

Quantification of pathogens and markers of fecal contamination during storm events along popular surfing beaches in San Diego, California

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ABSTRACT

Along southern California beaches, the concentrations of fecal indicator bacteria (FIB) used to quantify the potential presence of fecal contamination in coastal recreational waters have been previously documented to be higher during wet weather conditions (typically winter or spring) than those observed during summer dry weather conditions. FIB are used for management of recreational waters because measurement of the bacterial and viral pathogens that are the potential causes of illness in beachgoers exposed to stormwater can be expensive, time-consuming, and technically difficult. Here, we use droplet digital Polymerase Chain Reaction (digital PCR) and digital reverse transcriptase PCR (digital RT-PCR) assays for direct quantification of pathogenic viruses, pathogenic bacteria, and source-specific markers of fecal contamination in the stormwater discharges. We applied these assays across multiple storm events from two different watersheds that discharge to popular surfing beaches in San Diego, CA. Stormwater discharges had higher FIB concentrations as compared to proximal beaches, often by ten-fold or more during wet weather. Multiple lines of evidence indicated that the stormwater discharges contained human fecal contamination, despite the presence of separate storm sewer and sanitary sewer systems in both watersheds. Human fecal source markers (up to 100% of samples, 20-12440 HF183 copies per 100 ml) and human norovirus (up to 96% of samples, 25-495 NoV copies per 100 ml) were routinely detected in stormwater discharge samples. Potential bacterial pathogens were also detected and quantified: *Campylobacter* spp. (up to 100% of samples, 16-504 gene copies per 100 ml) and *Salmonella* (up to 25% of samples, 6-86 gene copies per 100 ml). Other viral human pathogens were also measured, but occurred at generally lower concentrations: adenovirus (detected in up to 22% of samples, 14-41 AdV copies per 100 ml); no enterovirus was detected in any stormwater discharge sample. Higher concentrations of avian source markers were noted in the stormwater discharge located immediately downstream of a large bird sanctuary along with increased *Campylobacter* concentrations and notably different *Campylobacter* species composition than the watershed that had no bird sanctuary. This study is one of the few to directly measure an array of important bacterial and viral pathogens in stormwater discharges to recreational beaches, and provides context for stormwater-based management of beaches during high risk wet-weather periods. Furthermore, the combination of culture-based and digital PCR-derived data is demonstrated to be valuable for assessing hydrographic relationships, considering delivery mechanisms, and providing foundational exposure information for risk assessment.

Full Text

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