Permeable Reactive Barriers: A Non-Traditional Technology to Reduce Nitrogen Flux and Meet Estuary Nitrogen TMDLs

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Background/Objectives. On December 5, 2013, EPA announced a new collective framework for implementing the Clean Water Act (CWA) Section 303(d) program with states to implement a water-quality based approach to the CWA. This approach advanced impaired waters through a process of identification, determination of pollutant reduction requirements, development of total maximum daily load (TMDLs), followed by permits, restoration plans, and monitoring. TMDLs represent the implementation by EPA of a dynamic or load based standard versus a target concentration standard to achieve water quality restoration goals. TMDLs are a summation of the sum of wasteload allocations (WLA, point sources), sum of load allocations (LA, nonpoint sources and background), and margin of safety (MOS). The cost to bring Cape Cod communities in compliance with the Clean Water Act entirely through traditional wastewater treatment and sewering has been estimated to be $4.6 to $6.2 billion. To reduce the eventual overall cost, the Cape Cod 208 Water Quality Management Plan would implement traditional wastewater treatment in combination with non-traditional technologies for reducing nitrate mass flux to coastal waters. Denitrification permeable reactive barriers (PRBs) are one of the primary non-traditional technologies, and future installation of PRBs with combined lengths of hundreds to thousands of linear feet are being considered in numerous Cape Cod municipalities to reduce nitrogen mass loading to surface water. Since the denitrification PRB does not need to be designed to meet a target concentration, it can be sited to only treat the portion of the WLA or LA having the highest nitrogen load or flux, reducing the overall size and cost of the PRB versus one scaled and constructed to remove all of the nitrogen.

Approach/Activities. Numerous communities on Cape Cod have performed evaluations of denitrification PRBs, with activities ranging from site selection assessments, site investigations, column studies, and in situ demonstration tests. Fast groundwater flow (1 to 2 feet per day) and high fluxes of nitrate and dissolved oxygen are design challenges. Column studies were performed to demonstrate the nitrate treatment capability of emulsified vegetable oil (EVO) PRBs and determine critical PRB design parameters using nitrate contaminated soil and groundwater from a representative site on Cape Cod. Different EVO formulations and loadings were tested at groundwater flow rates expected for Cape Cod. Based on public concerns of EVO migration, Terra Systems Inc., tested modified EVO formulations to make the EVO amendment stickier to soil to minimize migration of oil and improve retention in a high flow aquifer. Two EVO injection events have been performed for in situ demonstration tests of denitrification PRBs in 2016 and 2018.

Results/Lessons Learned. The presentation will highlight lessons learned from site selection assessments, bench scale and field scale demonstration tests, and design considerations for full-scale denitrification PRBs. Estimating nitrogen flux that can be removed from a PRB has been a key parameter for site selection as well as for comparative evaluation for other nitrogen control technologies. In bench-scale column testing, EVO using a larger droplet size and anionic surfactant was retained on soil matrix better than EVO typically used for enhanced bioremediation for chlorinated solvents. In situ demonstration test injections have applied a customized EVO blend tested at bench scale. Nearly two years of quarterly monitoring following the first PRB injection in the Town of Orleans, Massachusetts has demonstrated EVO's effectiveness at reducing nitrate to low concentrations resulting in the significant reduction of nitrogen mass flux through a PRB. Yet optimum design criteria for EVO PRB longevity such as PRB width, EVO dilution, pore volume loading still need to be determined.