Long Island Geologist Conference April 2020

Nitrogen Removing Biofilters: Prospects for mitigating contamination in groundwater from residential wastewater on Long island.

Waugh, S.[1], C.Asato[1] and C.J. Gobler[1,2]

[1] NYS Center for Clean Water Technology, Stony Brook University
[2] School of Marine & Atmospheric Sciences, Stony Brook University

Formatted: Font: Bold
Formatted: Centered

The median value of total nitrogen (TN) in residential wastewater is ~ 60 mg N L^{-1} (Lowe et al. 2007). Using 75% of Suffolk County's minimum design flow for a septic system for a four bedroom house (440 G d^{-1}) as a conservative estimate of actual indoor water usage, un-sewered residences on Long Island (n ~ 520,000) produce ~ 15,700 tons of TN yr^{-1}. For comparison, New York and Connecticut's baseline TN loadings to Long Island Sound used to calculate TMDL targets were 29,300 and 11,700 tons of TN yr^{-1} respectively (NYS DEC & CT DEP 2000). The entirety of Long Island's residential wastewater is delivered to the Upper Glacial and Magothy aquifers (the sole sources of LI drinking water) from which after varying residence times it is discharged to coastal estuaries. Excess nitrogen (N) loading has been associated with a cascade of negative impacts in aquatic ecosystems as declines in water clarity result in a losses of sea grasses and benthic biodiversity and increases algae including harmful algal blooms engender subsequent hypoxia and fish kills (Valiela et al. 1992; Howarth 2008; Hattenrath et al. 2010; Gobler et al. 2012a; Gobler et al. 2012b). N pollution of drinking water has been associated with a variety of human health problems including methemoglobinemia (Wolfe and Patz 2002) and epidemiological studies have suggested connections with non-Hodgkin's lymphoma (Ward et al. 1996) as well as multiple cancers (Weyer et al. 2001; Espejo-Herrera et al. 2016; Jones et al. 2016; Schullehner et al. 2018). EPA drinking water limits for nitrogen in drinking water are set at 10 mg-N L^{-1} as a precaution against methemoglobinemia; studies in Spain and Denmark have associated increased risks of colorectal cancers with N levels < 10 mg-N L^{-1} (Espejo-Herrera et al. 2016; Schullehner et al. 2018). Median levels of nitrate in SC water districts in Suffolk County range between non-detectable and 6.7 mg-N L^{-1} with 7 of 24 district reporting > 5 mg-N L^{-1} (SCWA Annual Report 2019). Beyond nitrogen, residential wastewater is also a source of organic contaminants from pharmaceuticals and personal care products to coastal ecosystems, groundwater and drinking water (Schaider et al. 2017).

Although a number of proprietary onsite wastewater treatment systems designed to reduce total nitrogen in effluent have been commercialized in the last several decades (Oakley et al. 2010; Addy et al 2016), a simple nitrifying sand bed coupled to a denitrifying woodchip-based biofilter achieved lower total nitrogen in final effluent than other more equipment- and energy-intensive proprietary systems (Oakley et al 2010). To achieve widespread utilization of this nonproprietary technology which harnesses naturally occurring microbes to oxidize wastewater nitrogen to nitrate and then denitrify it to inert N_2 gas, the NYS Center for Clean Water Technology has tested three prototype designs for the past 3.5 years at the Massachusetts Alternate Septic System Test Center (MASSTC) and installed replicates of each design in Suffolk County as Article 19 Experimental phase units during the prior two years. The 3 designs referred to as Nitrogen Removing Biofilters (NRB's) are all passive systems which utilize one pump to deliver effluent from a septic tank to a distribution system over a drain-field consisting of 18 inches of sand overlaying either (1) a lined, 18" bed of sand and woodchips; (2) an unlined, 18" bed of sand and woodchips or (3) adjacent to a precast concrete or plastic box filled with woodchips. The purpose of the liner is to keep woodchips always anoxic and to prevent wet and dry cycles which may shorten the carbon longevity of the woodchips; the woodchip box allows woodchips to be accessible and is designed for shallow water table applications. The purpose of these experimental installations has been to assess performance of different designs at different wastewater loading rates and thereby optimize system size (MASSTC) and to acquire system performance experience with actual residential usage (SC).

NRBs have proven highly effective at removing N and other contaminants from domestic wastewater. Suffolk County installations for each design generally has reduced TN from septic tank effluent to average values of 4.4 mg-N L^{-1} (lined), 6.9 mg-N L^{-1} (unlined) and 6.1 mg-N L^{-1} (woodchip box) since their individual start-up dates (Figure 1). Data from MASSTC show TN in final effluent of ~ 8 mg-N L^{-1} for all designs over a 15^{+} month period at optimal loading rates. These results contrast with reports from Suffolk County on commercial I/A OWTS where 12 month rolling averages of TN in final effluent ranged from 10.6 – 19.2 mg- N L^{-1} from Aug 2018 to August 2019 (https://www.reclaimourwater.info/Portals/60/docs/2018_Performance_Evaluation_of_IAOWTS_Appendices_11-18-2019.pdf). Monitoring of NRBs at MASSTC and in SC have also shown these systems effectively removed 90- 99.9% of organic contaminants from pharmaceuticals and personal care products for 10 of 11 analytes tested including acetaminophen, DEET, sulfamethoxazole and trimethoprim (Gobler et al. *submitted*).

It is important to note groundwater leaching thru natural soils underlying pressurized drain systems at two sites in Suffolk County did not produce any coherent pattern of total nitrogen reduction (Fig. 2). TN removal from wastewater relies on a sequenced coupling of oxidation in permeable sand next to an anoxic environment with available carbon heterotrophic denitrification to occur.

Results to date indicate NRBs offer a low maintenance, energy efficient solution to substantial reducing N loading to Long Island aquifers and marine ecosystems.

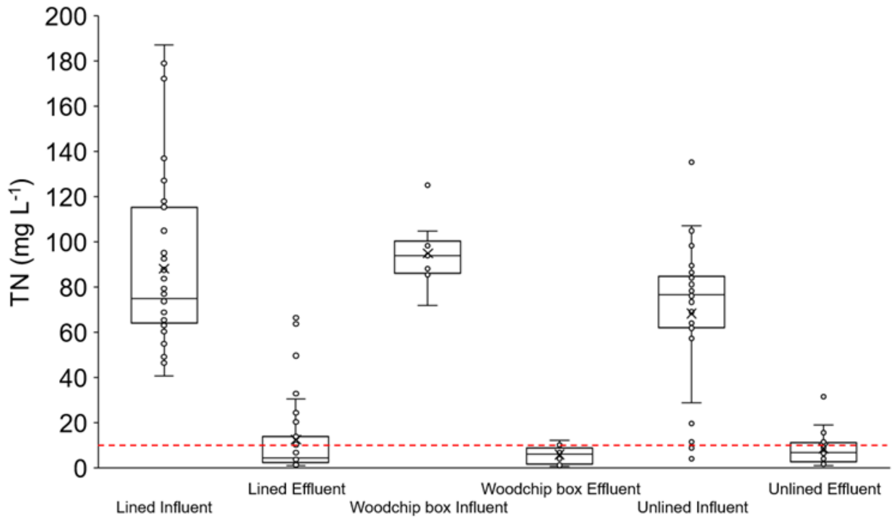

Fig. 1. Total nitrogen (mg-N L^{-1}) in septic tank effluent and final effluent of 3 different designs of Nitrogen Removing Biofilters.

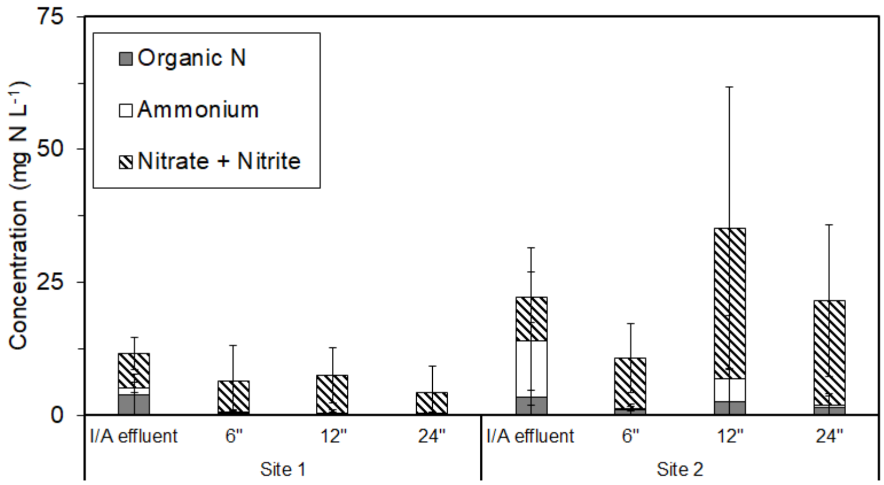

Fig. 2. Nitrogen speciation in effluent from two I/A systems distributed by pressurized distribution systems over drain-fields of natural Long Island soils.

References:

Addy, K., Gold, A. J., Christianson, L. E., David, M. B., Schipper, L. A., and Ratigan, N. A. (2016). “Denitrifying bioreactors for nitrate removal: A meta-analysis.” *J. Environ. Qual.* 45(3), 873-881. https://doi.org/10.2134/jeq2015.07.0399.

Gobler, C.J., Burson, A., Koch, F., Tang, YZ., and Mulholland, M.R. (2012a). “The role of nitrogenous nutrients in the occurrence of harmful algal blooms caused by *Cochlodinium polykrikoides* in New York estuaries (USA).” *Harmful Algae* 17: 64-74. https://doi.org/10.1016/j.hal.2012.03.001.

Gobler, C.J. and Sunda, W.G. (2012b). “Ecosystem disruptive algal blooms of the brown tide species, *Aureococcus anophagefferens* and *Aureoumbra lagunensis*.” *Harmful Algae* 14, 36-45. https://doi.org/10.1016/j.hal.2011.10.013.

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. https://doi.org/10.1016/j.hal.2010.02.003.

Howarth, R. W. (2008). “Coastal nitrogen pollution: a review of sources and trends globally and regionally.” *Harmful Algae* 8(1): 14-20. https://doi.org/10.1016/j.hal.2008.08.015.

Jones, R. R., Weyer, P. J., DellaValle, C. T., Inoue-Choi, M., Anderson, K. E., Cantor, K. P., Krasner, S., Robien, K., Freeman, L. E. B., Silverman, D. T., and Ward, M. H. (2016). "Nitrate from Drinking Water and Diet and Bladder Cancer Among Postmenopausal Women in Iowa." *Environ. Health Perspect.* 124(11), 1751-1758. https://doi.org/10.1289/EHP191.

Oakley, S. M., Gold, A. J., and Oczkowski, A. J. (2010). “Nitrogen control through decentralized wastewater treatment: Process performance and alternative management strategies.” *Ecol. Eng.* 36(11): 1520-1531. https://doi.org/10.1016/j.ecoleng.2010.04.030.

Schaider, L. A., Rodgers, K. M., and Rudel, R. A. (2017). "Review of Organic Wastewater Compound Concentrations and Removal in Onsite Wastewater Treatment Systems." *Environ Sci Technol*, 51(13): 7304-7317. https://doi.org/10.1021/acs.est.6b04778.

Schullehner, J., Hansen, B., Thygesen, M., Pedersen, C. B., and Sigsgaard, T. (2018). “Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study.” *Int. J. Cancer* 143(1): 73-79. https://doi.org/10.1002/ijc.31306.

Valiela, I., Foreman, K., LaMontagne, M., Hersh, D., Costa, J., Peckol, P., and Brawley, J. (1992). “Couplings of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts." *Estuaries*, *15*(4): 443-457. https://doi.org/10.2307/1352389.

Ward, M. H., Mark, S. D., Cantor, K. P., Weissenburger, D. D., Correa-Villasenor, A., and Zahn, S. H. (1996). "Drinking water nitrate and the risk of non-Hodgkin's lymphoma." *Epidemiology* 7(5): 465- 471. https://www.jstor.org/stable/3702144.

Weyer, P. J., Cerhan, J. R., Kross, B. C., Hallberg, G. R., Kantamneni, J., Breuer, G., Jones, M. P., Zheng, W., and Lynch, C. F. (2001). "Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study." *Epidemiology* 11: 327- 338. https://www.jstor.org/stable/3703710.

Wolfe, A. H. and Patz, J. A. (2002). "Reactive Nitrogen and Human Health: Acute and Longterm Implications." *AMBIO* 31(2): 120- 125. https://doi.org/10.1579/0044-7447-31.2.120.