Some Factors Affecting the Toxicity of Aldrin to Fishes

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Aldrin is quite toxic to fishes, though not the most toxic of the insecticides. A table from Henderson, Pickering, and Tarzwell (2) shows that a .026 ppm aldrin solution will kill half of a sample of fathead minnows in 96 hours at 25 degrees C. The same table shows that endrin is about twenty times as potent, and that DDT is not quite as lethal as aldrin. Tarzwell and Henderson (4) showed that a related compound, dieldrin, was more toxic to fathead minnows than to equal-sized bluegills or green sunfish. Pickering, Henderson, and Lemke (3) ascertained that small bluegills were more susceptible to organic phosphorus insecticides than were large bluegills; they showed, too, that bluegills were more sensitive than fatheads, guppies, and goldfish to both organic phosphorus and chlorinated hydrocarbon insecticides of various kinds.

Some general symptoms of aldrin poisoning are as follows: As the poison takes effect, the fish become very irritable. When stimulated by a slight sound, by agitation of the water, by turning on an electric light, or simply by a movement nearby, they often dash wildly or swim in circles. The dash sometimes ends in a state of shock, with the gills motionless and distended, from which the fish may die almost at once or may partially recover and live on for hours or days. A few of the larger fish injure themselves by bumping violently into the sides of their containers. Aldrin-poisoned fish also have a tendency to gulp air at the surface, as if they were suffering from lack of oxygen.

In at least one fish, the brindled madtom (*N. miurus*), it seems very likely that respiratory failure brings about death somewhat before other toxic effects have progressed to the point of lethality. I watched two madtoms apparently die; they became quite motionless and their gills were distended. I placed them in a shallow tray with ¼ inch of fresh water so that their backs were exposed to the air, and they revived. Three days later, the two fish seemed quite healthy. But within minutes after I had placed one in deep water, it was gulping at the surface, and within an hour it was dead. The other madtom shortly thereafter developed a swollen red area on its abdomen from its gills to its anal fin, and also succumbed.

Some fishes seemingly recover from rather large doses of poison. One large spotfin shiner (*N. spilopteris*) was removed to fresh water when it became the last one of 91 minnows of that species to remain alive. It was observed for two months afterward, during which time it remained without observable symptoms. (This does not preclude possible chronic physiological changes.)

Also, I had occasion to observe that the symptoms of fishes differ to some extent from those of large aquatic insects (hellgrammites, dragonfly nymphs, and adult water scorpions) and crayfish. These invertebrates all seemed to very gradually lose their powers of locomotion and just fade away, whereas fish were able to balance themselves and swim almost until they died. Two adult crayfish outlived the fish in an experiment in a five-gallon aquarium, but they had reached the stage where their legs waved aimlessly; they lived on for 8 and 17 days in fresh water without recovering their locomotor ability. Five of six dragonfly nymphs died within a few hours of the time the median fish death occurred in a 275-fish experiment. At about this same time an adult water scorpion seemed normal and was making efforts to capture food; it died at about the same time the 220th fish died. Two hellgrammites also died at about the same time.

My intention had been to perform the study according to a standardized procedure developed by Doudoroff *et al.* (1). In this procedure a series of aquariums containing different dosages of the poison being tested is used to establish a median tolerance limit (the elapsed time at which 50% of the fish have died). I found, however, that I did not have enough aquariums to carry the work forward on a satisfactory scale and also that I was unable to exercise sufficient control over the temperature to allow comparison between any tests that were not run concurrently.

As a preliminary measure, I sought to determine for myself the approximate minimal dose of aldrin that would produce short-term fatality. With the limits imposed by my lack of control over the temperature, I confirmed the results of Henderson *et al.* (2) as follows: Fifteen liters of water and 10 small (average length 1½ inches) common shiners were placed in each of two aquariums. After three days, aldrin was added in sufficient quantity to make a .02 ppm concentration in one aquarium and .08 ppm in the other. In the .02 ppm aldrin, only one minnow died within 96 hours; in the .08 ppm aldrin, the sixth minnow died at 52 hours. Neither aquarium was aerated artificially. The water was cold, ranging from 9 to 14 degrees C. I re-ran this experiment, using aquarium heaters to keep the temperature over 20 degrees C. Again, only one of ten common shiners died in the .02 ppm concentration. The median death in the .08 ppm aldrin was at 12 hours, a much smaller figure than in the test with colder water. In either case, the 96-hour median tolerance limit was fixed at between .02 and .08 ppm.

Though temperature has one of the more obvious effects upon survival time, as noted above, and as was recognized by Doudoroff, I ran one more test with temperature as the experimental factor. In this test, I again used 15 liters of water in each of two aquariums. Enough aldrin was added to form a 1 ppm concentration. The fish used were half-grown redfin and common shiners (*N. umbratilis* and *N. cornutus*). The water temperature in one aquarium ranged from 13 to 16 degrees C. with the median death occurring in 12 hours. In the other aquarium (heated), the temperature reached 24 degrees with the median death occurring in 5½ hours. (In each aquarium, the average survival time of the redfin shiner was slightly longer than that of the common shiner; the redfins were comparatively more mature, however, in spite of the similar sizes, and this could account for the difference.)

Minerals dissolved or suspended in water have been shown by Tarzwell and Henderson and by Pickering, Henderson, and Lemke to have at least a slight effect upon the toxicity of insecticides to fishes. I made an attempt to verify this, using pond water (total alkalinity 80 ppm, total hardness 74 ppm), creek water (total alkalinity 290 ppm, total hardness 910 ppm), well water (total alkalinity 600 ppm, total hardness 0 ppm), and distilled water (not analyzed). The experiment was more or less of a failure because of my use of fairly large creek chubs (*S. atromaculatus*) as the test fish. Six were placed in .08 ppm aldrin in each aquarium; there were no deaths within a week. At least I can say that none of the waters greatly increased the toxicity of the poison.

To test the effect of artificial aeration on the toxicity of aldrin, I set up two aquariums with 15 liters of water and 1 ppm aldrin. An air stone was placed in one aquarium, and air was bubbled through it for 48 hours. At the end of this time, the oxygen was about 9 ppm in each aquarium. Twelve small minnows were placed in each aquarium. In the aquarium that had been pre-aerated, only one fish was dead at 15 hours; in the other aquarium, only one fish was alive at 15 hours.

The bulk of the study was concerned with the comparative sensitivity of various species and sizes of fishes to aldrin. For this phase of the project, a 14-foot aluminum boat was used as the poisoning chamber. It was large enough to test several species simultaneously in 300 liters of water. The water used was the same pond water mentioned previously. Fish were held in the unpoisoned water for three days, during which time injured or diseased specimens were discarded. No food was given during the experiments. At the end of the three days, enough aldrin in water emulsion was introduced to make a concentration of .0164 ppm of the active principle. The same amount was added at four-hour intervals thereafter, throughout each experiment. The aldrin was always scattered over the surface drop by drop and then was mixed with the water in the boat by means of a circulating pump.

In one boat experiment, 275 fish were used. The water was aerated through air stones, and the oxygen level was 6 ppm at the start of the poisoning. It arose gradually to 8 ppm as the number of live fish decreased. The temperature in this test, which lasted for some 250 hours, fluctuated between 17 degrees and 26 degrees C. As the fish died, they were sorted into ½-inch size groups.

In the above experiment, small centrachids of all three species present in the boat were the first fish to die, at about 40 hours and .2 ppm aldrin, along with some small spotfin shiners. By 96 hours, after .4 ppm aldrin had been added, median deaths had occurred among 1½-inch bluegills (*L. machrochirus*) and green sunfish (*L. cyanellus*), 2-inch redfin shiners, and 2½-inch largemouth bass (*M. salmoides*). At 144 hours and .6 ppm aldrin, median deaths had occurred among 2-inch spotfins, 2-inch bluegills, 2-inch river shiners (*N. blennius*), 3-inch green sunfish, and 4-inch common shiners. By 192 hours and .6 ppm aldrin, median deaths had occurred among large adults of the following species: 1½-inch blackstripe topminnows (*F. notatus*), 2-inch fantail darters (*E. flabellare*), 3-inch spotfin shiners, and 3-inch madtoms. By 240 hours and .8 ppm aldrin, median deaths had occurred among large adults of the following species: 2-inch Johnny darters (*E. nigrum*), 2-inch rainbow darters (*E. caeruleum*), and 2½-inch greenside darters (*E. blennioides*). At 250 hours and the conclusion of thet test, median deaths had not occurred among large adult 5-inch stonerollers (*C. anamalum*) and 5½-inch hogsuckers (*H. nigricans*). Note that by the end of this experiment, about 30 times the recognized lethal dose (96 hour median tolerance limit) of aldrin had been administered.

In two more experiments that I will outline briefly, no artificial aeration was provided. Even though the dissolved oxygen did not fall to levels that in themselves would have been fatal, the lack of aeration seemingly was responsible for two important effects: The survival times were much shortened, and the various darters, which had been among the most resistant species with aeration, reversed their position and became among the most sensitive of species.

In one of these experiments, the oxygen stayed between 5 and 6 ppm. Small darters began dying at 30 hours and .12 ppm aldrin. By 40 hours and .17 ppm aldrin, the median 1½-inch spotfin, the median 1½-inch common shiners, and the median 2-inch greenside darter had died. By 50 hours and .21 ppm aldrin, the median 2-inch Johnny darter and 2-inch rainbow darter had died, as had the median 2-inch silverjaw minnow (*E. buccata*). By 60 hours and .25 ppm aldrin, the median adult 3-inch spotfin shiner and the median 3½-inch silvery minnow (*H. nuchalis*) had died. The median 2-inch river shiner died at 78 hours.

In the other experiment, in which the oxygen dropped to a range of 3 to 4 ppm, immature centrarchids (bluegills, green sunfish, and largemouth bass) died before mature minnows (common shiners, stonerollers, spotfin shiners, and creek chubs). Among the centrarchids, bluegills of 2 inches died at approximately the same time as bass of 5 inches, and bluegills of 3 inches died at approximately the same time as bass of 7 inches.

To summarize the work, it appears that, among the fishes I used, closely related fish are affected similarly by aldrin. The most sensitive fishes were small centrarchids of all three species, together with small members of three species of shiners (common, spotfin, and redfin).

It would appear that aeration not only dissipates aldrin to some extent but also affects the fishes and their survival times directly. Aeration's effect on survival time is not the same for all species. Adult Johnny, greenside, rainbow, and fantail darters were comparatively sensitive at low levels of oxygen and resistant at the higher levels characteristic of their natural environment. Certainly the dissolved oxygen should be recorded most carefully in toxicity studies and should probably be kept at saturation for median tolerance tests. So far as I can tell from the literature, this has not often been done in the past.

The aldrin needed to kill fish varies greatly (at least up to 30-fold), depending on how it is administered. It seems likely that in natural waters many times the dose calculated from median tolerance limits would be needed to effect a fish kill. I say this because in natural waters there would probably be a high oxygen content, photosynthetic aeration, and slow mixing.

Immature fish in general die more rapidly than mature fish in aldrin concentrations. All of the adult fish in the artificially aerated experiments survived longer than fish which were half-grown or smaller, regardless of species.

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