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Quantification of Pathogenic Viruses, and Bacteria in Storm Water Discharging to Beaches with Year-round Surfer Populations in San Diego, California

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Abstract

California receives the bulk of its rainfall during winter months, and has year round surfer populations at many of its beaches. Water quality at these beaches worsens during and following rainstorms with dramatic increases in fecal indicator bacteria (FIB) concentrations, leading to well-known 72-hour rain advisories. These advisories were originally established using the relationship of FIB concentrations to pathogens in raw sewage, but the relationship between FIB concentrations and pathogens in stormwater has not been sufficiently explored. Further, the pathogenic bacteria and viruses in stormwater that likely cause illness have historically been measured using molecular approaches that are not sensitive enough to accurately quantify dilute pathogens in complex water matrices. Digital PCR now offers the sensitivity to enable direct quantification of pathogenic viruses and bacteria, without the impacts of inhibition. Using traditional culture methods and digital PCR assays, we measured microbial water quality in wet weather stormwater discharges at two beaches in San Diego, CA that are frequented by large, year-round surfer populations. Tourmaline Creek drains a small urban watershed and the San Diego River drains a large mixed urban/undeveloped watershed. Stormwater samples were collected during six events with total precipitation ranging from 0.19-2.5" from January-March 2014 and December 2014-March 2015. Stormwater composite samples were collected during the rain event, and grab samples were collected over 72 hours following the beginning of rainfall. *Enterococcus* spp., and total and fecal coliform concentrations were measured in Tourmaline Creek and San Diego River discharge and samples were also taken at proximal beaches. Previously published and validated molecular markers specific to human, dog, and bird feces were quantified in the stormwater using digital PCR. Pathogens in stormwater were directly quantified with digital PCR for *Campylobacter* (including *C. jejuni*, *C. coli*, and *C. lari*), *Salmonella*, human Norovirus GI and GII, human adenovirus, and human enterovirus. In every storm measured, we found high FIB and pathogen concentrations in both the large and small watershed stormwater during the storms and in the 3 days following rainfall. Molecular source tracking markers revealed dog and bird fecal sources in addition to human sources in the stormwater, but concentrations along the beaches were diluted. Human norovirus genotype II and *Campylobacter* spp. were detected most often, while *Salmonella* and human adenovirus were rarely detected, and enterovirus was not detected. We found no consistent relationships between FIB and pathogen concentrations. FIB concentrations measured at the beach decreased with distance from the mouth of the San Diego River, but did not change with distance from Tourmaline Creek, reflecting differences in the dispersal of the stormwater plume by waves and ocean currents at each site. The markers and pathogens measured suggest multiple

sources of microbial pollution within the San Diego River and Tourmaline Creek watersheds. The ability to quantify pathogens, even at low concentrations, in stormwater provides the ability to more precisely estimate the risk of illness to public health.