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Concentrations of Metals and Bacterial Spores in Sediments near the Massachusetts Bay Outfall before and after Discharge Began

Introduction

Federal and state officials and the public have expressed great interest in the environmental impact of the Massachusetts Bay Outfall (Fig. 1) that began discharging an average of 380 million gallons per day of treated sewage effluent on September 6, 2000. Baseline monitoring of bottom and suspended

Figure 1. Locations of the Massachusetts Bay Outfall (red rectangle), the outfall tunnel (dashed line), the USGS mooring, and sediment sampling stations where time-series data from oceanographic instruments and chemical measurements have been made since 1989.

sediments near this outfall has been carried out by the USGS since 1989 in order to determine the cause, magnitude, and possible consequences of chemical changes prior to and after the outfall startup. The biggest change in concentration of sewage indicators in bottom sediment occurred in the pre-outfall period, and is attributed to offshore sediment transport by a major storm in December 1992. In samples analyzed *since* the outfall startup, no change has been observed in concentrations of heavy metals or bacterial spores in bottom sediments and only modest changes have been measured in suspended sediment. These

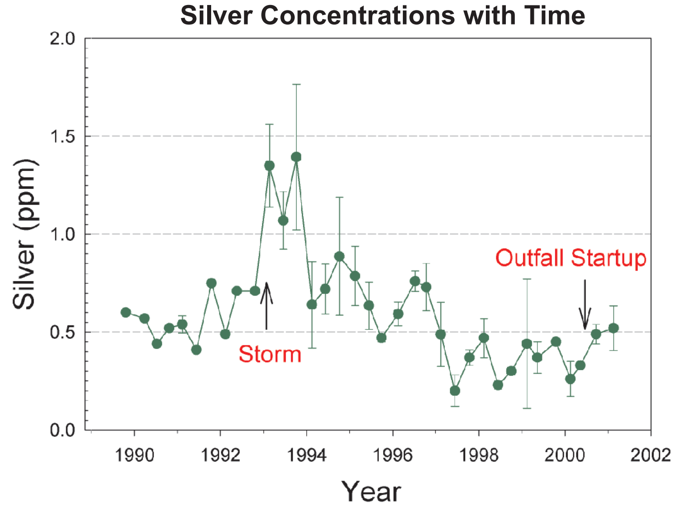

Figure 2. Silver concentrations in surface sediments (0-0.5 cm) at Station 3 since the outfall startup are in the same range as observed since 1997. The increase in February 1993 is attributed to contaminated sediment transported to this location during the intense storm of December 11-16, 1992. Error bars are defined by analysis of replicate (2-3) samples.

studies of sediment chemistry are one aspect of a multi-disciplinary USGS program in Massachusetts Bay (http://woodshole.er.usgs.gov/project-pages/bostonharbor/).

Monitoring Bottom Sediment

A long-term baseline of data on sediment composition defines the range of variability due to natural processes, and provides a critically important reference for interpreting the magnitude of any change that is observed following startup of the new outfall. In this study, silver, used in film processing, has been found to be a sensitive inorganic chemical tracer for sewage particles in marine sediments. Between 1989 and mid-October 1992, the concentrations of silver (Fig. 2) in the

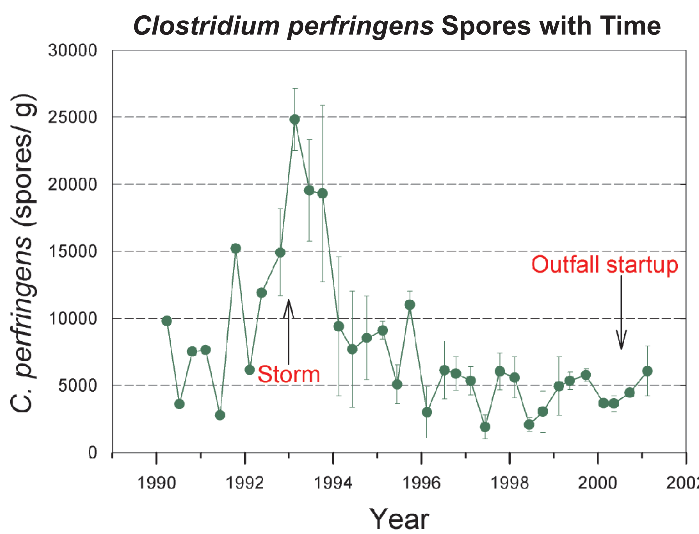

Figure 3. Post-outfall concentrations of *C. perfringens* at Station 3 were within the range observed in surface sediments (0-0.5 cm) since 1997. The change in concentrations after the storm of December 11-16, 1992 was similar to that of silver.

muddy surface sediments at Station 3 were between 0.41 ppm and 0.75 ppm. By the sampling cruise in February 1993, silver concentrations had suddenly increased more than twofold and remained elevated for more than one year. Similar changes were measured in other variables, such as inventories of natural radioisotopes, clay content, and spore counts of *Clostridium perfringens*, a benign bacterial spore found in sewage (Fig. 3). Based on numerical models of circulation and the sediment data, we conclude that the unusually violent storm of December 11-16, 1992 (wave heights reached 8 m) caused resuspension and transport of fine sediments and associated contaminants from inshore areas to the deeper depositional areas offshore such as Station 3. Winnowing, bioturbation, and accumulation of cleaner sediment could account for the return to pre-storm values by 1994.

These data highlight the importance of a long-term baseline. Had the outfall started in January of 1993, one might have incorrectly assumed that the new outfall was responsible for the increase in silver and *C. perfringens* concentrations.

The last two data points in Figures 2 and 3 represent samples collected after the Massachusetts Bay Outfall became operational. The concentrations of silver and *C. perfringens* spores are within the range of natural variability observed since the beginning of 1997 (after the storm-related increase). Statistically there is no evidence, at the 95 % level of confidence, that the post-outfall mean values are different from pre-outfall concentrations.

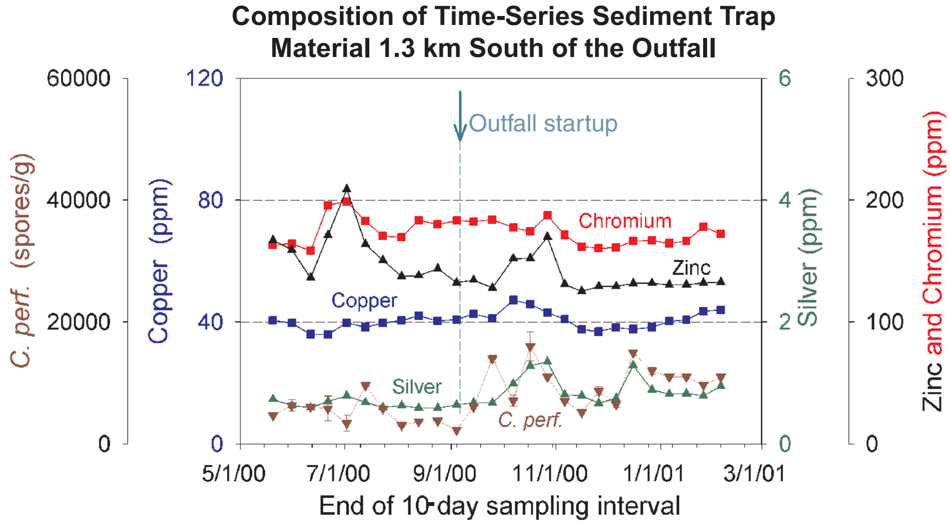

Figure 4. The average concentrations of chromium, copper, and zinc in post-outfall suspended sediment samples are the same as in pre-outfall samples. There is a 38% increase in the concentrations of silver and a factor of 2 increase in *Clostridium perfringens* in the post-outfall samples. The silver increase is well below the warning thresholds adopted for the outfall monitoring program. *C. perfringens* is considered a benign tracer of sewage particles.

Monitoring Suspended Sediment

Our environmental monitoring has also included analysis of suspended sediments collected by means of a time-series sediment trap moored 1.3 km south of the outfall at 4.2 meters above bottom in water depth of about 30 meters. The trap provides particulate matter samples collected during discrete 9-day intervals over a typical 4-month deployment period. The trap samples collected during non-storm periods are expected to be a more sensitive monitor of sewage contamination than bottom sediments. This is because trapped particles are isolated, unlike bottom sediments that are continuously mixed with older sediment of different composition by benthic organisms. The concentrations of chromium, copper, and zinc in sediment trap samples show no persistent changes following the start of discharge from the new outfall on September 6, 2000 (Fig. 4). Silver is the only metal which shows a slight increase in average concentration (0.25 ppm ± 0.06 ppm) between pre- and post-outfall. *C. perfringens* concentrations are higher in the post-outfall trap samples by about a factor of two, and there is a general correspondence between small changes in silver and *C. perfringens* over time, suggesting that effluent is the source for both (Fig. 4). Although they are elevated compared to samples collected just prior to the outfall startup, silver and *C. perfringens* concentrations are within the range of values determined on earlier trap samples collected between late 1996 and 1997 when the outfall was at the mouth of Boston Harbor and the level of sewage treatment was only primary.

The current levels of metal concentrations in bottom sediment are ≤25% of the warning thresholds established for Massachusetts Water Resources Authority's (MWRA) Outfall Monitoring Program (Fig. 5). The metal concentrations in suspended sediment are <50% of warning levels.

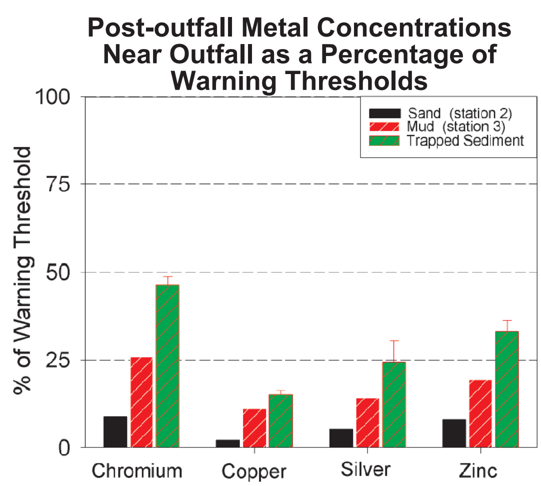

Figure 5. Metals in surficial bottom sediments (0-0.5 cm) are ≤25% of Massachusetts Water Resources Authority's warning threshold. Metal concentrations in suspended sediments are not used to guide regulatory action, but their relations to sediment quality guidelines serve as an early indicator of potential impacts on the bottom sediments. The thresholds are defined as the Effects Range - Median (ERM) levels of Long and others, (Environ. Management, v. 19, p. 81-97, 1995), and are 3.7, 370, 270, and 410 ppm for silver, chromium, copper, and zinc, respectively.

Continuing Work

This time-series of sediment chemistry data supplements the larger monitoring program conducted by MWRA. Measurements of metals in suspended sediments are scheduled through 2003 and will continue to provide an early indication of the types and magnitude of contamination potentially added to bottom sediments.

For more information, please contact:
Michael H. Bothner
U.S. Geological Survey
Woods Hold Field Center
384 Woods Hole Road
Woods Hole, MA 02543-1589
Telephone: (508) 457-2240
E-mail: mbothner@usgs.gov