Acute Effects of Cadmium on *Ictalurus punctatus* (Catfish)

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Cadmium has been found in varying concentrations in air, food, soil, and water (FLICK et al. 1971). Due to the toxicity of cadmium, drinking water containing over 10 ppb can be rejected according to United States Public Health Service Drinking Water Standards (FLICK et al. 1971). Studies have shown that freshwater fish can concentrate cadmium to levels 10 to 1000 times higher than the cadmium concentration of ambient water (FLEISCHER et al. 1974). Although the toxic effects of cadmium for man have been described (FRIBERG et al. 1971), little is known about the biochemical and physiological effects of this metal on aquatic vertebrates.

The following study was undertaken with two objectives: 1) to determine the uptake and tissue distribution of cadmium in catfish (Ictalurus punctuatus) exposed to varying concentrations of cadmium and 2) to determine whether the cadmium exposure effected alterations in the hematological constituents of the fish.

Materials and Methods

Cadmium stock solutions were prepared by dissolving $CdSO_4 \cdot 8H_2O$ in one liter of tap water. The stock cadmium solution was added to six, 96 liter aquaria containing dechlorinated tap water to give concentrations of 0, 50, 100, 200, 400, and 800 ppb cadmium. The calcium content of the water was 4.7 ppm. Eight catfish were placed in each aquarium and were maintained for a three week exposure period. The fish weighed an average of 106.8 gm and ranged in body weight from 61.6 to 215.0 gm.

During the three week exposure period, fish which became moribund were bled and sacrificed. At the end of the three week exposure, blood was collected from all remaining fish. Approximately 2.5 ml of nonheparinized blood was collected from the caudal artery of each fish. Packed red blood cell volumes were determined using heparinized capillary tubes. Hemoglobin values were determined as cyanmethemoglobin (NATELSON 1957). Following blood collection, the fish were weighed and sealed in individual plastic bags. The fish were stored at -20 C for subsequent cadmium residue analysis.

Serum transaminase (SGOT) activity was determined by a SIGMA procedure. The determination of serum triglycerides was based on a modified Levy procedure (GOTTFRIED and ROSENBERG 1973). Sodium content of

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serum was determined by flame emission (Varian Techtron - Model 1000) and serum magnesium level was analyzed by atomic absorption. Total serum protein (TSP) was determined with a Goldberg refractometer (American Optical Co.). Microzonal electrophoresis (Beckman Instrument Co.) was employed to quantitate serum proteins.

The cadmium content of each liver, kidney and brain was determined by atomic absorption. Each sample was ashed in a muffle furnace at 450-500 C (MORGAN 1972). The ash was dissolved in 1 N nitric acid and then chelated with NDDC and extracted into MIBK (CHILDS and GAFFKE, 1974a, 1974b).

Results and Discussion

Cadmium residue analysis revealed differences in the uptake and tissue distribution of cadmium. Trace amounts of cadmium were found in the brain. In 40% of the brains no cadmium was detected. Concentration of cadmium by the brain did not appear to be related to cadmium exposure.

Both the liver and kidney were found to accumulate cadmium. As in studies with bass and bluegills (CEARLEY AND COLEMAN, 1974), the amount of cadmium accumulated in these tissues increased as the exposure increased. The greatest accumulation of cadmium occurred in the kidney (Table 1). The amount of cadmium accumulated in the kidney increased as the cadmium exposure increased ($r = 0.505^{**}$) (Fig. 1). In a study with bluegills, EATON (1974) observed that the cadmium concentration in the kidney did not increase with increasing cadmium exposure. Similarly, MOUNT and STEPHAN (1967) found that uptake of cadmium by the kidney of the bluegill was variable and was not closely related to cadmium exposure.

In the present study, the greatest biological magnification occurred at the lowest (50 ppb) cadmium exposure level (Table 1). At this exposure level, the kidney accumulated approximately 41x the amount of cadmium present in the aquaria water. As the exposure concentration increased the biological magnification was reduced. At the highest exposure level (800 ppb), the kidneys accumulated approximately 5x the amount of cadmium in the aquaria water.

As the cadmium concentration in the water environment was increased, the amount of metal accumulated in the liver increased ($r = 0.714^{**}$) (Fig. 2). However, the average amount of cadmium accumulated by the liver was less than the average amount accumulated by the kidneys (Table 1). In bluegills, EATON (1974) observed that the highest cadmium residues were found in the liver rather than the kidney.

The greatest biological magnification (12x) occurred at the lowest cadmium exposure level (Table 1).

TABLE 1

Average Concentration and Biological Magnification of Cadmium in Liver and Kidney of Catfish Exposed to Cadmium Sulfate

Cd Exposure ppb	Average Cd Concentration of liver, ppb	Biological Magnification by Liver	Average Cd Concentration of Kidney, ppb	Biological Magnification by Kidney
0	80	-	380	-
50	580	12x	2040	41x
100	640	6x	1540	15x
200	810	4x	3050	15x
400	1090	3x	2560	6x
800	1620	2x	4080	5x

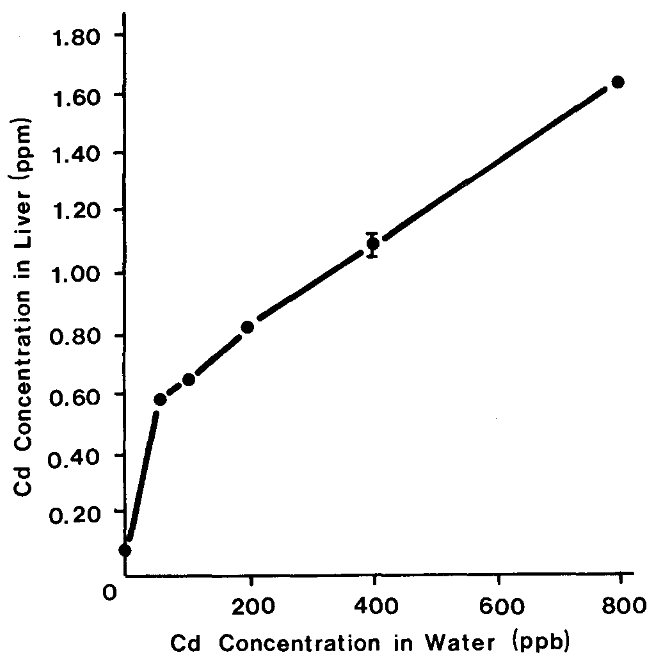

Figure 1. Average concentration of cadmium in the livers of catfish exposed to five levels of cadmium in their water environment. Standard deviation is depicted by bracket.

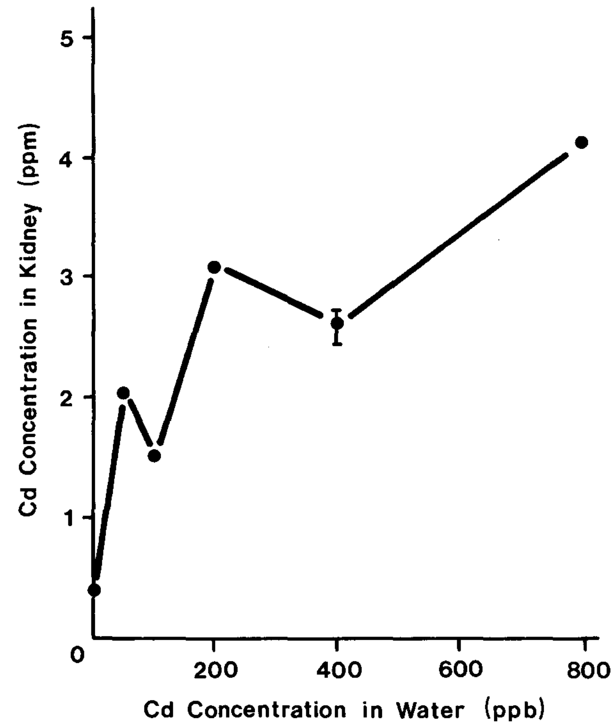

Figure 2. Average concentration of cadmium in the kidneys of catfish exposed to five levels of cadmium in their water environment. Standard deviation is depicted by bracket.

The biological accumulation declined with increasing exposure concentrations. At 800 ppb exposure, the biological magnification reached its lowest point (2x).

To study the possible effects of cadmium on the organ systems of the catfish, several hematological constituents were analyzed. Effects of cadmium on the hematopactic system were monitored by the determination of microhematocrits and hemoglobins. Anemia has been observed in rats fed cadmium containing diets (FRIBERG et al. 1971). Low hemoglobin levels have been correlated to high cadmium blood levels in workers exposed to cadmium oxide dust (FRIBERG et al. 1971). Adipose tissue mobilization was monitored by measuring serum triglycerides. Some studies have revealed a correlation between cadmium concentration in city air and death rates from hypertension and arteriosclerotic heart disease (FRIBERG et al. 1971). In order to monitor alterations in liver function, the catfish serum was analyzed for SGOT, TSP, and albumin to globulin ration. To test kidney function, serum sodium and magnesium was determined. In normally functioning catfish kidneys, sodium ions are almost completely reabsorbed from the plasma ultrafiltrate as it passes through the kidney tubules (HICKMAN and TRUMP, 1969). Magnesium is also reabsorbed in the kidney (HICKMAN and TRUMP, 1969).

Exposure of the catfish to cadmium did not produce significant differences in the hematological constituents between control and principal fish (Table 2). Several of the catfish in the 100, 200 and 800 ppb cadmium exposure levels exhibited extremely elevated SGOT levels. However, due to the high degree of variability among individual fish, there was no significant difference between the control and principal fish.

When exposed to cadmium in ambient water, catfish accumulate cadmium in the kidney and liver, with the kidney accumulating more of the higher concentration of cadmium. Although the amount of cadmium accumulated by these organs increased with exposure, the biological magnification of cadmium decreased. Therefore, tissue levels of cadmium cannot be correlated with ambient cadmium levels. None of the hematological constituents assayed appear to be valuable as a diagnostic test for cadmium exposure.

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TABLE 2

Changes in Selected Biochemical Constituents
of Serum of Catfish Exposed to Cadmium Sulfate

Cadmium Exposure ppb	PCV 1/ Volume %	Hemoglobin mg/dl	SGOT 2/ Sigma Units	TRIGLY 3/ mg/dl	TSP 4/ g/dl	Albumin/ Globulin	Magnesium meq/l	Sodium meq/l
0	27 ± 4	5.8 ± 0.9	61 ± 14	155 ± 50	3.2 ± 0.6	0.76±0.24	3.06±0.58	99.4± 2.8
50	23 ± 8	4.8 ± 2.1	136 ± 92	159 ± 169	2.5 ± 1.8	0.71±0.24	2.98±1.41	106.0±34.3
100	26 ± 10	5.2 ± 1.9	172 ± 248	243 ± 157	3.3 ± 1.1	0.81±0.10	2.46±0.54	106.4±20.0
200	27 ± 5	5.3 ± 1.3	293 ± 358	182 ± 77	3.6 ± 1.1	0.55±0.34	2.96±0.84	97.4± 1.4
400	30 ± 4	6.4 ± 1.1	78 ± 29	137 ± 100	4.2 ± 0.2	0.70±0.08	3.16±0.42	113.0±32.6
800	24 ± 12	6.5 ± 1.3	235 ± 398	107 ± 37	3.2 ± 1.7	0.91±0.54	1.96±0.64	99.1± 2.5

Values are means ± SD

1/ Packed Cell Volume

2/ Serum glutamic - oxaloacetate transaminase

3/ Triglycerides

4/ Total serum protein

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