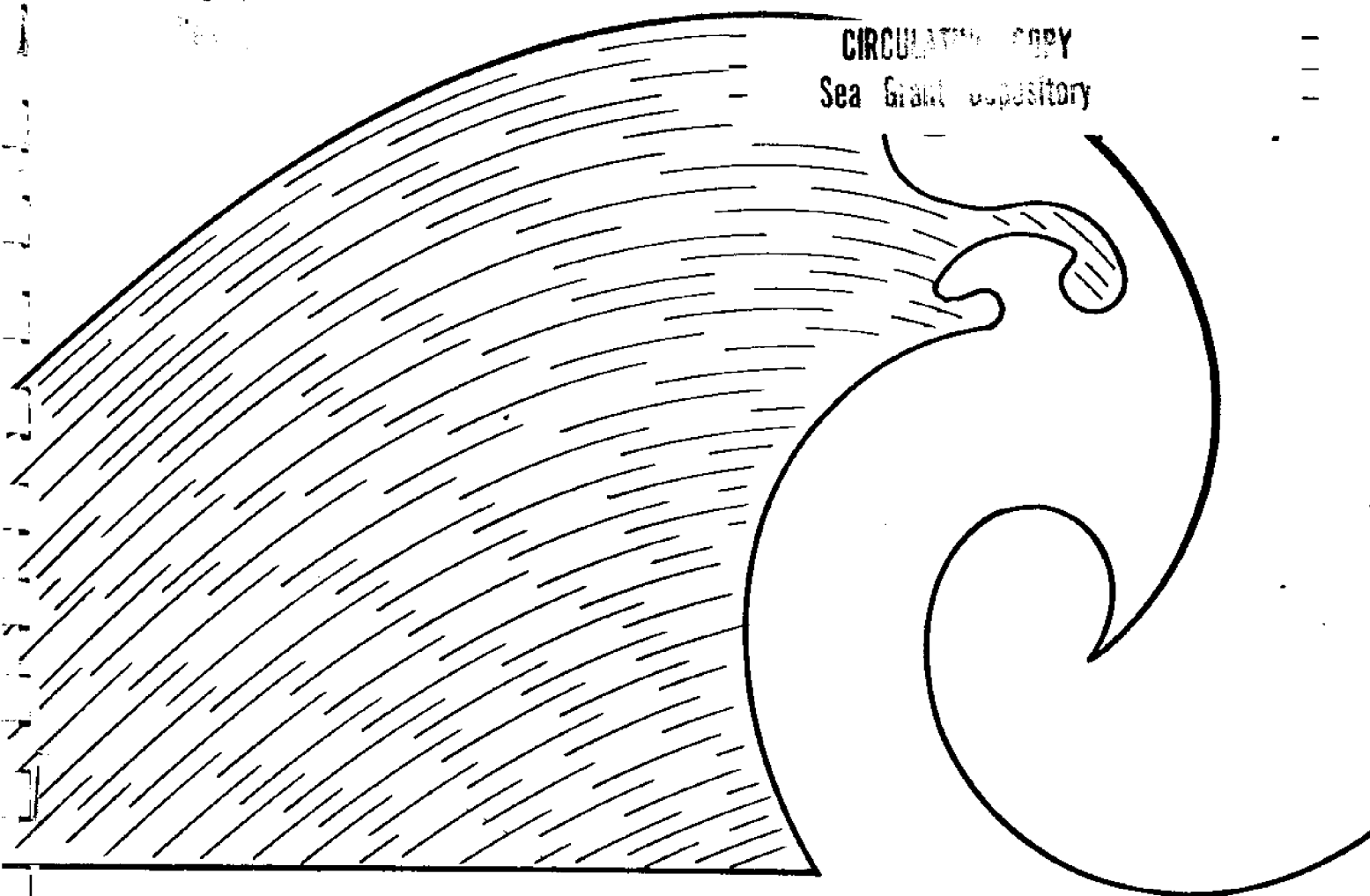


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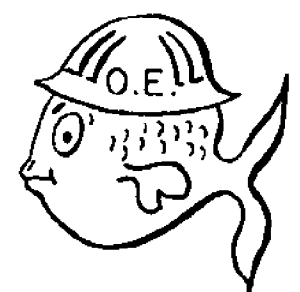
Report Number 8

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SEDIMENT POLLUTION STUDY OF NARRAGANSETT BAY

BY
U. NACCI, C. POON, AND M. HUSTON

20 NOVEMBER 1970



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SEDIMENT POLLUTION STUDY OF
NARRAGANSETT BAY

by

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University of Rhode Island

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SEDIMENT POLLUTION STUDY OF NARRAGANSETT BAY

V. Nacci; C. Poon; M. Huston

1.0 Introduction

While pollutant concentration levels in estuarine waters usually define the ecological state of the system, for many reasons a knowledge of the concentration level in the sediments may be more revealing and important in establishing the quality of the estuary.

Pollution levels in bay waters tend to respond to tidal, seasonal, temporal, etc. influences and must be sampled accordingly. In addition, the very low level of many pollutants often defy analyzation.

On the other hand, the residence time of pollutant material in bottom sediments is usually significantly longer and more stable than in the water column. The concentration factor is enhanced by deposition of solid wastes, particularly by flocculation; flocculation of organic clays, and silt, occurs when these particles are transported from fresh to salt water, and by feeding and burrowing benthic organisms capable of concentrating pollutants.

The role of sediments in a body of water has not been seriously considered in pollution survey works. The role of sediments varies with their composition, the amount of mixing with the water, and biological transformations which occur on the sediment-water interface. Sediments may only serve to support the water, or they may have a profound effect on the quality of that water which comes in contact with them.

In a body of water which man has not polluted seriously, and which has not received large amounts of land runoff, the bed will resemble the soils of the surrounding land. When the water receives runoff from fertilized fields and sewage as well as industrial-wastes discharge, the sediments assume different characteristics due to the materials that become a part of them.

Materials present in the sediments become more numerous, the soil chemistry more complex, and biological populations become more numerous and complex. Sediments begin to reflect man's influence on the entire water system. The bed of a water body, therefore, must be considered as an integral part of the aquatic system.

Although sediments consist primarily of settling particles, soluble matter is also transported to the sediments by ion-exchange and sorption mechanisms. Nutrients, metals, petroleum-products, pesticides can therefore accumulate in sediments. Organic matter mostly in the form of dead micro-organisms, also accumulate in sediments.

Depending on the chemical, biological and physical nature of the system, pollutants can be transferred between sediments and the overlying water at different rates. Chemical exchanges are considered to be rapid and reversible. Sorption and ion exchange reactions both play important roles in the chemical exchange mechanisms. Ferric iron is the center of an insoluble complex, which under aerobic conditions will hold the nutrients in the bottom materials.

When the overlying water is depleted of oxygen, the iron is reduced to ferrous state and together with nutrients, phosphates, ammonia, bases and other reducing material, goes back into the water. When dissolved oxygen level in this water is raised, the iron is oxidized to the ferric phosphate ($Fe_2P_2O_7$) and absorb phosphorus and nitrogen to ferric hydroxide ($Fe(OH)_3$). The iron can be prohibited from re-solution in the presence of sulfide which permits the formation of ferrous sulfide (FeS) and is precipitated as an insoluble compound to the sediments.

Sorption is affected by the presence of hydrogen sulfide and alkalinity. Phosphorus absorbed to $Fe(OH)_3$ precipitate for example can be brought into solution by H_2S or H_2CO_3 and $(Ca(HCO_3)_2)$.

A major factor in the ion exchange process is the availability of hydrogen ions that will replace the nutrient ions bound to the particles. A source of hydrogen ion in water is the decomposition of organic materials which produces CO₂ or carbonic acid. Higher concentrations of nutrients are found in the soluble state in deoxygenated waters such as polluted or deep uncirculated ocean, where decomposition of organic materials has produced an increase in hydrogen ion concentration. Metal concentrations are remarkably affected by hydrogen ion concentrations in the water. Insoluble metals are made soluble in acid environment. For example, in the anaerobic hypolimnion of Wiggons Mill Pond, North Carolina, concentrations of phosphorus, ammonia, iron and manganese were found at double, triple, five and eight times, respectively, the concentration in the aerobic epilimnion.

Biological exchanges generally are slow and enter into complex biochemical cycles of nature. It is known that bacteria are capable of liberating phosphate from organic compounds and transforming insoluble compounds of phosphorus into soluble ones. Bacteria living within mud, as well as at the mud-water interface, therefore, affect nutrient exchange. Releasing of nutrients and metals into overlying water have been detected at a rate proportional to metabolic activities. In addition, benthic organisms may re-suspend or redeposit nutrients on the mud surface through burrowing activities.

2.0 Sediments of the Bay

The probable origin of Narragansett Bay dates prior to the carboniferous time when, after long periods of erosion, sands and muds were deposited in the region. Evidently the subsidence of this area kept pace with deposition and much of the deposit was converted into gneiss and schist. During the Paleozoic epoch, shale and sandstone formed from deposits that had accumulated. The sedimentary rocks were then folded and metamorphosed by forces that acted during the rise of the Appalachian Mountains.

During glacial periods, the whole of the basin was occupied by glacial ice. Undoubtedly by this time, the rocks of the basin were deeply decayed and therefore, greatly subject to the erosional effects of ice and subglacial streams. Probably this region was depressed several hundred feet below its present level. As the ice retreated, abundant glacial deposits were laid down.

Borings indicate that at the present time, the rock surface beneath the bottom sediments of the bay, is highly irregular, to depths of about 400 feet in places and with almost no cover in others. Glacial deposits, ranging from cobbles and till in the upper reaches of the bay to considerable thicknesses of outwash sands and silts in the mid and lower bay areas where deep gorges of entrapped silt and clay are often encountered. Recent organic silts from a few to 30 feet often overly the glacial deposits.

3.0 Scope of Study

As a start in the pollution survey program, the effort was limited to measuring a few chemical parameters. It was hoped that some indication of the state of pollution in Narragansett Bay could be established.

Data collected for this part of the study can be summarized in Table 1.

3.1 Analytical Methods

Hydrogen ion concentration (pH) -- electrometric (pH meter)

Metal -- Atomic absorption (Beckman AAU)
(Cu, Cr, Ni)

1. Water extraction -- overnight-shaking
2. Acid extraction -- sulfuric and nitric acids digestion with heat

Organic content -- Hydrogen Peroxide

Calcium carbonate -- Acid Neutralization

3.2 Discussion

Originally zinc was also chosen as one of the metals to be analyzed from

sediment samples. Unfortunately the lamp with zinc element for the Beckman AAU was not functioning properly. As a result, only copper, chromium and nickel were measured. These metals were selected for the study because they are frequently found in sewage and industrial wastes.

Before examining the metal concentrations of the samples, an explanation of the purpose of using different methods of extraction for the determination of metal concentrations is in order. In water extraction, the sediment sample is shaken and suspended overnight in a known amount of distilled water. Metals which are soluble in water will be released from the sediment into solution. Insoluble metals will remain intact except for any biological transformation that might have occurred in the shaking period. This extraction procedure resembles what takes place in nature when sediments are scoured by under current and burrowing activities of benthic organisms. In acid extract, strong acids are used in digestion of sediments so that all metals studied will become soluble and are released into solution. This takes place in nature only when vigorous anaerobic-metabolism by benthic organisms is in effect. Anaerobic decomposition of organic matter releases acids as by-products which will in turn release metals into the overlying water. Since acid extraction in the laboratory is much faster and more complete, the metal from such sediment samples will be released in smaller amounts and at a much slower rate. However, such data (metal concentration from acid extraction) should serve as an indication of the ultimate pollution load in the sediment. Physical condition (under-flow current) and biological condition (anaerobic metabolism and burrowing activities) will dictate the amount and the rate at which metals will be released into the overlying water.

4.0 Sediments--Chemical Parameters

The stations from which sediment samples were taken stretch from the head to the mouth of the bay. Since Whale Rock is situated in the mouth of

the Bay, where pollution is considered little or none, concentrations of pollutants there are taken as the background with which concentrations in other stations will compare. Only small amounts of copper and nickel were found in the acid extract sample. No chromium was detected at all. With this information, metal concentrations in other stations and their relative locations can be compared for assessing possible pollution levels. Starting with the head of the Bay, samples were taken and analyzed at stations Q, P, O, L and I. The northern most station, Q, at Gaspee Point is expected to show much pollution since large amounts of municipal and industrial wastes, treated and not treated, are discharged at or near the station area. This is proven to be the case by examining the nickel concentration at Station Q. The nickel concentration from the acid extraction solution shows an unusually high level compared to that of all other stations, including that of the background concentration. The presence of high nickel content is a good indication of industrial waste pollution. Other stations, P, O, L, and I show metals concentrations similar to that of the background levels. Apparently, significant accumulation of pollution materials in the sediments has not yet reached station P and further south.

Analysis of samples taken from the north end of West Passage (Quonset Point across to northern tip of Conanicut Island) reveal a striking change of the pollution picture. Although nickel concentrations from these samples are essentially the same as background concentrations, chromium and copper concentrations, however, were much higher. These insoluble metals may not present any pollution problem if they are retained in the sediment in moderate to high D.O. level and neutral pH conditions. Unfortunately, pH and D.O. concentrations in these stations were not determined to provide this vitally important information.

In the Dutch Island Saunderstown area, sediment samples G1, G2, and G3 show metal concentrations at the same level as in the reference station. Sample G1 has relatively high copper concentration compared to samples in the same general location. No obvious reason can be offered at this time to explain this phenomenon.

Both organic content and calcium carbonate content of the sediment samples are low. The effect of organic matter in the sediment on nutrient exchange with overlying water would be minimized.

5.0 Sediments--Physical Parameter

At a number of fixed permanent stations and at random stations in a limited area in West Passage, both water column and sediment samples were taken. Sediment samples were taken with a 3 ft. Kullenberg corer. Location of the stations is shown in Figures 1 and 2. All cores were taken in plastic core liners, removed from the corer, and sealed with caps. Cores were returned to the laboratory after each cruise and were refrigerated within 6 hours of sampling.

At least two cores were taken at each station, generally tests were made on the upper and lower core limits. No estimate of disturbances due to coring is made.

5.1 Color

The study area extended from the West Passage of Narragansett Bay to selected stations at mid-bay and the lower reaches of the Providence River. In general the sediments in West Passage are grey to grey-green while at mid-bay usually grey to black. Color of samples taken at the mouth of the Providence River are black to grey-black. Upon splitting many of the cores it was noted that a color change from green to grey took place within an exposed hour or two. Table 2 summarized the core description.

5.2 Grain Size

The distribution of particles size by weight was determined by sieve and hydrometer methods. The bulk of the sediment is sand and silt size, and little distinction with regard to location is apparent. However, within the narrower confines of West Passage, a reduction in silt or clay size is noted--probably due to greater water energy. Particle size distribution is shown in Table 2.

5.3 Shear Strength

The shear strength of the top few inches of sediment is seldom of concern insofar as engineering works are concerned, however, the sediment strengths along with porosity and permeability are part of the environmental system that determines the fitness of the environment for organisms.

The shear strength determination for the almost fluidic sediments were made upon the split cores with a penetrometer. The results, Table 2, are sporadic and inconclusive. However, the severe disturbance primarily due to the coring procedures would make any strength data almost worthless.

5.4 Water Content

The quantity of interstitial water in sediments was determined by drying weighed samples to constant weight at 105 C. A pronounced difference in water content between black and grey sediments is evident, Table 2.

6.0 Summary

As a result of data accrued from the chemical and physical investigation of the sediments of Narragansett Bay, future investigation of sediment pollution and water column-sediment pollutant exchange mechanisms seem justified. The stations studied were more or less randomly chosen and indicated that pollution in terms of settled heavy metals (chromium, copper, and nickel) was not high. Undoubtedly, had the stations been chosen relative to known industrial discharge sources higher concentrations would occur. The area near Quonset where the naval station as well as several large industrial plants discharge into the bay had significantly higher metal concentrations in the sediment.

In the upper bay, organic contents are higher and at one station the nickel content significantly higher. From the limited data there is little correlation between physical and chemical parameters except for water content, odor, color, and organic content.

Future work should include the analysis of overlying water samples for relationship to the sediment.

In addition, iron content, sulfide content, and nutrients such as nitrogen and phosphorous of the sediments should be analyzed in order to give a better assessment of pollution loadings and nutrient exchange in the Bay.

REFERENCES

- Hayes, F. R. & Anthony, E. H., "Lake Water and Sediment Characteristics and Water Chemistry of Some Canadian East Coast Lakes", *Limnol. & Oceanog.*, 3:3:299 (1958).
- Hutchinson, G. E. & Wollach, A., "Studies on Connecticut Lake Sediments 11", Chemical Analysis of a Core from Linsley Pond, Worth Branford, *San. Jour. Sci.*, 238:7:493 (1940).
- Meyers, Allen C., "A Study of a Sedimentary Environment in Narragansett Bay, Rhode Island", Report to Dr. McMaster.
- Mortimer, C. H., "The Exchange of Dissolved Substances Between Mud and Water in Lakes", *J. Ecol.* 29:280 (1941); "The Exchange of Dissolved Substances Between Mud and Water in Lakes", *J. Ecol.*, 30:147 (1942); "Underwater Soils, A Review of Lake Sediments", *J. Soil Sci.*, 1:63 (1950).
- Pomeroy, I. R., Smith, E. E. & Grant, C. M., "The Exchange of Phosphate Between Estuarine Water and Sediments", *Limnol & Oceanog.*, 10:12:167 (1965).
- Rigler, F. H., "A Tracer Study of the Phosphorus Cycle in Lake Water", *Ecology*, 37:550 (1956).

TABLE 1
SEDIMENT CHEMICAL ANALYSIS

Station Or Location	Sample No	pH	Metal Concentration ng/g of Sediment x10 ⁻³						CaCO ₃ %	Organic %
			Cu		Cr		Ni			
			W	A	W	A	W	A		
Cross Section West Passage	H-1		1.8	31.8	0	21.7	0	1.7	2.14	
	H-2		1.6	21.4	0	15.0	0	1.3	2.22	
From Quonset Point to the	H-3		1.3	10.8	0	15.1	0	1.4	6.10	
	H-4		1.3	14.2	0	16.7	0	1.5	6.49	
Northern tip of Conanicut	H-5		0	12.2	0	15.2	0	1.6	5.62	
	H-6		0	33.2	0	18.2	0	1.7	5.75	
Island	H-7		1.5	25.5	0	13.2	0	1.0	1.70	
									0.27	
Upper Bay	I	7.18	0	3.8	0	0	0.3	1.0	7.01	
	Q	7.20	0	1.3	0	0	0.3	15.2	3.87	
	P	8.00	0	0.8	0	0	0.3	1.0	7.40	
	O	7.70	0	2.9	0	0	0.3	1.1	3.63	
	L	7.30	0	3.0	0	0	0.3	1.1	15.6	
	R								13.10	
Dutch Island	G-1	6.18	0	11.2	0	0	0.4	1.6	9.70	
Saunderstown	G-2	4.15	0	1.1	0	0	0.5	1.1	21.10	
									14.00	
Area Whale Rock	G-3	6.15	0	2.9	0	0	0.4	1.1	3.82	
	2	6.32	0	1.4	0	0	0.4	1.4	2.89	
	2A	6.00	0	1.4	0	0	0.4	1.3	3.80	
	F	6.40	0	3.2	0	0	0.4	0.6	5.32	
									10.15	
									32.3	

Remark: W=water extract from sediment; A=acid extract from sediment

TABLE 2
SEDIMENT PHYSICAL ANALYSIS

Station	Sample No	Water Content %	Liquid Limit	Plastic Limit	Sand %	Silt %	Clay %	Shear Strength kg/cm ²	Color
Q	1	44	132	60	50	40	10	0.014	Black
	2	28	60	16				0.80	
	3								
P	1	125	61	35	55	35	10	0.18	Grey-green
	2	85						0.40	
O	1	165	84	43	60	40		0.08	Black
	2	131						0.15	
I	1	44			90	10		0.075	Grey-black
	2	28						0.30	
L	1	138	88	38	70	25	5	0.058	Grey
	2	123	86	36				0.08	
H	1	35	18		82	17	1	0.03	Grey
	2	27	48					0.08	
	3	72	62	32	55	38	7	0.25	Grey
	4	66	65	28	50	40	10	0.34	Grey
G	1	87	73	29				0.17	Grey
	2	89	60	24	85	15		0.17	Black
	3	47						0.18	Black
B	1	24	41	24	45	45	10	0.19	Grey-black
	2	59	49	27	75	25		0.39	Black
	3	65						0.11	
R	1	32			82	18		0.46	Grey-black
	2	33						1.05	
R	1	134	109	61	55	45		0.075	Grey-black
	2	74	90	39				0.19	

TABLE 2
SEDIMENT PHYSICAL ANALYSIS

<u>Station</u>	<u>Sample No</u>	<u>Water Content</u> %	<u>Liquid Limit</u>	<u>Plastic Limit</u>	<u>Sand</u> %	<u>Silt</u> %	<u>Clay</u> %	<u>Shoar Strength</u> kg/cm ²	<u>Color</u>
S	5	59	61	26	58	34	8	0.07	Grey-green
	6	70	69	23	70	27	3	0.30	Grey-green
	7	61	40	17	70	27	3	0.46	Grey-green
H	5	82	61	26	58	34	8	0.07	Grey-green
	6	70	69	23	70	27	3	0.30	Grey-green
	7	34	334	25	80	17	3	0.20	Grey-green
		56	22					0.46	
		25	21					0.55	Grey-green

FIGURE 2

