Fate and Transport of Fecal Indicator Bacteria in Flume Systems Mimicking an Oligotrophic River

Evelyn Walters

The impairment of surface water with enteric microorganisms as a result of combined sewer overflows is a recurring theme which plagues many cities. Such contaminations impact not only human health, but also affect the quality of life of a city's inhabitants. Many advances have been made with respect to creating accurate water quality models which can predict exceedance of fecal indicator standards. These models work to combine hydrodynamics with a varying number of mechanisms that lead to pathogen removal. However, there is still a significant knowledge gap surrounding the behavior of enteric microorganisms upon release into the aquatic environment. In the present work, lab and large-scale flumes were used to investigate various processes impacting the fate and transport of enteric pollution in oligotrophic alpine streams. Specifically, the roles of deposition, natural inactivation, and resuspension were targeted. Furthermore, the influence of suspended solids on *E. coli* and enterococci persistence in the water column as well as the potential for streambed sediments to harbor such indicator microorganisms was evaluated.

In a set of experiments conducted at the lab scale and repeated in the large-scale flume, the persistence of fecal indicator bacteria (FIB) in the water column at a constant discharge was evaluated. Interestingly, FIB removal from the water column of the lab-scale flume consistently occurred four times slower than in the large-scale flume. Although the depth:length ratios and residence times in both flumes were comparable, as were the nutrient concentrations, temperatures, and suspended solids concentrations, the significant difference in removal rates suggests that hydraulic parameters such as turbulence and bed shear stress impact persistence. In the lab-scale flume, a further investigation was performed to approximate the contributions of deposition and natural inactivation to overall FIB removal from the water column. Here it was seen that during the first 24 h, approximately 83 % of FIB removal resulted from natural inactivation (low temperature, nutrient levels), while 17 % was attributed to deposition onto the flume bed. This suggests that there should be little to no accumulation of culturable enteric microorganisms in the bed sediments of oligotrophic alpine rivers.

With the aim of evaluating the influence of suspended solids (TSS) on FIB removal from the water column, further experiments were conducted in the large-scale flume. Interestingly, at TSS concentrations of roughly $50\,\mathrm{mg\,l^{-1}}$, FIB removal from the water column occurred nearly four times slower than at a TSS concentration of approximately $20\,\mathrm{mg\,l^{-1}}$. This finding is of great importance as suspended solids levels during heavy rain events can well surpass the $100\,\mathrm{mg\,l^{-1}}$ mark, indicating the possibility of more widespread downstream pollution. Subsequent analyses of the dissolved organic carbon (DOC) associated with the suspended solids and water, indicated that TSS contributed mainly to the more readily degradable, low-weight fraction of DOC. Contrary to this, DOC associated with the water had a higher fraction of high-weight DOC, which is considered to be less readily degradable. This result implies that the presence of TSS in the water column and continuous release of a low-weight fraction of DOC from it, could increase the persistence of suspended FIB.

Finally, experimental work was performed in both the lab and large-scale flumes to explore the potential of oligotrophic streambed sediments to harbor enteric pollution at different bed shear stresses and sediment depths. Under ideal conditions (*e.g.* no UV light or grazers/predators and low bed shear stress), *E. coli* persisted twice as long as enterococci, regardless of whether a thin (µm) biofilm was investigated or a thick (cm) sediment layer was considered. However, as soon as experiments were conducted with a realistic bed shear stress, the thicker sediment layer harbored FIB $1.5 - 2\times$ longer than the thin biofilm. Moreover, with the introduction of grazers/predators into the flume system operated at a realistic bed shear stress, *E. coli* and enterococci persistence was identical. This suggests that washout and/or grazing/predation control FIB concentrations in natural streambeds exposed to high shear.