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Metal Accumulation and Depuration by the American Oyster, *Crassostrea virginica*

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INTRODUCTION

Accumulation and depuration of metals by the oyster have been studied by several investigators (SHUSTER and PRINGLE, 1969; PRINGLE et al., 1968; CUNNINGHAM and TRIPP, 1973). All of these studies, however, dealt with metals in seawater and did not consider those in sediment or food. WOLFE and RICE (1972) have stated that nearly all of the elemental metallic content of aquatic ecosystems resides in sediments and water. They reported "the fraction residing in the biota is small - with phytoplankton and zooplankton constituting the most important living elemental reservoirs....." Since oysters feed on phytoplankton, their food supply could be an important pathway for metal accumulation. BROOKS and RUMSBY (1965) studied the biogeochemistry of metals uptake in New Zealand bivalves, but were unable to demonstrate uptake of metals directly from sediment by the animals (including oysters). FRAZIER (1976) studied certain environmental effects on metal accumulation in the American oyster and found that the relative enhancement of metals in soft tissues of oysters exposed to the contaminated environment over controls reflected the pattern of metal contamination in sediments.

In the present study, accumulation and depuration of silver, cadmium, copper and zinc by oysters, Crassostrea virginica, were studied in natural systems. Oysters were transferred from relatively unpolluted water of North Carolina to Milford Harbor water to determine uptake of metals, and oysters were transferred from the Housatonic River, Connecticut, to North Carolina water to determine depuration of these metals. Depuration studies also were conducted on oysters transferred from the Housatonic River to Milford Harbor.

MATERIALS AND METHODS

Uptake Study

Oysters were transferred by air iced in styrofoam coolers from Beaufort, North Carolina, to Milford, Connecticut. At the Milford laboratory, they were held in sand-filtered seawater for about a week before the experiment began. Oysters were then placed in 60-liter glass tanks, 25 per tank, and held under the following experimental conditions: Tank #1 - flowing seawater

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(unfiltered) from Milford Harbor; Tank #2 - flowing seawater from Milford Harbor, plus black, muddy sediment from Milford Harbor; Tank #3 - water obtained from the outflow of Tank #1 and filtered through swimming pool filter sand; Tank #4 - water obtained from the outflow of Tank #2 and filtered through swimming pool filter sand. Two liters of a suspension of mixed phytoplankton were added to each tank daily as food for the oysters.

Depuration Studies

Three different studies were conducted: oysters were transferred from the Housatonic River, Connecticut, to: (1) Milford Harbor water; (2) sand-filtered Milford Harbor water; and (3) water at the National Marine Fisheries Service laboratory, Beaufort, North Carolina. For studies (1) and (2), oysters were held in 60-liter glass tanks, 25 per tank; in study (3), oysters were held in a plastic tray system, about 30 per tray.

Chemical Analyses

The method of GREIG et al. (1975) was used for metal analyses of oyster meats. Oysters were prepared for analysis by shucking, draining and then placing the meats individually in beakers. In most cases, 10 oysters were analyzed per exposure period.

Muddy sediment from Milford Harbor was analyzed by the method of GREIG and McGRATH (1977).

RESULTS AND DISCUSSION

Uptake Study

With four exceptions, significant (Student's "t" test, $P = 0.05$) uptake of silver, cadmium and copper occurred in North Carolina oysters exposed to different Milford Harbor water systems (Table 1). For the exceptions, there was no significant uptake of silver or copper in oysters exposed 11 weeks to muddy sediment from Milford Harbor, and for copper there was no significant uptake at 11 weeks for both sand-filtered water treatments.

In the case of silver and cadmium, no single treatment gave higher tissue residue levels than any other treatment. There were differences, however, for exposure times within each treatment. A conclusion from these data is that silver and cadmium were not obtained directly from sediment. A further explanation for this conclusion is that oysters held in muddy sediment had silver and cadmium levels similar to all other treatments; if these metals were taken up from the sediment, residue levels in these oysters would be greatest.

TABLE 1

Metal concentrations in oysters held under various experimental conditions

Location	Time[a] (weeks)	Mean ppm (top) and s.e. (bottom) (wet weight)			
		Ag	Cd	Cu	Zn
North Carolina	0	<0.16 -	<0.28 -	8.4 1.45	515. 33.1
Tank #1 Unfiltered Milford Harbor water	11	0.36 0.048	0.66 0.035	29.3 3.49	563.[b] 70.7
Tank #1	22	All Oysters Dead[c]			
Tank #2 Muddy sediment[d] from Milford Harbor	11	<0.15[b] -	0.43 0.083	10.7[b] 2.29	444. 23.6
Tank #2	22	0.49 0.105	1.2 0.06	41.6 11.29	410.[b] 105.1
Tank #3 Sand-filtered water from Tank #1	11	0.28 0.035	0.51 0.041	11.6[b] 1.67	422. 50.2
Tank #3	22	0.76 0.083	1.0 0.12	18.4 2.24	346.[b] 212.4
Tank #4 Sand-filtered water from Tank #2	11	0.26 0.019	0.51 0.041	11.4[b] 1.24	281. 22.5
Tank #4	22	1.0 0.15	1.5 0.30	24.0 4.89	437.[b] 125.4

[a] Time held under various experimental conditions.

[b] All values were statistically different from controls, Student's "t" test, P = 0.05, other than those noted with b.

[c] No explanation was found for these deaths. Mortalities were low for all other exposures, no more than 3 oysters over 22-week exposure period.

[d] Muddy sediment had the following metal concentrations (ppm, dry weight): Ag, undetermined; Cd, <2.5; Cu, 180; Zn, 108.

The copper content of North Carolina oysters held in unfiltered Milford Harbor water was significantly greater than all other treatments for the 11-week exposure period; unfortunately, all oysters at this treatment died sometime between 11 and 22 weeks. After 22 weeks of exposure, oysters held in muddy sediment, plus unfiltered Milford Harbor water, had significantly greater copper concentrations than the other two treatments. These data, along with those on Tanks #3 and #4 (Table 1), suggest that, in addition to obtaining copper from seawater and/or their food, these oysters obtained copper either from suspended particulate or possibly directly from sediment. However, because we analyzed the entire oyster and not specific organs or tissues, we cannot say whether the copper was metabolized by the oyster or merely remained attached to particulates ingested by the animal.

Zinc concentrations in oysters from North Carolina either significantly decreased or were not significantly different after exposure to the four treatments under study (Table 1). Decreases in zinc concentrations could mean that Milford Harbor water contains less zinc than Beaufort water; however, results were too inconsistent to reach this conclusion. This, nevertheless, is in contrast to data of CHIPMAN et al. (1958), who showed that Milford water contained greater zinc concentrations (0.0188 µg/g) than Beaufort water at 0.0046 µg/g.

Depuration Studies

Oysters were transferred from the Housatonic River to unfiltered or sand-filtered Milford Harbor water in hopes that depuration of relatively high metal concentrations would occur. Unfortunately, for the most part the metal levels remained fairly constant or increased during the holding experiments. Zinc levels significantly increased for both Milford Harbor water treatments (Tables 2 and 3). Cadmium levels increased significantly after the oysters were held 30 weeks in sand-filtered water, while cadmium levels increased significantly for some, but not all exposure periods for the unfiltered harbor water. Silver levels in oysters remained essentially the same during the entire holding period for both treatments. Copper concentrations in oysters increased from 363 to 702 ppm after 12 weeks of exposure to unfiltered Milford Harbor water, but levels decreased after 24 weeks and reached a level of about 200 $\pm$ 50 ppm at the 30- to 48-week period (Table 2). In contrast, copper concentrations in oysters held in sand-filtered water did not change significantly, except for the 24- and 42-week holding periods (Table 3).

Silver, cadmium and zinc concentrations did not decrease substantially in oysters transferred from the Housatonic River to Beaufort, North Carolina, over the 40-week period of study (Table 4). Mean copper levels in oysters decreased, but only

TABLE 2

Metal concentrations in oysters transferred from the Housatonic River to Milford Harbor water

Time[a] (weeks)	Mean ppm ± s.e. (wet weight)			
	Ag	Cd	Cu	Zn
0	1.3 ± 0.15	3.2 ± 0.44	363 ± 42	959 ± 72
6	1.3 ± 0.21	4.4 ± 0.38	408 ± 67	895 ± 121
12	1.2 ± 0.29	3.9 ± 0.38	702 ± 147	1150 ± 155
18	1.1 ± 0.19	4.6 ± 0.66	642 ± 121	1267 ± 192
24	1.6 ± 0.24	4.3 ± 0.48	347 ± 76	1700 ± 228
30	1.9 ± 0.36	3.4 ± 0.46	237 ± 60	1238 ± 270
36	1.9 ± 0.30	4.2 ± 0.31	197 ± 38	1282 ± 206
42	2.3 ± 0.42	3.4 ± 0.29	248 ± 69	1369 ± 230
48	1.9 ± 0.26	3.3 ± 0.36	171 ± 8	1292 ± 103

[a] Experiment ran from February 1974 to January 1975.

TABLE 3

Metal concentrations in oysters transferred from the Housatonic River to sand-filtered Milford Harbor water

Time[a] (weeks)	Mean ppm ± s.e. (wet weight)			
	Ag	Cd	Cu	Zn
0	1.6 ± 0.12	3.2 ± 0.22	232 ± 18.2	1228 ± 102
6	1.3 ± 0.21	3.2 ± 0.50	217 ± 34.9	1327 ± 141
12	1.7 ± 0.17	3.6 ± 0.51	266 ± 32.9	1510 ± 131
24	1.2 ± 0.13	4.2 ± 0.31	174 ± 12.5	1110 ± 75
30	1.9 ± 0.21	5.1 ± 0.33	250 ± 27.8	1910 ± 237
36	1.9 ± 0.22	5.2 ± 0.31	272 ± 33.1	1980 ± 139
42	1.3 ± 0.21	4.9 ± 0.30	305 ± 41.1	1670 ± 200

[a] Experiment ran from December 1974 to October 1975.

the 27-week period was significantly lower than controls (0 weeks). These data indicate that oysters retain their metal content when transferred to relatively unpolluted waters. Evidence that the North Carolina water is relatively unpolluted, compared to the Housatonic River, is provided by metal data obtained on oysters from Beaufort, North Carolina (Table 1, 0 weeks samples).

TABLE 4

Metal concentrations in oysters transferred from the Housatonic River to Beaufort, North Carolina

Time[a] (weeks) held in North Carolina water	Mean ppm ± s.e. (wet weight)			
	Ag	Cd	Cu	Zn
0	1.2 ± 0.14	2.8 ± 0.14	150 ± 16.0	1500 ± 139
14	0.82 ± 0.114	2.6 ± 0.26	114 ± 21.3	1215 ± 155
27	1.3 ± 0.10	2.7 ± 0.15	112 ± 8.2	1455 ± 75
40	1.2 ± 0.13	2.2 ± 0.18	126 ± 17.5	1380 ± 104

[a] Experiment ran from August 1975 to June 1976.

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