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TRACE METAL CONTAMINATION OF THE ROCK SCALLOP, *HINNITES GIGANTEUS*, NEAR A LARGE SOUTHERN CALIFORNIA MUNICIPAL OUTFALL[1]

Los Angeles County's submarine discharge of municipal wastewater from the Joint Water Pollution Control Plant (JWPCP) off Palos Verdes Peninsula is the single largest anthropogenic source of trace metals to the marine ecosystem off southern California. The 1974 annual mass emission rates of chromium, copper, and zinc via this discharge (4.8×10^{11} l/yr, which underwent primary treatment only) were about 400, 300, and 850 t, respectively; these were approximately 10 times the corresponding inputs measured in 1971-72 surface runoff from southern California (Young et al. 1973). As a result, bottom sediments around this submarine outfall system are highly contaminated by a number of trace metals (Galloway 1972; Young et al. 1975). Here we report abnormal levels of seven metals in three tissues of the filter-feeding rock scallop, *Hinnites giganteus*,[2] that was collected in the discharge zone and thus had been exposed to suspended wastewater particulates. (The adductor muscle of this bivalve mollusc is considered to be a delicacy, and scallops near the discharge are sought by sport divers.)

Procedures

During 1974, divers collected eight scallops within the size range generally consumed (10 to 25 cm in diameter) from depths of about 20 m at three stations in the discharge zone between Whites Point and Point Vicente: these stations were <1 km off Palos Verdes Peninsula. Six scallops in the same size range also were taken from control stations at similar depths off Santa Catalina and Santa Barbara Islands (Figure 1). To check our 1974 results, during 1976 eight specimens within this size range were again collected from this region in the discharge zone. However, we were not able to obtain additional island samples; therefore, five specimens were collected from each of two coastal stations located approximately 50 km to the north and south of Palos Verdes Peninsula. The samples were frozen in plastic bags after collection. Later, digestive gland, gonad, and adductor muscle tissues were excised from each specimen before it was fully thawed, using a new carbon steel scalpel and a cleaned Teflon[3] sheet; the tissues were placed in cleaned polyethylene vials. Care was taken to avoid contaminating the gonadal or muscle tissue samples with sediments or juices from the digestive glands.

Following dissection, each sample (1 to 2 g wet weight) was digested in 10 ml of a 1:1 nitric acid

[1]Contribution No. 85 of the Southern California Coastal Water Research Project.

[2]Formerly *Hinnites multirugosus* (Roth and Coan 1978).

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

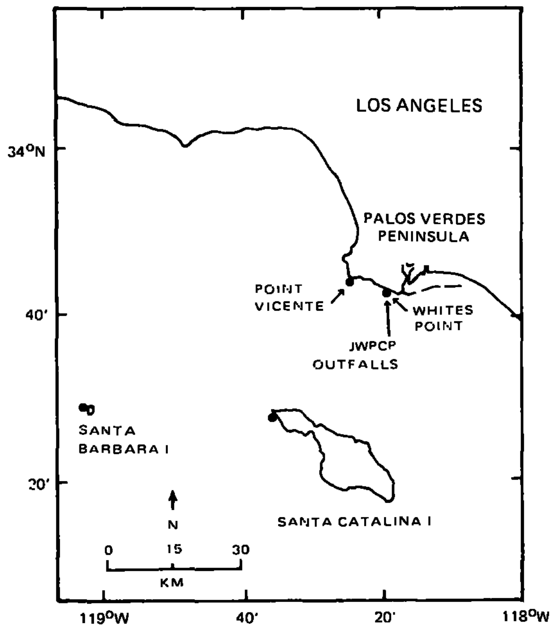

FIGURE 1.—Outfall and island control sites off Los Angeles, Calif., for collection of rock scallops.

solution (ultrahigh-purity reagent grade) until the remaining volume was about 3 ml. This procedure was repeated once, and the final residue was filtered through an acid-washed Whatman No. 40 filter. The filtrate was then diluted to an appropriate volume, and the treated sample was analyzed by atomic absorption spectrometry. Silver, chromium, copper, nickel, and lead were measured by injecting 2.5 μl of sample into a graphite furnace; cadmium and zinc levels were determined by aspirating the sample into an air-acetylene flame.

Process blanks were analyzed with all samples. Typical blank corrections were <10% of the gross concentrations observed, except for chromium, nickel, and zinc in adductor muscle, where the blank corrections were 15-20% of the gross concentrations. To test digestion efficiency, residues collected after filtration were redigested following the same procedure employed initially but using only 5 ml of 1:1 nitric acid solution; levels measured in the residue generally were <5% of the concentrations found in the first digestion. In addition, using this procedure on Standard Reference Material No. 1571 (orchard leaves) we have obtained values for our target metals which are within the ranges reported by the National Bureau of Standards (NBS); in all cases our results agreed within ±20% of the NBS values.

Results and Discussion

A comparison of the 1974 and 1976 results indicated that, for each of the seven metals studied, there were no significant differences between levels in the Palos Verdes scallops collected during the 2 yr. Therefore, the data from these 16 specimens have been combined to obtain an estimate of metal concentrations in scallops around the JWPCP submarine outfalls (Table 1). However, distinctly higher levels of silver, chromium, and copper were measured in the specimens from the other two coastal stations, compared with those in the scallops from the island control sites. Alexander and Young (1976) also observed elevated concentrations of these three metals in digestive glands of the intertidal mussel *Mytilus californianus* collected within 100 km of Los Angeles, indicating the widespread influence of municipal wastewater discharges on distributions of silver, chromium, and copper in the nearshore marine ecosystem of southern California. Therefore, we have used only the data from the six island specimens to estimate natural concentrations of the target trace metals in the three scallop tissues investigated (Table 1). For each metal we have calculated a "contamination factor," defined as the

TABLE 1.—Trace metal concentrations (mg/wet kg) in tissues of rock scallops collected during 1974-76 from the Palos Verdes outfall zone (16 specimens) and from island control stations (6 specimens). Single and double asterisks indicate experimental results are significantly different from control results at $P<0.05$ and $P<0.01$, respectively.[1]

Metal	Digestive gland		Gonad		Adductor muscle	
	Outfall	Control	Outfall	Control	Outfall	Control
Silver:						
Mean	2.0**	0.31	0.21**	0.018	0.016	0.010
±SE	0.34	0.068	0.071	0.008	0.004	0.003
Cadmium:						
Mean	430	550	5.0	5.5	0.92**	0.34
±SE	76	61	1.4	2.3	0.070	0.027
Chromium:						
Mean	42**	2.2	8.8**	0.39	0.33**	0.050
±SE	5.7	0.48	3.0	0.049	0.038	0.025
Copper:						
Mean	210**	65	3.7*	2.3	0.32*	0.16
±SE	25	16	0.52	0.49	0.058	0.042
Nickel:						
Mean	1.1	1.5	0.36	0.26	0.14	0.12
±SE	0.13	0.11	0.12	0.10	0.034	0.050
Lead:						
Mean	9.3	4.4	<0.08	<0.06	<0.05	<0.03
±SE	1.8	1.4	—	—	—	—
Zinc:						
Mean	120	100	38*	20	22	22
±SE	10	17	3.9	7.2	1.7	0.69

[1]Determined by the nonparametric 2-sided Mann-Whitney *U* Test.

ratio of the mean concentrations for the outfall and control samples (Table 2).

It seems clear from these data that rock scallops living inshore of the JWPCP discharge accumulate trace metals at above-normal levels. Application of the 2-sided Mann-Whitney *U* Test (Tate and Clelland 1957), a nonparametric test which assumes neither normality nor homogeneity of variance, indicated that, in 10 of the 19 comparisons, the experimental (JWPCP) results are significantly different from those of the controls (Table 1). In all 10 of these cases the experimental means are higher.

In our past studies with molluscan bioindicators, we have generally used digestive gland concentrations to locate possible metal contamination because concentrations are usually higher in this tissue than in the gonad or adductor muscle (Alexander and Young 1976; Eganhouse and Young 1976). However, these values may not be representative of the degree to which metals are actually incorporated into the body tissues because the digestive gland sample may contain ingested particulates contaminated by metals that are not biologically available. Therefore, the gonad and muscle contamination ratios found in this study are of special interest. In 7 of the 12 comparisons, the experimental results were found to be significantly higher than those of the controls (Table 2). For five of the six metals measurable (lead was undetectable in these tissues), at least one of the two contamination ratios is essentially ≥2. In addition, we found the mean concentration (±1 SE) of total mercury in adductor muscle of three Palos Verdes scallops to be 0.059±0.005 mg/wet kg. This value is more than twice the mean concentration measured in three island specimens (0.027±0.008 mg/wet kg). However, it should be noted that mercury levels in the Palos Verdes specimens were still an order of magnitude below the U.S. Food and Drug Administration action level of 0.5 mg/wet kg in seafood intended for interstate commerce.

As shown in Table 1, the mean concentration of lead in the digestive gland of the outfall scallops was 9.3 mg/wet kg, approximately 100 and 200 times the upper limit concentrations measured in the gonadal and muscle tissues, respectively. These results indicate that elevated concentrations of other metals measured in the gonad and muscle tissues were not caused by contamination from the digestive gland during dissection. Thus, rock scallops exposed to municipal discharges do appear to be capable of physiologically incorporating at least six potentially toxic trace metals in their gonadal or muscle tissue to levels at least twice normal concentrations.

The mean values for cadmium in the digestive gland and gonads of the Palos Verdes specimens were somewhat lower than those for the island controls (Table 1); the respective outfall-to-control ratios were 0.80 and 0.92. We have made similar observations in previous studies of metals in flatfish taken by trawl from the two areas (de Goeij et al. 1974; McDermott, Alexander, Young, and Mearns 1976). Liver tissue from Dover sole, *Microstomus pacificus*, collected during 1971-72 and known by their high DDT levels and high incidence of fin erosion disease to have inhabited the highly contaminated sediments, were shown by neutron activation analysis to have significantly lower concentrations of cadmium than did the livers of island control specimens; the outfall-to-control ratio was 0.33 (de Goeij et al. 1974). Analyses of subsequent collections (1972-73) using a different laboratory and analytical technique (arc emission spectroscopy) confirmed this observation, yielding an outfall-to-control ratio of 0.59 (McDermott, Alexander, Young, and Mearns 1976). In addition, analyses by atomic absorption spectroscopy recently conducted in our laboratory revealed depressed cadmium concentrations in livers of diseased flatfish collected during 1976 and 1977 off Palos Verdes Peninsula and in Seattle's Duwamish River Estuary (two regions highly contaminated by chlorinated hydrocarbons); relative to control levels, the corresponding concentration ratios were 0.60 and 0.30, respectively.[4] Further, analyses of digestive glands of intertidal mussels we collected at the base of the

TABLE 2.—Contamination factors[1] for seven metals in three tissues of rock scallops from the Palos Verdes outfall zone and island control stations. Factors indicate experimental to control ratios for mean concentrations (Table 1).

Metal	Digestive gland	Gonad	Adductor muscle
Silver	6.5**	12**	1.6
Cadmium	0.78	0.91	2.7**
Chromium	19**	23**	6.6**
Copper	3.2**	1.6*	2.0*
Nickel	0.73	1.4	1.2
Lead	2.1	—	—
Zinc	1.2	1.9*	1.0

[1]Single and double asterisks indicate significant differences between experimental and control results at $P<0.05$ and $P<0.01$, respectively.

[4]Sherwood, M. J. 1977. Fin erosion disease and liver chemistry: Los Angeles and Seattle. *In* Coastal water research project annual report, p. 213-219. South. Calif. Coastal Water Res. Proj., El Segundo. NTIS PB274463/AS.

Palos Verdes outfalls and at island control stations during 1971 yielded[5] an outfall-to-control ratio for cadmium of 0.81.

The relatively low cadmium levels often found in some tissues or organisms living around the Palos Verdes outfalls may be related to the high levels of chlorinated hydrocarbons that have accumulated there from past wastewater discharges. Concentrations of total DDT and total PCB in mussels, sediments, and flatfish from the region are 100 to 1,000 times those measured in samples from island control areas (Young et al. 1976: McDermott, Young, and Heesen 1976). Recently, Nimmo and Bahner (1976) reported that exposure of a penaeid shrimp to methoxychlor (a chlorinated pesticide somewhat similar to DDT and PCB) appeared to depress concentrations of cadmium in this organism. It is possible that animals off Palos Verdes are showing a similar effect.

Conclusions

The data presented here indicate that the submarine injection of primary-treated municipal wastewater can lead to distinct trace metal contamination of filter-feeding rock scallops within a few kilometers of the discharge. Mean values for silver, cadmium, chromium, copper, mercury, and zinc in gonadal and/or muscle tissue of specimens collected near the Los Angeles County outfalls ranged from approximately 2 to 23 times the corresponding means for control specimens. These elevations do not appear to be artifacts caused by contamination from particulates in the digestive gland, but rather to result from actual physiological uptake of the metals. Although the results of this study point to a potential problem from waste metals discharged via municipal outfalls, we do not yet know the degree to which such elevated metals affect the rock scallop or its predators.

Acknowledgments

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[5]Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management. South. Calif. Coastal Water Res. Proj., El Segundo, TR 104, 531 p. NTIS PB274462/AS.

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