

The Effect of Flow Rates on the Absorption of Nutrients in Artificial Wetlands

Foster Lerner, Jodie Clementson, Shaun Kuoni Baylor University, Waco, TX 76798

Abstract

The purpose of the experiment was to determine an optimal flow rate for the extraction of nutrients by an artificial wetland. The magnitude of nutrient extraction was determined by algal growth (Lau et al., 1994). Three flow rates of 200, 400, and 800 mL min⁻¹ ± 50mL min⁻¹ were selected based on previous experimental data (Stark et al., 1994). These flow rates were tested in three identical pairs of artificial tracks. Each pair consisted of two tracks with identical flow rates. Three tracks contained the algae (*Cladophora*), while three tracks served as controls, with no algae. Runoff water from each track was tested for total Nitrate/Nitrite and total Phosphorus levels to determine differences in nutrient absorption. The initial mass of the algae was recorded, and the post-experimental mass was taken to measure total growth as an indicator of absorption (Wong and Tam, 1999). It was found that the highest flow rate allowed for the greatest absorption of nutrients within the range of flow rates that were tested. From these results it can be concluded that flow rate does have a significant effect on algal absorption of Nitrogen and Phosphorus. Therefore, the Optimal Nutrient Absorption Flow Rate (ONAFR) appears to be closer to 800mL min⁻¹ and not less than 200mL min⁻¹. Further investigations could narrow and determine the specific ONAFR of water through a wetland.

Introduction

At the Lake Waco Wetlands, there appear to be different flow rates present throughout the cells. Based on these observations, it was speculated that these varying flow rates might cause the organisms in the wetland to more efficiently absorb nutrients from the water. The issue of absorption is a significant issue because water filtration and impurity absorption is one of the primary purposes for the existence of artificial wetlands. If the existence of an Optimal Nutrient Absorption Flow Rate (ONAFR) through the wetlands could be determined, then the design and performance of future wetlands could be optimized. A similar study based on heavy metal retention in mesocosm wetlands with varying flow rates had been done (Stark, 1994). Similarly, this experiment was designed to determine if an ONAFR exists for algae absorption of nitrates/nitrites and phosphorus.



Fig. 1: The tracks set up between two mesocosms with container/tubing flow-control system.



Fig. 2: Setup of 400 mL min⁻¹ during the algae die-off period

Materials and Methods

To create approximately identical environments with variable flow rates, a system of tracks in which the flow rate could be adjusted was devised. Using six empty 1135.6 L mesocosms as collecting tanks, two level tracks (305cm x 15cm x 13 cm) that ran between two mesocosms were constructed. One of these tracks was used as a control with a specific flow rate while the other track contained algae and was assigned the same flow rate. The tracks flowed in opposite directions and emptied into separate mesocosm tanks. An inflow pipe with untreated water from the North Bosque River was introduced to a flow control system that distributed water to each of the tracks with appropriate flow rates (200 mL min⁻¹, 400 mL min⁻¹, and 800 mL min⁻¹ ± 50 mL min⁻¹). This experiment was run for two weeks using algae. The mass of the algae in each track was measured using a rough balance at the beginning and end of the two weeks. The water in each collecting mesocosm as sampled and measured for nitrate/nitrites and phosphorous levels at the beginning, after the first week, and at the end.

Results

Results show no uniform trend in the levels of phosphorus and nitrate/nitrite as flow increases in the control tracks. But in the algae tracks, these levels tend to decrease with increasing flow rate, with the exception of the measurements taken from the Algae 400 mL min⁻¹ mesocosm (Fig. 3, Fig. 4). In the second week, it was noted that the algae in the the 400 mL min⁻¹ track had undergone a die-off, whereas the other tracks showed no such die-off of algae. As flow rates of algae tracks increase, algae final mass tends to increase, with the exception of the 400 mL min⁻¹ algae which did not show significant growth (Fig. 5).

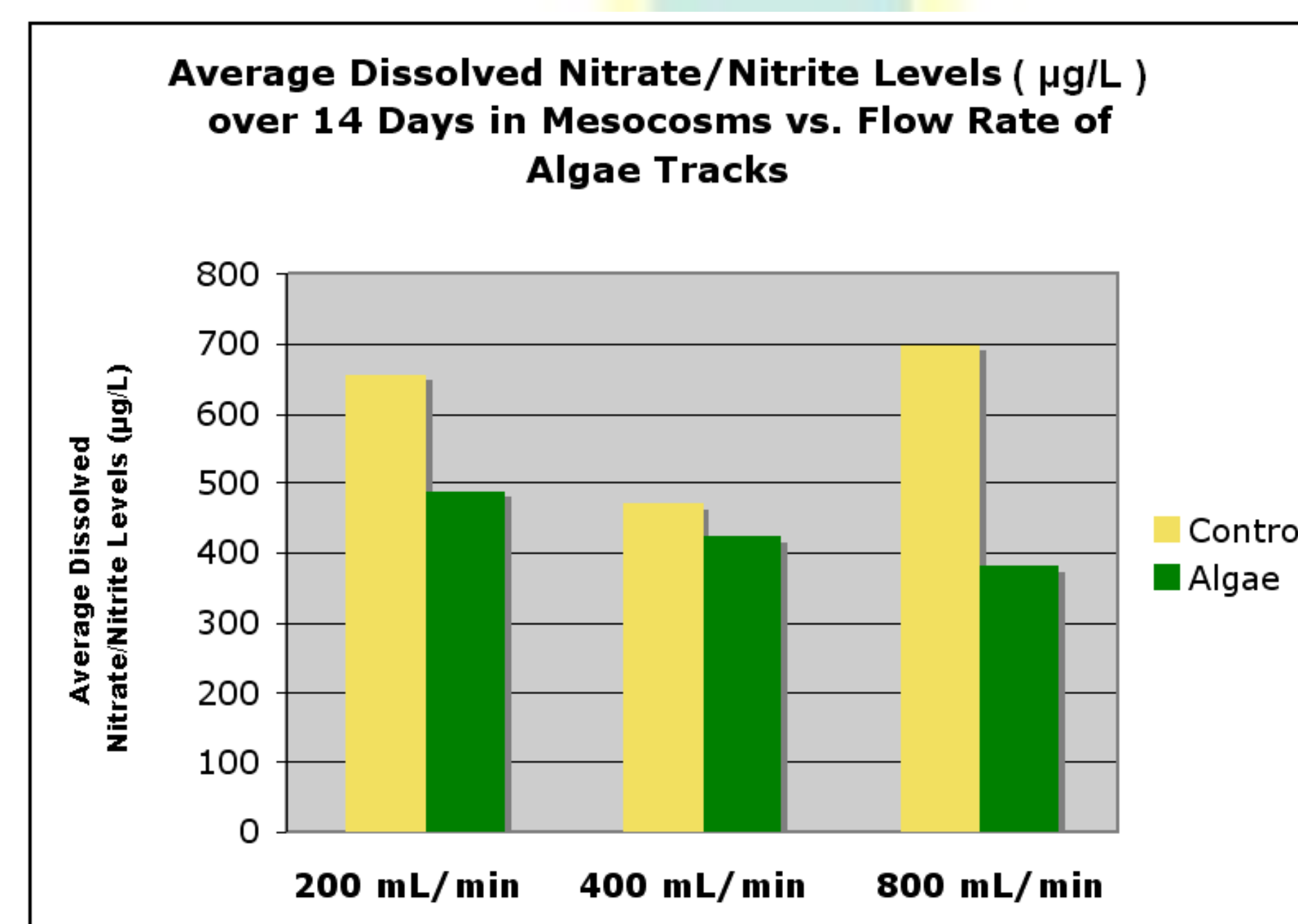


Fig. 3

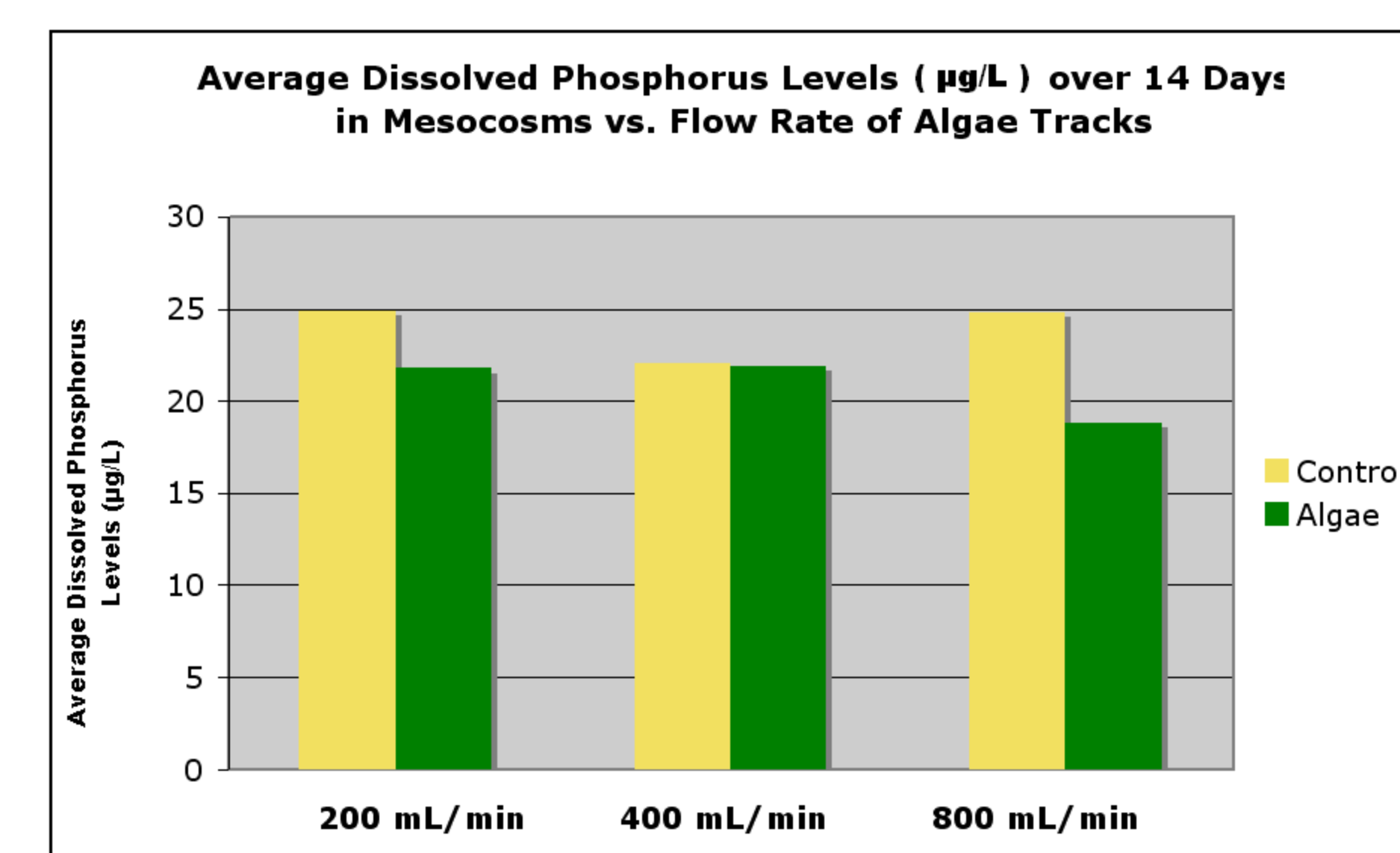


Fig. 4



Fig. 5

Discussion

Though the flow rate of 800 mL min⁻¹ was found to be the most efficient flow rate for the removal of nutrients within the tested range, an ONAFR was not determined. The data suggest that the ONAFR should be nearest to 800 mL min⁻¹ within the range of flows tested. The 400 mL min⁻¹ flow rate data was inconclusive due to an algae die-off between the first and second weeks (Fig. 2) and therefore did not follow the general trend that nutrient absorption efficiency increases as flow rate increases. The flow rates that were tested were higher than those used in the longer-term experiment by Stark et. al (1995). Even so, they follow the same trend of increasing flow rates providing greater nutrient absorption. The specific flow rate could be determined by conducting a similar experiment with a more effective design and by altering the flow to be within a range around 800mL min⁻¹.

Conclusion

Wetlands are important in treating nutrient-enriched water, and in order to maximize their efficiency, an ONAFR should be implemented in the design. The data suggests a specific flow rate will maximize the removal of nutrients although an exact ONAFR value was not obtained. It can be inferred that up to a certain point, higher flow rates increase nutrient absorption because higher concentrations of nutrients are available to organisms for absorption per unit of time. If a specific ONAFR were to be determined in a future investigation, it could be implemented in the design of future artificial wetlands to improve efficiency.

Acknowledgements

We would like to thank Dr. Marty Harvill (Professor of Biology), Jeff Back (Center for Reservoir and Aquatic Systems Research), Nora Schell (Lake Waco Wetlands), Dr. Robert Doyle, Amanda Hartman, Anica Debelica, Jordan Wiegand, Baylor College of Arts and Sciences, and The Baylor Department of Biology.

Literature Cited

Lau, P.S., N.F.Y. Tam, and Y.S. Wong (1994) Effect of algal density on nutrient removal from primary settled wastewater. *Environmental Pollution* 89:1:59-66.

Lloyd R. Stark, William R. Wenerick, Frederick M. Williams, Paul J. Wuest (1995) The effects of pH, flow rate, and carbon supplementation on manganese retention in mesocosm wetlands. *Journal of Environmental Quality* 24:816-826.

Tam, N.F.Y. and Y.S. Wong (1999) Effect of immobilized microalgal bead concentrations on wastewater nutrient removal. *Environmental Pollution* 107:1:145-151.