DISTRIBUTION OF COPPER, LEAD, AND ZINC IN SELECTED COMPONENTS OF A POND ECOSYSTEM[1]

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Concentrations of copper, lead, and zinc in several components of an aquatic ecosystem were determined by atomic absorption spectrophotometry. Concentrations of all metals were found to be lowest in the water and greatest in the sediments and biota. No increase in the amount of metals could be associated with increasing trophic levels. Domestic ducks and tree leaves from the pond's perimeter contributed heavy metals to the pond ecosystem.

Heavy metals are natural components of the earth's crust and are present in soil, streams, and lakes. Increased amounts of metals from industrial and municipal wastes have been released to many ecosystems since the advent of our technological society (1). Although data on heavy metal distribution in different components or ecosystems are scarce, studies suggest that heavy metals are unevenly distributed (1, 2). Metals are generally found in trace quantities in water and are more concentrated in sediments and biota (2, 3). The objectives of the present study were to (a) measure the concentrations of copper, lead, and zinc in the components of a small ecosystem, (b) compare concentrations of metals among components within the system, and (c) compare the concentrations found in organisms of different trophic levels.

Theta Pond, located on the Oklahoma State University campus, was chosen for the study because it was readily accessible. Theta Pond has an approximate surface area of 2250 m^2, mean depth of about 1 m, and a maximum depth of 2.3 m. The pond is maintained at bankful conditions and occasionally overflows. Imported material enters the pond from feeding domestic ducks and surface water runoff from lawns, asphalt parking lots, and streets on the campus.

METHODS AND MATERIALS

Selected components of Theta Pond were sampled within a 4-hr period on November 15, 1972. Thirteen water samples were collected and acidified to pH 2 with concentrated nitric acid. Three plankton samples each were concentrated from 60 net hauls in surface water. Benthic macroinvertebrates collected from 10 hauls of a 15 x 15 cm Ekman dredge were combined to make one sample. Two samples each of *Physa* and *Gyraulus* were obtained from submerged rocks near the pond's perimeter. Twelve black bullheads, *Ictalurus melas* (Raf.), 10 orangespotted sunfish, *Lepomis humilis* (Girard), and 13 mosquitofish, *Gambusia affinis* (Baird and Girard) were collected by seining and baited minnow traps. Fish were separated according to species and frozen in polyethylene bags. Eighteen benthic detrital samples were collected with an Ekman dredge, washed with pond water to remove mud, and frozen. Eight sediment samples were collected on two transects with a weighted vertical core sampler fitted with polyethylene inserts. Duck feathers, duck feces, and tree leaves were collected by hand.

Biological materials were prepared for analysis by (a) oven drying at 105 C for 12 hr to obtain dry weight, (b) wet digestion with four cycles of boiling in concentrated nitric acid to near dryness, (c) ashing in a muffle furnace at 500 C for 16 to 20 hr, and (d) dissolving residues in 1 N hydrochloric acid. Snail shells and soft tissues were separated by dissolving the shell in 25 ml 2 N hydrochloric acid.

Sediment core samples were prepared for analysis by sectioning the top 15 cm into five 3 cm subsamples. Approximately 3 g of sediment from each subsample were extracted by shaking for 12 hr in polyethylene flasks containing 25 ml 1 N nitric acid.

Metal concentrations in samples were determined by atomic absorption using a

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Varian Techtron AA-5 Spectrophotometer. Low concentrations not detectable by conventional flame atomic absorption were determined using a Perkin-Elmer HGA 70 heated graphite furnace attachment to the spectrophotometer. Metal concentrations in tissues and sediments, i.e., $\mu g/g$ in the sample, were calculated by the formula:

$$\frac{\text{mg/l solution x ml of solution}}{\text{dry weight (g) sample}} = \mu g/g \text{ in sample}$$

RESULTS AND DISCUSSION

The mean copper, lead, and zinc concentrations of Theta Pond water were 0.005, 0.013, and 0.016 mg/l, respectively (Tables 1, 2, and 3). The metal concentrations are intermediate to levels found by other investigators. High levels reported in aquatic ecosystems are 0.28 mg/l copper in the Monogahela River, Pennsylvania; 0.14 mg/l lead in the Ohio River, Indiana; 1.182 mg/l zinc in the Cuyahoga River at Cleveland, Ohio (4). Low concentrations of 0.0012 mg/l copper, 0.0005 mg/l lead, and 0.0015 mg/l zinc have been found in the water of High Sierra Lakes in California (5).

Aquatic organisms accumulated heavy metals in Theta Pond (Tables 1, 2, and 3). Net phytoplankton and zooplankton had the highest levels of lead and zinc in the biota. *Physa* tissues contained the highest copper concentration. These organisms are in the lower trophic levels. The orange-spotted sunfish and mosquitofish, representatives of higher trophic levels, had much lower concentrations. The detritus-eating benthos and omnivorous black bullhead had metal concentrations intermediate to those found in plankton and carnivorous fish.

Copper and zinc concentrations in Theta Pond benthos were higher than were the concentrations found in the sediments and detritus. Conversely, in the benthos the lead concentration was the lowest of the three metals, but lead was the most concentrated metal found in the sediments. Tubificids in the Illinois River had heavy metal concentrations similar to those found in the river's sediments (2), and both tubificids

TABLE 1. *Concentrations of copper, lead, and zinc in selected components of Theta Pond, November 15, 1972.*

	Component ($\mu g/g$ dry weight)					
	Copper		Lead		Zinc	
	Mean ± S.D.	(n)	Mean ± S.D.	(n)	Mean ± S.D.	(n)
Water[a]	0.005 ± 0.002	(13)	0.013 ± 0.013	(10)	0.016 ± 0.003	(13)
Net plankton	618 ± 111	(3)	281 ± 101	(3)	477 ± 70	(3)
Benthos	234 ± —	(1)	37 ± —	(1)	410 ± —	(1)
Snails						
Physa (tissues)	731.0 ± 514.6	(2)	8.7 ± 4.3	(2)	86.9 ± 6.1	(2)
Physa (shells)	97.9 ± 3.3	(2)	46.2 ± 2.3	(2)	57.8 ± 2.9	(2)
Gyraulus (tissues)	76.4 ± 5.4	(2)	1.3 ± 0.2	(2)	33.2 ± 4.4	(2)
Gyraulus (shells)	9.9 ± 1.5	(2)	17.0 ± 0.9	(2)	26.8 ± 4.6	(2)
Black bullhead	135 ± 87	(12)	34 ± 10	(12)	313 ± 103	(12)
Orangespotted sunfish	14.6 ± 3.0	(10)	[b] ± —	(10)	18.6 ± 1.0	(10)
Mosquitofish	46.9 ± 7.8	(13)	11.5 ± 2.02	(13)	265.1 ± 44.8	(13)
Detritus	23.8 ± 1.4	(18)	198.7 ± 20.1	(18)	234.3 ± 20.1	(18)
Sediments by depth from water-sediment interface						
0-3 cm	51.4 ± 16.0	(8)	529.0 ± 194.1	(8)	219.6 ± 56.3	(8)
3-6 cm	42.6 ± 17.5	(8)	393.2 ± 192.1	(8)	165.2 ± 64.7	(8)
6-9 cm	37.3 ± 13.8	(8)	250.4 ± 86.0	(8)	137.9 ± 30.6	(8)
9-12 cm	35.3 ± 11.5	(8)	243.6 ± 122.8	(8)	137.9 ± 42.9	(8)
12-15 cm	34.0 ± 20.1	(7)	206.2 ± 75.9	(7)	119.8 ± 31.7	(7)
Duck feathers	11.8 ± 1.9	(10)	2.7 ± 1.1	(10)	88.8 ± 18.9	(10)
Duck feces	25.1 ± 5.0	(8)	76.1 ± 43.3	(8)	174.8 ± 56.5	(8)
Leaves	2.9 ± 2.0	(4)	15.2 ± 2.7	(4)	35.8 ± 7.7	(4)

[a] Concentrations in water = mg/l; concentration in other samples = $\mu g/g$ dry weight.
[b] Not detected.

and sediments were in lower concentrations than those found in Theta Pond.

Zinc was present in higher concentrations in the detritus than in the sediments, whereas those of copper and lead were lower in the detritus. These differences may be due to collection and separation methods.

The ratio between concentration in the top layer of the bottom sediment and water was 10,280 for copper, 40,692 for lead, and 13,725 for zinc (Tables 1, 2, and 3). Lower ratios for the Illinois River were 1,900 for copper, 13,333 for lead, and 2,531 for zinc (2).

The concentrations of copper, lead, and zinc in the surface sediments decreased with depth. Theta Pond sediments decreased 17.4 μg/g in copper, 322.8 μg/g in lead, and 99.8 g/g in zinc in the top 15 cm. A decrease of 85 μg/g copper, 70 μg/g lead, and 140 μg/g zinc was reported in the upper 6 cm of Lake Michigan sediments (6).

Higher concentrations of copper, lead, and zinc were present in the duck feces than in the feathers. Both sources of allochthonous material appear to add significant amounts of heavy metals to this ecosystem.

Leaves, with suspected metal contamination from automobile exhaust, contributed more lead and zinc than copper to Theta Pond. Two streets located near the pond have heavy traffic. Leaves from broadleafed perennial plants located near highways were higher in lead concentration than were those located greater distances from highways (7). Kahn reported 11.4 μg/g lead in leaves from a location 3 m away from slow, heavy traffic, whereas 15.2 μg/g was the concentration of lead found in leaves from Theta Pond.

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