Hyporheic Zone Management: *Nitrate Removal from Treated Wastewater Effluent using an Engineered Hyporheic Zone as a Bioreactor*

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Abstract:

The hyporheic zone (HZ) is a natural bioreactor within streambed sediments. The dynamic interface of streamwater and groundwater creates a diverse microbial community that has potential to provide substantial contaminant removal. However, insufficient water exchange between the stream and the HZ is often a limiting factor for improved streamwater quality. Modular subsurface hydraulic conductivity (K) modifications with the addition of organic carbon substrates have been proposed as a means to increase hyporheic exchange and enhance natural water treatment via denitrification. Subsurface K modification flow paths are well understood from previous computer modeling and tracer testing studies, but treatment capabilities have yet to be tested in physical systems.

This research applied chemical and molecular biological techniques to investigate nitrate removal and microbial community structure in a bench-scale stream simulation with subsurface K and carbon modifications. The system received treated wastewater effluent containing soluble nitrogen primarily in the form of nitrate at concentrations fluctuating from 4-7mg/L. To gain insight into denitrification potential and relative microbial activity along hyporheic flow paths, profiles of nitrate fate, total bacterial presence and the density of the denitrification genes (nirS and nirK) were quantified spatially.

Nitrate tests showed a decrease from ~7mg/L in the influent to less than 1mg/L along hyporheic flowpaths. This was accompanied by an increase in 16S rRNA copies (representative of total bacterial biomass) from approximately 200000 gene copies in the influent zone to 630000 gene copies in the effluent zone. Also, the bacterial communities had a greater presence in the upper 6cm of the sediment layer with nirS amplifying 4-5 cycles earlier than nirK in the PCR analysis. The nirS gene concentration was nearly an order of magnitude greater in the effluent zone than the carbon modified zone, suggesting that leached dissolved organic carbon was fueling the process downstream. Our findings show the value of coupled chemical, hydrological and microbial analyses for the optimization of engineered denitrification zones in HZ systems and could further present monitoring tools for assessing environmental performance in situ.

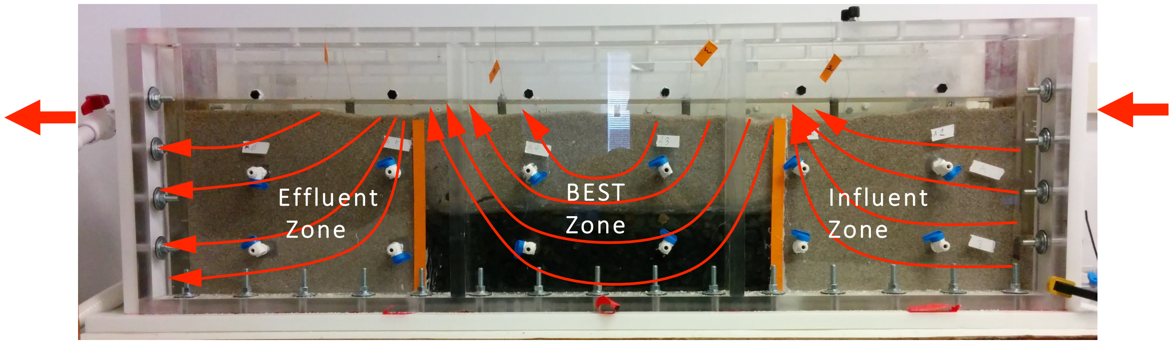

Figure 1. Bench Scale model flowing from right to left. Impermeable walls are the vertical orange tape. The high hydraulic conductivity block is the black box at base overlaid by the soil layer amended with woodchips. Assumed flow lines from modeling and tracer tests are shown in red.

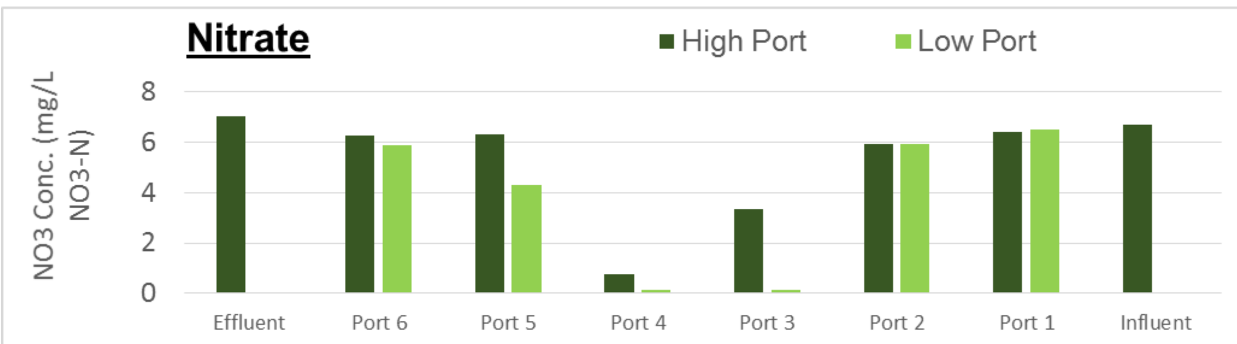

Figure 2. Nitrate concentrations from sample ports. Ports 3 and 4 show denitrification in the BEST. In addition, the ammonia and nitrite concentrations were either very low or below the spectrophotometer detection limit for all ports (data not shown).

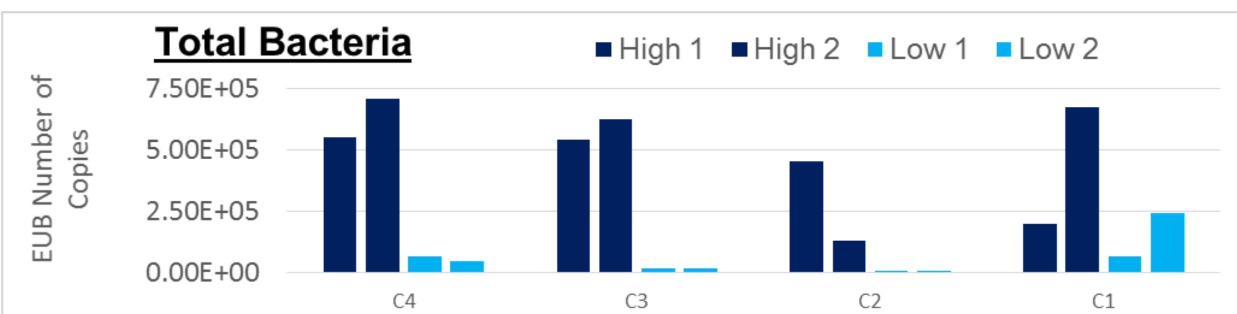

Figure 3. 16S gene copies with respect to column and depth. There is a denser bacterial community in the upper 6cm of the sediment. Except for sample C1 high-replicate 2, the bacteria community increases as it approaches the end of the system.