BIOTREATMENT SYSTEM PROJECT

Prepared for
Environmental Science 102B
Tuesdays, 1:00 to 4:00 PM
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INTRODUCTION

MISSION STATEMENT
Our mission is to design and develop a small-scale biotreatment system concentrating on controlling algae growth in the treatment of greywater. The results gleaned from our bench test may be considered in the design of the proposed CCBC Library, recycling the greywater from the restroom sinks to be utilized as a source of water used to flush the toilets. We are committed to this project of cleaning up and reutilizing greywater to preserve and make better use of our natural water sources.

THE SCIENTIFIC METHOD
The scientific method consists of:
• Observing a problem or developing a question.
• Forming a hypothesis.
• Testing the hypothesis.
• Developing data.
• Concluding whether the hypothesis is disproved.
• Finally there is peer review to test reproducibility.

RESEARCH
Some of the pertinent facts we found during our research at the beginning of the semester included the following:

• The term reproducibility means whether an experiment can be repeated. This is the main point of the peer review in the scientific method. Procedures are tested for accuracy and substantiated results. Future scientists will depend on our findings.

• Root density provides a home for microorganisms that will degrade the waste material. Dense roots absorb nutrients from greywater that will help with the algae control. Microorganisms break down polluting nutrients. Microorganisms will also come into our system on the plants and animals that we add to the system.

• Algae was very difficult to control in previous experiments. A very diverse ecosystem is needed to prevent algae. Our main focus is to determine when algae problems occur in relation to the beet juice dosage. Beet juice will be added at ½ % doses.
• Odor and algae was a previous issue when water flow was lost. Residence time is very important to regulate this. A fast residence time takes too much oxygen away from the plants. Residence time is calculated by dividing the volume of water in the aquarium by the flow rate. Flow rate is calculated by measuring the water flow of a system in a beaker per minute.

• The main stages of the Penn State Living Machine consist of four reactors (aerobic and anaerobic), the clarifier and the fluidized bed. Sunlight is the primary source of energy. It took approximately four days for the wastewater to pass through the Living Machine at Penn State University. Our system should clear up in approximately one and a half days.

• Art Ludwig, in *Create an Oasis with Greywater*, describes systems in which the wastewater is discharged into the soil on the premises of the system to irrigate the plants or trees through underground or aboveground lines.

• Greywater contains pathogens and should not be touched or consumed as potable water.

• Adding large quantities of tap water can actually cause algae, because it has an abundant amount of nutrients.

• All graphs need an even spacing of dates. Nature is charted in curves.

• Floating plants as well as submerged plants are needed for diversity. More plant information is mentioned later in this report.

**BRIEF DESCRIPTION**

In order to create a balanced ecosystem, we decided to use a 10-gallon aquarium for our ecosystem arranged with rocks, plants and aquatic animals. A pump would be installed to circulate water through a hose to an overflow reservoir where the water would then be recirculated to the aquarium through double showerheads. These heads would aerate the water adding oxygen. This system should not only clean the water, but control the algae. A detailed description is forthcoming.

**BALANCED ECOSYSTEM**

Our research to date finds that the natural way to limit algae growth is to maintain a balanced ecosystem, consisting of the five following elements:

• **Circulation.** Keeps the water moving.

• **Aquatic plants.** Shades the water’s undersurface from the sun and consuming the same nutrients algae needs to grow and reproduce.
• **Aquatic animals.** Snails and fish that have a primary diet of algae and other debris accumulating in the ecosystem.

• **Aerobic bacteria.** ‘Good’ bacteria that starve the algae introduced through microorganisms on the ecosystem’s plants.

• **Rocks and gravel.** Provides a place for aerobic bacteria to live, while it helps to filter the water and anchor the rooted plants.

### WHAT IS DISSOLVED OXYGEN?

Dissolved oxygen (‘DO”) is the amount of oxygen dissolved in a given volume of water at a given temperature and atmospheric pressure and is usually expressed in parts per million (‘ppm”). The amount of oxygen dissolved in water is a good indicator of water quality and of the kinds of life it will support. Water with an oxygen content above 6 ppm will support game fish and other desirable forms of aquatic life. Water with less than 2 ppm oxygen will support mainly worms, bacteria, fungi, and other detritus feeders and decomposers. Oxygen is added to water by diffusion from the air, especially when turbulence and mixing rates are high, and by photosynthesis of green plants, algae, and cyanobacteria. Oxygen is removed from water by respiration and chemical processes that consume oxygen.

The addition of certain organic materials, such as sewage, paper pulp, or food-processing wastes, to water stimulates oxygen consumption by decomposers. Two methods of measuring DO in class were with a DO testing kit and with an oxygen electrode. The DO content of water depends on factors other than pollution (for example, temperature and aeration), but is usually more directly related to whether aquatic organisms survive.

The effects of oxygen-demanding wastes on water depend on volume, flow and temperature of the water. Oxygen decline is called the oxygen sag. Oxygen levels begin to fall as decomposers metabolize waste materials. The water may become so oxygen-depleted that only the most resistant microorganisms and invertebrates, known as cysts, can survive.
RESULTS

DESIGN

Our bench test started with a 10-gallon aquarium. A metal platform straddled over the top of the aquarium toward one side. The platform held our ‘overflow’ bucket (reservoir), with an expectation that this vertical positioning would aid water flowing through the system by gravity. The bottom of the aquarium was covered with larger stones and then topped with a layer of finer pebbles. The base aided in water filtration and harbored aerobic (good) bacteria. A submersible pump was buried into the larger stones to minimize clogging while not impeding water flow, and was connected to the overflow bucket (reservoir) by a clear hose. Using the clear hose allowed us to observe algae growth. Two showerheads (double heads) were attached to the overflow bucket designed to sprinkle ecosystem water back over the water’s surface in the aquarium. We believed that the circulation would help control the algae and replace oxygen into the system through aeration. Duct tape was used on the outside of the tank to mark the water level. Materials were bought at Home Depot. Approximately $90.00 in total was spent on the design, plants and, etc. (diagram, photos and material list attached in Appendix)

AQUATIC PLANTS

All aquatic plants were purchased from The Aquarium Center in Randallstown, MD. Although it was difficult to locate plants indigenous to the area at this time of year, the store’s Aquatic Plants Manager suggested the following plants for our ecosystem. It should be noted that, while these plants worked well for our short-term experiment, they would not be suggested for the CCBC Library. Illustrations of the below described aquatic plants can be found in the Appendix.

**DUCKWEED** (Lemnaceae sp.), is available locally and indigenous to Maryland. This was our primary choice floating plant. The plant generally grows to 0.10” to 0.125” long, and less than 0.10” wide. Each frond has a small, hair-like rootlet extending 0.125” to 0.250” beneath it. The plants cluster in colonies to form what appear to be green blankets of plant mass on the water’s surface. This blanket shades the water’s subsurface from the sun, helping to block out algae growth by removing its ability to photosynthesize. Duckweed multiplies quickly, and becomes dormant in cold water temperatures. It is, however, able to live in its dormant state until more favorable temperatures return. This plant also removes ammonia nitrogen from wastewater.

**WATERSPRITE** (Ceratopteris thalictroides) is rather unique in that it can be planted in rocks or floated on the surface of water. The leaves or
fronds resemble chrysanthemum leaves. It is also an excellent oxygenating plant and contributes to the biological filtration in the tank. Watersprite thrives in most fresh water conditions preferring soft, slightly acid water and does best at temperatures above 20 degrees C. It likes moderate to bright, direct or indirect, incandescent, fluorescent and/or natural lighting. It doesn't seem to be hindered by algae growth, or snail infestations.

**AMAZON SWORD PLANT**, *Echinodorus amazonicus* is a Rosette plant native to Brazil. It will grow either partially or fully submerged, with some growing submerged part of the time and some never being totally submerged. For this reason, they have developed in a way that they are dependent to a large extent on root feeding. It is capable of reaching approximately 20 inches in height under proper water conditions. The Amazon Sword Plant has short rhizomes, numerous lance shaped leaves that are pale to dark green with sharply pointed tips, and fairly short stems. The Amazon Sword Plant thrives in a loose substrate rich in iron. It requires sunlight and a water temperature from 72°-82°F and a pH of 6.5-7.5.

**EUROPEAN FROGBIT**, *Hydrocharis morsus-ranae*, can reach 20cm (8in.) in length. The plant is free-floating (unattached to the bottom of the water body). The leaves of this plant are usually floating, but if the vegetation is dense enough, they can be emergent. The leathery, glabrous leaves are cordate-orbicular in shape and measure 1.2-6cm (0.5-2.25in.) in length and (0.5-2.5in.) in It is able to form large colonies that appear as dense floating mats of vegetation. Its rapid vegetative spread and ability to form dense mats can limit light penetration and fill the water column in shallow areas. In doing so it can strongly affect native aquatic life.

**GREEN FOXTAIL FILIGREE**, *Myriophyllum pinnatum* is an oxygenating plant that will reduce algae by competing for nutrients in the water. It is found as a submersed and emergent plant. Stem elongate, ascending, floating or erect, leaves arranged in whorls, or sometimes alternate or opposite, leaves spaced along stem at regular intervals, adventitious roots often produced from basal nodes.

**AQUATIC ANIMALS**

The Aquatic Animals were also purchased at The Aquarium Center. They were chosen with the assistance of the Aquatic Animal Manager. Illustrations of the aquatic animals can similarly be found in the Appendix.
**SWORDTAIL FISH**, *Xiphophorus helleri*, get their name from the elongated shape of their lower tail fin. The tail fin is less prominent on the females. They need little attention and are very hardy fish. Water temperature should be between 70 and 79 degrees Fahrenheit, with a pH of 7 to 8. Swordtails are livebearers when breeding and are algae eaters.

**BLACK MYSTERY SNAILS**, *Ampularia cuprina*, were added to the ecosystem because they eat algae, decaying plant matter and debris that falls to the bottom of the tank. They prefer to stay underwater, although if their enclosures are not sufficiently aerated, they will sometimes come to the surface in order to get more oxygen. Most Black Mystery Snails are fully-grown when they are between 0.75 of an inch and 1.50 inches in diameter. Their bodies are usually the size of a ping pong ball. The most popular coloration is a black body and a gold shell. However, brown, black, and gold varieties are all available. They do well in cooler temperatures. The acceptable range is 20 to 30 degrees Celsius. The pH level should be between 6.5 and 7.5. Snails breed with little encouragement attaching their eggs to rocks or plants.

**SCHEDULING & MONITORING**

Once the system was up and running, it was dosed and tested during every class. The crucial monitoring times were the two days following the dosing, which included three testings during that time period. This information was important because a system of our size would recover relatively quickly. We each volunteered for these tests.

**MANAGEMENT**

The project was managed by making the changes and modifications considered necessary to the operation of our physical plant throughout the project.

- Manual removal of algae clogging filters, hoses and the pump was administered.
- Leaks were repaired as needed.
- Evaporated water was replaced weekly.
- Animal and plant life was observed closely.
- Greenhouse shades were lowered as necessary.
- Weekly results were charted.

In addition to managing the above tasks, it should be noted that our teamwork effort was effective through our:
• Individually devoting extra time outside of class to monitor and conduct testing;
• Individually sharing the various tasks;
• Having consistent, frequent and open communication via email and telephone (this was found to be key);
• Working well together as a group; and
• Sharing the expenses.

SUMMARY OF LAB NOTES
The first DO test we conducted on March 15 was only 3.5 ppm probably due to the very low amount of Sulfamic Acid available in the testing kit. The DO dropped considerably after each dosing (April 5,12,19), due to the microorganisms, plants and animals using up oxygen to eat the pollutant. The DO increases again as the water clears. Temperature also affects DO because cold water holds more DO than warm/hot water. The water has more DO at night than during the day. When our system exhausted itself, the low DO was responsible for the foul odor. Dead animal life uses more oxygen to decompose. Please refer to detailed lab notes.

Low water flow resulted from: the duckweed clogging the double heads, algae clogging the clamped area in the hoses and water evaporation, which in turn gave us a low RT (April 19). Low water flow contributes to the odor and low DO (April 26). Please refer to detailed lab notes.

The pH remained at 6.0 throughout the experiment which is neutral. When the system exhausted itself (April 26), it did change to 7.0 indicating less acidic water. Please refer to detailed lab notes.

RT was shorter after each water evaporation loss (March 8, 15, 22, 29 and April 5, 12, 19, 26 and May 3, 10). Please refer to detailed lab notes.

A small leak developed midway through the experiment in one of the “arms” coming from the reservoir. This was easily remedied by turning the reservoir slightly to allow the leak to drip into the tank.

Algae was first discovered on April 12 after the first dosing cleared up. This problem could be the result of various things:
• Too much sunlight from the greenhouse shades being raised.
• Not using indigenous plants.
• Not using enough plants.
• Not using enough animal and plant life.
Colorimetric Measurement

Once the "wastewater treatment system" was set up and operational, testing of its effectiveness was carried out. This was done by dosing the system with an organic solution, beet juice, on three separate occasions. Following the dosing, the clarity of the solution was tested over time in order to learn how the system would break down the beet juice. This colorimetric testing was done by visually comparing a sample of the solution to a color chart of known color concentrations that represented a percentage of concentration. Each concentration also had a numerical scale number associated with it. This method of testing the concentration of the beet suspension was an alternative to using a spectrophotometer, the advantage being that it could be done quickly "in the field" without expensive equipment. One disadvantage to this visual method, however, was that it was more susceptible to "human error" since readings were influenced by the acuity of eyesight.

The data in Chart A-I was collected between April 5, 2005 and May 20, 2005 and is summarized on Graphs A-1 and A-2.

Other Quantitative Data

Graphing our quantitative data was one of the most beneficial visual aids that we employed. Despite a few gaps here and there due to our inaccessibility to the greenhouse for monitoring, the graphs clearly chart our quantitative data at relatively equal intervals.

Most noticeable is in Dose #1 and Dose #2, where, when the temperature rises in the mid-to-late afternoon, the dissolved oxygen plummets. This appears to occur as the warm air temperatures force the gas (which in this case is the oxygen) out of the water.

This DO:Temperature relationship also worked inversely, as shown in the Dose #1 and Dose #2 graphs, where, when the temperature decreased, the dissolved oxygen level increased. Our conclusion derived from this observation is that the dissolved oxygen level in ppm is a function of temperature, which in this case, is measured in Centigrade degrees.
DISCUSSION

Our objective was to clean polluted water using living organisms, which is referred to as bioremediation. The focus of our project was to determine what the conditions are when the algae starts as well as clean up the water from the pollutant.

Although the aquarium plants that we used did a good job, they were expensive and did not develop as dense a root system as desired. Indigenous plants to the area would have been larger with denser root systems and given us a better plant life to water ratio, therefore minimizing the available nutrition for the algae to grow without the expense. However, we still established a healthy ecosystem. Frogbit and water hyacinth do a great job cleaning up the water, however, they are known to clog up waterways.

The fish and snails did a good job eating the algae and debris. The snails reproduced representing a healthy ecosystem. Perhaps a few more fish or larger ones may contribute more.

The pollutant (beet juice) was cleared up each time with no red/pink color to the water. However the water took on a lake water brownish color mimicking nature. The double heads would have worked better if we had not used the duckweed. They were clogged up every week. This affected our aeration, which in turn affected our DO, water flow/RT.

The first signs of suspended algae appeared one week (April 12) after the first dose of beet juice, but six weeks after the system was operational. The dosage measured 0.375 % - #8 on the scale. Raising the greenhouse shades probably contributed to this. In retrospect, the greenhouse gets enough sunlight with the shades down. One week (April 19) after the second dose, algae (suspended and string) was a #4 on the scale. By April 26 the system had exhausted itself, which shows that if humans keep on polluting the waterways there will be no pure water left. Now we know when the algae starts.

As previously noted, once the "wastewater treatment system" was set up and operational, testing of its effectiveness was carried out. This was done by dosing the system with an organic solution, beet juice, on three separate occasions. Following the dosing, the clarity of the solution was tested over time in order to learn how the system would break down the beet juice. This colorimetric testing was done by visually comparing a sample of the solution to a color chart of known color concentrations that represented a percentage of concentration. Each concentration also had a numerical scale number associated with it. This method of testing the concentration of the beet suspension was an alternative to using a spectrophotometer, the advantage being that it could be done quickly "in the field"
without expensive equipment. One disadvantage to this visual method, however, was that it was more susceptible to "human error" since readings were influenced by the acuity of eyesight.

We had no signs of insects like some of the prior classes. This may be due to the fact that we used Aquarium plants. Indigenous plants may carry eggs with them.

The experiment was successful because we accomplished what we set out to do: E.I. clean the water of the pollutant and determine when the algae starts.

This semester should bring the future CCBC Library’s biotreatment system closer to the realization of Intellectual Design. It is a known fact that the greywater can be cleaned up by Mother Nature. With an adequate size and proper plant and animal to water ratio designed for the planned ecosystem, the algae should also be controlled. While the initial construction and installation expense might not appear to be cost effective, a far-reduced operating cost should provide some balance to the overall concept. All the while, this system will operate as a “green” innovation, participating in the college’s effort to reduce wastewater volume at the treatment plant, while protecting our water supply.
SITE VISIT TO THE
PATAPSCO WASTEWATER TREATMENT PLANT

CHERYL DUNN’S COMMENTS

The site visit to the Patapsco Wastewater Treatment Plant was very interesting and educational. Our tour guides were professional and knowledgeable. I was impressed with the cleanliness of the site and the odor was not as bad as anticipated. The size of the facility as well as the amount of water they treat was surprising, considering this was not the largest plant in the area. Employment consists of 100 operators and 50 maintenance personnel. Patapsco treats 99% water and only 1% solids, which enter the plant through a 96 inch pipe. The water they release after treatment is cleaner than the Bay water.

Patapsco has the same steps as a Living Machine, but theirs is treated with chlorine and liquid oxygen, while Mother Nature and natural oxygen treat the Living Machine. Some similarities between the two were algae and duckweed control, DO testing and clean water at the end. They manually test for DO just like we did for accuracy.

I would be interested in visiting a water treatment facility and an industrial site to see how they control pollution and hazardous waste.

JONATHAN REID’S COMMENTS

After visiting the Patapsco waste water treatment plant, the similarities between the plant and our scale model became evident. While theirs was on a much larger scale both of our objectives were parallel in that the water needed to be safe enough to return to the natural environment. The scale that the treatment center used was one that would be able to sufficiently handle 60 million gallons of waste water a day (mgd) using a 96 inch diameter pipe. Our scale model was sufficient enough to carry 10,080 liters per day however; these measurements could not stay consistent due to the clogging of pipes. The conveyer belt that was recently installed in the plant to filter out larger debris had a similar purpose as our rocks did covering up the pump. As we moved through the treatment plant, some of the problems that the facility were having closely resembled some of our own. One for example was the immense amount of algae that were growing in their tertiary tanks and the growth inside our return tube and inside our reservoir tanks. Patapsco had a cleaning crew that would remove algae daily and unfortunately we were not able to provide this type of service. Another problem they were continuously having, was an appropriate procedure to measure the amount of dissolved oxygen in the tanks. While their equipment was being troublesome our
method left a lot of room for human error. Some of the differences that we had were the way oxygen was introduced to the system. We mimicked a natural method while the plant used liquid oxygen, (then turned to gas) that could be monitored closely. They also had a residence time that was much greater than ours and would allow for a more thorough cleaning. By the end of the tour it was clear how closely our small scale model resembled a real life water treatment plant. Only now because of this trip am I more aware of what I put down the drain, how fortunate we are to have this treatment center and the need for these types of treatment centers around the world. The only way we would be able to truly appreciate this technology would be to visit a third world country where a water treatment does not exist.

**CHARLES SPENCE’S COMMENTS**

I was impressed with the amount of wastewater that is processed in one day at Patapsco Waste Water Treatment Facility. On a given day they process 60 million gallons of water. At this treatment facility they do not use atmospheric air in the aeration stage of the process. They use 98% pure oxygen, which is manufactured in an on-site plant.

There were several similarities between this plant and our controlled laboratory system. I was surprised to find out that with all of the advanced technology available that the Patapsco Facility conducts dissolved oxygen tests manually. This is done because the technology available to do this test does not measure the level of dissolved oxygen accurately. We had the same problem working in our controlled waste water system in our laboratory; we also had to conduct the dissolved oxygen tests manually. I also noticed that in their tertiary filter tanks there a problem with algae growing in the tank. We also experienced algae problems in our controlled experiment. Thirdly, in one of their tertiary tanks there was a problem with controlling the growth of duckweed. Our duckweed also grew more prolifically than we had thought. I concluded that in our controlled experiment we encountered some of the same problems with technological instruments, algae, and duckweed that a real-world functioning wastewater treatment plant is encountering.
CONCLUSIONS & RECOMMENDATIONS

CONCLUSION

The research we have done in this class has opened our eyes to the importance of our earth’s natural resources and how everyday human activities can affect our environment. This project has shown us how we are all connected to each other. Living Machines developed with attention to Intellectual Design seems to be the primary solution to conserve our water supply.

Our group worked well together as a team. We each volunteered for the various tasks and kept an open line of communication via email and telephone. Our system was up and running one week before all others and we kept very detailed laboratory notes throughout the experiment. A lot of time outside of class was spent on the project.

RECOMMENDATIONS FOR FUTURE RESEARCHERS

• Get started as soon as possible at the beginning of the semester so there is ample time to do the report at the end of semester. The report needs to be worked on simultaneously with the experiment the entire semester. We had our system up and running one week before the other groups and we still felt rushed at the end of the semester.

• Do not use duckweed, as it clogs everything up. Although the other plants worked well for our short-term experiment, they would not be recommended for the CCBC Library. Although water hyacinth and frogbit do a great job cleaning up the water, they reproduce so quickly that they are known for blocking waterways. DO USE a variety of plants that are indigenous to the area. They will develop denser root systems than the plants that we used. A water lily and cattails may be worth looking into.

• Keep the reservoir “arms” one-inch longer than we did to help eliminate splashing, but allow enough space to create aeration. The double heads worked well for aeration, but this was affected when the duckweed continually clogged them up.

• Add stones and snails to the overflow bucket to help control algae in that area. Fish would also be a good addition to the overflow bucket, if a way to prevent them from getting caught in the system can be implemented. (Our fish was caught).

• Keep communication lines open with your group via email and telephone.

• Assign tasks equally and keep the laboratory notes current.

• Monitor the project as much as you can outside of class.
LABPRO DATA AND CHARTS

In the Pre-dose Chart the intervals were in 24-hour (daily) intervals. We were focused on setting up our ecosystem during this time and consequently, not much testing was conducted.

In both the Dose #1 and Dose #2 charts our data was calculated to 6-hour, 4 times daily intervals. This interval was chosen because of the fast rate that our ecosystem appeared to be cleaning the water. By frequently checking our system, we felt that there would be less opportunity for missed data that may have led to inaccurate calculations. Also, our not reporting by equal time intervals to correctly represent the collected data could be extremely misleading to an observer. The third dose was collected using a Labpro that was able to collect Dissolved Oxygen (“DO”) data on a 24-hour basis. Assuming that the Labpro was working correctly, accurate measurements giving a full spectrum of data were provided and recorded. With its fast turn around time and constant monitoring ability without human subjectiveness, the Labpro would have also worked better in our measuring and recording the water temperature, pH and possibly the colorimetric, as well as the DO. Our information would have been more detailed, with less potential for human error.

Despite a few gaps here and there due to our inability to gain access to the greenhouse, the graphs clearly represent our hypothesis data in relatively equal intervals. This is most noticeable in the Dose #1 and Dose #2 charts, where, when the water temperature rises in the mid-to-late afternoon, the DO decreases. The warm air temperatures appear to force a release of the gas (which in this case is the Oxygen) from the water. As our focus was more on looking for the temperature to affect the increases and decreases in the quantity of microorganisms and its affect the DO in the tank, the relationship between the temperature and DO was assumed to be ignored on the graphs.

More important, however, was our observed dip in DO. This shows that, although the ecosystem suffered from an initial shock when the waste water was introduced, it was able clean the water and return the DO to its normal standard. The graphs indicate these drops in the DO in Dose #1 and Dose #2. In Dose #3, however, there was the initial shock, but the ecosystem was unable to recover over the following days, with the DO remaining close to zero. The amount of waste water that was added to the tank through Dose 3 was apparently too much for the microorganisms and other organisms in the ecosystem to handle, causing dead water, as shown on the Dose #3 chart. For the most part our findings, as developed through the collected data, represented what we thought and expected; that when the waste water introduced into the balanced ecosystem surpassed a certain percentage of the overall water quantity, the water quality would be deprived of the Oxygen needed to support the ecosystem’s microorganisms and other organisms, and they would die, ending the functionality and ability of the ecosystem to naturally clean the water.
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<th>DOSE OF BEET JUICE</th>
<th>COLORMETRIC PERCENT</th>
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**Graph A-1 Colormetric Percent**

**Graph A-2 Colormetric Scale**
Dose #1

Days

DO mg/l

PH

Temp C

0 1 2 3 4 5 6 7 8

0 5 10 15 20 25 30 35
## Quantitative Data

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### Pre-Dose

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LABORATORY NOTES

March 8, 2005  We calculated our first Residence Time (RT), dividing the volume of the water in the tank by the water flowing into the tank from the overflow bucket (reservoir). The water flow was measured by determining the amount of water transferred from the reservoir in a minute, then calculating this to the flow volume per hour. Each of the double heads was individually measured and the two flow rates combined.

Using the formula $RT = \frac{\text{volume}}{\text{flow rate}}$, our RT was very fast at 5.5 min. This was probably due to the double heads and the distance between the heads and the water line exposing more of the spray to evaporation.

March 14, 2005 All mechanical systems appear to be functioning normally. Plants are still green and healthy. Water level is down considerably due to evaporation, probably due to the double heads.

March 15, 2005 Residence time: 4.7 min.
  DO (Dissolved Oxygen): 3.5 ppm (parts per million)
  pH: 6.5 (Average acidic)
  The residence time was very fast; demonstrated by the 7.0 L of water that evaporated. 7.0 L of water was added. The DO was very low, suspect to the very low amount of Sulfamic Acid available in the testing kit.

March 22, 2005 pH: 6.0
  21.0 L of water was added to the project to compensate for evaporation over our Spring break.

April 5, 2005  1:10 PM
  Residence time: 8.7 min.
  DO: 8.0 ppm
  pH: 6.0
  The two Foxtail plants grew a good bit in size, while the exposed portions (out of the water due to evaporation) of the Frogbit and Amazon Sword turned a little brown at the top. We raised the shades in the greenhouse half way to expose the plants to more light. Some of the Duckweed turned white and some black. It looked like the other plants were encroaching upon the Broadleaf Water Sprite, a floating plant. There were no signs of algae yet. We added 9.0 L of water, due to
evaporation and splashing from the double heads. Three Swordtail fish (1 male: 2 females) and 6 Mystery snails were added.

April 5, 2005  2:00 PM  Second test
DO: 7.4 ppm
pH: 6.0
# 1 Dose: 0.375 % beet juice
Colorimetric: 0.375 % - #8 on the scale
The DO is expected to fall off after dosing and increase again as the water clears. This is due to the microorganisms taking the DO out of the water while they are eating the pollutants (beet juice).

April 6, 2005 – 10:30 AM
DO: 9.0 ppm
pH: 6.0
Colorimetric: 0.375 % - #8 on the scale
The water level was down one inch. There was a considerable amount of Duckweed missing, probably due to the appetites of the Swordfish and the Mystery snails. The animal and plant life appears healthy.

April 6, 2005 – 4:45 PM
DO: 5.4 ppm
pH: 6.0
Colorimetric: 0.19 % - #9
Temperature: 29°C
The water level was down one inch. The Greenhouse was very sunny due to our previously raising the shades. Water is coming through the overflow hose. This was assumed to be due to blockage in the tubing, based upon the deposits observed, as well as a possibility that Duckweed was clogging the double heads. Continued browning on the exposed portions of the Amazon Sword plant was observed. Blockages were cleared.

April 7, 2005 – 1:50 PM
DO: 8.0 ppm
pH: 6.0
Colorimetric: was not done
Temperature: 22°C
April 12, 2005 – 1:10 PM
RT: 7.3 min.
DO: 8.6 ppm
pH: 6.0
Colorimetric: less than 0.19 % - #9
Temperature: 18°C
There was severe water loss due to splashing and evaporation of double heads. The water was only coming out of the runoff tubing, because the heads were plugged up with duckweed. One head was shut down after the duckweed was flushed out to try and control the water loss due to evaporation. The water was not red or pink, but a slightly brownish color. Some suspended algae growth was discovered in the clear tubing, with the growth measured as a #2 on a scale from 1-10, with #10 being the highest. We determined that the equilibrium in the tank seemed to shift with the water temperature. When the temperature is higher, the DO level is down and conversely, when the water temperature is cooler, the DO level is greater. There was more browning on the part of the plants that were out of the water due to evaporation. Raising the shades in the greenhouse probably contributed to this. There also was an odor from the tank, again measured as a #2 on a scale from 1-10, with #10 being the highest. The animal life was healthy and our snails reproduced in just one week. We added 9.6 L of water to the tank, dosed it, and tested again.

April 12, 2005 – 2:00 PM Second Test
RT: 15.4 min.
DO: 7.0 ppm
#2 Dose: 1.5 % beet juice
Colorimetric: 1.5 % - #6
Temperature: 16.5°C
The Residence time doubled because we closed one of the heads. The DO dropped, apparently because the microorganisms were busy eating the pollutant, which was a considerable amount more than the first dosing.

April 13, 2005 - 9:32 AM
DO: 7.5 ppm
pH: 6.0
Colorimetric: 1.5 % - #6
Temperature: 15°C
Water level was fine. All systems seemed to be functioning normally. Plant and animal life were healthy.
April 13, 2005 – 3:15 PM
DO: 5.0 ppm
pH: 6.0
Colorimetric: 0.75 % - #7
Temperature: 26°C
New growth on the Broadleaf Water Sprite. Other plants turning brown. Animal and plant life healthy. The duckweed is looking scarce. The animal life is feeding on it, and this particular plant is getting stuck in the double heads. Water level has dropped ½ inch.

April 14, 2005 – 9:30 AM
DO: 6.4 ppm
pH: 6.0
Colorimetric: 0.375 % - #8
Temperature: 15°C
The odor and suspended algae remain a #2 on the scale. There is less water splashing with just one head. Animal and plant life appears to be healthy.

April 15, 2005 – 9:30 AM
DO: 6.0 ppm
pH: 6.0
Colorimetric: 0.19 % - #9
Temperature: 16°C
Suspended Algae is slowly invading the tubes, the double heads, and the rocks placed in the water along the sides of the tank. Water level has dropped a total of 1 and ½ inches.

April 19, 2005 – 1:10 PM
RT: 3.3 min.
DO: 8.0 ppm
pH: 6.0
# 3 Dose: 0.19 % beet juice
Colorimetric: 0.19 % - #9
Temperature: 24 degrees C
The water level was down 2 total inches, or about 5L. Odor was #3, Algae was #4 with both kinds of algae present. Filamentous (string) algae were observed in the reservoir. Duckweed had both heads clogged, with only a trickle of water coming out. We had to clean out all the hoses and fittings with brushes from the lab. Water was added to replace the evaporated loss. The temperature was measured at 24° C, which is
considered tropical heat. The exposed part of the Amazon Sword plant was burning up from the sun, so we lowered the greenhouse shades half way. The sun also caused the algae to grow, so we covered the outside of the hoses with duct tape, hoping to shield the hoses from the sun. We cleaned out the double heads to have them both working again. Heat appears to be driving the oxygen out. There was an extra 4’ of hose coiled outside of the tank that the water was flowing through. This was cut off to provide fewer places for algae to grow. This will also affect the residence time, however, making the RT faster with the shorter route. Animal life looked fine. One fish and one snail were taken from the tank and put into the overflow bucket to help with the algae problem there. The fish got caught in one of the heads. It was taken out and put back into the tank, but didn’t look very well.

April 19, 2005 – 2:30 PM Second Test after dosing with 0.6 L of beet juice.
RT: 8.0 min. before dosing
RT: 8.24 min. after dosing
DO: 4.2 ppm
pH: 6.0
Colorimetric: 3.0 % - #5
The temperature and DO probes were added to the tank and hooked up to the computer in order to monitor the results at a rate of about once every 4 minutes while we are gone. The DO was measured 4.5 ppm with the computer, which was only 0.3 more than our manual test.

April 20, 2005 – 10:25 AM
DO: 0.7 ppm
pH: 6.0
Colorimetric: 3.0 % - #5
Temperature: 22.559°C
One dead fish was removed. This apparently was the one that was injured when caught in one of the heads. These readings were taken off of the computer from the probes. The system reached its maximum handling capacity.

April 20, 2005 4:30 PM
Couldn’t get into lab.

April 21, 2005 – 9:45 AM
Couldn’t get into lab.
April 26, 2005 – 1:10 PM

DO: 3.2 ppm  

pH: 7.0 – Neutral  

No Dose  

Colorimetric: No red or pink, brownish, slimy and cloudy  

Temperature: 22°C  

Nitrate Test: 0 - Not even on the chart  

Ammonia Test: 0.01  

Glucose Test: negative  

Suspended algae were on all plants and everything. A small amount of string algae (#1) was in the reservoir. There were no algae in the clear tubing, probably due to the duct tape that was added. Double heads were at a low trickle. Water was very slimy and level was 2 inches low. Odor, algae and brownish color were all #10 on the scale. Plants looked half dead, but their root systems looked good. The Frog bit root system grew the largest. All plant and animal life died except one snail. Since the DO was 3.2 six days after the 0.7 DO reading, the system must have recovered somewhat since then. We cleaned the algae as best we could and removed the dead animals. The double heads were also cleaned and water was added to the water line. The pump was taken apart for the first time and cleared of a slight bit of slimy algae. Burying the pump in the rocks helped to keep it clean throughout the experiment. The ecosystem exhausted itself. It reached its limit with the last dosing. The system is expected to recover somewhat by next week.

May 3, 2005 - 1:10 PM  

pH: 7.0  

Colorimetric: No red or pink. Water was Brownish with a slightly goldish green tint.  

The system did not recover. Algae is everywhere. The last snail died. Water was very slimy and level was down 2 inches. Odor was a #12 on a scale of 1 to 10. The system exhausted itself. The last dosing (April 19) at 3.0 % beet juice was more than the system could handle.
Material Sheet

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Maxijet 600 and accessories</td>
</tr>
<tr>
<td>1</td>
<td>10 gallon aquarium tank</td>
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**Reservoir Stand**

<table>
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<tr>
<th>Quantity</th>
<th>Description</th>
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<tbody>
<tr>
<td>6'</td>
<td>90° slotted metal</td>
</tr>
<tr>
<td>2</td>
<td>lockwashers</td>
</tr>
<tr>
<td>4</td>
<td>3/8&quot; machine bolt</td>
</tr>
<tr>
<td>4</td>
<td>3/8&quot; machine nut</td>
</tr>
<tr>
<td>1</td>
<td>11&quot; diameter 1/2&quot; wooden plate</td>
</tr>
<tr>
<td>4'</td>
<td>felt protective padding</td>
</tr>
<tr>
<td>3</td>
<td>white zip tie buttons</td>
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**Reservoir**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>two gallon bucket</td>
</tr>
<tr>
<td>XXX</td>
<td>Orange PVC cement</td>
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</tbody>
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~~Flow into the reservoir from the tank (pump)~~

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/2&quot; nylon barb to nip adapter</td>
</tr>
<tr>
<td>1</td>
<td>1/2&quot; PVC T-shape fitting</td>
</tr>
<tr>
<td>1</td>
<td>1/2&quot; PVC end cap</td>
</tr>
<tr>
<td>10&quot;</td>
<td>1/2&quot; PVC pipe</td>
</tr>
<tr>
<td>4'</td>
<td>clear 1/2&quot; tubing</td>
</tr>
<tr>
<td>1</td>
<td>Hose clamp</td>
</tr>
</tbody>
</table>

~~Overflow~~

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/2&quot; nylon barb to nip adapter</td>
</tr>
<tr>
<td>18&quot;</td>
<td>clear 1/2&quot; tubing</td>
</tr>
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</table>

~~Return to Tank~~

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1/2&quot; PVC 135° angle fitting</td>
</tr>
<tr>
<td>4</td>
<td>1/2&quot; PVC threaded to smooth adapter</td>
</tr>
<tr>
<td>10&quot;</td>
<td>1/2&quot; PVC pipe</td>
</tr>
<tr>
<td>2</td>
<td>Brass adjustable spray shower</td>
</tr>
</tbody>
</table>
MISSION STATEMENT

Our mission is to design and develop a small-scale biotreatment system concentrating on controlling algae growth in the treatment of greywater. The results gleaned from our bench test may be considered in the design of the proposed CCBC Library, recycling the greywater from the restroom sinks to be utilized as a source of water used to flush the toilets.

DESIGN HYPOTHESIS

Our bench test starts with a 10-gallon aquarium. A wood platform will straddle over the top of the aquarium toward one side. This platform will hold our ‘overflow’ bucket, with an expectation that this vertical positioning will aid water flowing through the system by gravity. The bottom of the aquarium will be covered with larger stones covered with a layer of finer pebbles. This base should aid in water filtration and harbor aerobic (good) bacteria. A submersible pump, placed inside a plastic flowerpot to minimize clogging while not impeding water flow, will be set into the large gravel at the bottom of the aquarium and connected to the overflow bucket by a rubber hose. Stones may also be added to the bottom of the overflow bucket to further assist filtration. A rubber hose will be connected from the pump to the overflow bucket. Three spray nozzles will be attached to the overflow bucket, designed to sprinkle ecosystem water back over the water’s surface in the aquarium. We believe that this circulation will help control the algae and replace oxygen into the system through aeration. The use of an ionizer and/or an ultra violet bulb was also considered for controlling algae and disinfecting the water. (diagram attached)

AQUATIC PLANTS

Duckweed (Lemnaceae sp.), available locally and indigenous to Maryland, is our primary choice floating plant. This plant generally grows to 0.10” to 0.125” long, and less than 0.10” wide. Each frond has a small, hair-like rootlet extending 0.125” to 0.250” beneath it. The plants cluster in colonies to form what appear to be green blankets of plant mass on the water’s surface. This blanket shades the water’s subsurface from the sun, helping to block out algae growth by removing its ability to photosynthesize. Duckweed multiplies quickly, and becomes dormant in cold water
temperatures. It is, however, able to live in its dormant state until more favorable temperatures return. This plant also removes ammonia nitrogen from wastewater.

Although cattails and irises were discussed as rooted plants that might be utilized in our ecosystem, more research is needed to determine if they can survive in the limited space available in our small aquarium. The important factor in our selection of the rooted plants chosen will be an assurance that whatever element on which the root system thrives must be beneficial to our targeted end result.

AQUATIC ANIMALS

The introduction of four to six Black Mystery snails were discussed for our project, since they eat algae, plant and animal matter, and debris that falls to the bottom of the tank. Adding fish to our ecosystem may also be considered as the right species could also be beneficial in controlling algae and cleaning up other debris in the water to a larger scale than can be accomplished with the snails. More research into this, however, is needed.

BALANCED ECOSYSTEM

Our research to date finds that the natural way to limit algae growth is to maintain a balanced ecosystem, consisting of the five following elements:

- Circulation. Keeping the water moving.
- Aquatic plants. Shade the water’s undersurface from the sun and consuming the same nutrients algae needs to grow and reproduce.
- Aquatic animals. Snails and fish that have a primary diet of algae and other debris accumulating in the ecosystem.
- Aerobic bacteria. ‘Good’ bacteria that starve the algae, introduced through microorganisms on the ecosystem’s plants.
- Rocks and gravel. Provides a place for aerobic bacteria to live, while it helps to filter the water and anchor the rooted plants.

SCHEDULING & MONITORING

The ecosystem should be ready for the introduction of plants on March 8, and it is hoped that the snails and fish, if we elect to use them, can be added on March 15. The greywater can then be integrated into the system beginning on March 22.

Algae formation will be monitored by our initially adding ½ % of greywater (about 7 ounces of greywater per 10 gallons of water in the ecosystem) and then increasing the greywater density ½ % weekly in our Tuesday lab sessions, to determine at what level of greywater algae growth starts. Adjustments may be needed periodically to compensate for water lost through evaporation.
Our plan is to monitor the ecosystem as reasonably needed, with a tentative schedule of a once daily inspection, with possible double inspections on Tuesdays and Thursdays. Our monitoring shall basically include:

- Making sure the system is running properly (the pump, filter, and leaks).
- Checking and adjusting the water flow.
- Checking the plant and animal life.
- Measuring the various element levels (oxygen, pH, glucose, nitrogen, etc.) in the water using the lab equipment and devices available.
- Possibly measure residence time of water flows as more is learned of this in class.

Our observations and testing results will be charted weekly.

**MANAGEMENT**

The project will be managed by our manual removal of any algae that may be threatening to clog filters, hoses or the pump, to repair leaks, and to make any changes or modifications we may consider necessary to our physical plant. By monitoring the water elements, changes to the ecosystem can be made as needed in an effort to control excessive algae growth or other elements. Plant and animal life must remain healthy or be replaced.

**SUMMARY**

The research we have done in this class has opened our eyes to the importance of our earth’s natural resources and how everyday human activities can affect our environment. We are committed to this project of cleaning up and reutilizing greywater to preserve and make better use of our natural water sources.

**BIBLIOGRAPHY**


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http://www.neaquatics.com/The_Ecosystem/AquaticPlants.htm.

http://www.dnr.state.sc.us/wild/freshfish/pondplants2.html
Watersprite
Ceratophyllum demersum
Amazon Sword Plant
Echinodorus amazonicus
European frogbit

*Hydrocharis morsus-ranae*
Green Foxtail

*Myriophyllum pinnatum*
Swordtail (Pineapple)

Xiphophorus helleri
Black Mystery Snail
Pomacea bridgesii
Ecosystem 1
Ecosystem 2
BIBLIOGRAPHY


http://www.neaquatics.com/The_Ecosystem/AquaticPlants.htm.

http://www.dnr.state.sc.us/wild/freshfish/pondplants2.html


http://www.neaquatics.com/The_Ecosystem/Algae.htm


Oral consultation and advise from Sedley Williams, Ph.D., CCBC Environmental Science Professor, Spring 2005

Oral consultation and advise from James Floyd, Ph.D., CCBC Environmental Science Professor, Spring 2005

This is an excellent report documenting a valuable research project. You show that a biotreatment system can be effective in treating wastewater, and you did a good job of establishing the limits, in terms of pollution loads, under which the system can work. You stated your hypothesis clearly, and then focused your experimental work on testing whether the hypothesis was supported. The data are presented quantitatively, displayed graphically, and analyzed in how they support the hypothesis. Your successful completion of this project is founded, at least in part, on the extensive background research you performed during the design phase. This report should guide future biotreatment researchers, both by inspiring new ideas to advance the development of these systems and by providing a model of how to effectively document their work.

Specific comments:

1. The discussion might be enhanced by bring the most important and informative graphs into the discussion section and analyzing the trends step by step. For example, the graph for “Dose #1” appears to show, once the variation in the DO levels due to temperature are considered, a decrease then recovery of DO over time. That is important because it is evidence of the effectiveness of the biotreatment. Your plot from the Vernier data seems to show that at the highest dosing, the system was unable to recover; that was an important and sought after piece of evidence.

2. The conclusion section should probably expressly state how well the experimental work supported the original hypothesis. You make such conclusions elsewhere, but this is the place to make sure it is available to readers.

3. Be careful that your bibliography is complete. There were a couple of references cited in the introduction section which were not included.

Comments by James L. Floyd, Ph.D., Assistant Professor