



0273-1223(95)00275-8

SAND, SOIL, AND PIGEON DROPPINGS: SOURCES OF INDICATOR BACTERIA IN THE WATERS OF HANAUMA BAY, OAHU, HAWAII

Robin Oshiro and Roger Fujioka

*Water Resources Research Center and School of Public Health, University of Hawaii
at Manoa, Honolulu, HI, USA*

ABSTRACT

To investigate the deteriorating bacteriological water quality of Hanauma Bay, Hawaii, samples of shoreline water, sand, land runoff, and mongoose and pigeon droppings were analysed for fecal coliforms, *E. coli* and enterococci. The results indicate that the major sources contributing to periodic high levels of bacteria in the waters of the Bay are contaminants of the beach sand, such as pigeon feces.

KEYWORDS

Indicator bacteria, bacteriological water quality, enterococci, fecal coliforms, *E. coli*, seawater, sand, animal feces.

Introduction. Hanauma Bay is one of the most picturesque and popular beaches in the State of Hawaii. Since the conversion of the bay to a fish sanctuary, numerous tropical fish are readily visible. Unfortunately, the popularity of the bay has also resulted in its deterioration. Increased amounts of food have been added to the water due to the allowable feeding of fish. Restroom facilities cannot always accommodate the large numbers of people. The pigeon population at the bay has also increased alongside the higher densities of people and the availability of food on the beach.

The bacteriological water quality of Hanauma Bay has been regularly monitored. Although the bay does not receive any stream discharges, high concentrations of fecal coliform and enterococci are periodically recovered in numbers exceeding the traditional water quality standard of 200 fecal coliform/100 ml and Hawaii's present marine recreational water quality standard of 7 enterococci/100 ml. The cesspools which service the public restrooms located in the middle section of the beach have been suspected as the prime source of these bacteria, however tracer dyes added to the cesspools have never been detected in the nearby beach water. The objective of this study was to assess other possible sources of indicator bacteria which could have an impact on the quality of water at Hanauma Bay.

Experimental Design and Methods. Shoreline water samples were collected from three sectors (east, middle, west) of Hanauma Bay (Figure 1) and from Ala Moana Beach, another popular site on the island of Oahu. The bacteriological quality of Hanauma Bay sand was also compared to the sand at Ala Moana Beach. Contaminants of sand such as land runoff (shower/cleaning water, rain) and mongoose and pigeon fecal droppings from Hanauma Bay were tested as possible contributors of indicator bacteria. The standard membrane filtration technique was used to determine the concentrations of indicator bacteria in the samples. Selective media included mFC for fecal coliform, mTEC for *E. coli*, and mE for enterococci. In the analysis of sand samples, an equal volume of sterile 3.5% NaCl was added to the sand and mixed vigorously by hand (25 times in 10 sec.). The sand was allowed to settle for 1-2 min. and the supernatant obtained. Two such elutions were required to remove more than 90% of the bacteria from the sand. The supernatants were diluted and then membrane filtered.

Results. None of the water samples from Hanauma Bay or Ala Moana Beach contained elevated levels of fecal coliform exceeding 200 CFU/100 ml. The numbers of fecal coliform ranged from 0-45 CFU/100 ml in the eastern sector of the bay, 1-103 CFU/100 ml in the middle sector of the bay, and 1-8 CFU/100 ml in the western sector of the bay. The fecal coliform counts at Ala Moana Beach ranged from 0-19 CFU/100 ml. The enterococci numbers at these same sites ranged from 2-24 CFU/100 ml at Hanauma Bay east, 0-104 CFU/100 ml at Hanauma Bay middle, and 0-28 CFU/100 ml at Ala Moana Beach. Only two water samples from Hanauma Bay west were tested for enterococci, both resulting in 1 CFU/100 ml. The enterococci results also indicated that Hawaii's marine recreational water quality standard of 7 CFU/100 ml was not met in 25% of the samples from Hanauma Bay east, 33% of the samples from Hanauma Bay middle, and 8% of the samples from Ala Moana Beach. Of the three sectors sampled at Hanauma Bay, the highest concentrations of all indicator bacteria were recovered from the middle sector.

A comparison of the indicator bacteria levels recovered in various sand samples from Hanauma Bay and Ala Moana Beach revealed that the Hanauma Bay sand contained much higher concentrations of fecal coliform, *E. coli*, and enterococci than the sand from Ala Moana Beach. In the sand collected below two feet of water, the fecal coliform, *E. coli*, and enterococci concentrations were all less than 20 CFU/100 g at Ala Moana while 160 fecal coliform, 96 *E. coli*, and 68 enterococci/100 g were recovered at Hanauma Bay. In the wet sand collected at the surf zone, the Ala Moana samples contained less than 4 fecal coliform and *E. coli*/100 g, and 4 enterococci/100 g. In contrast, the surf zone wet sand from Hanauma Bay contained 320 fecal coliform, 44 *E. coli*, and 192 enterococci/100 g. The dry sand collected 10 feet inland of the water line at Ala Moana Beach contained less than 200 fecal coliform, *E. coli*, and enterococci/100 g while that from Hanauma Bay contained 184,000 fecal coliform, 160,000 *E. coli*, and 32,000 enterococci/100 g. The dry sand samples collected farthest inland at Ala Moana Beach contained less than 200 fecal coliform/100 g, 400 *E. coli*/100 g, and 16,000 enterococci/100 g. In marked contrast, the sand samples farthest inland at Hanauma Bay were determined to contain 2,420,000 fecal coliform/100 g, 976,000 *E. coli*/100 g, and 160,000 enterococci/100 g. The results for the various sand samples also indicated that the bacterial concentrations in the sand increased inland as the moisture content of the sand decreased and soil content increased.

To determine the sources of indicator bacteria in sand at Hanauma Bay, land runoff (shower/cleaning water, rain) and feces of pigeons and mongooses were analyzed for indicator bacteria. The numbers of indicator bacteria recovered in the land runoff samples included 7.6×10^4 fecal coliform/100 ml, 4.4×10^4 *E. coli*/100 ml, and 1.0×10^5 enterococci/100 ml. The pigeon feces contained, per gram, 1.6×10^8 fecal coliform, 1.7×10^8 *E. coli*, and 4.0×10^5 enterococci. The mongoose feces contained, per gram, 1.0×10^9 fecal coliform, 9.2×10^8 *E. coli*, and 1.2×10^7 enterococci. The high orders of

magnitude (10^4 - 10^9) of fecal coliform, *E. coli*, and enterococci recovered in these land runoff and animal fecal samples provide evidence that these sources can adversely impact the bacteriological quality of sand and thus water at Hanauma Bay.

Conclusions. This study has shown that the waters of Hanauma Bay occasionally fail to meet Hawaii's recreational water quality standard of 7 enterococci/100 ml, usually in the middle and most populated sector of the bay. In contrast to the sand at Ala Moana Beach, the sand at Hanauma Bay was determined to contain considerably higher concentrations of fecal coliform, *E. coli*, and enterococci. The higher levels of bacteria in

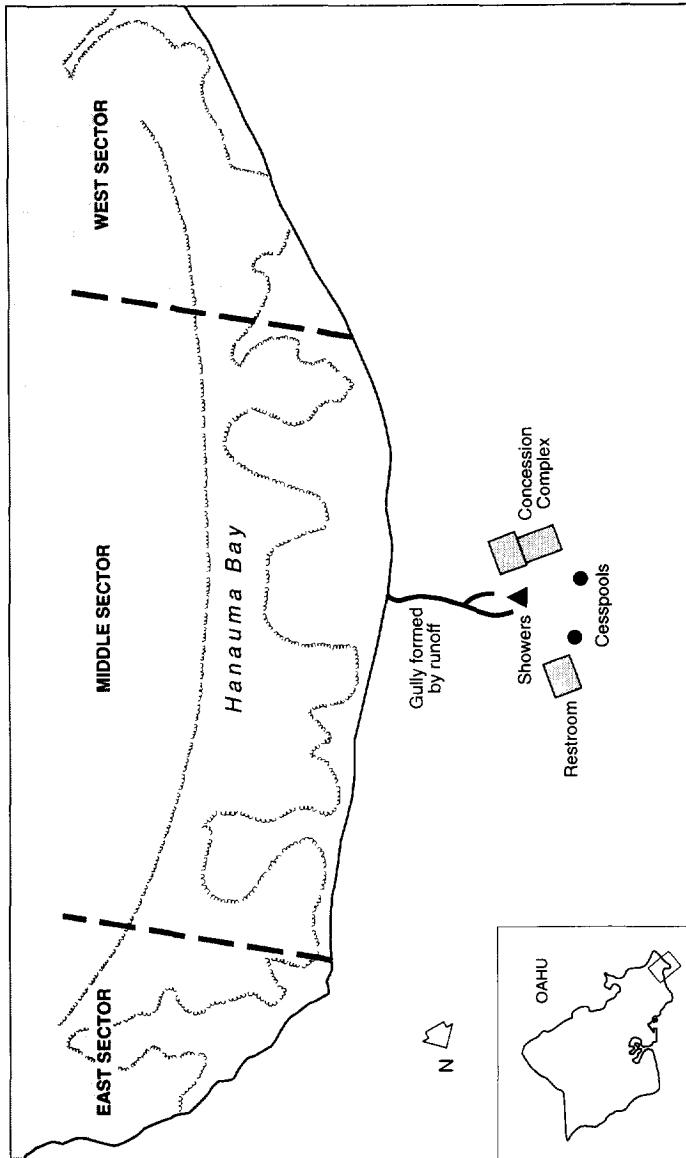


Figure 1—Schematic diagram of the three sampling sectors of Hanauma Bay Beach and location of public facilities.

Hanauma Bay sand can be partly attributed to a greater proportion of terrigenous sediment which was observed in Hanauma Bay sand. Soil from Hawaii's environment has been shown to contain high concentrations of indicator bacteria. The soil present in Hanauma Bay sand is an apparent result of being air-borne or run off from the cliffs surrounding the bay.

The concentrations of indicator bacteria in the sand increased inland as the moisture content of the sand decreased and soil content increased. Thus, the highest bacterial numbers were recovered in dry sand farthest inland from the water line. This represents the area where the majority of people also gather, sunbathe, and eat. The relatively lower concentrations of bacteria recovered from the wet sand samples indicate cleaner sand as a result of a washing effect by wave action.

The high concentrations of indicator bacteria recovered in the land runoff (shower/cleaning water, rain) and in the pigeon and mongoose fecal samples indicate that these sources are also highly potential contaminants of sand and water at Hanauma Bay. Both pigeons and mongooses have been observed to defecate on the beach sand at Hanauma Bay. Pigeons are much more numerous however, and mingle among the people on the sandy beach area throughout the day.

The results of this study suggest that sand, contaminated with indicator bacteria, is the major source contributing to the periodic high levels of bacteria in the waters of Hanauma Bay. The management of contaminants of sand is therefore necessary to control the indicator bacteria levels at Hanauma Bay.