Algal Wastewater System for the Town of Wolfville

Group 13

Sara Fedullo, Ruis MacDonald, Andrew Furlong, Breton Potter

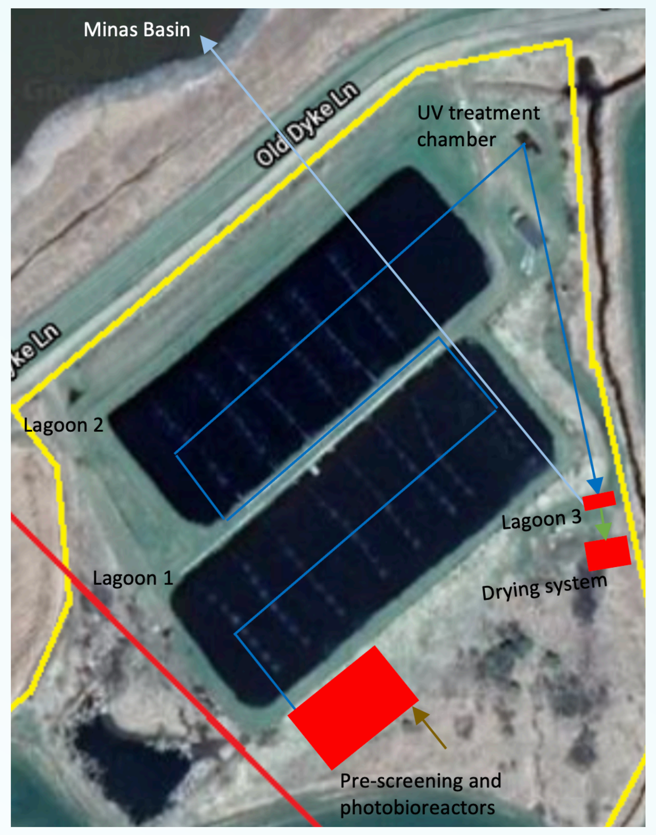
DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

Introduction and Project Description

The Town of Wolfville is investigating the addition of microalgae into their existing wastewater treatment system. This addition is intended to improve treatment efficiency, reduce greenhouse gas emissions, and potentially provide a microalgae-derived product as a new source of revenue.

The project objectives are:

- To design a low energy, low emission microalgae addition to Wolfville's current wastewater treatment system.
- To improve treatment efficiency.
- To decrease or eliminate regulatory exceedances.



Design Process

The cultivation system was designed using a *Chlorella vulgaris* growth model from literature. *Chlorella vulgaris* is the microalgal species chosen. The model was used to determine the design parameters required to achieve the desired output algal biomass concentration. The model was solved during Maple and calculations were done using Maple and Excel.

The harvesting lagoon was designed to include an overflow system. The lagoon was initially sized based on the known volume of the existing chlorine treatment chambers. To avoid the need of further treatment and to achieve the facility's sustainability goal, an organic flocculant (chitosan) is used to separate the microalgae and wastewater. Flotation was based on the principles of dissolved air flotation. All calculations were done using Excel.

The drying process was designed for a worst-case scenario, with 120% of expected algal production at 80 wt% water in the slurry. Heating requirements were based on air at -10 °C (maximum heat required), and air flow requirements for drying were based on air at 30 °C and 100% relative humidity (maximum compressor work required).

Details of Design

Microalgae converts light, carbon dioxide, water, nitrogen and phosphorous into algal biomass and oxygen. Light is provided by the sun or lamps, and carbon dioxide, water, nitrogen and phosphorous are provided by the wastewater. The microalgae grows as it flows through the photobioreactors, which are transparent tubes that allow the microalgae to adsorb the light required for growth.

The microalgae cultivation system includes a mixing tank, 21 parallel photobioreactors, and an aeration/filtration tank. The fresh wastewater first flows into the mixing tank where it is mixed with recycled microalgae and wastewater, then into the photobioreactors, then into the aeration/filtration tank, then into the first lagoon.

Microalgae is recycled and mixed with the fresh wastewater in order to continue cultivation. The microalgae and wastewater is aerated in the aeration/filtration tank to remove accumulated oxygen produced during growth, and is filtered to achieve a high algal concentration recycle stream; a high concentration recycle stream results in a lower recycle flowrate required, therefore a lower total flowrate through the photobioreactors. This reduces the number of photobioreactors needed, thus the capital and operation cost.

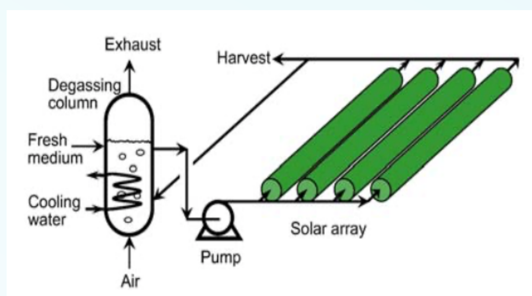


Figure 1

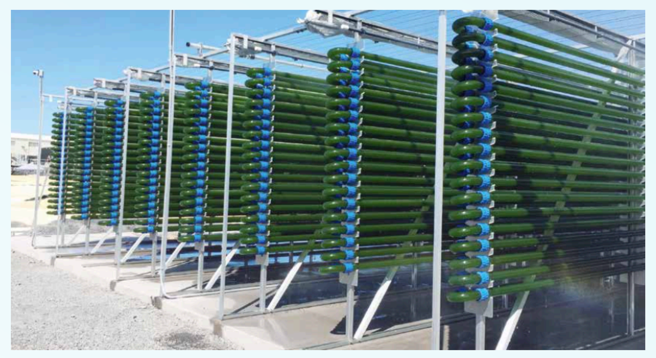
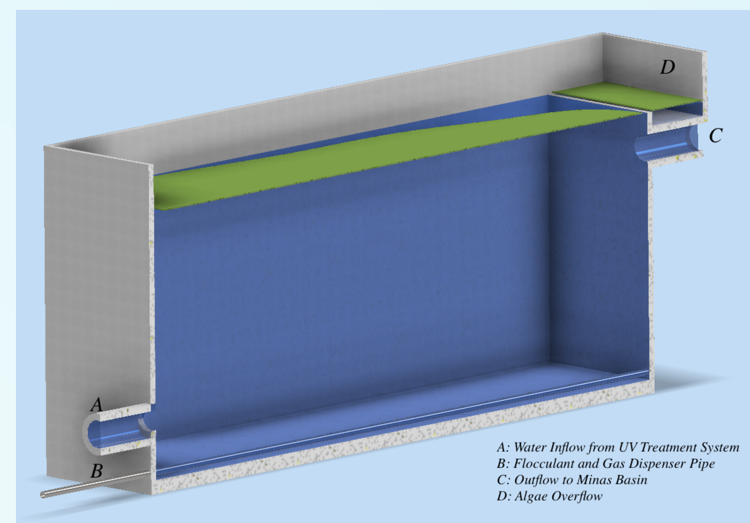


Figure 2

Following the photobioreactor, the wastewater and microalgae travel through two 20,150 m^3 lagoons. These lagoons have a retention time of 9 days and 3 hours. During this time, the wastewater is broken down by the symbiotic relationship between the algae and the aerobic bacteria in the wastewater. The wastewater then flows through a UV treatment chamber to be disinfected, and then to the harvesting lagoon.

A safety consideration for the wastewater treatment is to lower the contaminants present in the wastewater. This is achieved by setting a target of 80% of the effluent discharge objectives (EDOs). These EDOs are currently not met by Wolfville's wastewater treatment system. The addition of *Chlorella vulgaris* results in lower nitrogen and phosphorus levels, which prevents eutrophication (increased production of algae and aquatic plants) in the Minas Basin.

A third lagoon equipped with an overflow system (D) is used for algal harvesting. A holed pipe (B) at the bottom of the lagoon provides chitosan flocculant and compressed air bubbles. The air bubbles result in mixing and flotation of algae to the surface. The overflowed algae is collected by a positive displacement pump, and its moisture is minimized using a hollow fiber filter.



Algae will be dried to produce a product suitable for sale using a spray dryer. A screw pump will supply the collected algal slurry at high pressure to the dryer through a centrifugal pressure nozzle; this gives a high degree of mixing. Drying air will be supplied with rotary sliding vane compressors in parallel, with the drive speed depending on the humidity of the air and the flow rate of the slurry. Additional heating will be supplied by resistive electric heating during cold months.

Dried algae will be collected using a bag filter, which retains more than 99% of dried algae and prevents release to the environment. This allows for safer operation and reduced risk of environmental contamination and unsupervised drying operations.

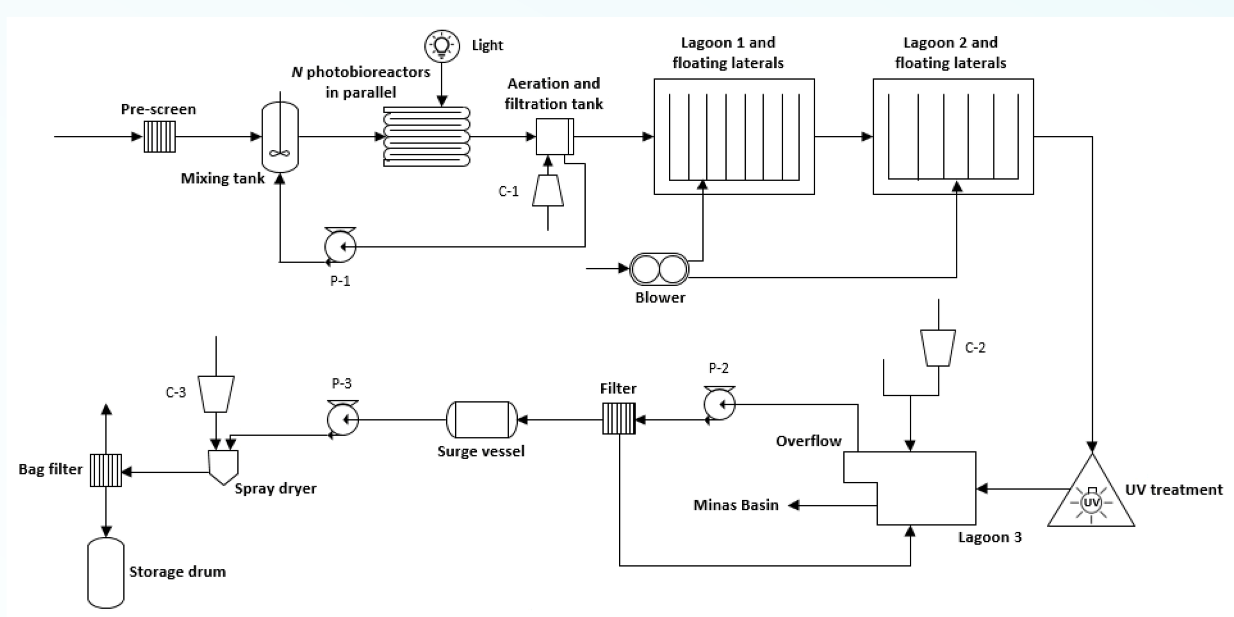
Safety and Sustainability

The use of microalgae for wastewater treatment has mild process conditions and introduces few new hazards. Heating systems to dry the algae and prevent burst pipes can cause burns, but this can be prevented using insulation. The dust from drying can explode, but this can be prevented using flame arrestors and discharge cylinders.

Chlorella vulgaris is found globally, therefore the potential harm of introducing an invasive species is low. The proposed separation system achieves high separation of microalgae from wastewater and air; this minimizes the release of environmental contaminants to the Minas Basin and atmosphere.

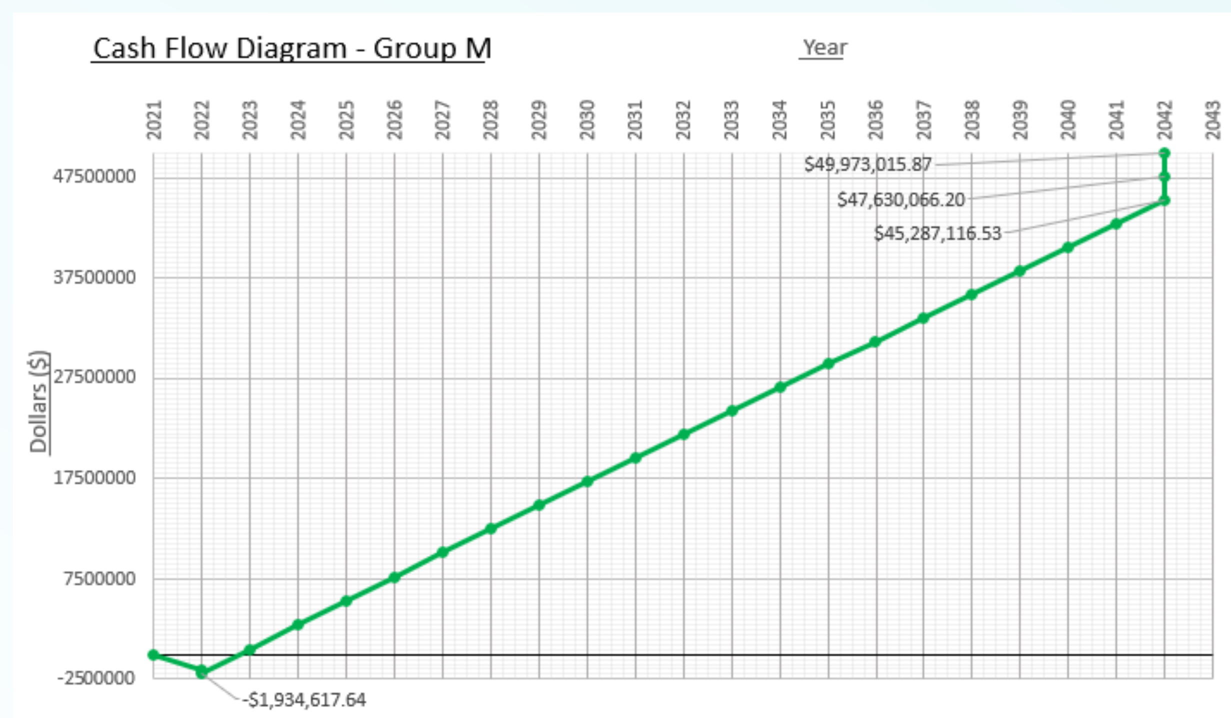
The proposed system produces a dried algae product with an energy input comparable to nitrogenous fertilizer. The reduced transportation requirements to local farms, compared to imported fertilizers, represents a decrease in energy consumption, meeting the client's goals.

Integrated System



Economic Analysis

The completed project is expected to require $1,935,000 of fixed capital investment, and $207,000 in annual operating expenses. Revenue from algal fertilizer sales is estimated at $2,800,000 annually. The expected payback period on this project is one year. The net present value of this process in 2042 will be approximately $45,300,000.



Conclusions and Recommendations

A system to improve wastewater treatment in Wolfville using microalgae has been developed. The cultivation and treatment systems were designed using mathematical models for *Chlorella vulgaris* growth and wastewater treatment from literature. Algae is cultivated using photobioreactors, is harvested using flocculation and flotation, and is dried using spray drying. The complete system is expected to cost $1,935,000 to build and $207,000 to operate annually. The expected annual revenue is $2,800,000, resulting in a payback period of one year. The project's net value in 2042 will be approximately $45,300,000.

Future work should include lab-scale testing to confirm the developed models are suitable for Wolfville's conditions. Testing the wastewater properties and other model parameters instead of using parameters from literature will increase model accuracy. Potential customers for algal fertilizer should be identified to ensure there is demand. Some further optimization may be required to account for extreme weather conditions.

References

Figure 1: Wen, Z. (2019, April 3). Algae for Biofuel Production. eXtension Farm Energy. https://farm-energy.extension.org/algae-for-biofuel-production/

Figure 2: Schott. (2021). Tubular Glass Photobioreactors. https://www.schott.com/d/tubing/2ec2a351-88b8-42bc-9313-3335f79c22f6/1.2/schott-tubing_brochure_pbr_us.pdf