Nitrogen Dynamics in Flow Through Microcosms of Nitrex®

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Introduction: Urbanization of Cape Cod has increased dramatically over the past decade. The increased number of households has also increased the input of nutrient concentrations from treated wastewater, residential septic systems, agricultural and residential fertilizer applications, and atmospheric deposition. The increased levels of nutrients result in increased rates of eutrophication of Cape Cod's bays and estuaries. Eutrophication can cause the replacement of eelgrass by macroalgae, low dissolved oxygen, periodic fish kills and other negative results.
It is very important to eliminate or at least reduce the amount of nitrogen entering the estuaries from all three sources, wastewater, fertilizers, and atmospheric deposition. The Marine Biological Laboratory in Woods Hole, MA began a project in June of 2005 called: Effectiveness of Reactive Barriers for Reducing N-loading to the Coastal Zone. The project uses a Nitrex® permeable reactive barrier placed at the groundwater/estuarine interface to intercept the nitrogen-rich water from all sources prior to entering the estuary. The Nitrex® medium which is essentially woodchips, acts as a carbon source to fuel denitrification. Therefore the N-rich groundwater entering the barrier will be denitrified and exit into the estuary N-deficient. In Fall 2005, I spent the semester in Woods Hole at the Marine Biological Laboratory as a student in the Semester in Environmental Science program.
During the last 5 weeks of the semester, I was provided with the opportunity to work on my own research project. I designed pilot-scale barriers in the laboratory to determine whether the Nitrex® medium would still be effective if exposed to saltwater since it was placed on the coastline. During my research time, I found out that the Nitrex® medium is still effective if exposed to a small amount of saltwater. However, a follow-up program revealed concerns that the barrier was being exposed to saltwater with each high tide. Therefore, during Spring 2006, I decided to test whether more saltwater would alter the Nitrex® medium's ability to denitrify the N-rich groundwater. From my results, thus far, adding more saltwater does not alter the Nitrex® medium's ability to denitrify the N-rich groundwater.

Figure 1. A picture of eelgrass found in Cape Cod estuaries and bays.

Figure 2. A picture of macroalgae which can replace eelgrass beds if Cape Cod estuaries are exposed to high concentrations of nitrate.

Materials & Methods:
Six miniature Nitrex® barriers were assembled in the laboratory. The structures of the barriers were made using an PVC pipe 10 in. in diameter, 2.5 ft. long. The ends were sealed using plastic circular disks with a nipple placed in the center of the base. Attached to the nipple is a plastic tubing that leads to 1 L volumetric cylinder that is sealed with a cork. The column was filled with woodchips. A mesh bag was placed over the woodchips and sand filled the remainder of the column. A Mariotte bottle was used to control the flow at 2.7 L/day. There were three treatments being tested in which the inflow water was varied. In treatment 1, the inflow water was groundwater from a well 14 ft. deep. In treatment 2, the inflow water was groundwater with pulsed saltwater for 4 hrs once a day. In treatment 3, the inflow water was saltwater.
The outflow was filtered and then sampled for nitrate, ammonium, and hydrogen sulfide using a spectrophotometer to measure absorbance. The nitrate was determined to be read at 540 nm using Lachat QuikChem. The hydrogen sulfide was measured at 670 nm using the N'Cline/Cline method. The ammonium was measured at 640 nm using the phenol-hypochlorite method.

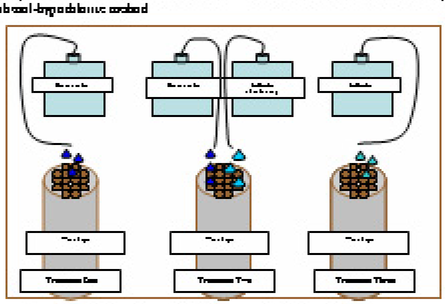

Figure 3. [illegible]

Figure 4. An actual picture of the microcosms located at the Marine Biological Laboratory in Woods Hole, MA.

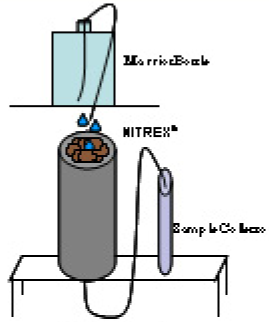

Figure 5. System set-up.

Results: Nitrate Concentrations: The nitrate concentration was measured in the inflow and outflow of both the groundwater and saltwater. In the different treatments, the concentrations of nitrate entering the microcosms is higher than the concentrations exiting the microcosms. This confirms that the nitrate is being denitrified in the microcosms of all three treatments.
Sulfide Concentrations: Hydrogen sulfide is produced as a product of sulfate reduction. Sulfate reduction has the ability to inhibit nitrate reduction because the nitrate reducers compete with the sulfate reducers. In treatment two and three, sulfate is being added in the form of saltwater, however no hydrogen sulfide is being added to any of the treatments. In treatments two and three, hydrogen sulfide is being produced in the outflow. This indicates that Nitrex® increases the reduction of sulfate. Interestingly, more hydrogen sulfide is being produced in treatment two which is pulsed with seawater, than in treatment three which is continuously exposed to seawater.
Ammonium Concentrations: Once microbial communities responsible for denitrification develop over time, they drive the system anaerobic and ammonium levels typically fall to zero. There is very little ammonium entering the microcosms of all three treatments, however, there is slightly more ammonium exiting the microcosms presumably due to reduction of nitrate. My work last semester indicated that ammonium concentrations eventually fall to zero but at present we do not know whether this is because it is absorbed onto the wood chips or because of something else.

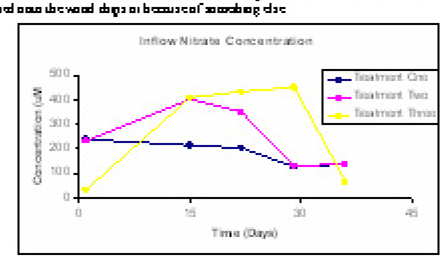

Figure 6. Concentrations of inflow nitrate in Treatments One, Two, and Three.

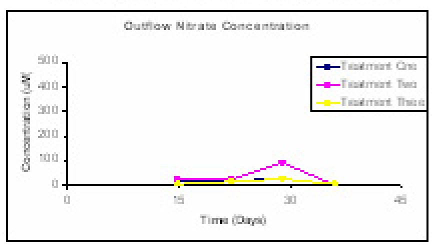

Figure 7. Concentrations of outflow nitrate in Treatments One, Two, and Three.

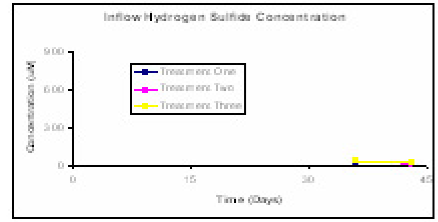

Figure 8. Concentrations of inflow hydrogen sulfide in Treatments One, Two, and Three.

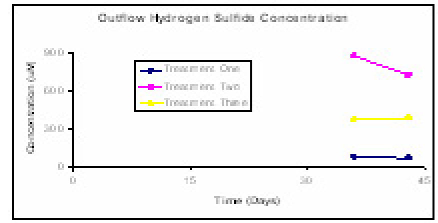

Figure 9. Concentrations of outflow hydrogen sulfide in Treatments One, Two, and Three.

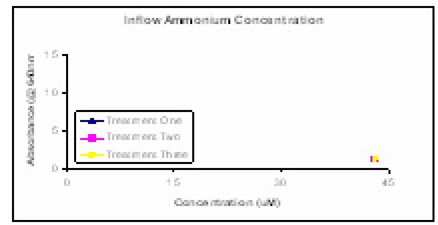

Figure 10. Concentrations of inflow ammonium in Treatments One, Two, and Three.

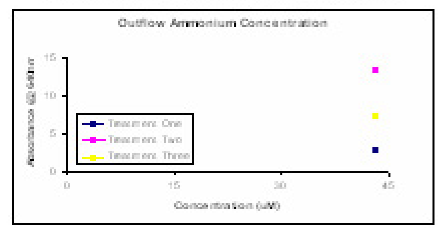

Figure 11. Concentrations of outflow ammonium in Treatments One, Two, and Three.

Future Directions:
- Continue sampling inflow and outflow for:
  - Nitrate
  - Ammonium
  - Hydrogen Sulfide
  - Salinity
  - Sulfate
- Perform Carbon, Hydrogen, and Nitrogen analyses on initial and final woodchips
- Sample nutrient concentrations at different depths within the core