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Acute Toxicity of Aldicarb, Aldicarb Sulfoxide, and Aldicarb Sulfone to *Daphnia laevis*

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Aldicarb, the active ingredient in the systemic nematocide-insecticide Temik , is a widely used, highly water soluble, and highly toxic pesticide. The oral LD50 of aldicarb in rats is 0.9 mg/kg (Gaines 1969). The oxidative metabolites of aldicarb, aldicarb sulfoxide and aldicarb sulfone, are also highly toxic (rat oral LD50's of 0.9 mg/kg and 24.0 mg/kg, respectively). These products are formed in soils in the presence of oxygen and soil biota (Jones and Back 1984), and preliminary evidence suggests that they may also occur in Florida surface waters (unpublished data).

The toxicity of aldicarb to certain fish species has been reported (Landow and Tucker 1984, Kumar and Pant 1984, Pickering and Gilliam 1982, Pant and Kumar 1981), yet we are aware of few toxicity data for other aquatic species. Union Carbide, the principal manufacturer of Temik-aldicarb, reports that the LD50 of aldicarb for Daphnia magna is greater than 1 mg/L (Union Carbide, 1983), but details on how these data were derived are not available. Sangha (1971) reported that the LD50 of aldicarb for D. magna was 350 ug/L. Since this value is significantly lower than the value reported by Union Carbide, we decided to examine the acute toxicity of aldicarb and its oxidative metabolites to an indigenous Florida cladoceran, Daphnia laevis.

We chose to examine D. laevis for several reasons. The species is one of the most common daphnids in Florida, and occurs primarily in ponds that lack vertebrate predators (Foran, 1983). Ponds lacking vertebrate predators likely abound near Florida's abundant citrus groves, and could be highly impacted by the nearly 4.5 million pounds of Temik applied on Florida citrus from January to April 1984. D. laevis is also the largest member of the Daphnidae occurring in Florida. Therefore, it may have a greater impact through grazing on phytoplankton standing crop than any other cladoceran occurring in the state.

We examine here the toxicity of aldicarb sulfoxide and aldicarb sulfone (as well as aldicarb), since we are not aware of any published aquatic toxicity data for these oxidative metabolites. Union Carbide (1983 and personal communication) contends that when aldicarb reaches a surface water system, it will be rapidly hydrolyzed to nontoxic products. Evidence suggests that this is true in sterile groundwater where aldicarb hydrolysis is the predominant reaction (Miles and Delfino 1984a), but we have found no reported work on aldicarb reactions in natural surface water systems. However, Freeman and McCarthy (1984) recently reported that aldicarb degrades rapidly in the presence of UV radiation under controlled laboratory conditions. In view of the rapid oxidation of aldicarb in soils in the presence of soil biota, it seems likely that oxidation should also occur in surface waters to form the toxic oxidized metabolites. This hypothesis is supported by preliminary detections of low levels of aldicarb, aldicarb sulfoxide and aldicarb sulfone in a Florida surface water system.

Data reported here are part of a larger examination of the acute and chronic toxicity of aldicarb to aquatic zooplankton species. The results are broadly applicable to closely related species in other geographic regions where Temik is used, and will form the basis for predictions of the effects of Temik and other pesticides on the community structure of aquatic biota.

MATERIALS AND METHODS

Laboratory cultures of Daphnia laevis Birge were initiated from organisms obtained from a small pond near Gainesville, Florida. Animals were cultured in aged (2-week), aerated, city tap water (pH 6.9, hardness - 58 mg/L as $CaCO_3$, chlorine eliminated by aeration), at 21°C with a 12 hour light-dark cycle. Animals were fed suspensions of the green alga Chlamydomonas reinhardi Dangeard daily.

Acute toxicity tests were conducted on both mature females and 1- to 3-day-old juveniles at 21°C, and at other conditions under which animals were reared. We initially used a 24 hour range finding test to determine ideal concentrations of toxicants from which to derive LC50 data. Once ideal concentrations were determined, we introduced seven individual organisms into each of three 400 mL beakers containing aged tap water and either aldicarb, aldicarb sulfoxide or aldicarb sulfone. Concentrations of aldicarb ranged from 10 to 200 ug/L; aldicarb sulfoxide - 10 to 200 ug/L; and aldicarb sulfone - 100 to 1250 ug/L. Therefore, 21 organisms (three replicates of 7 individuals each) were tested at each of five concentrations of each toxicant. Animals were fed C. reinhardi at a concentration of 1×10^5 cells/mL at the beginning of an experiment, and all experiments were run for 48 hours. Control experiments contained animals and food but no toxicants.

Toxicant concentrations were measured at the beginning of each experiment, after 24 hours, and at the end of each experiment. We used an HPLC technique that allowed us to detect aldicarb and its metabolites at concentrations as low as 10 ug/L (Miles and

Delfino 1984b). We found no change in toxicant concentration throughout any experiment, and we never detected the formation of hydrolytic or oxidative metabolites in experiments.

After 48 hours, animals were removed from beakers and examined with a binocular dissecting microscope. Animals that showed any swimming motion were considered alive, animals without heartbeat or antennal motion were considered dead, and animals lying on the bottom of a beaker and showing irregular heart beat or slight twitching of body parts were considered effectively immobilized. We therefore determined both the LC and EC50 (effective concentration), using the above criteria, for D. laevis. The EC50 and LC50 data were calculated using probit analysis (Finney 1971) and SAS (1982) programming techniques.

RESULTS AND DISCUSSION

The effective concentration (EC50) for aldicarb and aldicarb sulfoxide ranged from 43 to 65 ug/L for juvenile and adult D. laevis (Table 1). The EC50 for aldicarb sulfone was approximately an order of magnitude higher. EC50 data were higher for juveniles than for adults for the three compounds, but significantly higher only for aldicarb sulfoxide and aldicarb sulfone.

LC50 data were again nearly an order of magnitude lower for aldicarb and aldicarb sulfoxide than for aldicarb sulfone (Table 2). LC50 data ranged from 70 to 209 ug/L for aldicarb and aldicarb sulfoxide, and between 900 and 1200 ug/L for aldicarb sulfone. LC50 data were lower in these experiments for juveniles than for adults, but differences were only significant for aldicarb. It is noteworthy that aldicarb sulfoxide had a lower EC50 than aldicarb for both juveniles and adults and a lower LC50 for adults.

These data show that aldicarb and its oxidative metabolites are highly toxic to the cladoceran Daphnia laevis. EC50 data are near or below 0.5 mg/L for aldicarb sulfone, and for aldicarb and aldicarb sulfoxide are near or below 0.05 mg/L (50 ug/L). Our EC50 data are worthy of consideration here since animals showing random heartbeat or twitching motion never recovered after being removed from toxicant concentrations.

EC50 data reported here are only 40 to 60 ug/L above the USEPA allowable aldicarb level in drinking water (7 to 10 ug/L). No standards have been set as yet for surface waters. However, a 7 to 10 ug/L level in surface water may have significant chronic effects on aquatic biota, including D. laevis. We are presently conducting life history analyses at levels of 10 ug/L for aldicarb and aldicarb sulfoxide, and at 100 ug/L for aldicarb sulfone. The USEPA is considering raising the acceptable aldicarb concentration to 30 to 50 ug/L in drinking water. Our

Table 1. EC50 values (in ug/L) for adult and juvenile *Daphnia laevis* with 95% fiducial limits in parentheses. * denotes significant differences between adults and juveniles (student's t-test, $P < 0.05$).

	48 hour EC50		
Chemical	Adults		Juveniles
Aldicarb	51 (45 - 59)		65 (45 - 88)
Aldicarb Sulfoxide	43 (39 - 46)	*	57 (50 - 68)
Aldicarb Sulfone	369 (320 - 430)	*	556 (514 - 706)

Table 2. LC50 values (in ug/L) for adult and juvenile *Daphnia laevis* with 95% fiducial limits in parentheses. * denotes significant differences between adults and juveniles (student's t-test, $P < 0.05$).

	48 hour LC50		
Chemical	Adults		Juveniles
Aldicarb	209 (175 - 265)	*	70 (61 - 84)
Aldicarb Sulfoxide	103 (36 - 142)		84 (73 - 95)
Aldicarb Sulfone	1124 (993 - 1320)		910 (821 - 1099)

data suggest that these concentrations in surface water systems may have significant detrimental effects on aquatic biota.

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