Fecal Indicator Bacteria and Pathogen Persistence in Dry Beach Sand and Sediment Biofilms

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Our goals over the last year have been to investigate: 1) the influence of environmental factors such as sunlight intensity and temperature on solar inactivation decay constants for FIB in sand, 2) the potential for adverse health impacts due to exposure to sand at an impaired beach, and 3) the extent of sand contamination at two beaches impaired by inland freshwater sources.

In urbanized coastal watersheds, sand can become contaminated with pathogens and fecal indicator bacteria (FIB) from a variety of sources, including sewage spills, overlying water bodies, and contaminated freshwater sources such as storm drains or creeks. Little is known about the persistence and inactivation kinetics of FIB and pathogens in sand. Similarly, the potential for illness through exposure to sand is completely unknown. Our goals over the last year have been to investigate: 1) the influence of environmental factors such as sunlight intensity and temperature on solar inactivation decay constants for FIB in sand, 2) the potential for adverse health impacts due to exposure to sand at an impaired beach, and 3) the extent of sand contamination at two beaches impaired by inland freshwater sources.

Influence of environmental factors on solar inactivation decay constants for FIB in sand

On January 15, 2006, over 2 million gallons of raw sewage were spilled onto the sand at Manhattan Beach, posing a hazard to public health. In collaboration with the Los Angeles County Sanitation District, we set out to investigate solar disinfection of sand as an environmentally-friendly remediation alternative to chlorination, which can result in toxic disinfection by-products. From February 15-21, 2006, sand contaminated by the sewage was spread onto test plots in situ and raked several times a day to determine the effect of raking, as well as solar inactivation, on FIB inactivation rates and Salmonella persistence. Each of the drying beds showed a progressive decrease in both total coliform and E. coli levels throughout the experiment. After eight days of treatment, levels returned to near background, and the incidence of presumptive Salmonella decreased from 92% to 67%.

Bench scale studies were conducted to determine the effect of factors such as solar intensity, moisture, and temperature on inactivation kinetics following two alternative disinfection procedures: solar disinfection with mechanical mixing and iodine application. In both February and June 2007, decay constants measured in controlled experiments using sewage contaminated sand on a rooftop location were very similar to those measured in the field, even though both temperature and intensity of sunlight varied greatly.

Potential for adverse health impacts due to exposure to sand at an impaired beach

From May through September, 2007 and 2008, the Southern California Coastal Water Research Project, in cooperation with Orange County Sanitation District, Heal the Bay, and UC Berkeley, is conducting an epidemiology study of swimming-related adverse health outcomes at Doheny Beach and an impaired beach at Avalon, Catalina (2007) and Malibu Beach (2008). It is a prospective cohort study that will include at least 17,600 swimming and non-swimming beach-goers. Participants will be surveyed

for information with respect to gastro-intestinal, respiratory, dermatological, ear, eye, and other non-specific symptoms. Water samples will be tested for FIB, pathogens, and human-specific markers.

Our involvement in this project over the past year resulted in adding two critical components: investigating whether there is 1) a correlation between FIB and pathogen levels in the sediment; and 2) a correlation between health outcomes and FIB or human specific markers in sediment. Questions regarding extent and duration of contact with sand have already been incorporated in the survey. This new sediment component involves analysis of sand samples for E. coli, enterococci, and Salmonella. In addition, we are extracting DNA from sand samples for quantitative PCR analysis of Bacteroides and the esp gene, which are human specific markers.

Extent of sand contamination at two beaches impaired by inland freshwater sources

In 2006, our laboratory measured extremely high levels of FIB near a diverted storm drain under the Santa Monica Pier. The levels decreased exponentially with distance from the source, indicating movement of FIB toward the water. The diversion was renovated during the interval between the summers of 2006 and 2007.

To further explore the effect of a freshwater source on the background levels of FIB at urban beaches, we studied the site of the diverted storm drain under the Santa Monica Pier, and the sand-bermed outlet of the San Juan Creek at Doheny Beach. We took sand samples under the pier from the storm drain outlet down through the swash zone. In addition, we sampled roughly 50 feet north and south of the pier in the dry sand, sand still damp from the previous night's high tide, and sand from the swash zone, as well as corresponding water samples.

Interestingly, enterococci and E. coli levels were higher in 2007 than in 2006, despite the lack of standing water. E. coli levels near the storm drain outlet were 2000 MPN/dry gram in 2006 and almost 394,000 MPN/dry gram in 2007; enterococci levels near the outlet were 217 MPN/dry gram in 2006 and slightly over 16,000 MPN/dry gram in 2007. Again, levels decreased dramatically with distance from the diversion. These results indicate an ongoing issue with this location. Levels on both the north and south side of the pier were low in both years. Similarly, levels in the Doheny pool were very high, but dropped off immediately past the sand saturated with the heavily contaminated freshwater source. This could be due to either the steeper slope of the sand berm than the shoreline slope at Santa Monica, the constant solar exposure during daylight hours (no shading), or a combination of both.

Selected Professional Presentations

Mika, K., C. Lee, R. Moreno, G. Imamura, S. Thompson, V. Conway, G. Fernandez, C.C. Lin, R. Kampalath, J. Jay, Pilot and Bench-Scale Testing of alternative disinfection methods for sewage-contaminated sand, SoCal SETAC Spring meeting, Lake Arrowhead, April 9-10, 2007.

Jay, J.A. Role of environmental biofilms in mercury methylation and persistence of bacteria in beach sand. UC Davis Seminar Series. February 5, 2007; Calltech Seminar Series. January 3, 2007; Washington University, St. Louis, Seminar Series. June 8, 2007.

Collaborative Efforts

We have begun a very meaningful collaboration with Dr. Sharon Walker of UC Riverside. We have received funding from UC Marine Council for a project stemming from our Center for Water Resources Grant. The project involves: 1) addition of a sediment component to a large epidemiology study; 2) fecal source tracking; and 3) a bench-scale investigation of the factors controlling FIB survival and transport in beach sand.

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