Optimizing Engineered Algae Cultivation for Pollution Control in Western New York Watersheds

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INTRODUCTION

Nutrients such as nitrogen (N) and phosphorous (P) are common pollutants in regional water bodies. Human sources, such as agricultural runoff and urban sewage overflow, often raise these nutrients to excessive levels. As a result, algae growth can reach nuisance levels and create issues with water quality, a common problem known as *cultural eutrophication*. Systems can be engineered to cultivate the algae at high growth (and high rates of nutrient uptake). The harvesting of this algae effectively removes these pollutants from the water (Adey et al. 1993)

The objective of this research is to test an algal turf scrubber (ATS) system in the laboratory for cultivation of benthic attached algae for maximum growth and nutrient uptake.

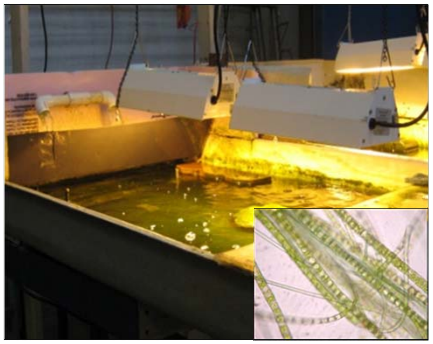

Figure 1: Photo of an operating ATS; *Cladophora* species (inset) is the dominant algae present

BACKGROUND

It can be expected that algae will grow in an ATS in a pattern resembling Limiting Factor Theory, which suggests that as necessary nutrients, conditions, supplies, etc. are increasingly applied to a system, the production of that system will increase. Then, the production will level off as one of these factors becomes limiting to its growth. In the case of the algae in this experiment, for a given light intensity and with excess phosphorus, nitrogen can become limiting. It can be expected that as the Nitrogen Loading Rate (NLR) increases, production will increase until light begins to limit its growth.

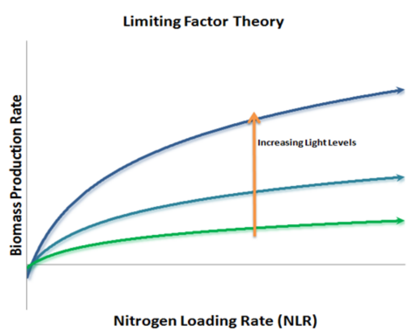

Figure 2: Graphical Representation of Limiting Factor Theory, showing that NLR is limiting for different light levels

MATERIALS AND METHODS

- •Algae grown in ATS system in the lab, seeded from a community in a nearby stream that is dominated by *Cladophora*
- •Flow Rate= 53 L/min, Tipping Frequency=5.9 min^{-1}
- •Average light level= 200 $\mu mol\ m^{-2}s^{-1}$, max light level=411 $\mu mol\ m^{-2}s^{-1}$
- •Fed daily a mineral nutrient solution with N:P ratio of 8:1 at prescribed NLR which was serially increased over time
- •3 harvests performed at each NLR and averaged for productivity
- •Algae harvested with shop vac, separated with 1mm filter bag, allowed to dry
- •Subsample oven-dried and ashed to calculate average daily productivity as g Ash Free Dry Mass (AFDM) $m^{-2}d^{-1}$

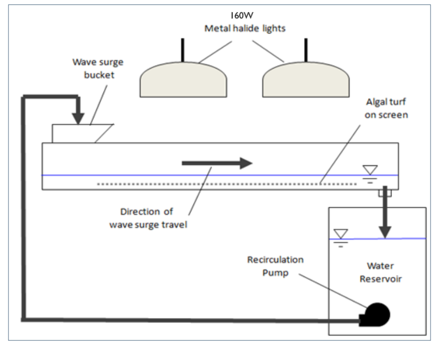

Figure 3: Schematic of lab-scale recirculating ATS used in this experiment

RESULTS

- •At first, an increase in NLR correlates directly to an increase in Biomass Production Rate
- •At an NLR of about 0.6 gN d^{-1}, the production levels off and then decreases
- •At an NLR of about 1 gN d^{-1}, pH significantly decreases
- •Maximum average biomass production was observed as 9.25 g $m^{-2}d^{-1}$ at an NLR of 0.35 gN d^{-1}, with an average of pH of 8.35 at that loading rate

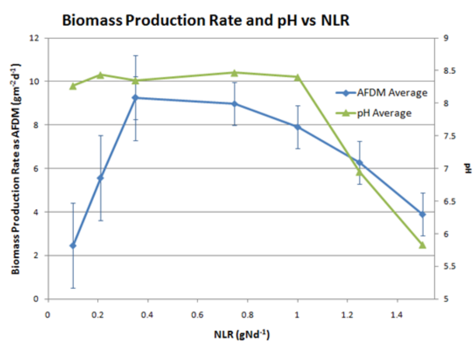

Figure 4: pH and daily average algae productivity at varying Nitrogen Loading Rates . Error bars represent standard deviation.

DISCUSSION

The growth rate of the algae reached a maximum at moderate NLR, but significantly declined with decreasing pH at higher NLRs. This suggests a mechanism of N-saturation and alternate N-utilization by the system (Fig. 5). At low NLR, algae utilizes all of the NH_4^+, but at high NLR, NH_4^+ is in excess and is oxidized by microbes through nitrification:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_20 + 2H^+$$

An increase in H^+ leads to reduced pH, which hinders algae growth.

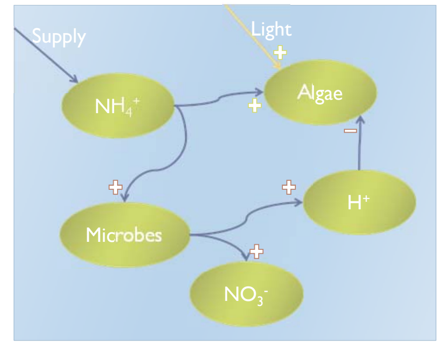

Figure 5: Conceptual Model of chemical/biological interactions in an ATS

CONCLUSIONS

- •With the current set-up, the maximum biomass production achievable is around 9.25 gd^{-1} at a loading rate of 0.35 gNd^{-1}
- •A possible method for increasing biomass production would be adding a buffer to the system to absorb the H^+ released through nitrification, thus keeping the pH higher
- •Past studies have shown productivities in excess of 20 g $m^{-2}d^{-1}$ at NLRs of >1 gN $m^{-2}d^{-1}$, suggesting this system is considerably light-limited.

Future Work

- •Test the correlations between algae species diversity and productivity
- •Test the productivity of an outdoor unit

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