EGU21-1301, updated on 20 Oct 2021
https://doi.org/10.5194/egusphere-egu21-1301
EGU General Assembly 2021

Pathogen persistence in fine particle standing stocks in an intermittent urban stream

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Rivers transport pathogenic microorganisms (including fecal indicator bacteria and human enteric viruses) from point and non-point sources over long distances, posing a direct risk for human health. Yet, pathogens in surface waters can be deposited and transitorily immobilized and accumulated together with other fine particles in streambed sediments, mostly within the top few centimeters. These dynamic fine particle standing stocks retain and delay downstream transmission of pathogens during baseflow conditions, but contribute to their resuspension and transport downstream during stormflow events. Direct measurements of pathogen accumulation in streambed sediments are rare. Further, it is unknown whether pathogen accumulation is constrained near to the point source inputs or if the continuous deposition and resuspension of pathogens results in the transmission of active pathogens further downstream.

In this study, we analyze fine particle standing stocks along a 1 km reach of an intermittent Mediterranean stream receiving inputs from the effluent of a wastewater treatment plant (WWTP), during a summer drought when the effluent constituted 100% of the stream flow, and thus, large accumulation and persistence of pathogens along the streambed was expected. We measured abundance of total bacteria, *Escherichia coli* (as a fecal indicator bacteria), and presence of enteric rotavirus (RoV) and norovirus (NoV). We also monitored environmental variables such as water temperature, dissolved oxygen, total benthic particulate matter, and fraction of organic matter. Abundance of *E. coli*, based on qPCR detection, was high (~ 1 ng/µL) along the first 100 m downstream of the WWTP effluent input, and we found trace amounts of RoV and NoV. Furthermore, *E. coli* was present along the first km downstream of the WWTP effluent input with a logarithmic decline in concentration with distance. These results were combined with a particle tracking model that uses stream water velocity as an input and accounts for hyporheic exchange, pathogen immobilization, degradation and resuspension during baseflow and stormflow conditions. Model results indicate that even at very low flows (<20 L/s), pathogens can be transported over long distances (> 1km), but that the extent of longitudinal transport varies among pathogen types. These results demonstrate that benthic standing stocks of fine particles

act as hot spots of pathogen accumulation in streams, and that the interplay between immobilization, degradation, the extent of resuspension and downstream transport during storms and time between storms determine pathogen concentrations in the streambed.