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USE OF ISOTOPIC, GENETIC, AND CHEMICAL DATA TO EVALUATE THE SOURCE OF FECAL INDICATOR BACTERIA NEAR MALIBU, CALIFORNIA

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Introduction

Each year, over 550 million people visit California's public beaches. To protect beach-goers from exposure to waterborne disease, California state law requires water-quality monitoring for fecal indicator bacteria (FIB), such as enterococci and *Escherichia coli (E. coli)*, at beaches with more than 50,000 yearly visitors. FIB are used to assess the microbiological quality of water because, although not typically disease causing, they are correlated with the occurrence of certain waterborne diseases. Periodically, tests show that FIB concentrations exceed U.S. Environmental Protection Agency (EPA) public health standards for recreational water in Malibu Lagoon and at several Malibu beaches (fig. 1).

Figure 1. Selected sample locations, Malibu, California.

There are several potential sources of FIB to Malibu Lagoon and the nearby coastline including:

- Seepage from commercial and residential onsite sewage treatment systems that may enter the lagoon or near-shore ocean water through the groundwater system
- Discharge or runoff from commercial and residential developments into Malibu Creek and Malibu Lagoon.
- Bird and wildlife feces, either deposited directly into the lagoon or onto beaches, or washed into these areas by tides and storms.

Conclusions

For onsite wastewater treatment systems to be a source of FIB to Malibu Lagoon or the near-shore ocean, bacteria must first move through the groundwater system. Low FIB concentrations in wells having a high fraction of imported water suggest that this is not occurring. In addition, large changes in microbial populations suggest that bacteria are being removed by death or attenuation after discharge from treatment systems. Isotopic data were useful in estimating the fraction of wastewater in groundwater samples and to evaluate the timing of groundwater discharge to the near-shore ocean. In contrast to FIB, wastewater indicator compounds increase as the fraction of imported water in a sample increases - confirming the presence of wastewater in the system.

Birds in Malibu Lagoon, a potential source of fecal indicator bacteria, Malibu, California, July 2009

Overview of fecal indicator bacteria concentrations

More than 450 samples were collected from wells, Malibu Creek, Malibu Lagoon and the near-shore ocean as part of this study (fig. 1). Onsite sewage treatment systems, groundwater, and surface water including Malibu Creek, Malibu Lagoon, and near-shore ocean sites (Surfrider Beach and Malibu Colony beach) were sampled and analyzed for enterococci, *E. coli*, and total coliforms. Most samples were collected during the dry season (July 2009), and at the end of rainy season (April 2010).

Enterococci were found at the highest concentrations in samples taken from onsite treatment systems (fig. 2). Groundwater samples had the lowest concentrations, usually less than the detection limit, during both the dry and wet season. Enterococci concentrations in Malibu Lagoon were greater than enterococci concentrations in groundwater samples. Water carrying FIB from onsite wastewater treatment systems must pass through the groundwater system before infiltrating into the lagoon and near-shore ocean. Low enterococci concentrations, generally less than the detection limit, in water from wells suggest that FIB are not moving through the groundwater system, and that groundwater discharge may not be an important source of FIB to Malibu Lagoon or the near-shore ocean.

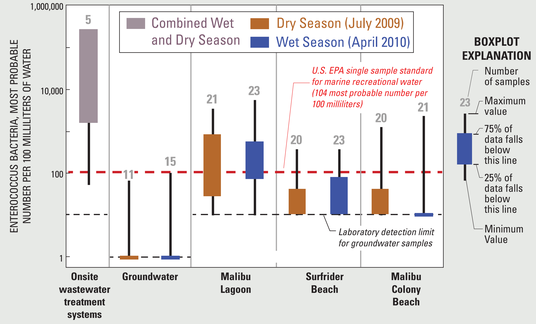


Figure 2. Enterococcus data from onsite wastewater treatment systems, groundwater, Malibu Lagoon and near-shore ocean, Malibu California, 2009-2010

Identification of wastewater and groundwater discharge

The naturally-occurring, stable isotopes of oxygen and hydrogen in the water molecule (oxygen-18 and deuterium, respectively) were used to determine the percentage of imported water that was used for water supply and then discharged as treated wastewater in a sample. This technique works because all the water used for public supply in the study area is imported from either northern California or the Colorado River and has an oxygen-18 and deuterium composition different from that of native water (fig. 3). Some groundwater samples contained as much as 70 percent treated wastewater, but did not contain detectable concentrations of FIB.

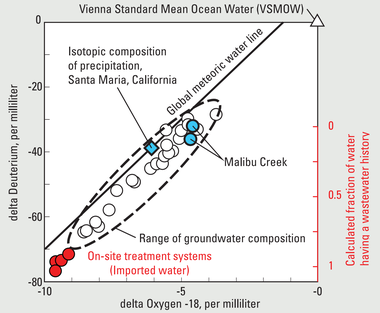


Figure 3. delta Oxygen-18 and delta deuterium data in water from onsite wastewater treatment systems, wells, and Malibu Creek, near Malibu, California, July 2009 and April 2010

Radon-222 is a naturally occurring radioactive isotope that has high activity in groundwater and low activity in surface water. Radon-222 activity increases in surface water with increasing groundwater discharge. Increased radon-222 activity was used to evaluate changing FIB concentrations as groundwater discharge was occurring to Malibu Lagoon and the near-shore ocean. For example, in November 2009, there were small increases in enterococcus concentrations in the near-shore ocean at low tide as water from Malibu Lagoon discharged through the sand berm separating the lagoon from the ocean (fig. 4). In contrast, FIB concentrations remained below the detection limit as radon-222 activity increased and groundwater discharged at low tide adjacent to unsewered residential development in Malibu Colony.

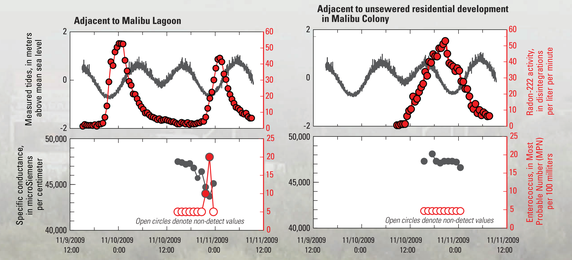
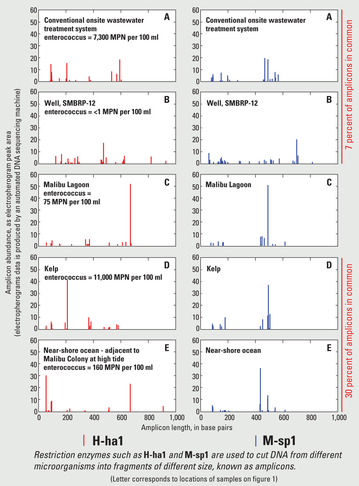


Figure 4. Tides, radon-222 activity, specific conductance, and enterococcus concentrations in the near-shore ocean adjacent to Malibu Lagoon, Malibu, California.

Genetic and chemical tracers of fecal indicator bacteria and wastewater

A combination of genetic, and chemical techniques were used with isotopic data to identify the source of FIB in groundwater, Malibu Lagoon, and the near-shore ocean. Terminal-Restriction Fragment Length Polymorphism (T-RFLP), uses restriction enzymes to cut DNA from microorganisms into fragments of different sizes known as amplicons. Microbial communities present in the discharge from onsite wastewater treatment systems and groundwater having as much as 70 percent wastewater have only 7 percent of amplicons present in both samples (fig. 5A and B). In contrast, as many as 30 percent of amplicons measured in samples from both kelp and the near-shore ocean were present in both samples (fig. 5D and E) consistent with possible contributions of FIB from kelp accumulated along the wrack line to the ocean at high tide.



Restriction enzymes such as **H-ha1** *and* **M-sp1** *are used to cut DNA from different microorganisms into fragments of different size, known as amplicons.*

(Letter corresponds to locations of samples on figure 1)

Figure 5. Selected T-RFLP amplicons from onsite wastewater treatment systems, a well having had fraction of treated wastewater in malibu lagoon, near Malibu California, July 2009.

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Sixty nine organic compounds, including caffeine, fecal sterols, personal health-care products, and other compounds associated with human use, were analyzed. Indicators of human use were frequently detected in treated water from within onsite wastewater treatment systems and from sampled wells with a high percent of treated wastewater (fig. 6). However, these samples did not contain FIB. Although wastewater compounds are transported with the groundwater, FIB are removed.

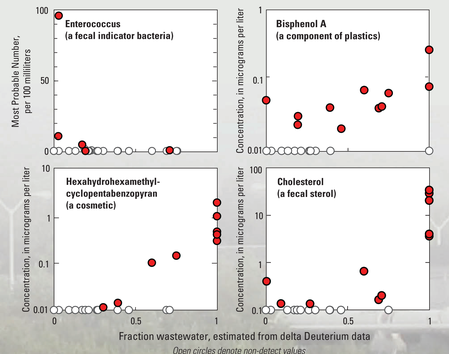

Figure 6. Enterococcus and selected wastewater indicator compounds in water from wells, as a function of the fraction wastewater, Malibu, California July, 2009 to April 2010.