Q-477 Sediments as a Reservoir of Fecal Indicators at Baby Beach, Dana Point Harbor, California

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ABSTRACT

Most of the recent studies on fecal indicator levels in coastal sediments have been conducted in tropical areas such as Florida (Solo-Gabriel, et al., 2000), Hawaii (Oshiro and Fujioka, 1995) and Australia (Davies, et al., 1995). However, fewer data are available from temperate waters or small embayments. Baby Beach, located in southern California, is subject to chronic bacterial contamination. The beach is situated in an artificial harbor protected from ocean swell and currents by a series of breakwaters. A circulation/bacterial monitoring study conducted in September 2002 indicated that water quality problems may be exacerbated due to limited circulation. Although surface currents in the area are generally slow, tides, wind, and eddies can trap surface water along the beach and also resuspend bacteria present in the sediments. Sediments may be seeded with bacteria from storm drain discharges and birds. To assess indicator levels in sediments, samples collected along transects near storm drains, bathing areas, and a control site were analyzed for *E. coli*, total coliforms, and enterococci. Sediment samples were resuspended in 1% sodium metaphosphate solution and sonicated for 30s at 30% output (Bronson ® Sonifier 450) to extract bacteria from sediment particles. Fecal indicators were enumerated from sediment suspensions and water using membrane filtration (APHA, 1998). High levels of total coliforms (3 x 10^5 CFU/10g) were obtained in sediments along a 15 ft. transect from the storm drain. *Enterococcus* counts ranged between 200 and 14,250 CFU/10g and the majority of *E. coli* levels were at or near the detection limit (200 CFU/10g). A grain size analysis was done on sediments to correlate with concentrations of bacteria. Preliminary results indicate a trend of higher indicator levels in fine-grained sediments. Sediments from storm drain transects had higher proportions of silt and clay as compared to those from near shore sites. Understanding the role of sediments as a reservoir of fecal indicator bacteria is critical for agencies involved with water quality monitoring and management of coastal waters.

INTRODUCTION

Baby Beach is located in an urbanized harbor and is widely used by families with toddlers and young children (Figure 1). Water quality throughout the harbor is generally good with the exception of the beach area located between 2 storm drains. Since 1996, the beach has frequently been posted as unsafe for swimming due to violation of the Ocean Water Contact Sports Standards. In California, the single sample standard for fecal indicators (FIB) per 100 ml recreational ocean water is 10,000 total coliforms (TC), 400 fecal coliforms (FC), 104 *Enterococcus* (ENT) or >1,000 TC if the ratio of FC/TC exceeds 0.1. Since the storm drains are not connected to sanitary sewer systems, they convey storm and urban runoff contaminated with FIB into the harbor. Shorebirds and pigeons, which can number up to the hundreds, can also contribute significant levels of FIB. Other potential sources of fecal contamination to Baby Beach include humans, domestic and wild animals and boating related activities. Identifying predominant sources of FIB has been complex and difficult. Since 1996, the County has conducted numerous investigations including:

? Dye testing of restroom facilities, including moored vessels
? FIB testing of the water column, sediments, storm drain discharges, groundwater seeps on the beach and groundwater monitoring wells
? Video taping of sewer lines and storm drains
? Blocking storm drain outlets during the summer using drain plugs
? Dredging the sand off the beach and replacing it with clean sand
? Increasing animal excrement control and cleanup
? Reducing landscape irrigation
? Installing bird netting to discourage nesting
? Educating the public about littering and bird feeding
? Increasing cleaning of parking lots and streets

Despite the intensive efforts to reduce fecal pollution at the beach, the postings continue. Monitoring data from 1997 – 2002 indicate a long-term decrease in the concentration and frequency of TC and FC contamination, suggesting some benefit of mitigation efforts. In 1999, the County began monitoring for ENT in addition to monitoring for TC and FC. Since then, most of the postings at Baby Beach have been due to exceedances of ENT standards.

Previous studies indicate FC densities in coastal sediments can be significantly higher than in the overlying water and when resuspended, can result in increased levels in water (3). However, there is little information as to the occurrence of FIB in coastal sediments in temperate climates.

In 2002, Orange County Public Health Laboratory conducted several studies to identify sources of FIB at Baby Beach, including a detailed study of the sediments throughout the beach. The concentrations of TC, FC, *E. coli* and ENT in sediments obtained near storm drains, the intertidal zone and dry beach areas were determined. The sediment particle sizes were also correlated with FIB densities to examine the possible relationship of FIB levels to sediments with higher proportions of silt and clay.

MATERIALS AND METHODS

Sample locations. A total of 145 sediment samples were collected at various intervals along transects on the beach, above and below the low-tide drop-off line and near the west storm drain area as shown (Figures 2 – 4, Table 1). Sediment samples were also collected from a shoal area located inside of the jetty (Figure 1) located distant to the storm drains.

Sample collection. Water samples (100 ml) above sediments were collected prior to collecting sediments using sterile, disposable bottles. The bottle was clamped to a 5-ft. pole to collect samples in deeper water. Sediment from 5 – 7 ft. depths below the water surface was collected by a diver. Sediment samples were generally collected during minus tide levels. Approximately 100 g of sediment was collected from the top 2 cm of sediments.

Enumeration of bacteria. Bacteria were separated from sediment particles by suspending 10 g of sediment in 100 ml 1% sodium metaphosphate and sonicating for 30 s at 30% output, using a Branson® Sonicator 450. Small volumes (0.1 – 10 ml) of the suspended sediments were then filtered similarly to water using the membrane filtration technique (1). Total coliforms, fecal coliforms, *Escherichia coli*, and *Enterococcus spp.* was recovered using m-Endo, m-FC, m-Tec, and m-EI media (9), respectively and enumerated as colony forming units (CFU) per 100 ml water or 10 g of sediment.

Sediment particle size determination. After removing 10 g for bacterial enumeration, the sediments (N=95) were dried overnight in a drying oven at 105 °C. Approximately 100 g of dry sediment was separated into 5 particle size classes using 4 screen sieves (Hubbard Scientific) stacked on top of each other as follows: #5, #10, #60 and #230 sieves for particles >5 mm, >2 mm, >250 µm and >63 µm, respectively (5,7). Finer sediments (< 63 µm) were obtained from the bottom pan. Each sub-sample was weighed to determine the percent weight by size classes and total weight.

RESULTS

There was high variability in concentrations of TC, FC, *E. coli* and ENT in sediments throughout the beach. The levels of ENT and TC in 10 g of sediment ranged from below the detection limit (< 90 CFU) to 200,000 CFU. The maximum densities of FC and *E. coli* in sediments were 12,300 CFU/10G and 100 CFU/10g, respectively. The geometric mean values for FIB concentrations in 10 g of sediment (for up to 14 samples at various points along transects) are shown in Figure 2. The geometric mean value for samples with FIB concentrations below detection are indicated as "1 CFU/10g".

Previous investigators reported detecting higher levels of FIB in fine-grained sediments with high proportions of silt and clay as opposed to coarse sand (2,4). Therefore, a particle size analysis was conducted to characterize the sediment type at various locations at the beach (Figure 5) as well as a control site (shoal) (Figure 1). A direct correlation between FIB levels and fine sediments (particles with a diameter < 0.250 mm) was not found in this study. Although elevated levels of enterococci were mainly found in fine sediments along transects at 5 – 50 ft. from the west storm drain outlet, the sediments immediately below the west storm drain had moderate to high proportions of gravel and coarse sand. Finding FIB in coarse sediments at random sites where a number of seagull droppings were observed on the sand, further complicated finding a correlation to fine sediments. The average concentration of enterococci found in seagull droppings (N=18) was 1.4 x 10^7 CFU/g.

The mean levels of ENT was determined for 5 samples each of sediments and overlying water collected daily near the storm drain outlet over a 4 day period. The mean concentrations of ENT were generally higher in sediment than in the overlying water (Figure 6). In contrast, ENT and *E. coli* levels in sediment obtained at a control site distant to the storm drains were below the detection limit.

Figure 1. Baby Beach, Dana Point Harbor

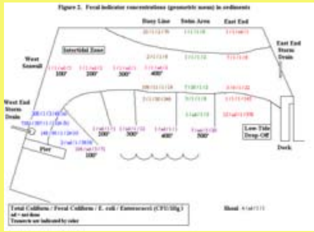


Table 1. Sampling transects.

West End Storm drain
(a) Up to 50 ft. north of the mouth of the drain.
(b) From the drain mouth to 12 ft east at the waterline.
(c) From below the waterline to a distance of 15 ft east, at 2 ft. water depth.
(d) From below the waterline to a distance of 20-50 ft. east, at 7 ft. water depth

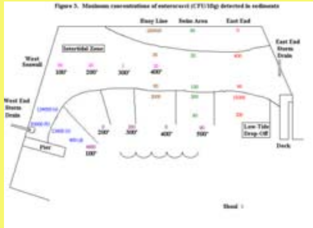
Buoy Line
60 ft. and 30 ft. above the Low-Tide Drop-Off. 0 ft., and 5 ft. below the Low-Tide Drop-off; to a maximum depth of 5 ft.

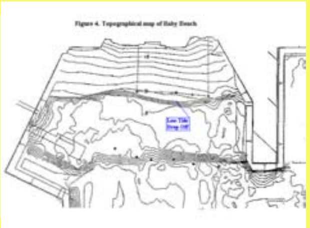
Swim Area
60 ft. and 30 ft. above the Low-Tide Drop-Off. 0 ft., 5 ft., and 30 ft. below the Low-Tide Drop-off; to a maximum depth of 5 ft.

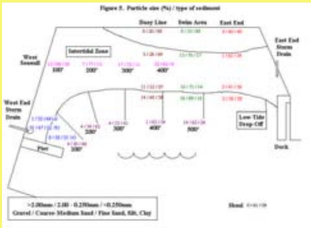
West Seawall
Every 20 ft. from 0-400 ft. east of the West Seawall, adjacent to the water line

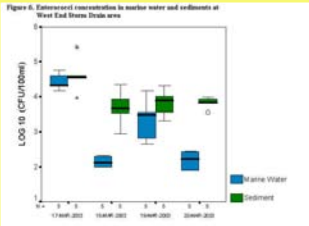
East End
60 ft. and 30 ft. above the Low-Tide Drop-Off. 0 ft., 5 ft., and 30 ft. below the Low-Tide Drop-off; to a maximum depth of 5 ft.

Low-Tide Drop Off
Every 25 ft. along the lower edge of the Low-Tide Drop-Off beginning in-line with the mouth of the west storm drain and extending 475 ft. east; to a depth of approximately 5 ft.









Storm drain

Intertidal zone

Deep water sampling

Enterococcus spp. on mEI media

DISCUSSION

The high densities of fecal indicator bacteria in sediments at Baby Beach may be attributed to the geography/topography, harbor design and poor water circulation. Thus, FIB contributed by storm drains, seagulls or other sources can be localized to waters and sediments at the nearshore areas. The storm drains also contribute nutrient-rich, fine-grained sediments to Baby Beach. Since the grain size of sediments is correlated with the energy of the depositional environment, fine sediments can accumulate in areas that are not heavily impacted by currents and waves. Survival of FIB may be enhanced in sediments due to the availability of nutrients, as well as protection from solar irradiation and predators. Currently, there are no standards for FIB levels in sediments. In this study, we did not determine how the densities of FIB in 10 grams of sediment relate to levels in 100 ml of water. The 30-day log mean standards for TC, FC and ENT are 1,000, 200 and 35 organisms/100 ml of water. It is very possible that high levels of TC and ENT found in sediments at Baby Beach could contribute bacteria to the overlying water to concentrations that exceed these limits. Enterococci may be more resistant to environmental and have higher a survival rate in sediments as compared to the other FIB. Recently, Craig et al. (2002) reported higher decay rates for *E. coli* as compared to *Enterococcus*. The high densities of ENT detected suggest that these organisms may even be growing in the sediments. If sediments are sources of ENT in water, these organisms may not be indicative of recent fecal pollution of water. TC levels in water have not correlated well with gastrointestinal illness, as some coliform bacteria are found in environmental sources such as decaying vegetation. In this study, *E. coli* was generally not detected in sediments, thus elevated levels of this indicator in water may provide a more accurate assessment of fecal contamination as compared to TC and ENT. Further studies are needed to determine the spatial and geographic distribution of FIB in coastal sediments. Perhaps unsafe-recreational water advisories should be based on levels of both ENT and *E. coli* rather than a single indicator.

CONCLUSIONS

? The high concentrations total coliforms, and especially enterococci, found in sediments above and below marine water suggests that these organisms may accumulate and persist in sediments, particularly those impacted by storm drain runoff, seagulls and poor circulation of water.

? A direct correlation between higher bacterial levels and fine-grained sediments was not found since high densities of indicators were also found in coarse sediments directly below the storm drain and at areas frequented by a number of seagulls.

? In this study, *E. coli* was generally not detected in sediments. Thus, elevated levels of *E. coli* in water may provide a more accurate assessment of fecal contamination in comparison to total coliforms and enterococci, which also include species that are non-fecal in origin.

? Further studies are needed to determine the reliability of fecal indicator bacteria, which may accumulate or multiply to high densities sediments, as indicators of fecal contamination in water.

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