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Toxicity of the Herbicides Endothall and Diquat to Benthic Crustacea

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Endothall and diquat are herbicides commonly applied in lakes to control troublesome macrophytes. Chemical treatments such as these, however, may perturb an aquatic ecosystem through toxic effects on non-target species. In this study endothall and diquat were tested and compared on a sample of freshwater benthic macroinvertebrates taken from Lake Waban, Wellesley, Massachusetts. Endothall and diquat control all the primary weed species (Myriophyllum spp., Potamogeton spp., Najas sp.) in Lake Waban except for Nymphaea sp. (New England Research Inc. 1978); in consequence, these two herbicides have in recent years been applied periodically in parts of this lake for the control of aquatic vegetation. Preliminary static studies indicated that there is a significant difference in the effects of the two herbicides and a difference in the responses of the experimental species. The same herbicides were subsequently tested with a flow-through protocol designed to approximate field conditions, and those results are reported here.

MATERIALS AND METHODS

The benthic invertebrates Hyalella azteca (Sassure) (Amphipoda) and Asellus communis Say (Isopoda) were chosen as the test organisms because these species are the most abundant benthic macroinvertebrates in the littoral zone of the source lake. In addition, Buikema and Cairns (1980) recommend the use of crustacea in bioassays, and the abundance and distribution of these species suggest that they are good indicator organisms for toxicity studies. H. azteca is widely distributed in North America (Chace et al. 1959), while A. communis is found throughout the northeastern U.S. and southeastern Canada and occasionally in the western U.S. (Williams 1972). Experimental animals were collected from Lake Waban using an Ekman dredge at a depth of approximately 2m, with all collecting away from areas of prior treatment. Organisms were separated from bottom material with a 1mm sieve.

Commercially available forms of the herbicides were tested. Aquathol-K is a dipotassium salt of endothall (7-oxabicyclo(2,2,1)-heptane-2,3-dicarboxylic acid) in liquid form, with 40.3% active ingredient. Diquat dibromide (6,7-dihydrodipyrido(1,2-a:

2',1'-c)pyrazinedium dibromide) is also a liquid, with 35.3% active ingredient.

The experimental apparatus consisted of water reservoirs and inflow-outflow aquaria. The manufacturers' recommended dosages for each of the herbicides is 1-2 ppm, so concentrations near these dosages - 0, 1, 3, and 10 ppm - were chosen to see if normal usage might affect the test organisms. Berry et al. (1975) discovered hot spots of endothall and diquat after field application, indicating that the experimental concentrations may well occur with normal usage. Dilutions prepared and stored in reservoirs above the test chambers flowed by gravity into a manifold for distribution to each of four replicate chambers per concentration. Each plexiglass chamber contained 0.6 liter water at 6cm depth, with nylon netting preventing the organisms from escaping. The average flow rate into each of the test chambers was 12 liters/day for a turnover rate of 20/day.

To ensure that the experiment closely approximated the natural setting, 3mm of sieved mud from the lake bottom was added to each of the test chambers to allow adsorption of the herbicides. It is known, for example, that diquat binds to clay minerals and becomes largely unavailable (Scott and Weber 1967; Yeo 1967). Ten _H. azteca_ and two or three _A. communis_ were added to each chamber and were monitored for five days. Water quality was measured at the beginning and end of the experiments to ensure that no deterioration occurred; dissolved oxygen remained saturated near 10 ppm, conductivity was 265-280 micromhos (standardized to 25° C), pH ranged from 6.5 to 7.3, and water temperature was approximately 17° C. Light in the laboratory was diffuse, with a photoperiod of 11:13 hours light:dark.

RESULTS AND DISCUSSION

In the continuous flow bioassay for endothall, the mortality for each species did not significantly exceed that in the controls. The highest mortality observed was 10% for both species at 120 hr. It is important to associate the low level of these effects with the dipotassium salt of endothall, however, since other commonly used forms (e.g., Hydrothol 47 and 191) can produce toxic effects at 1/600 the concentration of the form examined here (USDI Fish and Wildlife Service 1980; Finlayson 1980). Similar results have been found elsewhere for the dipotassium salt. The 24hr LC_{50} is greater than 100ppm for _Gammarus lacustris_ (Sanders 1969), and Serns (1974) found zooplankton populations of two ponds to be unaffected by endothall. Similarly, Walker (1963), using the disodium salt, concluded that concentrations of 5-10 ppm have no toxic effect on pond invertebrates. Fish are also little affected by endothall; for example, Walker (1963) found disodium endothall to be relatively non-toxic to nine species of fish, obtaining a medium tolerance level of 95-150 ppm.

The results reported here indicate that dipotassium endothall has a negligible effect on the representative benthic macroinverte-

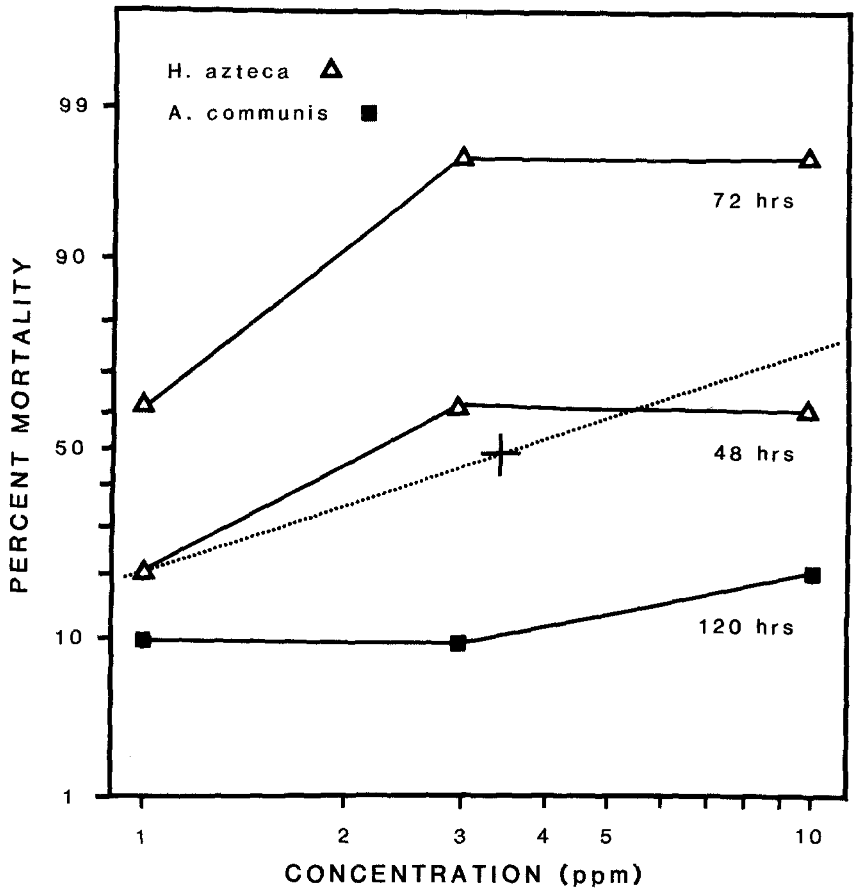

Figure 1. The mortality of Hyalella azteca and Asellus communis in different concentrations of diquat. The 48hr LC_{50} for H. azteca is 3.4 ppm.

brates Hyalella azteca and Asellus communis. Once applied, endothall normally disappears from the water after ten to twelve days, with slow initial degradation followed by rapid breakdown (Holmberg and Lee 1976). The small effects of endothall seem to be retricted to the dipotassium and disodium salts, though, and further study should consider why different forms of endothall produce such different toxic effects.

Mortality of the experimental animals in diquat over the test period differs strongly from that in endothall (Fig. 1). In contrast to mortality of the controls not exceeding 10%, mortality in 10 ppm diquat was 100% for H. azteca, while mortality for A. communis was only 20% at the highest concentration. Probit analysis (Sokal and Rohlf 1969; Fig. 1) yields a 48hr LC_{50} of 3.4 ppm for H. azteca from a linear regression of the transformed diquat data. In other studies, the 96hr median tolerance limit for diquat was found to be quite low at 0.048 ppm for Hyalella azteca (Wilson and Bond 1969), and the IC_{50} higher at 7.1 ppm for Daphnia magna (Crosby and Tucker 1966). Naqvi et al. (1980) found the 48hr LC_{50} for copepods to be 19 ppm, while Mullison (1970) concluded that 0.4-3 ppm concentrations of diquat have no effect on fish food organisms except for crustacea. Among vertebrates, sublethal effects have been found for trout with less than 2 ppm diquat (Dodson and Mayfield 1979).

The results obtained here are consistent with previous conclusions that crustacea are highly susceptible to diquat. Percent mortality (120 hr) for H. azteca was high at all concentrations of at least 1 ppm, and the 48 hr LC_{50} is very close to the concentration recommended for its use. Single applications of diquat may, therefore, produce far-reaching effects in lacustrine food webs, even without considering the accumulation that can develop with repeated use (Birmingham 1983). A. communis was not as strongly affected, however, not reaching 50% mortality in these experiments, so it should be noted that variation exists among crustacea in sensitivity to diquat.

Comparing the two herbicides in a protocol which approximates field conditions, dipotassium endothall produces significantly fewer toxic effects on these non-target crustacea than does diquat.

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REFERENCES

Berry CR, Schreck CB, Van Horn SL (1975) Aquatic macroinvertebrate response to field application of the combined herbicides diquat and endothall. Bull Environ Contam Toxicol 14:374-379

Birmingham BC, Colman B (1983) Potential phytotoxicity of diquat accumulated by aquatic plants and sediments. Water, Air, and Soil Pollution 19:123-131

Buikema AL, Cairns J (1980) Aquatic invertebrate bioassays. American Society for Testing and Materials, Philadelphia

Chace FA, Mackin JG, Hubricht L, Banner AH, Hobbs HH (1959) Malacostraca. In: Edmondson WT (ed) Freshwater biology. John Wiley, New York, p 869

Crosby DG, Tucker RK (1966) Toxicity of aquatic herbicides to Daphnia magna. Science 154:289-291

Dodson JJ, Mayfield CI (1979) Modifications of the rheotropic response of rainbow trout (Salmo gairdneri) by sublethal doses of the aquatic herbicides diquat and simazine. Environ Pollut 18:147-157

Finlayson BJ (1980) Acute toxicities of the herbicides Komeen and Hydrothol-191 to Golden Shiner (Notemigonus crysoleucas). Bull Environ Contam Toxicol 23:676-681

Holmberg DJ, Lee F (1976) Effects and persistence of endothall in the aquatic environment. J Water Poll Contr Fed 48:2738-2746

Mullison WR (1970) Effects of herbicides on water and its inhabitants. Weed Science 18:738-750

Naqvi SM, Leung T, Naqvi NZ (1980) Toxicities of paraquat and diquat herbicides to freshwater copepods (Diaptomus sp and Eucyclops sp). Bull Environ Contam Toxicol 25:918-920

New England Research Inc (1978) Control of aquatic vegetation in the Commonwealth of Massachusetts, Vol 2. Worcester, Mass

Sanders HO (1969) Toxicity of pesticides to the crustacean Gammarus lacustris. Tech Paper 25, Bur Sport Fish Wildlife, USDI, Washington

Scott DC, Weber JB (1967) Herbicide phytotoxicity as influenced by absorption. Soil Sci 104:151-158

Serns S (1974) The effects of a dipotassium endothall treatment on the ecology of a small pond. Report Wisc Dept Nat Res, Madison, Wisconsin

Sokal RR, Rohlf FJ (1969) Biometry: The principles and practice of statistics in biological research. WH Freeman, San Francisco

USDI Fish and Wildlife Service (1980) Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. Resource Publication 137, Washington

Walker CR (1963) Endothall derivatives as aquatic herbicides in fishing habitats. Weeds 11:226-232

Williams WD (1972) The freshwater isopods (Asellidae) of North America. Biota of freshwater ecosystems identification manual no 7, Environmental Protection Agency, Washington

Wilson DC, Bond CE (1969) The effects of the herbicides diquat and dichlobenil (casoron) on pond invertebrates. I. Acute toxicity. Trans Amer Fish Soc 98: 438-443

Yeo RR (1967) Dissipation of diquat and paraquat and effects on aquatic weeds and fish. Weeds 15:42-46

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