The influence of plants on nitrogen biogeochemical cycling in constructed wetlands

Samantha C. Nyer[1,2], Roy E. Price[1,2], Nils Volkenborn[1,2], Robert C. Aller[2,], Molly Graffam[1,2], Qingzhi Zhu[1,2], Christopher J. Gobler[1,2]

Affiliations
[1] The New York State Center for Clean Water Technology, Stony Brook University, Stony Brook, NY 11794
[2] Stony Brook University, School of Marine and Atmospheric Sciences, Stony Brook, NY 11794

Nutrient pollution due to anthropogenic loading poses extensive threats to the quality of our water and has consequences for both human health and coastal ecosystems globally. As wastewater constitutes a dominant source of excess reactive nitrogen to the marine environment, low-cost wastewater treatment technologies that reduce nitrogen at the source can be of great ecological importance. Constructed wetlands (CWs) are soil-based systems that can be applied to circumvent nitrogen pollution by treating wastewater at the source. These systems are part of a suite of innovative/alternative on-site wastewater treatment systems (I/A OWTS) being considered in regions where large sewage treatment facilities are not feasible. Despite their potential, nitrogen removal in CWs is highly variable, reflecting our limited understanding of the relative contributions and fundamental biogeochemical processes influencing nitrogen cycling. Additionally, many critical processes pertaining to nitrogen transformations in CWs are thought to occur in microzone "hotspots", such as the plant root zone or rhizosphere, highlighting the need for studies with sub-cm spatial resolution of porewater geochemical data.

In a series of bench-scale studies, high resolution chemical imaging coupled with porewater nitrogen measurements during dosed application of nitrogen-rich artificial wastewater provided direct evidence of plant-induced changes in sediment redox dynamics. These plant-mediated changes translated to improved nitrogen removal (~3x) by presumably stimulating the coupling between nitrification and denitrification in saturated, oxygen-depleted wetland soils. The ultimate fate of nitrogen in these systems was subsequently further assessed through innovative techniques utilizing nitrogen isotopes to determine in-situ rates of N_2 production under different boundary conditions. Results indicated significantly higher rates of denitrification in planted systems (4 mmol m^{-2} d^{-1} vs 0.1 mmol m^{-2} d in unplanted systems), whereas potential alternative pathways such as feammox and anammox prevailed in the anoxic, carbon-limited unplanted systems. Measurements of total iron in porewater were consistent with the occurrence of feammox and indicate potential associations between nitrogen and iron cycles in CWs that should be explored further.

Collectively this work provides new insights into controls on nitrogen biogeochemical cycling in CWs. In particular, this research highlights the divergence of the dominant nitrogen transformation pathways in planted and unplanted systems. Plants play a critical role in regulating nitrogen transformations by creating a highly heterogeneous system characterized by complex coupled redox reactions which vary spatially and temporally. With careful consideration, CWs designed to promote wetland plants' function can enhance the performance of these systems and lead to their application as inexpensive and effective nitrogen abatement strategies that are so urgently needed.