# Cadmium Uptake and Time Dependent Alterations in Tissue Levels in the White Catfish *Ictalurus catus* (Pisces: Ictaluridae)

by

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The toxicity of cadmium (Cd) to living systems has been known for over 100 years. Measurements of acute toxicity in fishes have documented species dependent toxic thresholds varying from less than 10 parts per billion (ppb) to greater than 55 parts per million (ppm)(Anderson, 1950; Schweiger, 1957; Eisler, 1971). Moreover, acute human cadmiosis ('itai-itai' disease) in Japan has been linked to consumption of shellfish containing Cd.

The presence of Cd at concentrations exceeding the U.S. Public Health Service guideline of 0.01 ppm has been revealed in a survey of the freshwater systems of the United States (Kopp and Kroner, 1969; McKee and Wolf, 1963). Also, it has been found in the tissues of numerous species of fishes in concentrations ranging from approximately 10 ppb to greater than 100 ppb (Thomas, 1972; Lovett et al., 1972; Lucas et al., 1970).

Although acute toxicity data for fishes is extensive, little detailed information is available describing the tissue distribution of Cd. Mount and Stephan (1967) observed that intoxication can be detected in juvenile bluegills by analysis of the Cd concentration in the gill filaments. Lesser amounts were detected in the liver and kidney. Recently, Hibbs and Ulrikson (1971) examined the distribution of $^{109}$Cd in bluegills. The major sites of concentration were the gastrointestinal tract, the liver and kidney.

Anatomical differences (compared to centrarchid and salmonid fishes) coupled with the commercial and sport-fishing importance of catfish prompted us to examine the time dependent distribution of Cd in the white catfish (Ictalurus catus).

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## Materials and Methods

Sub-adult white catfish were obtained from Zetts Fish Hatcheries, Drifting, Penna. They averaged 165 g (range 112-225 g) in weight. Twelve fish were placed in dechlorinated City of Buffalo tap water in a light gray epoxy-painted trough (61 x 61 x 183 cm) equipped with a recirculating limestone trickle filter which was a modification of that described by Murphy and Lipper (1972). It was operated at an average flow rate of 9.9 liters/min.

The average physicochemical characteristics of the recirculated water were: hardness ($CaCO_3$) = 426.75 ± 1.89 mg/liter; dissolved oxygen = 8.0 mg/liter; temperature = 24.4°C (range 20.6-27.8°C);pH=8.21.

The fish were maintained in a greenhouse under natural lighting conditions. During the 10 week acclimatization period and throughout the study, the fish were fed "STRIKE" pelleted fish food (County Best, Agway, Inc., Syracuse, N.Y.) at a rate of 3% of their aggregate body weight daily. They were not fed 48 hours prior to sacrifice. No deaths were recorded during the experimental period.

The fish were anaesthetized with MS-222 (Sigma Chemical Co., St. Louis, Mo.) at a concentration of 0.138 mg/liter, weighed and given an intragastric dose of 0.2 ppm Cd (0.2 mg/kg = 0.67 μCi/kg live weight) as the chloride salt via a 0.5 ml syringe connected to a 14 cm section of 0.014 i.d. polyvinyl tubing. They were immediately returned to the tanks until the time of sacrifice. All fish recovered from anaesthesia within 1 minute after return to the tanks.

The percent regurgitation was determined in a separate experiment. Three fish were dosed as above, placed individually in 2 liters of water, and 10 ml water samples were removed every 10 minutes for 1 hour. The percent regurgitation was calculated from the Cd content of the water.

Two fish were removed and sacrificed at 1 hr, 1, 4, 8, 14, and 21 days. The fish were dissected into 23 tissues/organs which were analyzed for Cd content with a Packard Model 3003 gamma scintillation spectrometer equipped with a NaI(Tl) detector.

TABLE I

Time dependent distribution of Cd expressed as the percentage of the total body activity at the time of sacrifice

| ORGAN | % Total Body Activity | | | | | |
|---|---|---|---|---|---|---|
| | | Days post administration | | | | |
| | 1 hr | 1 | 4 | 8 | 14 | 21 |
| stomach | 61.8 | 31.1 | 0.7 | 1.6 | 1.3 | 1.2 |
| esophagus | 10.2 | 1.9 | 0.1 | 0.2 | 0.1 | 0.1 |
| gill filaments | 22.9 | 1.0 | 0.5 | 1.7 | 0.9 | 1.3 |
| skin | 2.2 | -0- | 0.1 | -0- | -0- | -0- |
| 1st intestine | 3.2 | 47.1 | 62.0 | 78.0 | 52.2 | 39.9 |
| 2nd intestine | 0.2 | 16.0 | 4.4 | 4.7 | 5.0 | 3.5 |
| 3rd intestine | 0.1 | 0.4 | 27.1 | 6.1 | 17.7 | 12.2 |
| liver | 0.5 | 0.5 | 0.8 | 1.5 | 3.1 | 5.3 |
| kidney | 1.0 | 1.9 | 4.0 | 5.7 | 17.6 | 34.0 |
| organ x* | 0.2 | -0- | 0.1 | 0.2 | 0.5 | 0.7 |
| blood | -0- | -0- | -0- | 0.1 | 0.2 | 0.1 |
| ovaries | 0.1 | -0- | -0- | 0.3 | 0.1 | 0.6 |
| spleen | -0- | -0- | -0- | -0- | 0.2 | 0.2 |
| swim bladder | -0- | -0- | 0.1 | 0.1 | 0.1 | 0.3 |
| bile | -0- | -0- | -0- | -0- | -0- | -0- |
| barbels | 0.5 | -0- | -0- | -0- | -0- | -0- |
| dorsal sping | -0- | -0- | -0- | -0- | 0.1 | 0.1 |
| adipose tissue | -0- | -0- | 0.2 | -0- | -0- | -0- |
| heart | -0- | -0- | -0- | -0- | -0- | -0- |
| brain | -0- | -0- | -0- | -0- | -0- | -0- |
| muscle | -0- | -0- | -0- | -0- | -0- | -0- |
| bone | -0- | -0- | -0- | -0- | -0- | -0- |
| lens | -0- | -0- | -0- | -0- | -0- | -0- |

* organ x is an unidentified, highly vascularized, liver colored organ located posterior to the cardiac cavity along the dorsal spine.

-0- represents Cd content not statistically different from background radioactivity.

## Results and Discussion

The time dependent distribution of Cd resulting from the single intragastric dose of 0.2 ppm $CdCl_2$ is shown in Table I. The fish were found to regurgitate from 39% to 56% of the dose solution within the first hour. A similar response was noted by Järvenpaa et al. (1970) in pike (*Esox lucius*) given intragastric doses of mercuric chloride. Furthermore, the emetic properties of Cd have been documented in mammals by Decker et al. (1956). The variation in regurgitation prevented analysis of the data on mg Cd/kg wet tissue weight (ppm) basis. Therefore, the concentration in each tissue/organ is expressed as the % total body activity at the time of sacrifice. The total body activity was determined by summation of the activity of each tissue/organ. The total activity of the skin, muscle and bone was calculated from the activity of a representative sample.

After one hour, 75.1% of the Cd body load was contained within the gastrointestinal (GI) tract, with 61.8%, 10.2% and 3.2% in the stomach, esophagus, and first 1/3 of the intestine*, respectively. The gill filaments contained 22.9% of the total body activity.

Within 24 hours, there was a marked change in distribution. The relative concentrations in the stomach, esophagus, gill filaments and skin decreased to 31.1%, 1.9%, 1.0% and background, respectively, while the first and second portions of the intestine increased to 47.1% and 16.0%, at the same time the kidney concentration increased to 1.9%.

Maximum relative concentrations were attained by the stomach, esophagus and skin (61.8%, 10.2% and 2.2%, respectively) within 1 hour. The intestinal portions attained maximum levels at widely divergent times. Thus, the first, second and third portions of the intestine maximized at 78.0%, 16.0% and 27.1%, respectively, after 8, 1 and 4 days, respectively.

Outside the GI tract, the liver and kidney contained the highest percentages of the body load: 5.3%

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* The intestine was divided linearly into thirds. The first portion extends from the pylorus 1/3 the distance to the anus. The third portion includes the anus.

and 34.0%, respectively, at 21 days (termination of experiment). Examination of the liver and kidney data (Table I) suggests that these organs may not have reached their relative maximum concentrations at this time.

Other tissues/organs contained less than a maximum of 0.8% of the body load and conclusions which might be drawn from these data would be tentative. Nonetheless, there appears to be a trend toward accumulation in the blood, spleen, swim bladder and ovaries. On the other hand, there appears to be no trend toward accumulation in the muscle, bile, bone, brain and lens.

The presence of Cd in the gill filaments is probably an artifact of regurgitation. This hypothesis is supported by the observation that the level in the gill filaments and the esophagus decreases from 22.9% and 10.2% of the body load, respectively, to 1.0% and 1.9%, respectively, in 24 hours. Furthermore, within this time period the blood was not observed to contain a significant percentage (0.04%) of the body load.

The time dependent increase of Cd in the liver and kidney may indicate the induction of metallothionein synthesis in these organs (Piscator, 1969). This protein, isolated from the liver and kidney of rats, horses, pigs and humans, has been suggested as a primary detoxifying mechanism for Cd (Kagi and Vallee, 1961; Wiesniewska-Knypl and Jablonska, 1970; Evans *et al.*, 1970; and Pulido *et al.*, 1966).

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