PERMEABLE REACTIVE BARRIERS

Background

Groundwater is the primary source of drinking water for Long Island residents and its quality has been deteriorating in recent decades largely due to lack of effective wastewater treatment of a growing population. One of the major groundwater contaminants on Long Island is wastewater-derived nitrogen. In the 1970's Long Island's upper glacial aquifer groundwater had less than 1 milligram nitrate per liter ($\leq$1 mg $N\text{-}NO_3^-\ L^{-1}$) (Perlmutter and Koch 1972). By 2013 average nitrate concentration had more than tripled, with an average of 3.44 mg $N\text{-}NO_3^-\ L^{-1}$ (Bellone 2015). The EPA has set a maximum contaminant level of 10 mg $N\text{-}NO_3^-\ L^{-1}$ for drinking water and while average nitrate levels in Long Island groundwater are below the drinking water standard, some densely populated areas have concentrations well above regulatory limits. Beyond drinking water, wastewater-derived nitrogen also enters coastal water bodies through groundwater discharge. The dissolved nitrate can then become a major driver of coastal water eutrophication with far reaching consequences such as increased algae biomass and reduced water clarity, promotion of harmful algae blooms (Gobler et al. 2012), hypoxia and coastal water acidification (Wallace et al. 2014), and marine animal die-off (Gobler 2008). Nitrogen pollution of groundwater and coastal water therefore constitutes a serious problem threatening human health and coastal ecosystems around Long Island.

Denitrifying Permeable Reactive Barriers: An Innovative Solution

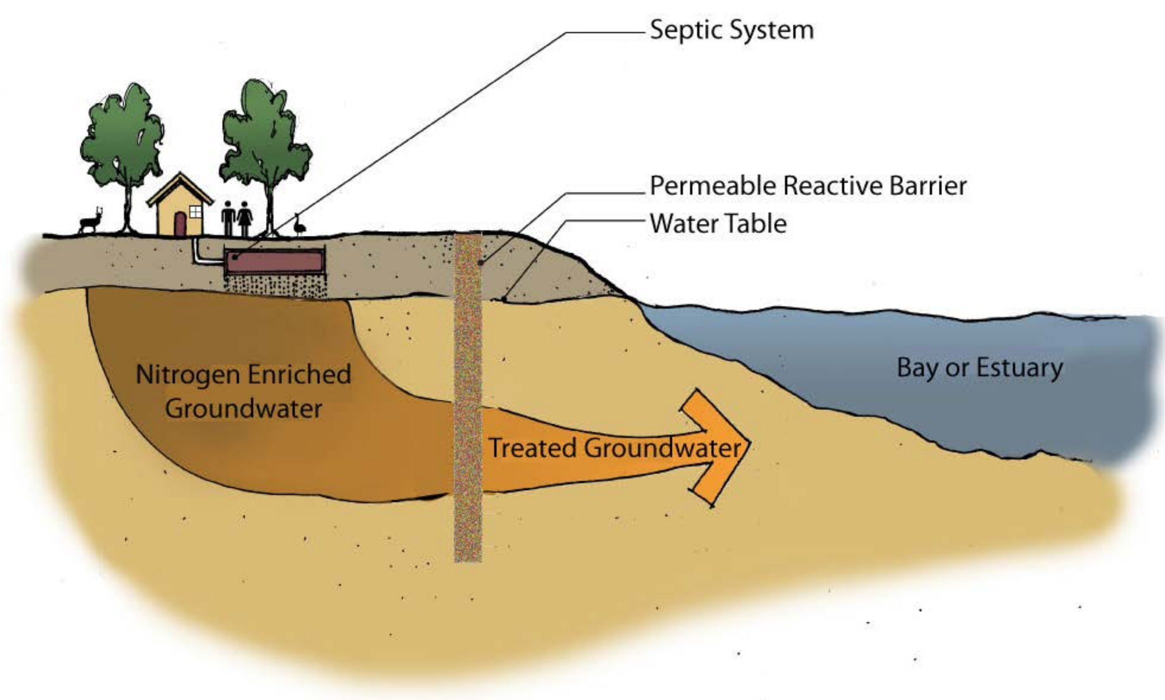

Figure 1: Schematic of PRB designed to treat a plume of nitrate-contaminated groundwater before it enters local surface waters. Modified from https://capecodgreenguide.wordpress.com/permeable-reactive-barrier/

Permeable Reactive Barriers (PRBs) are an innovative solution to address the problem of groundwater and coastal water nitrogen pollution. PRBs are passive, subsurface permeable barriers that intercept groundwater flow and provide conditions in which contaminants are absorbed or transformed. PRBs have been installed worldwide to treat a variety of contaminants including heavy metals, chlorinated compounds, and pesticides (Obiri-Nyarko et al. 2014). PRBs with organic material, such as woodchips, have been used for long-term nitrate removal from groundwater (Robertson and Cherry 1995; Schipper et al. 2005, Robertson et al. 2008). These PRBs rely on microbes that exist naturally in the environment. In the woodchip matrix, these microbes degrade carbon released from the woodchips and rapidly consume dissolved oxygen thereby providing conditions that allow microbes to convert nitrate to nitrogen gas, a process called denitrification. Nitrogen gas makes up about 80% of Earth's atmosphere and is a completely harmless form of nitrogen.

Research on PRBs at the NYS Center for Clean Water Technology (CCWT)

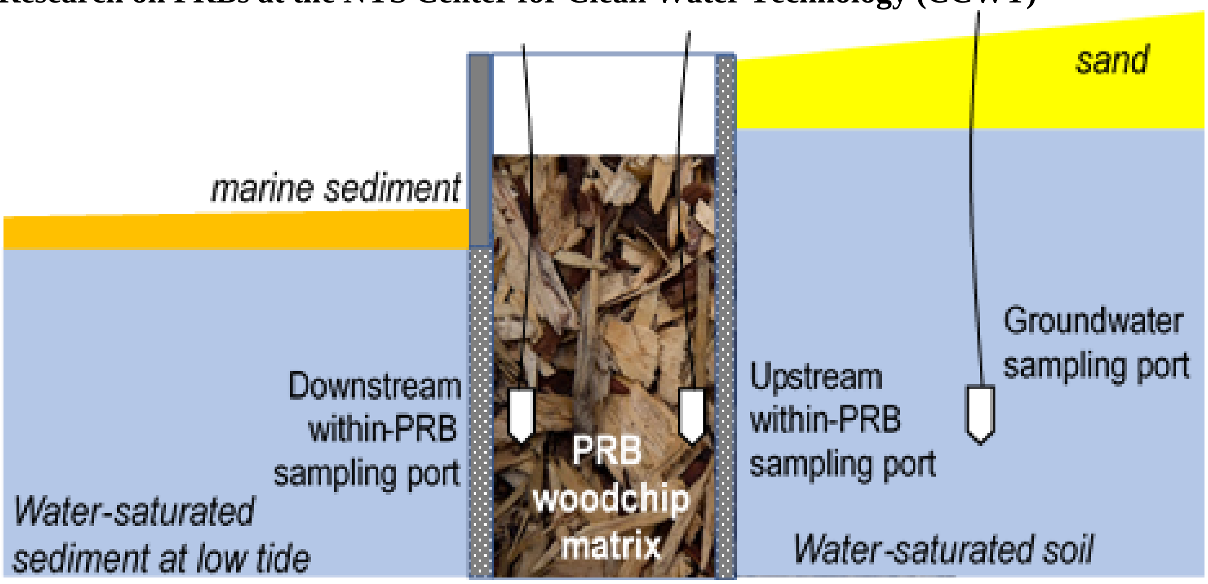

Figure 2: Bulkhead PRB side view. The 1-meter thick PRB test cell with a woodchip matrix was established behind partially perforated vinyl bulkhead. Nitrate is removed while groundwater is flowing through the matrix. Ports upstream and within the PRB are used to collect samples over tidal cycles to evaluate PRB nitrogen removal performance.

CCWT is involved in several projects that evaluate the performance of denitrifying PRBs. The goal is to identify site-specific, optimal PRB configurations to maximize nitrogen removal while minimizing the formation and release of undesired by-products. Current research focus on the potential and functionality of PRBs installed adjacent to marine bulkheads. This PRB configuration allows for nitrate removal just before it would enter coastal water bodies and, thus, could help to remove legacy nitrogen in the aquifer before discharging into surface waters. In collaboration with Cornell Cooperative Extension, we have been monitoring nitrogen removal in a bulkhead PRB test cell (Fig. 2). Despite variable conditions, such as salinity fluctuations associated with tidal flow, the PRB test cell consistently removes 80-100% nitrate from groundwater discharging through it. To determine whether nitrogen removal was affected by the presence of seawater, we have also performed experiments with aged woodchip material from the test cell and found no difference in nitrogen removal for PRBs experiencing seawater intrusion compared to those receiving fresh groundwater. We also found that presence of seawater in PRBs resulted in lower concentrations of methane compared to freshwater systems. This was most likely due to the presence of sulfate, which was preferentially used by microbes and thereby limited methane production by methanogenesis. Strategic placement of PRBs - including PRBs associated within shoreline bulk heading - could help to reduce the discharge of legacy nitrogen into coastal waters and provide relief for coastal water bodies in need of nitrogen mitigation.

References

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