

Metal Concentrations in Sediments of Boston Harbor and Massachusetts Bay Document Environmental Change

“Over the last decade, contaminants entering Boston Harbor have been significantly reduced. Although parts of the harbor still contain metals at concentrations above toxicity guidelines for bottom-dwelling animals, we have observed decreasing metal concentrations over time that are encouraging. We are learning which natural sedimentary processes significantly influence the fate and transport of metals in Boston Harbor and Massachusetts Bay.”

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U.S. Geological Survey studies show that the concentrations of metals in surface sediments of Boston Harbor are decreasing with time. This conclusion is supported by analysis of (1) surface sediments collected at monitoring stations in the outer harbor between 1977 and 1993 (fig. 1), (2) sediment cores from depositional areas of the harbor (fig. 2), and (3) historical data from a contaminated-sediment data base, which includes information on metal and organic contaminants and sediment texture. During the 16 years of the continuing study, chromium, lead, mercury, silver, and zinc concentrations in surface sediments have decreased by about 50 percent. Although these trends are indeed encouraging, concentrations of some metals in harbor sediments are still above levels considered toxic to certain bottom-dwelling organisms.



Figure 2. A hydraulically damped gravity corer collected sediment without disturbing the water-sediment interface. At-sea support has been provided by the U.S. Coast Guard aboard the Cutter *White Heath*.

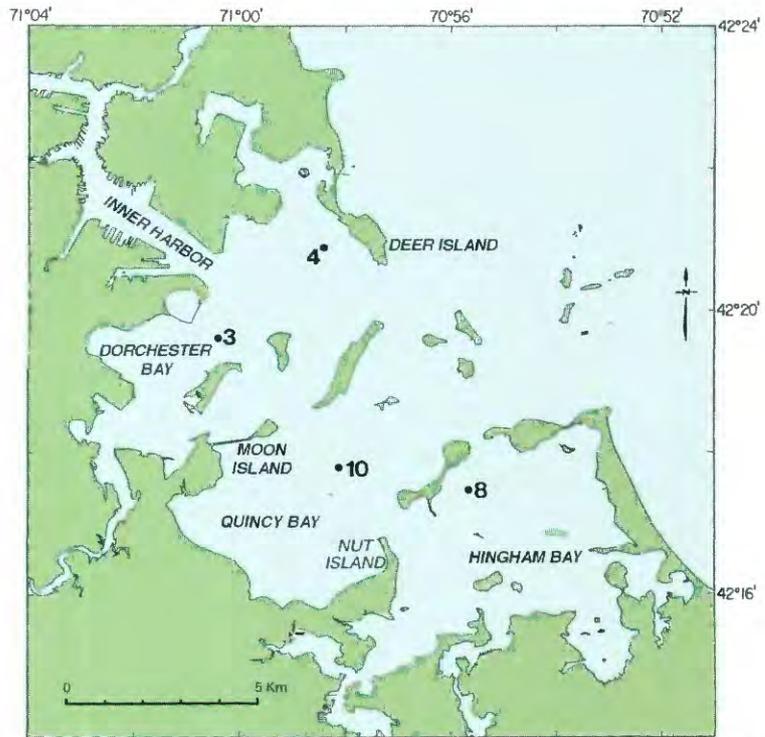


Figure 1. Four locations in Boston Harbor have been sampled periodically since 1977. Station 4 is in a sandy area and closest to the Deer Island sewage outfall. The remaining stations contain mostly silt and clay and are considered areas where sediment is actively deposited. The contaminated-sediment data base includes information on metal concentrations and other sediment parameters for about 3,000 samples collected throughout the harbor area. Numerals indicate monitoring station locations.

The quantities of contaminants being added to the harbor have been dramatically reduced as a result of Federal and State legislation and local action. The 1973 ban on lead in gasoline reduced the atmospheric flux of lead to the Earth’s surface. Aggressive enforcement of new regulations limits the amounts of contaminants in industrial wastewater. Elimination of sludge discharge to the harbor in 1991 reduced the metals added to the harbor with sewage by an estimated 50 to 75 percent during the time period of our study.

The decrease in concentrations of contaminant metals in sediments is consistent with other indications that Boston Harbor is becoming cleaner with time. As documented in the “State of Boston Harbor Report 1995” (Massachusetts Water Resources Authority (MWRA), 1996: MWRA Technical Report No. 96–6, 22 p.), beach closures are less frequent, the occurrence of disease in winter flounder is diminished, and oxygen penetration into the sediments is increasing.

A variety of natural sedimentary processes affect the rates and magnitude of reductions in sediment contamination. These processes include buildup of sediment on the sea floor, sediment mixing by animals that live in or on the sea floor, and upward diffusion of metals from contaminated underlying sediments. An additional process is sediment resuspension and transport, particularly by storms.

Despite the general decrease in metal concentrations in Boston Harbor surface sediments (fig. 3), the concentrations of Ag (silver) and Hg (mercury) measured at some outer harbor stations in 1993 were still at, or above, the level associated with frequent adverse effects to marine organisms (Ag 3.7 µg/g, Hg 0.71 µg/g) (Long, E.R., MacDonald, D.D., Smith, S.L., and Calder, F.D., 1995, Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments: Environmental Management, v. 19, no. 1, p. 81–97). Concentrations of the other metals listed were in the range considered to occasionally induce adverse biological effects.

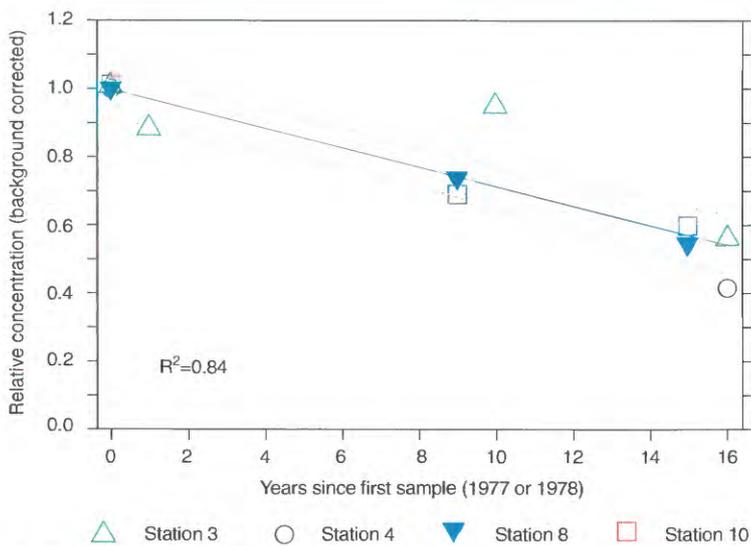


Figure 3. The normalized concentrations of lead in surface sediments decreased by 46 ± 12 percent during the 16-year period beginning in 1976. The concentrations of other heavy metals (Ag, Cr, Cu, Hg, and Zn) showed similar trends with time. R^2 is the coefficient of determination.

The longest historical record of lead use is preserved in a sediment core collected at station 8 in 1978 (fig. 4). Lead begins to increase above background at a sediment depth of about 136 cm, corresponding to 1895. After a rapid increase, the concentrations of lead in this core reached a maximum (250 $\mu\text{g/g}$) in about 1945. This profile may reflect the changing intensity of activities at the major shipyards and related industries during and after World War II. Cores collected on successive cruises in 1987 and 1993 at station 8 had lower concentrations of lead at the surface (fig. 4).

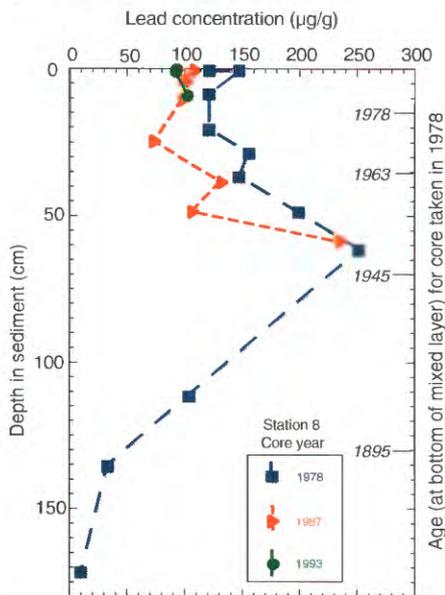


Figure 4. Profiles of lead concentrations in cores collected at station 8 between 1978 and 1993. Assignment of dates, biological mixing, and sedimentation rates (1.8 cm/yr at this location) are estimated from profiles of ^{137}Cs and ^{210}Pb .

Knowledge of the range in background contaminant concentrations and the sedimentary processes that influence them gives a needed perspective for the interpretation of environmental changes caused by man. On 24 occasions since the spring of 1989, sediment cores were collected near the future sewage outfall site in Massachusetts Bay, 15 km east of the harbor mouth. This long-term monitoring of metals in sediments of Massachusetts Bay has helped define the background concentrations and the natural variability in contaminant levels. It has also identified major storms as effective agents in contaminant transport.

Monitoring of silver showed that contaminant concentrations in surface sediments can change abruptly. Silver values were low and uniform in concentration through mid-October 1992 but had more than a twofold increase by the February 1993 cruise (fig. 5). Similar changes were measured in other variables, such as *Clostridium perfringens* spore counts, inventories of natural radioisotopes, and sediment texture. We conclude that the unusually violent storm of December 11–16, 1992, when wave heights reached 8 m, caused resuspension and transport of fine sediments and associated contaminants from shallower inshore areas to the deeper depositional areas offshore. Numerical simulations of ocean circulation suggest that, during a northeast storm, material resuspended from the bottom near the future outfall site moves offshore and southeast toward Massachusetts Bay and Cape Cod Bay.

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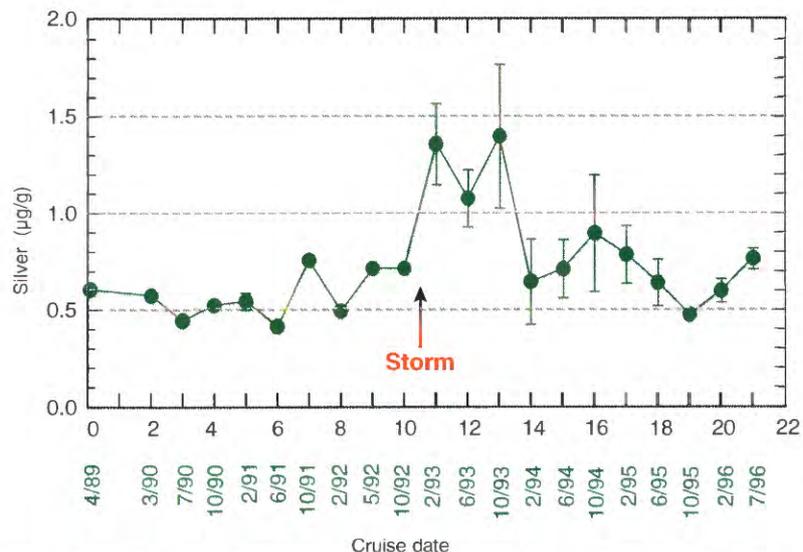


Figure 5. Concentrations of silver with time in the surface sediment layer (0–0.5 cm thick) at a muddy station near the future outfall in Massachusetts Bay. The increase after cruise 10 is attributed to the contaminants transported to this depositional center during the unusually intense storm of December 11–16, 1992.