Bull. Environm. Contam. Toxicol. 22,230-237 (1979)

Effects of Heavy Metals on Benthic Macroinvertebrate Densities in Foundry Cove on the Hudson River[1]

Thomas J. Occhiogrosso[2], William T. Waller[3], and Gerald J. Lauer[2]

New York University Medical Center, Institute of Environmental Medicine, 550 First Avenue, New York, N. Y. 10016

Foundry Cove is located on the Hudson River near the community of Cold Springs, New York. Sediments of the Cove are highly contaminated with certain heavy metals, apparently the result of discharges from the process associated with the manufacture of nickel-cadmium batteries. Cadmium is of special significance because of its high toxicity not only to aquatic organisms but also man. In addition, cadmium is known to concentrate in both marine and fresh water organisms (PICKERING and GAST 1972, FRIBERT et al. 1974, BIESINGER and CHRISTENSEN 1972, FULKERSON and GOELLER 1973). Cadmium has been found in elevated concentrations in fish collected from the mouth of Foundry Cove (SCHROEDER 1972).

The uniqueness of Foundry Cove as a study site lies in the degree of contamination found in the sediments. PERHAC et al. (1973) reported concentrations of cadmium in the bottom sediments of Joe Mill Creek in the Copper Ridge district of Northeast Tennessee of 3 to 5 ppm; in the Holston River sediments east of Knoxville, Tennessee, below the discharge from an industrial concern of 31 to 41 ppm; and in the Jintsu River sediment in Japan of 238 ppm. Cadmium and nickel concentrations from sediments of Foundry Cove have been reported by Oak Ridge National Laboratory personnel in excess of 60,000 ppm and 32,000 ppm respectively (BONDIETTI et al. 1973) and KNEIP et al. (1974) discuss the distribution, transport and potential effects of these heavy metals in the aquatic ecosystem.

The objective of this study was to determine the relationship of the sediment and the numbers and/or kinds of macroinvertebrate organisms observed in the sediments.

---

[1] Supported in part by funds from NSF Grant No. GI37312

[2] Present address: Ecological Analysts, Inc.
Middletown, New York 10940

[3] Present address: University of Texas at Dallas
Richardson, Texas 75215

0007-4861/79/0022-0230 $01.60

MATERIALS AND METHODS

Figure 1 shows the relative position of the ten sampling stations used for this study. Selection of stations in Foundry Cove were based on preliminary analyses of sediment samples for cadmium. Stations were selected to reflect what was felt to be a decreasing contamination of cadmium as one proceeded from Stations 1 through 4. Stations in the South Cove reference area (5 through 8) were selected to adhere, as closely as possible, to the depth profile of Stations 1 through 4 in Foundry Cove.

Benthic grab samples were collected at 9 stations in 1973; twice a month from April through October and once a month in March, November and December. In 1974, samples were collected monthly at four stations from March through October. Stations 1, 3, and 7 agreed in location with the 1973 stations and Station M-5 was a modification of the 1973 Station 5.

Three replicate samples were collected at each station using a 15 cm^2 opening Ekman dredge. Each sample was washed through a No. 30 mesh screen and preserved in 10% formalin solution to which rose bengal had been added. Samples were washed again in the laboratory and organisms were sorted for identification.

Depth, temperature, dissolved oxygen, pH and alkalinity were measured at each station at the time benthic collections were made. Standard methods were used for routine chemical analyses (APHA 1972). Statistical analyses of chemcial and benthic data followed procedures in SOKAL and ROHLF (1969).

Sediment samples collected for heavy metal analyses were dried for 24 h at 60 and then ground into fine particles. Following grinding 200 mg were dissolved in hot concentrated nitric acid. The solution was filtered, the filtrate evaporated to dryness and the residue dissolved in 5% nitric acid to a final volume of 25 mL. The final volume analyzed for cadmium, nickel, zinc, cobalt, iron and manganese by atomic absorption.

RESULTS AND DISCUSSION

Comparison of the routine chemical parameters (temperature, dissolved oxygen, pH and alkalinity) taken in conjunction with benthic samples indicate there was no difference between the stations. This is true for data collected during 1973 as well as 1974.

1973 Benthic Studies.

About 2 mo after the start of the benthic sampling program in 1973, dredging operation began in Foundry Cove. The operation was designed to remove sediments bearing greater than 10,000 ppm cadmium on a dry weight basis. A hydraulic dredge pumped sediment to an earthen lagoon and excess water was drained back into

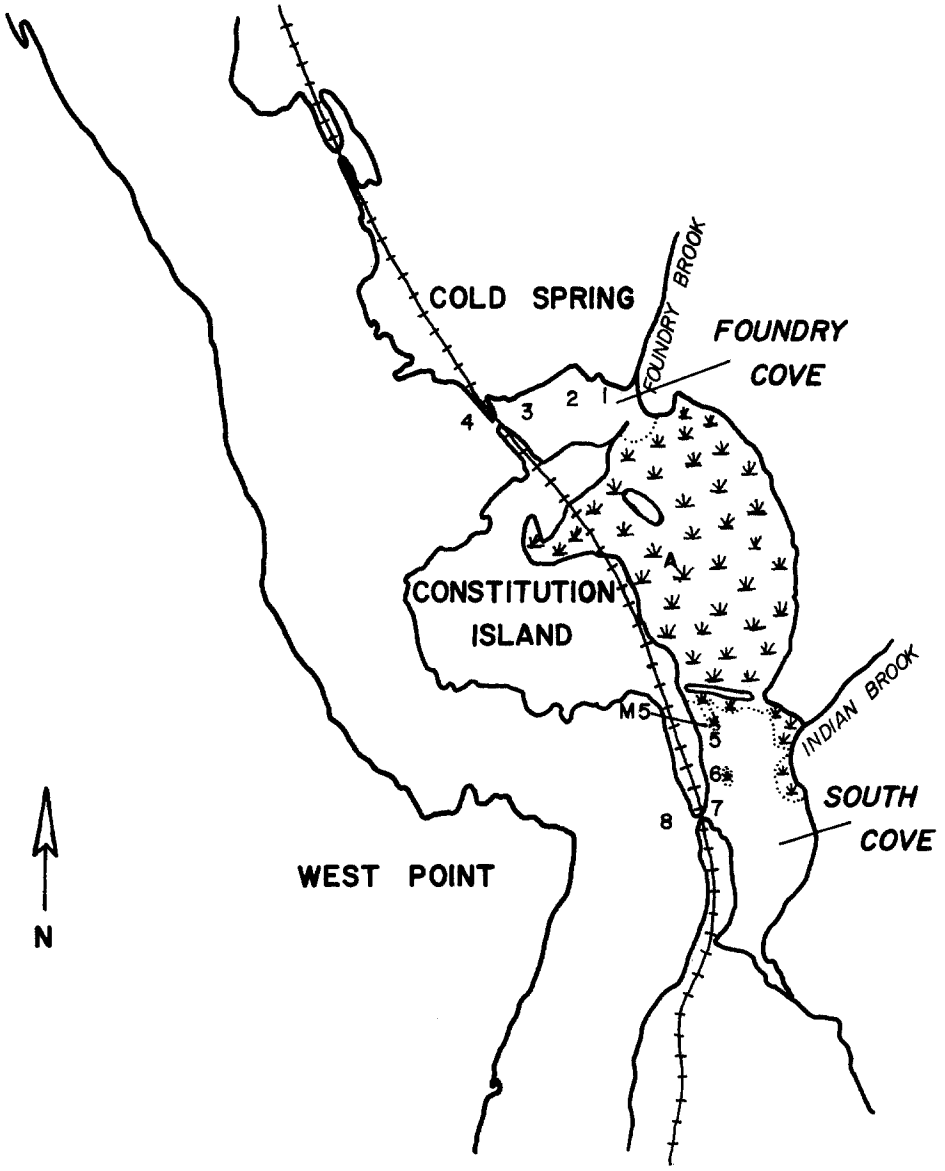

Fig. 1. Benthic Sampling Stations.

the cove. Analyses of the macroinvertebrate data for 1973 was divided into 3 periods; pre-dredge, dredge and post-dredge.

A one-way analyses of variance (ANOVA) was performed on numbers of macroinvertebrate organisms/m^2 collected from the pre-dredge period of March 27 to May 25, 1973. The results indicated a significant effect due to stations. An a posteriori test (Student Newman-Keuls) showed that the densitites of macroinvertebrate organisms/m^2 at Station 1 was significantly lower than densities collected from all other stations.

The dredge period included 4 sampling dates in June and July, 1973. Since these data violate the prerequisite for the ANOVA of homoscedasiticity, analyses of variance were not performed. However, a non-parametric test (Kruskal-Wallis) was performed and a significant difference due to stations was again indicated. A non-parametric a posteriori test (multiple comparison by simultaneous test procedure) showed that Station 1 was significantly different from all other stations.

The post-dredge period included nine dates from August 1 to December 6, 1973. The ANOVA showed a significant difference to stations and the Student Newman-Keuls test (SNK) showed that Station 1 was again significantly lower than all other stations.

The heavy metal analyses of Foundry and South Cove sediments are presented in Table 1. These data show that values, or ranges of values, for cadmium, nickel and cobalt are higher at Station 1 than all other stations.

The hypothesis of a cause-effect relationship between high heavy metal concentrations in sediments and reduced density of macroinvertebrates was supported by these preliminary data. However, other factors may have been responsible for this observation. Among these are substrate differences, dredging operations experienced at Station 1 and possible periodic tidal exposure of Station 1. Any of these could have been responsible totally or in part, for the reduced density observed at Station 1.

A soil mechanical analysis (BOUYOUCOS 1936) was performed on sediment collected from Station 1 on April 24, 1973 (pre-dredge). Sediment from Stations 1, 3, M-5 and 7 collected March 21, 1974 (post-dredge) was also analyzed by this method. Results showed that particle size distribution of the sediments, exclusive of organic material, was essentially the same (Table 2).

1974 Benthic Studies.

Analyses of the 1973 data indicated a significant difference in the density of macroinvertebrates collected from Station 1 when compared to all other stations. The 1974 studies focused on monitoring this difference and exploring various possibilities potentially responsible for this observation. Changes in the sampling program involved: reduction in the number of stations to 4;

modification of the 1973 Station 5 to insure periods of tidal exposure (M-5); and a change in sampling frequency to once a month. Justification for the changes in the sampling program were based on an analysis of the 1973 data which showed that results obtained from samples collected twice per month differed little from results obtained using data from alternate collections.

TABLE 1
1973 Heavy Metal Concentrations in Bottom Sediments (ppm dry weight)

Station	Cobalt	Cadmium	Nickel	Zinc	Iron	Manganese
1	84-1,020	3,450-48,100	1,700-11,400	352	13,800	497
2	13-34	3-903	27-408	266	18,000	507
3	15-29	39-945	59-313	660	25,600	617
4	16-20	71-135	85-134	350	15,900	548
5	15	29-44	42-59	467	26,600	412
6	6	10-19	25-40	376	1,920	527
7	16	20-135	46-104	463	24,000	636
8	17	11-22	41-43	347	6,630	824
A	19	245-361	219-241	358	17,800	443

TABLE 2
Soil Mechanical Analysis Results

	STATIONS				
	Pre-Dredge	Post-Dredge 1974			
	1	1	3	M-5	7
% Sand (2.0-0.005mm)	89 91	89	88	91	89
% Silt (0.05-0.005mm)	7 6	5	5	5	5
% Clay (0.005mm)	4 2	6	7	4	6

A one-way ANOVA was run on the density of macroinvertebrates collected during the 8 dates from March 21 to October 24, 1974. Results of the ANOVA indicated a significant difference due to stations. The SNK test again showed the density of macroinvertebrate organisms at Station 1 to be significantly lower than all other stations. These results agree with the 1973 benthic data.

Heavy metal analyses of Foundry and South Cove sediments was restricted to cadmium in 1974 and are presented in Table 3. Again, the range of values for Station 1 is appreciably higher than for all other stations.

TABLE 3
1974 Cadmium Concentrations in Bottom Sediments
(ppm Dry Weight)

Station	Cadmium
1	4,180-7,950
3	590-2,700
M-5	10-173
7	30-155

TABLE 4
Percentage Composition of Macroinvertebrates

Collected due to Oligochaetes and Chironomids
Based on Total Numbers of Macroinvertebrates Collected

1973 Post-Dredging (9 sampling dates)

Station	Oligochaete #	Oligochaete %	Chironomid #	Chironomid %	% of Total	Total Collected
1	606	90	55	8	98	674
3	1110	50	1020	46	96	2209
7	885	50	758	43	93	1759

1974 (8 sampling dates)

Station	Oligochaete #	Oligochaete %	Chironomid #	Chironomid %	% of Total % of Total	Total Collected
1	357	80	81	18	99	444
3	865	64	413	31	95	1342
7	1114	64	428	25	89	1737

Analyses of the macroinvertebrate density data show, in particular, a highly significant difference between Station 1 and Station M-5. Station M-5 was chosen to undergo periodic intervals of tidal exposure similar to that observed at Station 1. Therefore, tidal exposure was probably not responsible for the observed difference.

Table 4 compares percentage composition of the macroinvertebrate organisms composed of oligochaetes and chironomids at Stations 1, 3 and 7 in 1973 and 1974. 1973 data are based on the 9 sampling dates after completion of dredging operation in Foundry Cove. 1974 data are based on all 8 sampling dates.

Total organic carbon determinations were also performed on sediment samples from the 4 stations used in 1974. Results of these tests showed Stations 1 and M-5 as well as Stations 3 and 7 to be very similar in percentage of total organic carbon, particle size distribution, and tidal exposure, but significantly different in the density of macroinvertebrate organisms. These data suggest that these factors are not responsible for the observed reductions in the density of benthic macroinvertebrates at Station 1. However, the area of the most contaminated sediments, for which reductions in macroinvertebrate densities were observed, is small. The significance of these data may not be related to the observed decrease in benthic macroinvertebrate densities in the region of highest contamination, but rather related to the fact that macroinvertebrates survive in these sediments at all. Survival of fish food organisms under these conditions greatly increase the potential for concentration or "biological magnification" of these chemicals. Cadmium is known to concentrate in both marine and fresh water animals although there is no evidence at present that cadmium is "biologically magnified" (PREIGLE et al. 1968, FULKERSON and GOELLER 1973).

Additional studies are being carried out to examine transport and availability of cadmium in Foundry Cove. Regardless of current heavy metal availability, Foundry Cove remains in a sink of high heavy metal contamination and careful scrutiny should be given toward the development of the area. Rapid growth or uncontrolled development of the area might lead to a rapid increased availability of these metals to the aquatic biota and/or man.

ACKNOWLEDGEMENT

We acknowledge the cooperation of T. J. Kneip and H. Hirshfield as well as T. Hernandez, Gary Re', and K. Buehler for their help with the field sampling program and heavy metal analyses.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION: Standard Methods of the Analysis of Water and Waste Water. 13th ed. APHA Inc., N.Y. 874, (1971).

BIESINGER, K.E. and G.M. CHRISTENSEN: J. Fish. Res. Bd. Canada 29, 1691 (1972).

BONDIETTI, E.A., F.H. SWEETON, T. TAMURA, R.M. PERHAC, L.O. HULETT and T.J. KNEIP: Characterization of Cadmium and Nickel Contaminated Sediments from Foundry Cove, New York. First Annual NSF Trace Contaminants Conference, August 7-10, (1973).

BOUYOUCOS, G.J.: Soil Sci. 32, 225 (1936).

FRIBERG, L.T., M. PISCATOR, G.F. NORDBERG AND T. KJELLSTRAM: Cadmium in the Environment. 2nd ed. CRC Press, Inc. Cleveland 248, (1974).

FULKERSON, W. and H.E. GOELLER: Cadmium, the Dissipated Element. Oak Ridge National Laboratory, Oak Ridge, Tenn. 473, (1973).

KNEIP, T.J., G.R.E. and T. HERNANDEZ: Cadmium in an Aquatic Ecosystem: Distribution and Effects. In: Proceedings of the 8th Annual Conference of Trace Substances in Environmental Health, University of Missouri (1974).

PERHAC, R.M., F.H. SWEETON and T. TAMURA: Cadmium in Stream Sediments. In: Material Resources and Recycling, Report of Progress, January 1, 1971 to June 15, 1972. ORNL 134, (1973).

PICKERING, Q.H. and M.H. GAST: J. Fish. Res. Bd. Canada 29, 1099, (1972).

PRINGLE, B.H., D.E. HISSONG, E.L. KATZ and S.T. MULAWKA: Trace Metal Accumulation by Estuarine Mollusks. J. Sanit. Eng. Div. 94 (SE3), 455-75, (1969).

SCHROEDER, H.A.: Fish caught near a battery factory on Hudson contain up to 1000 times normal Cd. as reported by Lyons, The New York Times, Sunday, June 13, (1971).

SOKAL, R.R. and F.J. ROHLF: Biometry. W.H. Freeman, San Francisco. 776, (1969)