Bull. Environm. Contam. Toxicol. 22,643-647 (1979)

Trace Metal Uptake by Three Species of Mollusks

Richard A. Greig

National Marine Fisheries Service, Northeast Fisheries Center,
Milford Laboratory, Milford, Conn. 06460

Investigation of trace metal accumulation by bivalve mollusks in artificial systems is important to determine the mode of uptake by these animals. It is desirable to know if bivalves: 1) accumulate metal directly from seawater; 2) obtain it from their food; or 3) take it up from the bottom sediment in which they reside. If seawater is the prime source of the metal, removing metals from the waterways may result in relatively rapid depuration of metals from the tissues of these marine animals. On the other hand, if food or sediment is the source, a longer depuration period may be required. In the present study we examined only the first mode; however, we intend to investigate the other two modes in future studies.

Various investigators have studied the accumulation of metals by mollusks. For example, PRINGLE et al. (1968) studied the uptake of eight metals by several mollusks and found that the eastern oyster accumulated more metal (for most of the eight metals) than did the surf clam (the ocean quahog was not studied). SHUSTER and PRINGLE (1969) studied metal accumulation by the eastern oyster and found that this mollusk accumulated much more zinc and copper than either cadmium or chromium. EISLER et al. (1972) examined the uptake of cadmium by four different marine animals; during a 21-day exposure to 10 ppb cadmium, oysters and scallops took up nearly the same quantity of metal and both accumulated considerably more metal than either lobsters or mummichogs.

0007-4861/79/0022-0643 $01.00

In the present study we examined the uptake of silver, cadmium, and copper by ocean quahogs, surf clams, and oysters when they were exposed to all the metals simultaneously. This was done to determine if there was differential uptake of the metals by these three species.

MATERIALS AND METHODS

Ocean quahogs were obtained from East Matunuck, Rhode Island; surf clams from Huntly Island near Niantic, Conn.; and oysters from Northport, Long Island. These bivalves were kept in Milford Harbor for 2-3 weeks until the start of the experiment, April 27, 1977. The animals were then placed in black aquaria (about 228 liters of water) and flowing, sand-filtered seawater (containing 0, 10, and 20 ppb of Ag, Cd, and Cu) was introduced by using the diluter system described by MOUNT and BRUNGS (1967). The nitrate salt was used as a source for all three metals. The reference to "0" concentrations of these metals is used only to facilitate identification of the control seawater. Unfortunately, we were not able to analyze the concentrations of these metals in the control seawater. The work by WALDHAUER et al. (1978) shows that copper concentrations can reach levels as high as 10-20 ppb or even higher in some areas of Raritan Bay. It is certainly possible that the Milford Harbor water used in the present study could contain copper at concentrations similar to Raritan Bay. This point will be brought out again in the discussion.

Ten animals of each species were placed in each aquarium and there were 12 aquaria in all for the various exposures and time periods. The animals were not fed during the 6-wk holding period. The temperature of the seawater during this period ranged from 10° to 17°C, but most of the time it was at 12°-14°C; the salinity range was 25 to 28 o/oo.

Animals were removed at intervals of 0, 15, 29, and 43 days and analyzed for uptake of Ag, Cd, and Cu, using the procedure described by GREIG et al. (1975). The whole animal, minus shell, was used for analysis. Because these animals were not fed during the experiment, it is probable that they cleared their stomachs before the first sampling at 15 days.

RESULTS AND DISCUSSION

Tissue concentrations of Ag, Cd, and Cu are shown in Tables 1-3. The oyster took up all metals to a greater extent than either the quahog or surf clam. However, it was unexpected that surf clams took up nearly as much silver as oysters, especially at the 20 ppb exposure level (Table 1). Surf clams accumulated much less Cd and Cu than oysters. In fact, they were more similar to quahogs; thus, it was unexpected that they took up so much silver. The ocean quahog also took up more silver than it did cadmium; in fact, the amount of silver was similar to the amount of copper accumulated by this animal.

TABLE 1

Silver concentrations (mean ± std. dev.) in ocean quahogs, surf clams, and oysters exposed to various silver-seawater solutions*.

Time (days)	Quahogs	Surf clams	Oysters
		Controls	
0	3.8 ± 1.63	0.44 ± 0.315	1.6 ± 0.47
15	2.7 ± 1.15	1.4 ± 0.70	1.5 ± 0.33
29	3.2 ± 1.90	1.7 ± 1.20	1.5 ± 0.34
43	2.5 ± 1.51	0.75 ± 0.51	1.3 ± 0.35
		10 ppb	
15	4.5 ± 2.00	2.1 ± 0.80	5.4 ± 2.26
29	2.7 ± 1.38	3.1 ± 1.64	9.2 ± 4.75
43	3.5 ± 1.93	6.0 ± 2.65	15.4 ± 7.19
		20 ppb	
15	4.7 ± 2.16	6.1 ± 1.47	8.5 ± 3.28
29	5.0 ± 2.57	10.3 ± 2.98	13.7 ± 4.85
43	5.1 ± 2.45	20.4 ± 5.29	23.2 ± 7.51

* Ag, Cd, and Cu were introduced simultaneously to aquaria containing all three species.

The oyster uptake of copper was much greater than either the surf clam or quahog. The control oysters also contained a great deal more copper from their natural environment than the other two mollusks. Thus, it seems that oysters have a special affinity for copper, at least in comparison to surf clams and ocean quahogs.

Copper is an important trace element in the heme pigment of all these mollusks; thus, a logical question might be, "Why do oysters accumulate more copper than the other two species?" PRINGLE *et al*. (1968) suggested that copper may be concentrated by the mucous sheets of the oyster and particulate absorption may be suspected as a mode of uptake. Since surf clams and quahogs have physiologies somewhat similar to the oyster, this same mode of uptake for copper could apply to them also.

The concentrations of copper used in this study apparently are at a level that can occur in natural marine waters. WALDHAUER *et al*. (1978) studied the copper concentrations in Raritan Bay and found copper levels as high as 10-20 ppb in the soluble fraction of seawater, whereas in the acidified fraction (this should contain all copper in seawater, including that bound to organic materials) copper concentrations were as high as 65 ppb.

TABLE 2

Cadmium concentrations (mean ± std. dev.) in ocean quahogs, surf clams, and oysters exposed to various cadmium-seawater solutions*.

Time (days)	Quahogs	Surf clams	Oysters
		Controls	
0	0.36 ± 0.13	0.24 ± 0.09	1.8 ± 0.38
15	0.25 ± 0.10	0.17 ± 0.05	1.8 ± 0.22
29	0.27 ± 0.09	0.22 ± 0.10	1.6 ± 0.40
43	0.31 ± 0.15	0.19 ± 0.09	1.9 ± 0.44
		10 ppb	
15	0.31 ± 0.07	0.23 ± 0.07	2.9 ± 0.87
29	0.37 ± 0.06	0.32 ± 0.11	4.7 ± 0.74
43	0.55 ± 0.20	0.50 ± 0.16	7.5 ± 1.53
		20 ppb	
15	0.36 ± 0.15	0.25 ± 0.09	4.2 ± 0.94
29	0.37 ± 0.11	0.44 ± 0.14	7.1 ± 2.28
43	0.72 ± 0.21	0.93 ± 0.38	15.2 ± 4.31

* Ag, Cd, and Cu were introduced simultaneously to aquaria containing all three species.

It would have been desirable to analyze the control seawater in this experiment for all three metals, especially the copper, for comparison to the WALDHAUER et al. work. At the 10 ppb level of copper there was very little evidence of uptake by these mollusks, except perhaps for the surf clam, after 43 days of exposure. The mean of 84.3 ppm copper in oysters at 43 days is not significantly different from the controls as measured by the Student's "t" test (p = 0.05). This suggests to me that these animals came from an environment with copper levels similar to the 10 ppb exposure level. Also, the control seawater may have contained a similar level since the addition of an extra 10 ppb of copper had such a small effect on the accumulation of this metal by the three organisms.

How much of the copper is present as free ion, as compared to being bound to organic materials, is important. SUNDA and LEWIS (1978) stated "-- complexation of copper by organic ligands should considerably influence the toxicity of copper in natural waters through the effect of such complexation reactions on free cupric ion concentrations." Their work showed that free cupric ion was more toxic to algae than the organically bound copper.

TABLE 3

Copper concentrations (mean ± std. dev.) in ocean quahogs, surf clams, and oysters exposed to various copper-seawater solutions*.

Time (days)	Quahogs	Surf clams	Oysters
		Controls	
0	2.3 ± 0.71	1.2 ± 0.65	63.9 ± 20.4
15	2.8 ± 1.09	1.1 ± 0.28	60.3 ± 13.2
29	2.3 ± 0.84	0.7 ± 0.32	58.1 ± 21.7
43	1.9 ± 0.68	1.1 ± 0.34	69.5 ± 27.5
		10 ppb	
15	3.0 ± 0.86	1.8 ± 0.43	60.9 ± 23.1
29	2.9 ± 1.13	2.7 ± 1.18	67.2 ± 14.8
43	2.1 ± 0.30	3.2 ± 0.71	84.3 ± 23.0
		20 ppb	
15	3.2 ± 1.04	2.9 ± 1.17	67.0 ± 20.9
29	3.7 ± 1.21	3.8 ± 0.94	87.7 ± 25.7
43	4.2 ± 1.34	6.9 ± 2.38	117.0 ± 20.5

* Ag, Cd, and Cu were introduced simultaneously to aquaria containing all three species.

The fact that oysters took up more of all the metals studied here is not too surprising. PRINGLE *et al*. (1968) and SHUSTER and PRINGLE (1969) demonstrated that oysters took up metals to a greater extent than a number of other marine organisms. These investigators did not provide the metals simultaneously to the animals, as was done here, nor did they examine the uptake of silver. Thus, the work presented here provides new information about the accumulation of metals by these three species of mollusks.

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