Stony Brook University Center for Clean Water Technology

NITROGEN REMOVING BIOFILTERS FOR ONSITE WASTEWATER TREATMENT

Background. Nitrogen (N) pollution of groundwater can initiate a cascade of negative impacts on aquatic ecosystems as groundwater discharges to lakes and coastal marine waters. Groundwater N levels have risen by over 50% during the past several decades in Suffolk County (SCCWRMP 2015) and Long Island estuaries have suffered a series of negative effects associated with N overloading including harmful algal blooms (Gobler et al. 2008, 2012; Hattenrath et al. 2010), hypoxic and acidified conditions (Wallace et al. 2014), substantial loss of coastal wetlands and 90% loss of seagrass beds (NYSDEC 2009, 2014) and >90% decline in the landings of bivalves (Cosper et al. 1987; Krauter et al. 2008). While residential wastewater on the western half of Long Island is conveyed to sewage treatment plants, approximately 360,000 homes (74% of residences) in Suffolk County (SC) a~ 500,000 across all of Long Island are unsewered (SCCWRMP 2015). While cesspools and septic systems remove pathogens from wastewater, they do not remove N or other harmful organic contaminants (e.g. pharmaceuticals). Multiple studies have identified wastewater from cesspools and septic systems as the largest source of N to northern (Lloyd et al. 2016), southern (Kinney and Valiela, 2011) and eastern (Lloyd 2014) estuaries of Long Island. Recognizing the urgency of mitigating N pollution of Long Island's groundwater, New York State established the NYS Center for Clean Water Technology in 2015 to design and commercialize alternate innovative onsite wastewater technologies that will reduce large amounts of N and other contaminants, are simple to operate and maintain, and cost-effective.

Nitrogen Removing Biofilters. Nitrogen removing biofilters (NRBs) are designed to take advantage of naturally occurring microbes to convert reactive forms of N into inert N gas (N_2) which comprises about 80% of Earth's atmosphere. NRBs also effectively reduce a number of contaminants of emerging concern including pharmaceuticals. NRBs couple nitrification in an oxidizing sand layer to denitrification in an underlaying layer of sand and woodchips. Wastewater from a septic tank is delivered to a lateral subsurface soil distribution system by a single pump; subsequently, wastewater percolates through the nitrifying sand and denitrifying soil layers by gravity. Except for the pump, there are no mechanical parts making maintenance and operating costs low. Shallow depth profiles of NRBs (< 4 ft) make them an attractive option for areas with shallow water tables.

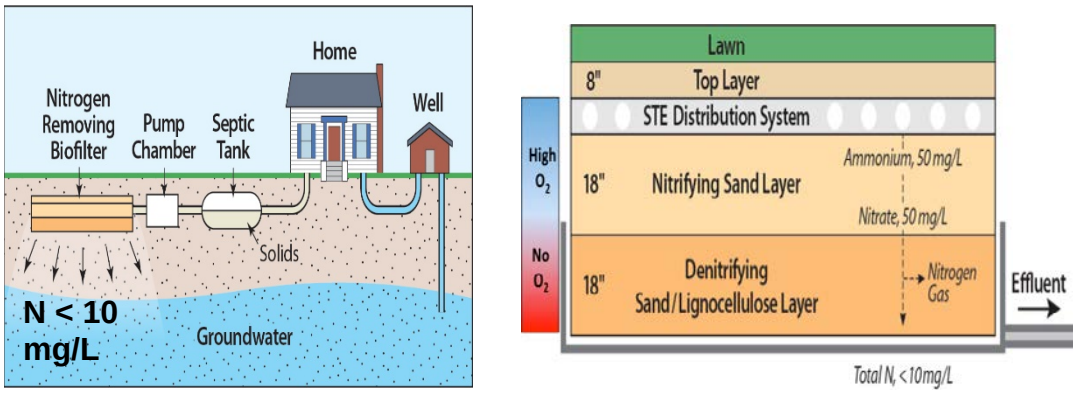
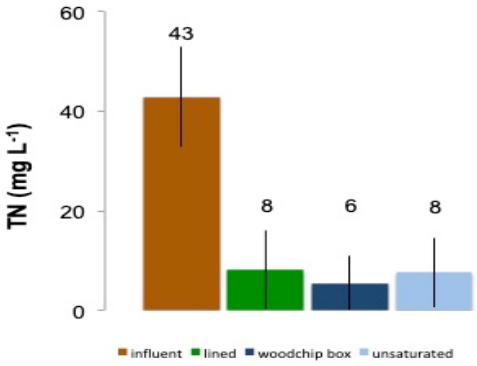


Fig. 1. In a NRB, N is removed from wastewater by nitrifying it in an oxic (high dissolved oxygen) sand layer and denitrifying the resulting nitrate in a sand: woodchip mix to inert N_2 gas.

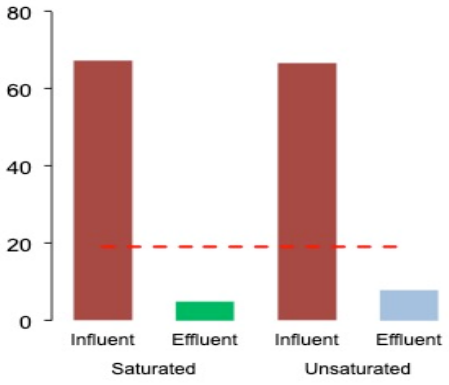
In a previous studies, mass balance calculations of woodchips used in soil to remove N from groundwater indicated that only 10% of the wood material was consumed after seven years of denitrification (Robertson et al 2010), suggesting NRBs can deliver stable N removal over decades.

In the fall of 2016, NYS CCWT designed and installed three NRBs based on coupled nitrification and denitrification at the Massachusetts Alternate Septic System Test Center. Two of the NRBs (lined and unlined) consist of sand filters positioned over sand and woodchip mix while the third comprises a sand filter located next to a woodchip box so the box is accessible should wood-chips need to be replaced after many years of use. Further, NYS CCWT has installed replicas of these three designs at multiple sites (n=7 as of June 2019) in SC as experimental demonstrations in order to gain regulatory approval for widespread use in SC.

Since the inception, each of these systems has produced total N in effluent of < 10 mg L^{-1} representing average N removal of 85% (Fig. 2). Total N removal in these systems compares favorably with more energy- and equipment- intensive technologies approved for provisional installation in SC. Beyond the removal of N, these systems have reduce more than a dozen drugs, anti-biotics, and other organic contaminants by more than 90% and often more than 99%.



N removal of 3 NRB designs Installed at MASSTC from fall 2016-March 2019



N removal of lined and unlined NRBs installed In Suffolk County Spring 2018-March 2019. Dashed red line indicates Suffolk County limit for I/A OSWT

Fig. 2. Performance of three types of NRBs designed and install by CCWT in Massachusetts and NY.

SC's Reclaim Our Waters Initiative. To encourage conversions to nitrogen removing onsite wastewater technologies, SC is offering grants of up to $30,000 to replace cesspools & septic systems with approved technologies for qualifying homeowners in priority areas with additional 3% 15 year loans up to $10,000 to cover additional costs (https://www.reclaimourwater.info). Upon completion of SC's approval process, NYS CCWT's NRB designs will be eligible for such funding.

References.

Cosper, E. M., Dennison, W. C., Carpenter, E. J., Bricelj, V. M., Mitchell, J. G., Kuenstner, S. H., ... & Dewey, M. (1987). "Recurrent and persistent brown tide blooms perturb coastal marine ecosystem." *Estuaries, 10*(4), 284.

Gobler, C.J. and Sunda, W.G. (2012) "Ecosystem disruptive algal blooms of the brown tide species, *Aureococcus anophagefferens* and *Aureoumbra lagunensis*." *Harmful Algae,* 14, 36-45.

Gobler, C. J., Berry, D. L., Anderson, O. R., Burson, A., Koch, F., Rodgers, B. S., and Tang, Y. (2008). "Characterization, dynamics, and ecological impacts of harmful Cochlodinium polykrikoides blooms on eastern Long Island, NY, USA." *Harmful Algae*, *7*(3), 293-307.

Hattenrath, T.K., Anderson, D.M., and Gobler, C.J., (2010) "The influence of anthropogenic nitrogen loading and meteorological conditions on the dynamics and toxicity of *Alexandrium fundyense* blooms in a New York (USA) Estuary." *Harmful Algae*. 9 (4), 402–412.

Kinney, E.L. and Valiela, I. (2011). "Nitrogen Loading to Great South Bay: Land Use, Sources, Retention, and Transport from Land to Bay." *Journal of Coastal Research*. 27 (4): 672 – 686.

Kraeuter, J. N., Klinck, J. M., Powell, E. N., Hofmann, E. E., Buckner, S. C., Grizzle, R. E., and Bricelj, V. M. (2008). "Effects of the fishery on the northern quahog (= hard clam, Mercenaria mercenaria L.) population in Great South Bay, New York: a modeling study." *Journal of Shellfish Research*, *27*(4), 653-666.

Lloyd, S., Mollod G., LoBue C., and Lindberg, M. (2016). "Modeling nitrogen source loads on the north shore of Long Island." Technical Report, The Nature Conservancy

Lloyd, S. (2014). "Nitrogen load modeling to forty-three subwatersheds of the Peconic Estuary." Technical Report, The Nature Conservancy

NYSDEC (2014). "Nitrogen Pollution and Adverse Impacts on Resilient Tidal Marshlands." New York State Department of Environmental Conservation Technical Briefing Summary.

NYSDEC (2009). New York State Department of Environmental Conservation. "New York Seagrass Task Force Final Report".

Robertson, W.D. (2010). "Nitrate removal rates in woodchip media of varying age." *Ecological Engineering*. 36 (11): 1581–1587.

SCCWRMP. (2015). "Suffolk County Comprehensive Water Resources Management Plan." Suffolk County Sanitary Code – Article 19 Page 19-1 "Management of Innovative and alternative onsite wastewater treatment systems."

Wallace, R. B., Baumann, H., Grear, J. S., Aller, R. C., and Gobler, C. J. (2014). "Coastal ocean acidification: The other eutrophication problem." *Estuarine, Coastal and Shelf Science*, *148*, 1-13