Assessing the Effectiveness of Different Carbon Sources in Stimulating Denitrification in a Wastewater Wetland Designed for Removing Nitrate

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BACKGROUND

Removing nitrogen, which can harm downstream ecosystems, is a key function of tertiary wastewater treatment. Denitrification, the final step of biological nitrogen removal, is the conversion of nitrate (NO_3) to nitrogen gas (N_2). The microbial community involved in denitrification requires an anaerobic (low oxygen) environment and a source of organic carbon for energy.

Wetland-based wastewater treatment systems, such as Oberlin College's Living Machine (LM), often incorporate a final marsh system to provide a chemical environment conducive to denitrification. Previous studies indicate that Oberlin's LM is deficient in organic matter necessary to stimulate denitrification (Haineswood & Morse 2003). Acetate is often introduced as a carbon source to denitrifying marshes (Rustige 2007) and has been shown to stimulate denitrification in samples taken from the Living Machine (Haineswood & Morse 2003).

GOALS

The objective of our study was to determine how different sources and amounts of carbon, some locally available, might stimulate denitrification in the final marsh of the LM. Specifically, we conducted bottle-incubation experiments to assess the denitrifying potential of woodchips, and taro leaves and compared these with acetate. Ultimately we are interested in information that can be used to better manage Oberlin's Living Machine as well as other similarly constructed wastewater treatment systems to improve their performance and create safer, cleaner water.

TREATMENTS

Wastewater samples were extracted from a sampling port near the inflow to the marsh. These anoxic samples were then incubated with four different carbon sources:

- **Acetate** acted as a reference to compare the efficacy of our other carbon sources against the industry standard. Concentrations were based on Haineswood and Morse (2003).
- **Woodchips** are a cheap source of carbon, and were soaked for two weeks to simulate the decomposition that would occur over an extended period of soaking in the Living Machine. Different masses of woodchips were then added to effluent samples.
- **Taro** leaves are a readily available carbon source, as they are already grown as a part of the wetland in the Living Machine. These samples were soaked in water and treated under the same conditions as the woodchips.
- **Fresh taro** leaves were ground up and added to samples for comparison with the decaying matter.

RESULTS & DISCUSSION

NO_3 Depletion as a Function of Substrate Concentration

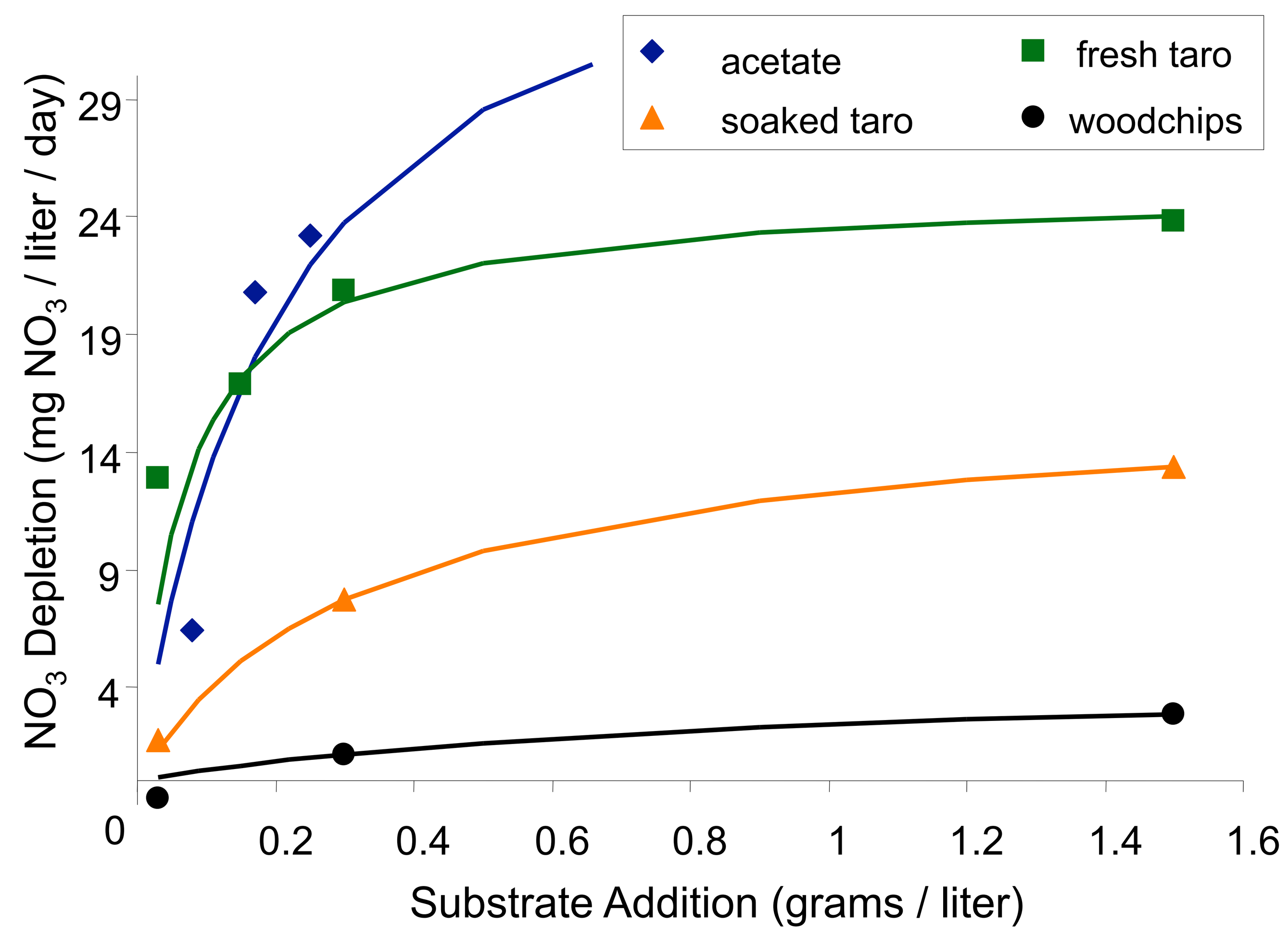

Figure 1. NO_3 depletion (denitrification) in marsh samples incubated at 20ºC for 2 days, following the techniques of Haineswood and Morse (2003). Depletion measured as the difference in NO_3 between control samples (no supplemental carbon added) and the treated samples after the incubation period.

- All of the carbon sources used resulted in higher rates of denitrification
- Different carbon sources caused different rates of denitrification
- The affects of all the carbon sources appeared to saturate as their Concentration approached 1.5 grams / liter

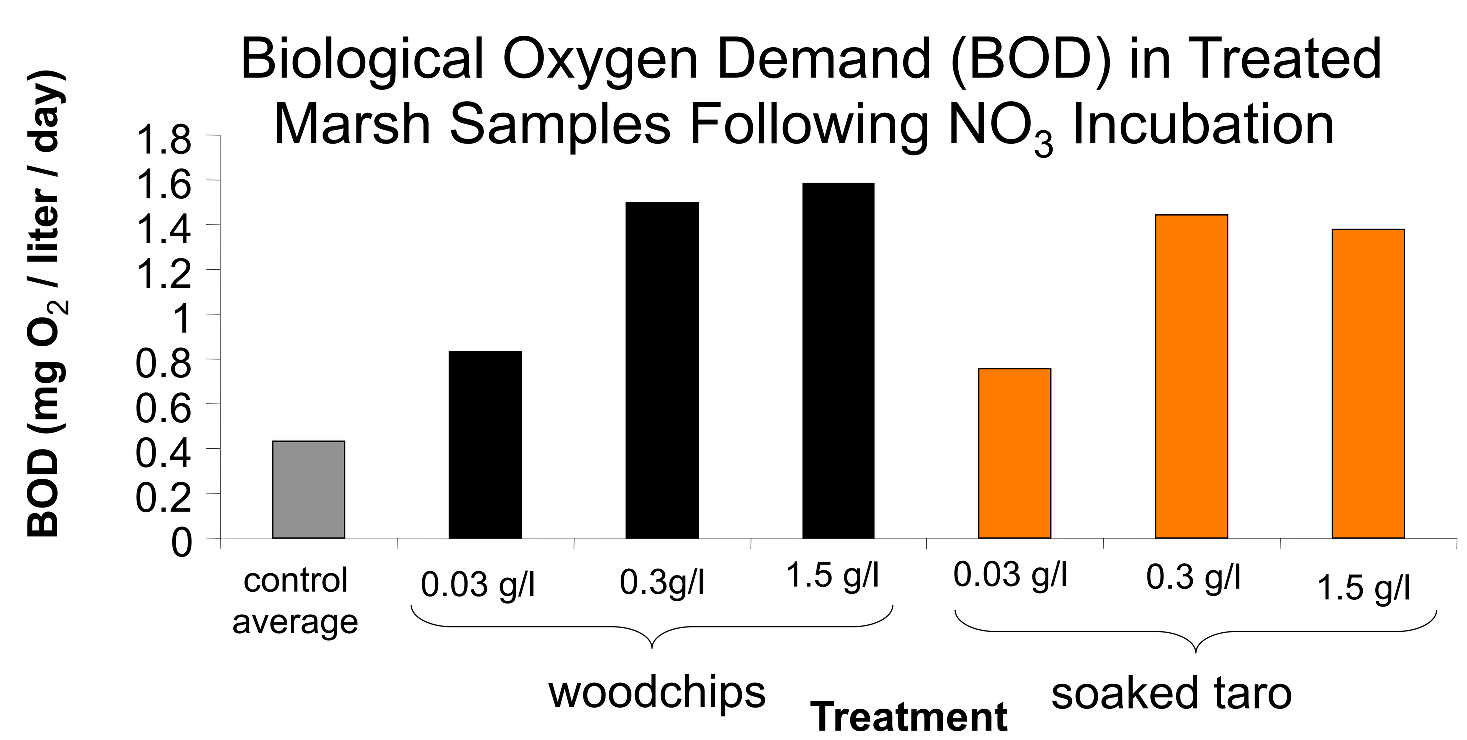

Figure 1. Rates of BOD for two treatment groups. The marsh samples used in Fig. 1 were saturated with oxygen following the NO_3 incubation, incubated for an additional 5 days, and BOD was measured.

- BOD in the control indicates presence of organic matter that can be broken down by microbes
- Increased BOD levels in the soaked taro and woodchips shows increase of organic matter necessary for microbial activity

CONCLUSIONS

- Incubating LM samples with additional carbon sources successfully increases the amount of denitrification occurring in the marsh water.
- Both acetate and taro leaves showed considerably reduced nitrogen levels in the LM marsh samples such that they should be considered for use as supplemental carbon sources.
- We found negligible reductions in nitrate when woodchips were added to samples, though BOD levels in these bottles were high. These results suggest that carbon quality may be more important than carbon quantity in increasing denitrification.
- However, while acetate drastically increased denitrification initially, it would have to be reintroduced into the LM continuously, while both woodchips and taro could provide more long term benefits to denitrification.

FUTURE RESEARCH

- Using woodchips at varying levels of decomposition over a longer period of time would be more indicative of its usefulness as a carbon source.
- Future studies could explore these treatments using a greater concentration gradient, as well as adding treatments directly to the Living Machine marsh and measuring NO_3 levels in the effluent.
- The taro leaf and woodchip treatments should be standardized for future studies, either by repeating experiments using dry weights of each or by calculating a dry weight coefficient for both taro leaf and woodchip treatments.
- Future studies should consider the effects of adding carbon to the LM on increasing the BOD.

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Rustige, H; Nolde, E. 2007. Nitrogen elimination from landfill leachates using an extra carbon source in subsurface flow constructed wetlands. Water Science and Technology. 56: 125-133

Haineswood and Morse. 2003. Low Organic Carbon Limits Denitrification in the Marsh of an Ecologically Engineered Wastewater Treatment Facility at Oberlin College. ENVS316 Research Project