

# **The Mineralogy and Metal Contamination of Sediments in the Apex of the New York Bight, NY, USA: An Integrated Laboratory and Field Study of Trace Metal Behavior in an Urban Estuary**

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Owing to past and present discharge of industrial and chemical wastes in the New York Bight (NYB), sediments and biota of the NYB have been shown to contain elevated levels of enviro-toxic trace metals. These trace metals, produced by anthropogenic activities, persist at elevated levels and pose health risks to humans and the ecosystem.

Past studies have described elevated contaminant in sediments and these earlier studies focused primarily on the concentrations and distribution of the trace metals without adequate consideration of the mineralogy of the sediments hosting the contaminant and the nature of the interaction of metal contaminants with sediments. Whilst the problem of metal pollution in the NYB is a long-standing one, there is still a considerable lack of information about the mineralogy of clays, the concentrations and distribution of trace metals in clay fractions, and mobility and behavior of trace metals in this unique environment. Such an understanding of the factors controlling mobility of metal pollutant in a dynamic hydrodynamic environment is necessary for predicting the fate of substances introduced into such aquatic environments. Clays play a significant role in a diverse range of environmental problems and awareness of this role is growing (Parker and Rae, 1998). A particular important property of clays is the chemical activity of their surfaces which arises due to surface charge. This charge is caused by a combination of broken bonds, surface-growth defect and cation substitutions in the lattice. Clays therefore, may play a major role in the mobility of trace metals in aqueous environments such as, the Apex of the NYB. Hence, the principal objectives of this research are therefore:

1. To determine trace metal concentrations as a function of particle size.
2. To obtain a better understanding of the mineralogy of the NYB sediments.
3. To quantify metal-mineral interactions in these marine environments.
4. To understand the dispersion pattern of dumped waste.
5. To understand the importance of clays in the transport and storage of trace metals.

Aquatic sediments play a commanding role in regulating the concentration of most dissolved reactive trace metals in soils and natural water systems and in the coupling of the components of hydrogeochemical cycles. Thus, aquatic sediments constitute the most important reservoir or sink of metals and other pollutants. Sediments often uniquely preserve the history of pollution. One of the most important issues regarding the presence of contaminants in aquatic environments, according to Förstner (1987) is the potential availability of the contaminants in the sediments for aquatic life. It is important to determine trace metal concentrations in marine sediments, because these could be important sources of contamination of marine organisms that reside there. It has been known for several decades that trace quantities of certain elements exert a positive or negative influence on plant,

animal, and human life. Thereby, the trace metal concentration will answer how toxic are the sediments. Knowledge of particle size distribution (PSD) may contribute a good deal of information to this research. The PSD may help clarify what controls the contaminant distribution and which fraction of sediment serves as the major sink for the trace metals. The trace elements chosen in this study are, lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), nickel (Ni), and chromium (Cr). Contamination of sediments by toxic metals has become an issue of concern in many areas of the United States. This concern is justified by the fact that these sediment concentrations of heavy metals which exceed designated thresholds have proven hazardous to biological system, including humans. The effect of heavy metals on biosphere is often evidenced by declines in once-abundant biota and modification of biota residence. These metals are frequent and important contaminants in aquatic sediments. They are subject to a number of reactions in the system including sorption and precipitation. As a consequence of changing environment condition, heavy metals can be released from these sediments. A clear understanding of the mobility of trace elements in this marine environment is therefore needed.

In this study, series of sediment samples were collected during active waste dumping on summer 1976, which includes sediment sampling from Mud Dump Site (MDS), Sewage sludge area, and near shore mud-patches. These sediments sampling offered us an opportunity to study the variability, distribution and behavior of trace metals associated with sediments of New York Bight marine environments.

The particle size distribution of samples from the apex of the NYB was determined by sieve analysis. Each sediment fraction was analyzed by flame atomic absorption spectrophotometry (AAS) to determine sediment Pb, Cr, Cu, Zn, Cd and Ni concentrations. Estimated clay mineral composition of the clay fractions was determined by powder X-ray diffractometry analysis (XRD).

This research indicates that past and current municipal and industrial discharges have created reservoirs of trace metals within the New York Bight environment. During full dumping the sediments from the apex of the NYB contained high concentration of trace metals, which exceed their corresponding background levels. Higher concentrations of trace metals occurred at MDS, sewage sludge dumpsite, and considerable amounts of trace metals were also found near shore, south of Jones Beach and Atlantic Beach. As evident, the clay fractions were the most contaminated and therefore, constitute an important sink for the trace metals. The mechanical disturbance and the hydrodynamic of the Bight have resuspended the contaminated clays to occupy the bathymetric "low" of Christiaensen Basin (CB), Cholera bank and near shore environments, which have the potential to adversely impact biological systems, including humans. Thereby, clay fractions play an important role in distribution of toxic metals and perhaps other aqueous species in the NYB ecosystem. XRD analyses show that illite is the dominant phase in the clay fractions from the NYB samples. The second and third major mineral phases are chlorite and kaolinite. Mixed-layer illite/smectite levels were very low to absent. These clays occur in small particle sizes and therefore have remarkably large surface areas, thus high surface reactivities for their weights. One common property of all clays is that, their surfaces contain functional groups which interact with metal ions. This process, called *sorption*, has a strong influence on the mobility and uptake of metals in aqueous environment such as NYB. Clay minerals (e.g., illite, chlorite and kaolinite) associated with trace metals can be considered both as a sink and as pollutants in the NYB. The trace metal levels associated with

these clays indicate the dumped wastes are migrating south and north of the dumping sites to occupy low energy environment, including near shore environment.

Additionally, NYB is sediment starved, the preexisting contaminated anthropogenic sediment are occasionally reworked and distributed by both, mechanical activities and storm events. Thereby, the health of the NYB can never be restored to its pristine condition. However, the existence of pools of contaminants in low bathymetric areas should be left undisturbed. As a consequence of changing environmental conditions, enviro-toxic metals can be released from mineral surfaces (a process called desorption). This disturbance will be then marked as Chemical Time Bomb (CTB).

The NYB a “bite” of the New York-New Jersey Harbor, which is the most populated region of the nation. It provides recreational opportunities including fishing, boating, and swimming to over 20 million residents, and yet it support a world class port for both passengers and cargo. For all these reasons and more, those who work and play here should consider the Bight as resource worthy of protection. Although we can never restore this extraordinary resource to its pristine condition, we can make a difference-each of us can. Because pollution has degraded the marine life of the Bight, all the preexisting dump-sites in the Bight has been formerly closed to any further ocean disposal.

Results from this study help establish a sound scientific basis on which managers can consider resources when wastes are introduced to coastal marine environment. This study further demonstrates the importance of particle size. Clays, being the most polluted fraction and sand the least contaminated fraction in the NYB environment. Because of these findings, government agencies or policy makers should 1) use clean sand to dilute or cap the preexisting contaminated materials, 2) use clay minerals as a principal mechanism for the removal of aqueous toxic species from any water column, and 3) remove of contaminated clays fraction for further decontamination. However, the disturbance of the contaminated clays may further pose health risk to the NYB ecosystem. Thereby, it is recommended not to mechanically agitate these heavily polluted bathymetric “low” of the Bight. Since pollution in NYB occurs at large scale, insights gained from this study may be of universal application.

AMAACH, N.H., 1996, Geochemical Study of Trace Metals in Soils of the Williamsburg Area, Brooklyn ,New York. MA, Thesis, Department of Geology, Brooklyn College NY., p.87

BUCHHOLTZ TEN BRINK, M.B., ALLISON, M.A., SCHLEE, J.S., CASSO, M., LOTTO, L., and BOPP, R.F., 1996. Sewage sludge and sedimentary processes in the New York Bight: where does it go from here? EOS Transactions 76, 14, abstract.

BUCHHOLTZ TEN BRINK, M.B., BOTHNER, M.H., MANHHEIM, F.T., and BUTMAN, B., 1997, Contaminant Metals in Coastal marine Sediments: A Legacy for the Future and a Tracer of Modern Sediment Dynamics:

<http://water.usgs.gov/osw/techniques/workshop/brink.html>

CARMODY, D.J., 1972. The Distribution of Five Heavy Metals in the Sediments of the New York Bight. PhD dissertation, Columbia University Teachers College University Microfilms, Ann Arbor Mich.

FÖRSTNER, U., and WITMAN, G.T.W., 1981. Metal Pollution in the Aquatic Environment, second revised edition. Sringer-Verlag, Berlin Heidelberg New York. 486p.

GIBBS, R. J., JHA, P.K., and CHAKRAPANI, G.J., 2000, Clay Mineralogy of the Hudson River Estuary. Northeastern geology and Environmental Sciences, v. 22, no. 1, pp. 26-30.

LANGMUIR, D. 1997, Aqueous Environmental Geochemistry. Pentice Hall Book Co., New Jersey p. 600.

MASSA, A.A., DEL VICARIO, MARIO, PABST, DOUGLAS, PECHKO, PATRICIA, LECHICH, ALEX, STERN, E.A., DIETERICH, ROBERT, and MAY, B., 1996, Disposal of Waste and Dredged Sediments in the New York Bight: Northeastern Geology and Environmental Sciences, v. 18 pp. 265-285.

PARKER, A., RAE, J.E., 1998. Environmental Interaction of clays. Springer, p. 271