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Applying Eco-Machine™ Technology to Local Wastewater Treatment Plant

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Abstract

In response to the growing pressure for clean water, Eco-Machines™, designed by Dr. John Todd, offer a wastewater treatment alternative to expensive, high-energy, conventional systems. Eco-Machines™ treat sewage effluent with a series of components containing plants, bacteria, fish, and fungus in symbiotic ecosystems. By utilizing nature's technology, Eco-Machines™ make an essential societal function more sustainable and aesthetically pleasing. Eco-Machines™ are being used for wastewater treatment by corporations such as Coca-Cola® and Tyson® as well as for national and international municipal wastewater. The technology is not yet being utilized in the local wastewater treatment plant. This study seeks to design a wastewater treatment component that incorporates Eco-Machine™ technology into the local Easton Wastewater Treatment Plant (EWTP) to demonstrate the benefits of sustainable systems to the community. Phosphorus removal was tested, as it is often the limiting nutrient in eutrophication. Phosphorus levels are currently not limited by the National Pollutant Discharge Elimination System (NPDES) permit at EWTP; however, phosphorus will be included in future permits. The EWTP wastewater tested was taken from the effluent of the secondary clarifier, before the chlorination process, as this is where the final design component will likely be implemented. Baseline tests indicated approximately 3.3 mg/L of total phosphorus in the wastewater. Previous research indicates that water hyacinths, a floating macrophyte species, are effective at removing phosphorus from water. Water hyacinths were batch tested for phosphorus removal. Tests consisted of two 24-hour batch tests using wastewater with a 24-hour tap water starvation period in between to determine how plants respond to varying phosphorus concentrations. Tests were preceded by an establishment period of one week to allow plant and bacterial growth. Water samples were collected throughout the testing period, and total phosphorus was measured. Phosphorus decreased at first but later increased. Future tests will study nitrogen removal, the second most limiting nutrient in eutrophication, and other plant species.

Keywords: Wastewater treatment, Water hyacinths, Phosphorus

1. Background

1.1 Technology

Ecological wastewater treatment systems, such as Eco-Machines™, offer a wastewater treatment alternative to expensive, high-energy, conventional systems in the midst of growing pressure for clean water and efficient land use.[1] Eco-Machines™ treat sewage effluent with a series of natural components including plants, bacteria, and fish in symbiotic ecosystems. Eco-Machines™ make an essential societal function more ecologically responsible, energy-efficient and aesthetically pleasing by utilizing nature's technology.[2,3]

1.2 Integration Into Conventional Wastewater Treatment Plant

The goal of this study was to determine how to integrate Eco-Machine™ technology into a conventional wastewater treatment system. The local Easton Wastewater Treatment Plant (EWTP) was used as a case study, as it currently uses conventional treatment processes. Nitrogen and phosphorus are often both limiting nutrients in eutrophication; however, phosphorus limits are not yet included in the EWTP National Pollutant Discharge Elimination System (NPDES) permit. This will change when the EWTP upgrades, after which phosphorus will need to be treated to 2.0 mg/L or less.[4] Baseline tests indicate approximately 3.3 mg/L of total phosphorus in wastewater taken from after the secondary clarifier, before the chlorination process. Therefore, Eco-Machine™ technology will be used for phosphorus removal.

Ecological wastewater treatment often employs a constructed wetland at the end of treatment process for low-level nutrient removal.[5,6,7] Therefore, the designed component for EWTP will be a constructed wetland implemented after the secondary clarifiers, before the chlorination process.

The optimal design will mimic the behavior of a natural wetland, with emphasis on phosphorus uptake, but will be intertwined within the framework of a conventional treatment plant. The final design will most likely be a wetland contained in an existing structure at EWTP such as an unused secondary clarifier.

1.3 Plant Selection

Literature indicates that water hyacinths are efficient at removing both nitrogen and phosphorus from water.[8] Water hyacinths are commonly used in higher concentrations of phosphorus than at the EWTP effluent; however, water hyacinths have also been observed to remove phosphorus at concentrations as low as 45.6 micrograms of total phosphorus.5[,9] Water hyacinths are also easy to grow. They can double in size every ten days in hot weather, space permitting.[10]

Water hyacinths are invasive in warm-weather climates; however, invasive species are, by nature, extremely adept at removing nutrients.[11] This characteristic, when applied to wastewater treatment, means that nutrients in wastewater can be removed quickly and in large quantities. Other invasive species such as *Phragmites australis* have also been recommended for constructed wetlands for their ability to uptake nutrients, even when compared other species such as *Typha angustifoilia* (cattails) and *Scirpus fluviatilis*.[12]

This study seeks to determine the effectiveness of water hyacinths grown in wastewater for phosphorus removal.

2. Methods

2.1 Setup And Sample Collection

Water hyacinths (*Eichhornia crassipes*) were grown in a series of batch tests to determine phosphorus uptake. Plants were grown in two clear, plastic bins measuring 0.591m x 0.475m x 0.312m (LxWxH) each. Water hyacinths were selected to be similar in leaf and root mass. Bins were filled approximately one third full with wastewater taken from the effluent of secondary clarifier #7 from the Easton Wastewater Treatment Plant (EWTP) in Easton, PA. Wastewater was added to the bins within a day of collection. The setup was duplicated for an unplanted control (see Figure 1). The four bins (two planted and two unplanted) were placed in an area that receives direct sunlight during the late afternoon hours. Bins were also artificially lit from 6:00am to 6:00pm throughout the testing period to supplement the sunlight (see Figure 2) One planted tank and one unplanted tank were placed on the side with more direct sunlight. Bins were shaken twice daily to evenly distribute nutrients.

Figure 1. Test setup with two planted and two unplanted bins

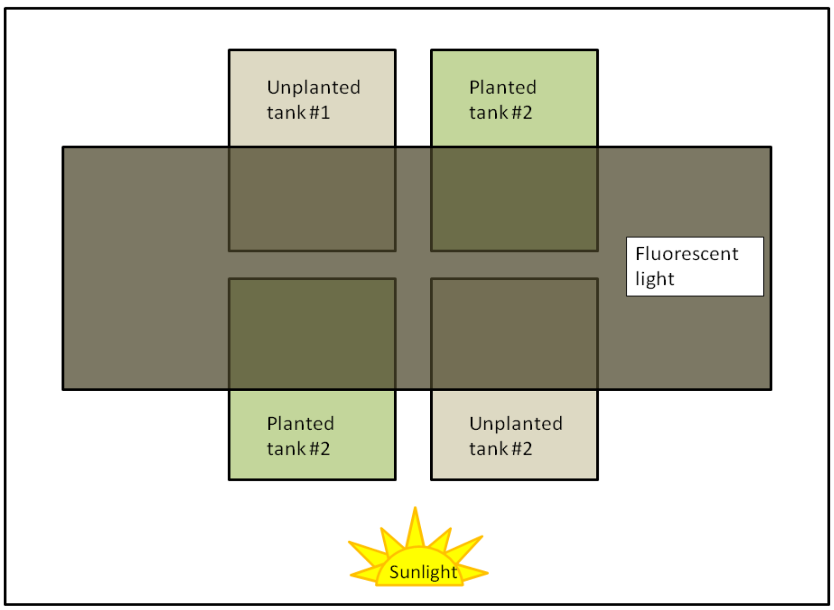

Figure 2. Location of artificial and natural lighting of test setup

Bins were filled with an initial wastewater sample as described above and were grown for one week to establish bacteria. After this initial growing period, a fresh batch of wastewater was collected from the same clarifier at EWTP. The four bins were drained and the fresh wastewater was added. Water samples were collected from each tank immediately after fresh wastewater was added and from then at an elapsed time of 15 minutes, 1 hour, 2 hours, 6 hours, and 24 hours. After the last sample was collected, wastewater was removed and replaced with tap water. Water samples were taken immediately after the tap water was added and 24 hours later before being replaced with a fresh batch of wastewater. Wastewater samples were collected from this fresh wastewater at the same time intervals as the first batch of wastewater.

To calculate evaporation losses, the water level of each tank was marked at the end of testing and again after 10 days.

3.2 Laboratory Test

Unfiltered water samples were analyzed for total phosphorus according to EPA Procedures P-16-115rl, P-16-42, and P-16-94 and in cooperation with the Philadelphia Academy of Natural Sciences. Samples were diluted at a ratio of 1:10, and the phosphorus concentration values obtained were converted back following the test. Standards were made using 1000 ppm Phosphorus AA standard diluted to 0, 0.05, 0.1, and 0.5 mg/L phosphorus. This range of sample concentrations was chosen based on prior phosphorus tests indicating approximately 3 mg/L of total phosphorus in the wastewater (diluted 1:10 was 0.3 mg/L). Standards were tested in the same way as samples.

Phosphorus was measured in the form of orthophosphate. All forms of phosphorus, including condensed phosphate and organic phosphate, were converted to orthophosphate by combining with an acidic ammonium persulfate reagent and heating the samples in an autoclave. The orthophosphate was then measured by mixing the samples with a combined reagent consisting of sulfuric acid, potassium antimonyl tartrate, ammonium molybdate, and ascorbic acid. This combined reagent reacts with the orthophosphate and makes the sample a shade of blue proportional to the amount of orthophosphate present. A Thermo Electron Corporation Aquamate spectrophotometer was used to determine what shades of blue (absorbance) samples were at 880 nm. The standards were used to create a linear relationship between absorbance and concentration of phosphorus (see Figure 3).

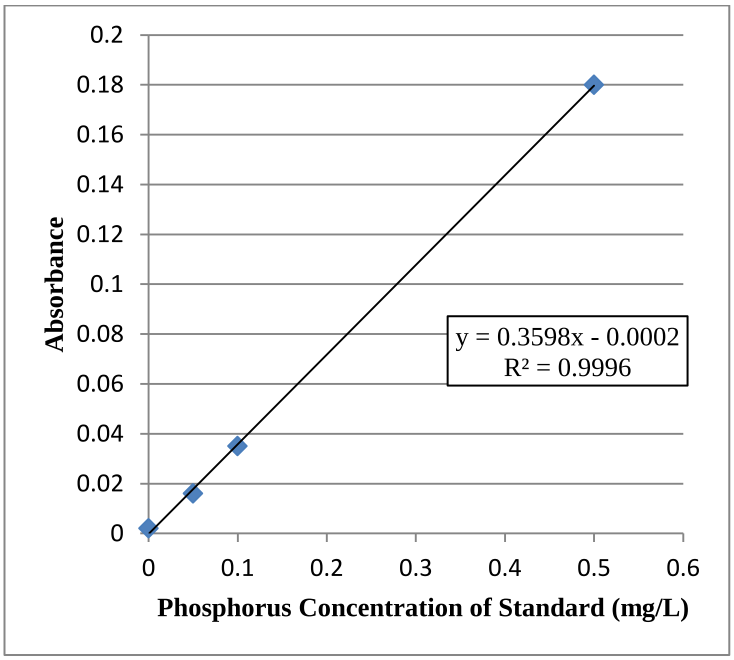

Figure 3. Absorbance versus phosphorus concentration of the standards

A selection of samples were filtered before being tested using 0.45 micron filter paper and syringe to determine if the total phosphorus differed significantly from the total liquid phosphorus. The same samples were tested unfiltered, and the results did not vary significantly (see Results and Discussion section).All remaining samples were tested unfiltered.

3. Results and Discussion

3.1 Observations

Throughout the testing period, there were green and brown algae observed in both tanks. There was more in the unplanted tanks than the planted ones. The brown algae started growing first followed by the green. Algae consisted of both floating masses and scum on the sides of the tanks.

Plant leaves also showed signs of deteriorating health such as brown and white spots, but also showed signs of new growth including many new leaves.

3.2 Data

Filtered samples were on average 2.5% lower than the unfiltered. Since this is a relatively small difference all other samples were tested unfiltered. About 10.6% of the water was lost to evaporation, on average of all four tanks.

As seen in Figures 4, 5, and 6, water hyacinths grown in wastewater did not universally decrease total phosphorus in the water. In the first batch of wastewater, there was a general downward trend in the phosphorus concentration, though there was a significant increase between 6 hours and 24 hours elapsed time. This trend was also observed in the second wastewater batch test, though there was also an increase at approximately 15 minutes to 1 hour from the starting time.

There was not a significant difference between the phosphorus concentrations in the planted and unplanted tanks. This could mean that increases and decreases in concentration were not the result of the water hyacinths.

Phosphorus concentrations increased during the tap water starvation period. Again, there was no significant difference in response between the planted and unplanted tank, so it may not be caused by the water hyacinths.

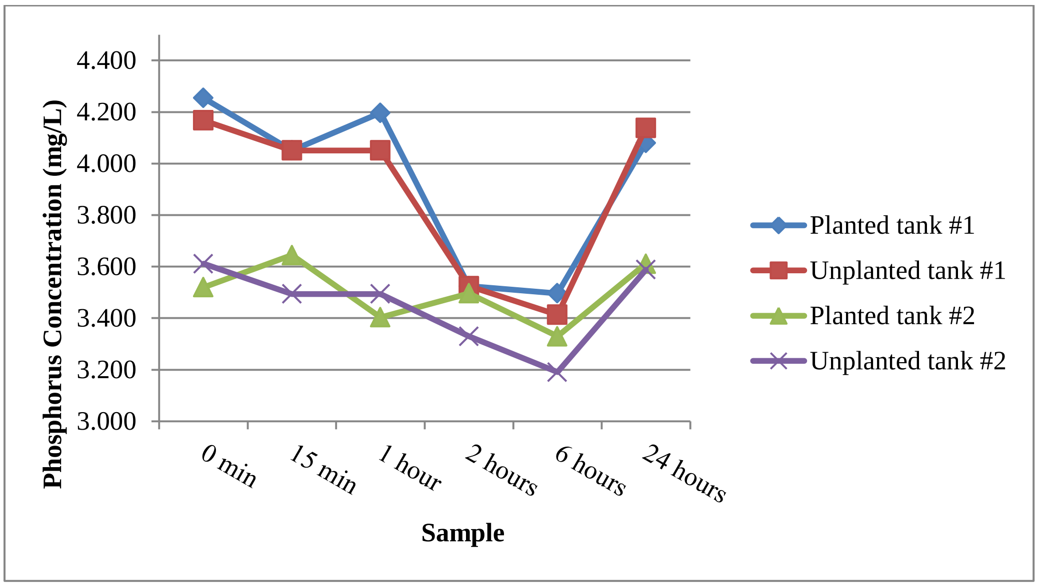

Figure 4. Phosphorus concentration versus sample for the first wastewater batch

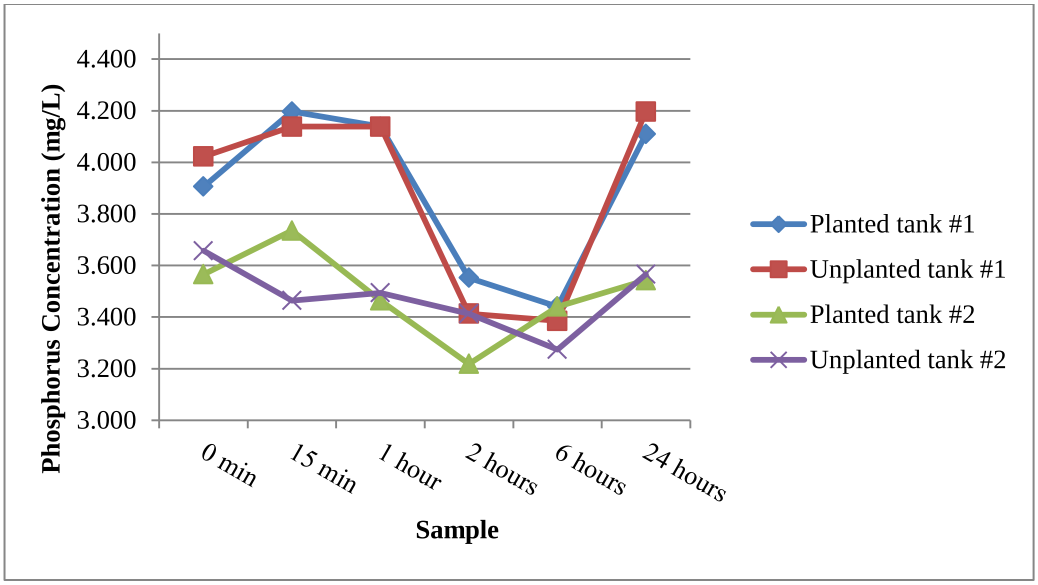

Figure 5. Phosphorus concentration versus sample for the second wastewater batch

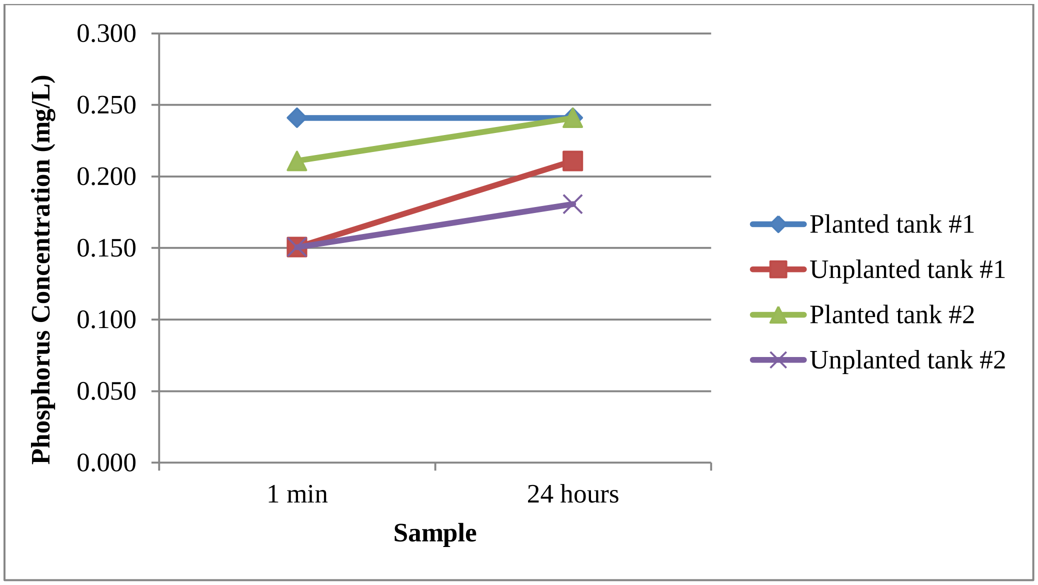

Figure 6. Phosphorus concentration versus sample for the tap water starvation period

Possible mechanisms behind phosphorus uptake include nutrient uptake by the plants and bacterial activity that increases sedimentation of phosphorus in the wastewater.[13]

4. Future Work

Future tests will likely include: varying the duration and timing of wastewater and tap water, continuous flow conditions, comparing different plant species, adding gravel substrate to the tanks, varying gravel composition. Laboratory tests would also be conducted to determine the seasonal differences in temperature and the effect on phosphorus removal. Literature indicates that constructed wetlands could continue to treat wastewater during winter months.[14] Upon completion of a preliminary wetland design, a small-scale version of the wetland would be implemented at the EWTP. The wetland would be housed in a greenhouse to ensure plant growth throughout winter months. Samples would be taken regularly to test levels of phosphorus and nitrogen removed.

5. Acknowledgements

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