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Retrospective evaluation of shoreline water quality along Santa Monica Bay beaches

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ABSTRACT

Santa Monica Bay (SMB) beaches are the most heavily used in the country, despite an increased number of water quality postings over the last several years. To assess whether water quality problems are concentrated at a small number of chronically affected sites or whether the problems are widely distributed, we compiled five years of monitoring data collected at 59 sites, 24 of which are sampled daily. Other locally available rainfall and sewage spill monitoring information data were added to this data set to assess whether sewage spills, dry-weather runoff, or wet-weather runoff contribute the most to exceedences of water quality thresholds. Approximately 13% of the shoreline mile-days along monitored beaches in SMB exceeded the State of California's beach water quality standards during the five-year study period. Most of the water quality exceedences occurred near urban runoff drains even though areas affected by drains represent only a small portion of the total shoreline. Although storms are relatively infrequent in southern California, the extent of water quality exceedences resulting from storm water runoff was similar to the extent of water quality exceedences found during dry weather. Sewage spills, while potentially more serious because they lead to beach closures rather than to the more limited posting of warning signs, represented less than 0.1% of the shoreline mile-days that exceeded water quality thresholds. During dry-weather conditions, most of the water quality problems occurred near five of the largest drains and at two beach areas that have unique physical characteristics, which limited mixing, dispersion, and dilution. During wet-weather conditions, water quality problems were more widespread.

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INTRODUCTION

Santa Monica Bay (SMB) beaches are the most widely used in the country, with their 50 million annual beachgoers exceeding that of beaches in any other state in the nation (Schiff *et al*. 2001). Almost a million swimmers visit SMB beaches on a typical summer weekend (SMBRP 1994), a level of usage that generates tremendous economic revenue. Tourism contributed $7.1 billion to the Los Angeles County economy last year, with beach visitation being the second most popular tourist activity.

Despite the importance of SMB beaches as a natural and economic resource, the number of beach closures and water quality warnings has increased over the last several years (California State Water Resources Control Board, personal communication). Considerable focus has been placed on dry-weather urban runoff as one of the reasons for the increase in beach warnings, largely in response to an epidemiology study demonstrating increased health risk from swimming near urban runoff outlets (Haile *et al*. 1999). This awareness has been heightened by the runoff-related closure of nearby Huntington Beach for the summer of 1999. Beach warnings, however, also result from wet-weather runoff, sewage spills, septic system failures, and localized concentrations of animal activity (e.g., birds, horses, etc.). Identifying the relative contribution to beach water quality exceedences of each of these sources is an important first step in understanding and managing beach water quality problems.

The SMB beaches are among the most comprehensively monitored for bacterial water quality in the nation, with more than one-third of the sampling locations being monitored daily. This wealth of data provides an unparalleled opportunity to characterize the nature of water quality issues. In this paper, we compile the existing monitoring data from SMB for the last five years to assess whether most of the water quality exceedences are concentrated at a small number of chronically affected sites or whether these exceedences are more widely distributed. We also combine the results of this study with other locally available rainfall and sewage spill data to assess whether sewage spills, dry-weather runoff, or wet-weather runoff contribute the most to exceedences of water quality thresholds.

METHODS

Fifty-nine sites within Santa Monica Bay are routinely sampled for bacterial water quality. Twenty-two of these sites are located 50 m upcoast or downcoast from urban runoff locations, 6 sites are located along rocky shoreline, 27 sites are located on open beaches away from known sources, and 4 sites are located along other shoreline types such as docks and restricted access areas. Total coliforms, fecal coliforms, and enterococci are measured at each site. Twenty-four sites are measured daily for total coliforms, 20 sites for fecal coliforms (or *E. coli*), and no sites for enterococcus; the remaining sites are typically measured weekly. Our study focused on the five–year period between January 1, 1995, and December 31, 1999, and included 112,295 data points (Table 1).

Rainfall data collected by the National Weather Service at Los Angeles International Airport were used to segregate samples into wet-weather and dry-weather categories. Wet-weather days were defined as any day within 72 h of a rainfall event of ¼ inch or more. Sewage spill data were obtained from the Los Angeles Regional Water Quality Control Board and included the location of the spill, the volume of the spill, the volume of the spill recovered, and whether the spill reached receiving waters. For the purposes of this study, we used the volume of spill that was not recovered as the volume of the spill discharged (if the spill was determined to have reached receiving waters). Based upon the location of the spill, shoreline monitoring station(s) were designated as potentially affected by each of the spill events. There were 17 sewage spills that reached SMB during the study period, potentially affecting 16 shoreline monitoring sites.

Our analysis focused on estimating the number of shoreline mile-days that exceeded water quality thresholds and differentiating what percent of these exceedences were attributable to dry-weather runoff, wet-weather runoff, and sewage spills, as well as what percent occurred on open beaches compared to areas near storm drains. To accomplish these goals, we assigned a shoreline distance of 200 m as the area affected by each water quality excursion, based upon the findings of Haile *et al.* (1999). The time period assigned to each water quality excursion was defined as the time until the next sample of that indicator type was collected at the site. This typically represented 24 h for total and fecal coliform since these indicators were collected daily at sites with a high incidence of exceedences, and 7 d for enterococci, which are measured weekly.

Water quality exceedences were defined using the State of California Health Department thresholds for single sample results: (1) total coliform > 10,000 organisms per 100 mL; (2) fecal coliforms > 400 organisms per 100 mL; (3) enterococcus > 104 organisms per 100 mL; or (4) total coliform per fecal coliform < 10, when total coliforms are greater than 1,000 organisms per 100 mL. To assess whether larger magnitude water quality exceedences had a different spatial or temporal distribution, we also repeated the analysis using higher thresholds. The higher thresholds ensured that the observed exceedence of the State threshold could not have resulted from natural laboratory measurement variability (McGee *et al.* 1999) and are as follows: (1) total coliform > 21,875 organisms per 100 mL; (2) fecal coliform > 875 organisms per 100 mL; and (3) enterococcus > 228 organisms per 100 mL.

RESULTS

Approximately 13% of the shoreline mile-days in SMB exceeded water quality thresholds during the five-year study period. Fifty-three percent of these threshold exceedences occurred near storm drains (Figure 1). Forty percent of the shoreline mile-day exceedences occurred on sandy beaches. Rocky and other types of shoreline accounted for the remaining 8% of the shoreline mile-days that exceeded water quality thresholds.

TABLE 1. Summary of sampling effort by stratum and indicator in Santa Monica Bay from January 1995 to December 1999.

Stratum	Dry or Wet	Enterococcus	Fecal Coliforms	Total Coliforms	Total
Beach	Wet	875	1,419	1,538	3,832
Beach	Dry	6,153	9,996	11,485	27,634
Dock	Wet	197	355	489	1,041
Dock	Dry	1,075	2,207	3,649	6,931
Rock	Wet	312	238	854	1,404
Rock	Dry	1,922	1,390	6,952	10,264
Storm Drain	Wet	759	3,241	3,241	7,241
Storm Drain	Dry	5,693	24,126	24,129	53,948
Total Wet		2,143	5253	6,122	13,518
Total Dry		14,843	37,719	46,215	98,777
Total		16,986	42,972	52,337	112,295

Most of the water quality exceedences were attributable to enterococci (Table 2). Exceedences of the enterococcus threshold occurred at approximately twice the frequency of fecal coliform and five times the frequency of the total coliform thresholds. Regardless of which indicator and threshold were selected, the most frequent water quality exceedences occurred near storm drains.

Although rainstorms are relatively infrequent in southern California, the extent of water quality exceedences in periods immediately following rainstorms was similar to those during dry weather conditions (Table 2). Only one-quarter of the samples were collected during wet weather, but approximately half of the enterococcus and fecal coliform shoreline mile-day exceedences, as well as two-thirds of the total:fecal coliform exceedences and total coliform exceedences, occurred during wet-weather. Sewage spills reaching the beach were relatively rare and accounted for less than 0.1% of the shoreline mile-days that exceeded water quality thresholds.

Five drain systems (Malibu Creek, Santa Monica Pier, Santa Monica Canyon, Pico-Kenter, and Topanga Point) accounted for over half of the drain-related shoreline mile-day exceedences during dry-weather conditions (Table 3). Bacterial contamination was more evenly distributed among storm drains during wet-weather conditions, with the same drains comprising only 36% of the shoreline mile-day exceedences (Table 3). Similarly, the top five most contaminated beach sites (three in Marina del Rey and two in Malibu) accounted for 48% of all beach water quality exceedences during dry-weather conditions and 34% of all beach water quality exceedences during wet-weather conditions (Table 4).

During dry-weather conditions, the frequency of large-magnitude water quality exceedences at storm drains was nearly double that of open beaches (Figure 2). Similarly in wet-weather conditions, drains had a greater frequency of large-magnitude exceedences than open beaches, but not nearly to the extent found during dry-weather conditions.

DISCUSSION

The extent of water quality exceedences we observed in SMB was almost triple that found in a recent study of regional beach water quality throughout southern California (Noble *et al.* 2000). Some of this disparity results because our study included sampling during wet-weather conditions, while Noble *et al.* (2000) was limited to the summer dry period. However, some of the difference may also be attributable to the higher density of storm drains in SMB relative to the rest of southern California. In this study, as well as in Noble *et al.* (2000), areas near storm drains were found to have a disproportionately higher incidence of

FIGURE 1. Proportion of water quality excursions by stratum and indicator in Santa Monica Bay between January 1995 and December 1999.

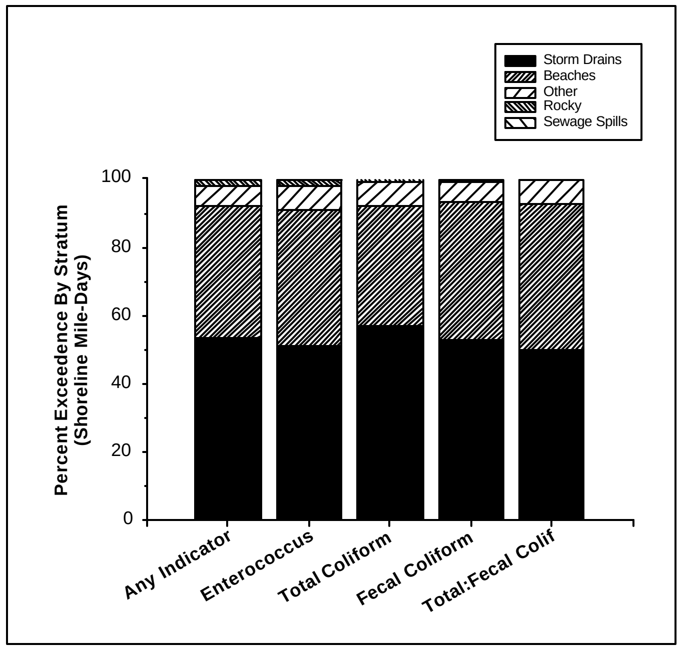


TABLE 2. Number and percent of shoreline mile-days (SMD) that exceeded water quality thresholds in Santa Monica Bay by stratum, rainfall (dry or wet), and indicator between January 1995 and December 1999. Indicators included enterococcus (Ent), fecal coliforms (FC), total coliforms (TC), total to fecal coliforms ratio (TC:FC), or any of the four indicators (Any).

	Dry or Wet	Any		Ent		FC		TC		TC:FC	
Strata		SMD	%	SMD	%	SMD	%	SMD	Site	SMD	%
Beach	Dry	428.6	27.9	241.9	21.4	161.6	24.5	16.3	7.3	113.5	24.5
Beach	Wet	179.1	11.6	207.3	18.4	105.9	16.1	60.8	27.2	84.9	18.3
Other	Dry	65.7	4.3	41.4	3.7	20.8	3.2	2.3	1.0	17.8	3.8
Other	Wet	27.0	1.8	34.3	3.0	18.3	2.8	14.0	6.3	13.4	2.9
Rock	Dry	15.4	1.0	13.2	1.2	1.0	0.2	0.7	0.3	0.3	0.1
Rock	Wet	11.0	0.7	12.0	1.1	4.2	0.6	0.8	0.4	0.9	0.2
Storm Drain	Dry	564.2	36.7	322.7	28.6	220.9	33.5	55.3	24.7	133.0	28.7
Storm Drain	Wet	246.7	16.0	254.3	22.5	125.5	19.1	69.5	31.1	96.3	20.7
Spills	-	0.7	0.1	0.7	0.1	0.5	0.1	0.4	0.2	0.4	0.1
Total		1,537.6	100.0	1,127.8	100.0	658.7	100.0	223.7	100.0	464.1	100.0

TABLE 3. Percent of shoreline mile-days (SMD) that exceeded water quality thresholds during wet and dry weather between January 1995 and December 1999 for each of the monitored storm drains in Santa Monica Bay.

	Percent SMD	
	Wet	Dry
Surfrider Beach, Malibu Creek	8.3	14.3
Santa Monica Pier	6.2	10.9
Santa Monica Canyon	6.1	10.1
Pico-Kenter	8.1	8.7
Topanga Point	6.2	7.4
Redondo Beach Pier	3.5	5.2
Ashland (City)	5.3	5.0
Pulga Canyon	5.6	3.8
Ballona Creek	7.0	3.8
Ashland (Health Dept.)	3.6	3.6
Malibu Point	1.8	3.6
Culver Blvd.	6.0	3.6
Wilshire Blvd.	3.0	3.3
Strand St.	3.9	2.7
Brooks Ave.	4.2	2.7
Windward	4.5	2.2
Imperial Highway	3.2	1.9
Ave. 1	2.9	1.8
Temescal	2.8	1.8
Hermosa Beach Pier	2.8	1.5
Montana Ave.	3.3	1.4
Herondo St.	1.8	0.7
Total	100.0	100.0

TABLE 4. Percent of shoreline mile-days (SMD) that exceeded water quality thresholds during wet and dry weather between January 1995 and December 1999 for each of the monitored beaches in Santa Monica Bay.

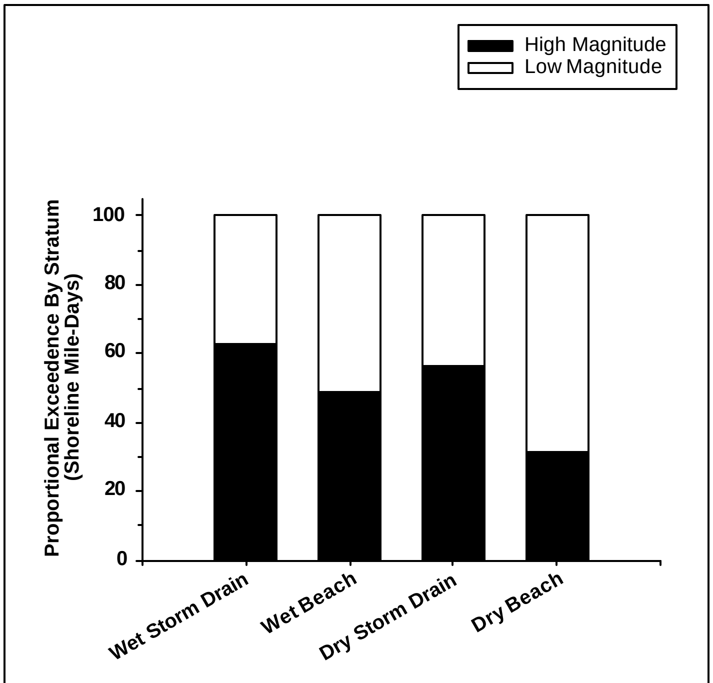
	Percent SMD	
	Wet	Dry
Surfrider Beach, Malibu (City)	7.4	11.1
Malibu Pier	5.6	10.0
Marina del Rey Lifeguard Tower (City)	9.2	9.4
Marina del Rey Beach	6.2	9.2
Marina del Rey Lifeguard Tower (County Health)	5.3	8.2
Big Rock Beach	4.6	6.0
Las Flores Beach	5.0	5.0
Paradise Cove	4.1	4.9
Malibu Beach (County Health)	4.9	4.5
Bel Air Bay Club	3.6	3.3
Pacific Palisades	3.4	2.8
Topaz Street	2.4	2.4
Topsail Street	4.7	2.4
San Vincente Blvd.	4.7	2.3
Trancas Beach	2.8	2.2
Corral Beach	1.5	2.1
Opposite Hyperion Plant	2.0	1.9
Westward Beach	2.6	1.8
World Way	3.2	1.7
Grand Avenue	2.6	1.6
Venice Pier	2.0	1.3
Broad Beach	2.6	1.3
26th Street	1.0	1.2
Cabrillo Beach	1.7	1.1
Leo Carrillo Beach	3.3	1.0
Manhattan Pier	2.2	0.9
Manhattan Beach	1.5	0.5
Total	100.0	100.0

bacterial contamination than other shoreline areas. The SMB is one of the most extensively developed regions in southern California, with more than 5,000 miles of storm drain infrastructure in Los Angeles County and more than 200 documented drains discharging to the ocean (SMBRP 1994). The watershed is nearly 50% developed and contains 25% impervious surface (Wong *et al.* 1997).

Similar to Noble *et al.* (2000), we found that a high percentage of the contamination, particularly higher magnitude concentrations, was focused on a small subset of the total shoreline. For Noble *et al.* (2000), that subset was primarily limited to storm drains. In our study, we found at least several open beach sites in which the chronic nature of the problem was as severe as at the worst drain sites. However, the chronic beach sites appear to reflect special circumstances related to the unique physical characteristics of the sites. Two sites are located 1,000 m or more from Malibu Creek, a known area of heavy contamination. Dye studies have shown that urban runoff from that creek receives minimal dilution and does not disperse readily before reaching the affected beach stations (SCCWRP, unpublished data). Three of the beach stations are located in Marina del Rey, a man-made marine lagoon system that receives limited mixing. It is unclear whether these beaches receive contamination primarily as runoff from the heavily urbanized areas that drain into the lagoon system, as spillage from the large concentration of nearby boats, or from the large number of birds that frequent the area. Unlike the open shoreline sites, however, there is limited flushing to dilute and disperse the bacterial inputs.

The influence of storm drains may have been underestimated in our analysis. This is mostly because the sampling sites were located 50 m from storm drains and any runoff-related impact may have occurred at less than 50 m. Conversely, the importance of storm drains may have been overestimated because: (1) an equal distance weighting was applied to each site; and (2) the open beach sites currently monitored represent only a small fraction of the total beach area. In contrast, the majority of shoreline near large storm drains is already monitored. To assess the importance of this assumption, we repeated our analysis, but treated the entire distance between two adjacent monitoring sites as contaminated if they both exceeded water quality standards. However, this variation did not change our conclusion as most of the adjacent pairs of contaminated sites were located in the vicinity of storm drains. Lastly, we may have

FIGURE 2. Magnitude of water quality exceedence by density of indicator bacteria at storm drain and beach strata in Santa Monica Bay during wet and dry weather from January 1995 to December 1999. High levels correspond to the density at which bacteria are so concentrated, they exceed water quality thresholds by more than what is attributable to laboratory variability.



overestimated exceedences by assuming that enterococcus samples, which are sampled weekly by the Department of Health Services, were representative of an entire week. Examination of daily data indicates that exceedences of enterococcus thresholds, which occur more frequently, do not appear to last much longer than exceedences of total or fecal coliform thresholds (Leecaster and Weisberg, 2001).

As important as it is to identify chronic problem sites, it is equally important to identify those locations and contamination types that were not the principal sources of concern. For example, several beaches (including Paradise Cove and Corral Beach) had a low frequency of water quality exceedences despite the presence of septic tanks in the area. Similarly, sewage spills accounted for a very small percentage of water quality exceedences. However, the importance of the sewage spills should not be discounted because the County Health Department typically closes the beach when a sewage spill occurs, whereas it only posts warning signs when the source is thought to originate from other urban influences.

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