry for 2 h on paper toweling. Weight change for each tuber was calculated and the data analyzed according to Wilcoxon's signed rank test (Wilcoxon 1945). Tests were run in duplicate, simultaneously, with three concentrations of each pesticide and a control.

RESULTS AND DISCUSSION

Calculated 48-h EC50 values for Daphnia pulex at 15°C in well water (pH 7.6; hardness 282 mg/L as $CaCO_3$) indicated that suspended sediment had little effect on the toxicities of the three chemicals used in this study (Fig. 1). Slight differences occurred for carbofuran, which had an EC50 of 35.0 µg/L (95% Confidence Interval [CI], 26.8 - 45.8 µg/L) without sediment and 45.0 µg/L (95% CI, 33.1 - 61.1 µg/L) with suspended sediment, and for atrazine 36.5 mg/L (95% CI, 28.8 - 46.3 mg/L) without suspended sediments and 46.5 mg/L (95% CI, 39.6 - 54.6 mg/L) with sediment. The values for alachlor were almost identical 10.4 mg/L (95% CI, 8.8 - 12.3 mg/L) without suspended sediment and 9.0 mg/L (95% CI, 7.2 - 11.2 mg/L) with suspended sediment.

The method of Litchfield and Wilcoxon (1949) was used for plotting the dose-response curves for D. pulex (Fig. 1) and to compare the EC50 values of the two treatments for each chemical. No significant difference ($p=0.05$) was observed between sediment and non-sediment treatments for any of the three chemicals tested.

In the acute toxicity tests with Lemna minor, no effects on growth were observed with carbofuran at concentrations up to 10 mg/L, with or without suspended sediment (Fig. 2). Although atrazine and alachlor produced marked effects on the growth of L. minor (Fig. 2), the presence of suspended sediment appeared to be relatively unimportant in reducing or increasing the toxicity of the pesticides. The EC50's of alachlor were 10.1 µg/L and 14.5 µg/L with and without suspended sediment respectively. No EC50 values were calculated for atrazine because the chemical was ineffective below a threshold of approximately 100 µg/L, with and without suspended sediment.

Results of the tests conducted with P. pectinatus tubers (Table 1) indicated that the chemicals had no effect on sprouting, and produced both inhibitory and stimulatory effects on early growth. Neither carbofuran nor glyphosate produced inhibitory effects at concentrations up to 10.0 mg/L; however, glyphosate stimulated growth at 1.0 mg/L. Atrazine significantly inhibited growth at concentrations as low as 0.10 mg/L. Alachlor inhibited growth at

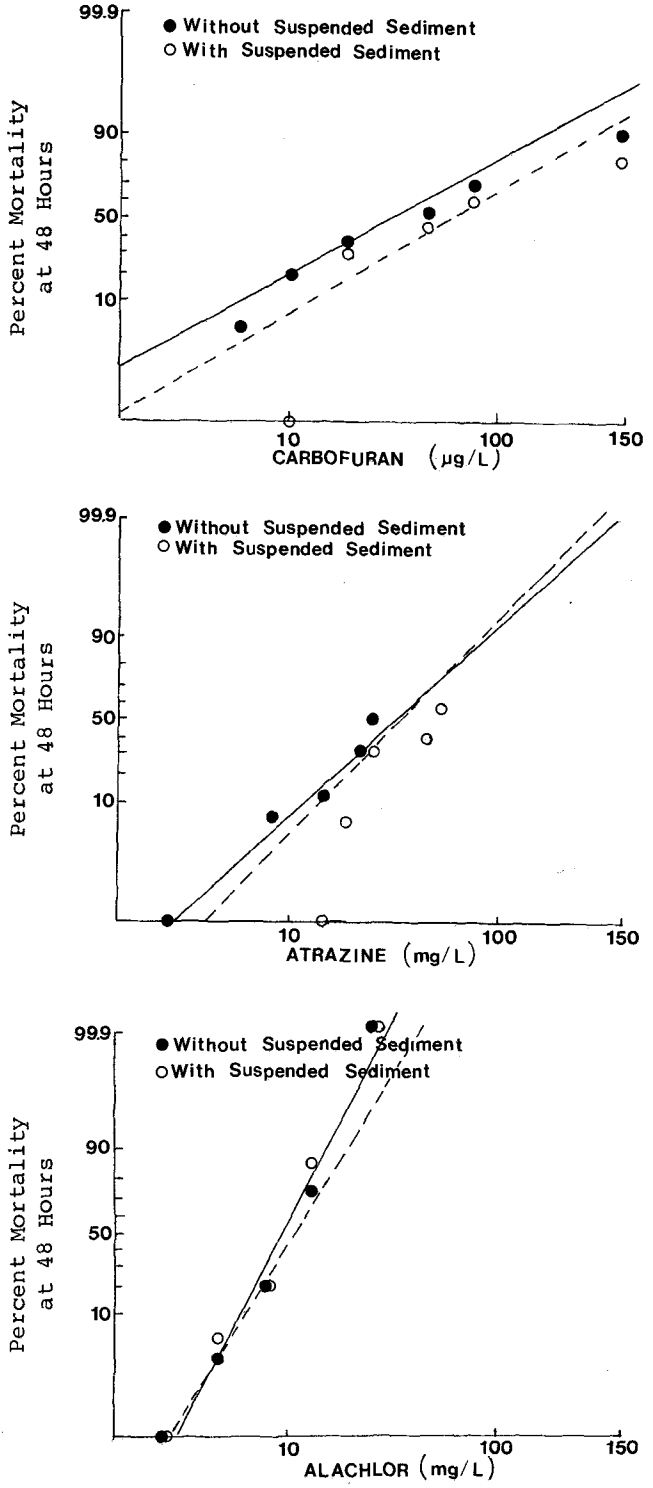
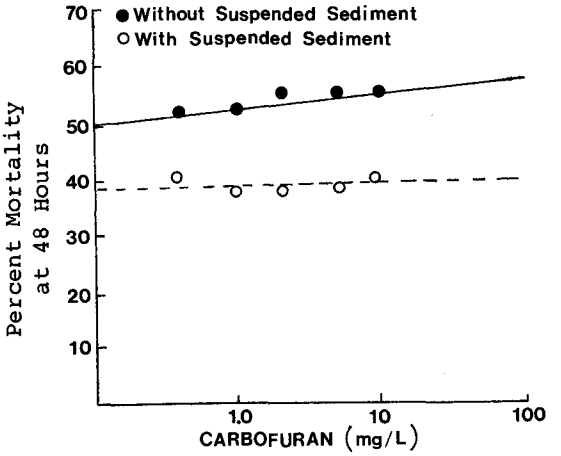
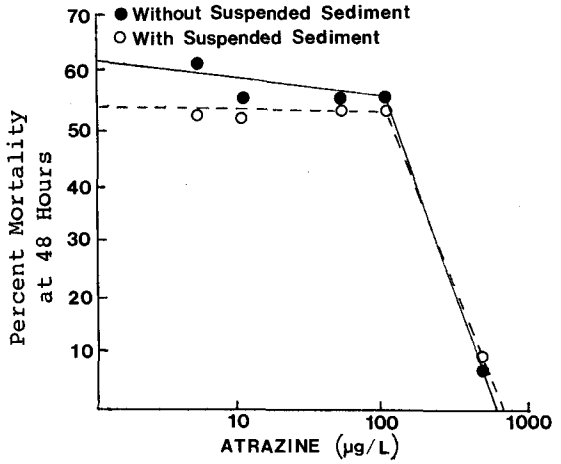


Figure 1. Toxicity of three pesticides, with and without suspended sediment to Daphnia pulex.





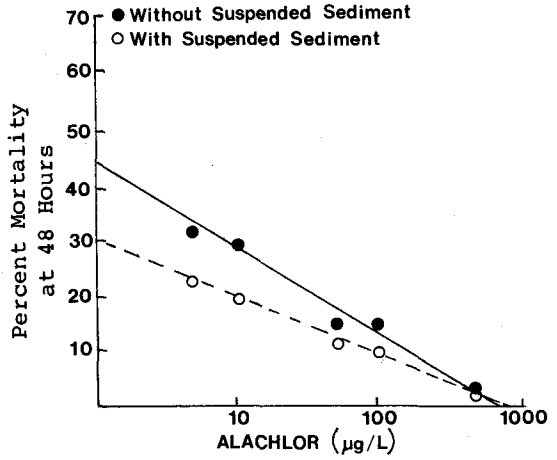


Figure 2. Toxicity of three pesticides, with and without suspended sediment to Lemna minor.

Table 1. Results of Wilcoxon's signed rank test for the effects of three herbicides and one insecticide on early growth of sago pondweed tubers. Values given are sums of ranked weight differences between control and treated tubers.

Concentration	Glyphosate		Atrazine		Alachlor		Carbofuran	
(mg/L)	Σ+	Σ-	Σ+	Σ-	Σ+	Σ-	Σ+	Σ-
0.1	34	18	0*	54	50	5**	15	30
1.0	50	4**	1*	54	10	45	12	33
10.0	23	29	1*	54	2*	53	9	40

* - Significant inhibition of growth ($p<0.05$)
** - Significant stimulation of growth ($p<0.05$)

10.0 mg/L, showed no effect at 1.0 mg/L, and stimulated growth at 0.1 mg/L.

It appears that suspended sediment had little influence on the acute toxicities of alachlor, atrazine, or carbofuran to D. pulex and L. minor. Alachlor, atrazine, and glyphosate are listed by the Committee of Scientists of the Agricultural Research Service (1975) to be potentially adsorbed onto suspended sediment, however, only the toxicity of glyphosate was significantly affected. Carbofuran is listed as having little or no potential for adsorption and behaved in the same manner as alachlor and atrazine. Comparison of the present results with those of Hartman and Martin (1984) makes it apparent that it is difficult to predict the bioavailability or toxicity of pesticides with and without suspended sediment to various aquatic organisms.

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