Microbial Sequestration of Carbon Dioxide and Subsequent conversion to Methane

By

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INTRODUCTION

The rising level of carbon dioxide in the atmosphere has been of growing concern in recent years. The increasing levels of carbon dioxide, the most dominant component of greenhouse gases, contribute to global warming and changing global weather patterns which could potentially lead to catastrophic events that could threaten life in every form on this planet.

The level of carbon dioxide in the worlds atmosphere has increased from about 280 ppm in 1850 to the current level of approximately 350 ppm. There are several natural sources and sinks of carbon dioxide such as respiration by plants (source), photosynthesis by plants (sink), and physico-chemical diffusion in the ocean (source and sink). However, these natural sources and sinks appear to have remained in balance for thousands of years. The recent population growth and change in life style, attributed to the increase in the combustion of fossil fuels and the deforestation of tropical areas. Not only are the carbon dioxide levels increasing, they are increasing exponentially.

Regulations to limit some greenhouse gases have gone into effect in many countries around the world. Attempts have been made to reduce the production of greenhouse gases on a global scale. In 1997, at the Conference of Parties III, Kyoto, Japan, the Kyoto conference on climate change took place. There, countries from around the world agreed to targets for cutting their emissions of greenhouse gases. Although negotiations left the treaty language less than clear, it is generally accepted that the developed countries, including the United States, would at a minimum seek to return by the year 2000, to the greenhouse gas emission levels they had in 1990. It commits developed countries to reduce their collective emissions of six key greenhouse gases, including carbon dioxide, by at least 5% by the period 2008-12. The Kyoto Protocol was a major step in identifying that the production of greenhouse gases is creating a global climate problem and preventative and adaptive measures need to be taken. However, the United States has missed its Year-2000 goal, and its congress has failed to ratify the treaty so far.

A number of technologies are under research stage to reduce this emission namely pumping and trapping it in into the geological formation, chemical adsortion, ocean sequestration and conversion using biological process. Most of the proposed physical and chemical processes are aimed to transfer CO_2 from one form to other and does not seem to provide any permanent solution.

The proposed research is a two step process to capture and convert CO_2 to biomass and then reuse this biomass for fuel and cattle feed. The initial results of the proof of concept of this technology is described in this paper.

Process Description:
The conceptual schematics of the proposed technology flowdiagram is shown in Figure 1 below.

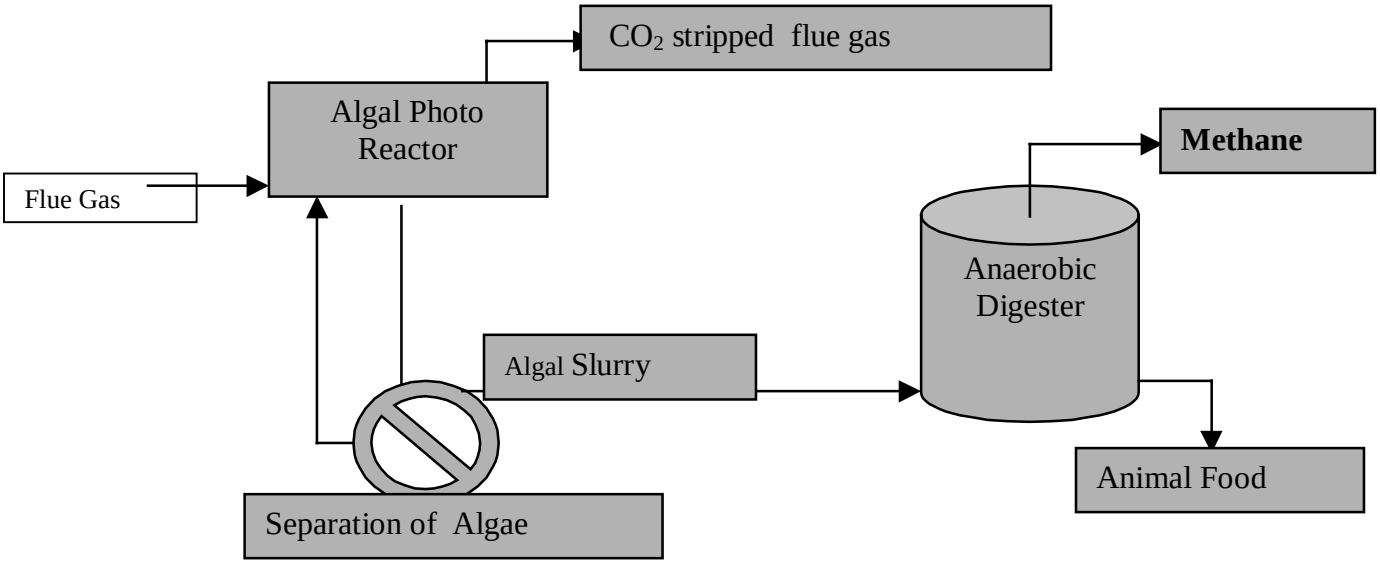


Figure 1: Conceptual schematics of the proposed Technology

The objective is to capture CO_2 and use that for growing photosynthetic algae. The algae will use the carbon dioxide as the carbon dioxide. The bioreactor slurry along with algae will be passed to a separation system, where the liquid will be strained and recycled back to reactor.

The concentrated algal slurry will be transferred to a anaerobic digestor tank, where the fungal biomass will be digested and methane will be used to generate electricity. After digestion is complete, the semi-solid byproduct can be dried and can be used as animal feed or as a soil amendment or fertilizer.

Materials and Methods:

Determination of Carbon Dioxide Concentration:

The dissolved carbon dioxide concentration was measured by measuring the pH of the solution and using proper dissociation constants.

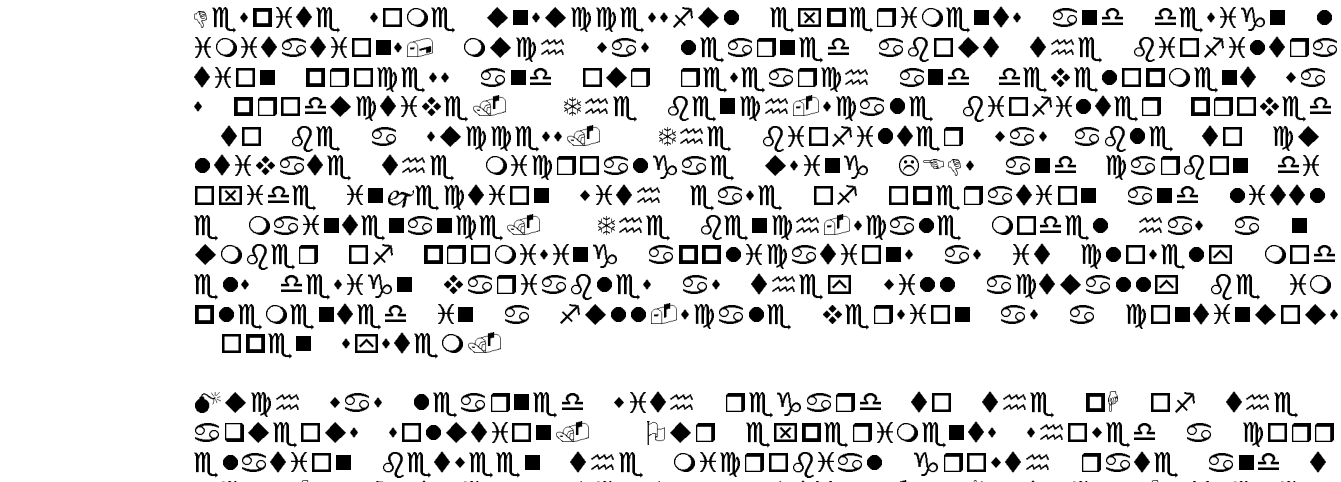
Despite some unsuccessful experiments and design limitations, much was learned about the biofiltration process and our research and development was productive. The bench-scale biofilter proved to be a success. The biofilter was able to cultivate the microalgae using LEDs and carbon dioxide injection with ease of operation and little maintenance. The bench-scale model has a number of promising applications as it closely models design variables as they will actually be implemented in a full-scale version as a continuous open system.

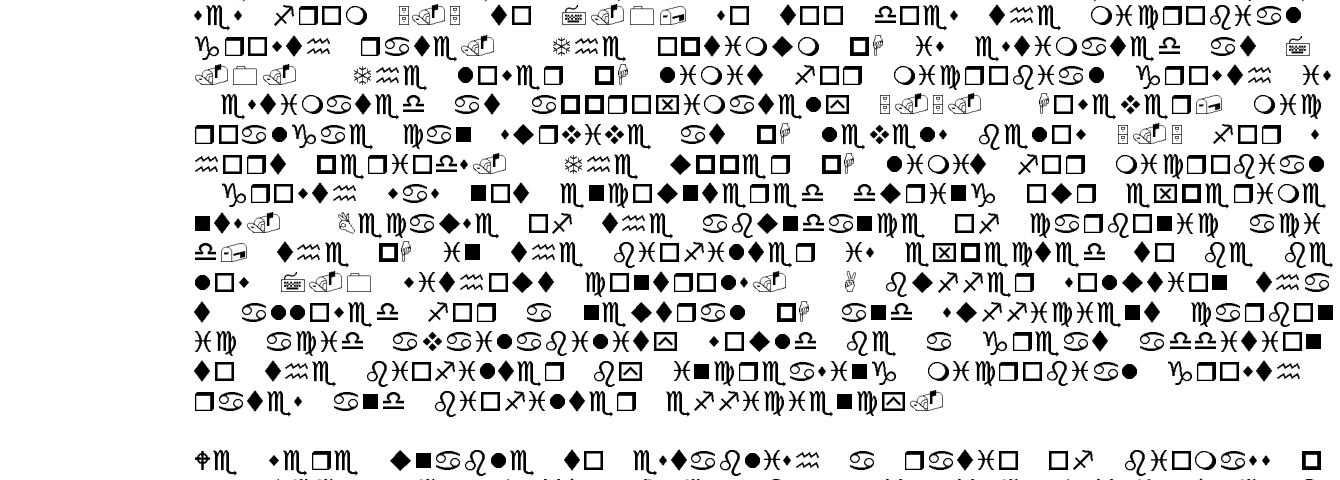
Much was learned with regard to the pH of the aqueous solution. Our experiments showed a correlation between the microalgae growth rate and the pH of the aqueous solution. As the pH increases from 5.5 to 7.0, so too does the microalgae growth rate. The optimum pH is estimated at 7.0. The lower pH limit for microalgae growth is estimated at approximately 5.5. However, microalgae can survive at pH levels below 5.5 for short periods. The upper pH limit for microalgae growth was not encountered during our experiments. Because of the abundance of carbonic acid, the pH in the biofilter is expected to be below 7.0 without controls. A buffer solution that allowed for a neutral pH and sufficient carbonic acid availability would be a great addition to the biofilter by increasing microalgae growth rates and biofilter efficiency.

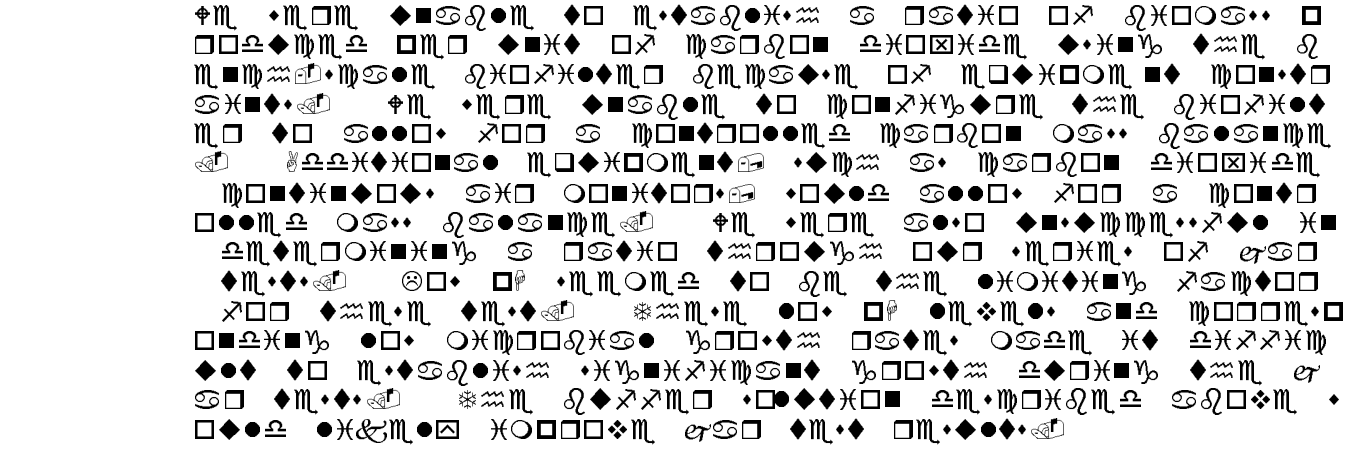
We were unable to establish a ratio of biomass produced per unit of carbon dioxide using the bench-scale biofilter because of equipment constraints. We were unable to configure the biofilter to allow for a controlled carbon mass balance. Additional equipment, such as carbon dioxide continuous air monitors, would allow for a controlled mass balance. We were also unsuccessful in determining a ratio through our series of jar tests. Low pH seemed to be the limiting factor for these tests. These low pH levels and corresponding low microalgae growth rates made it difficult to establish significant growth during the jar tests. The buffer solution described above would likely improve jar test results.

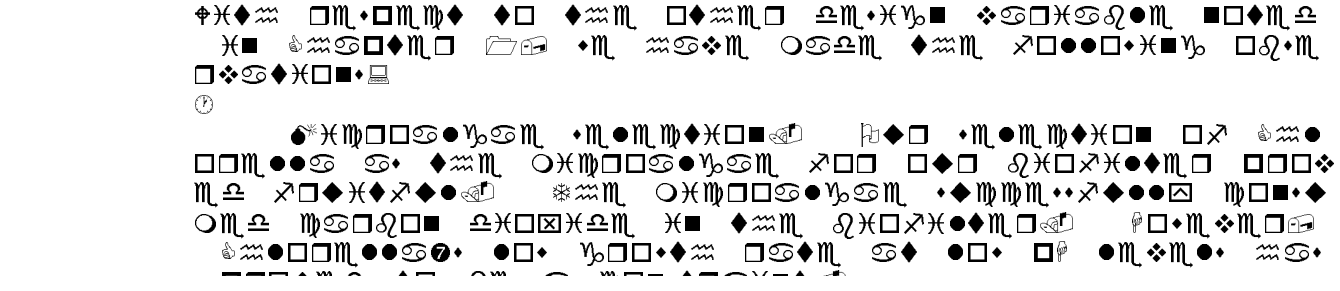
With respect to the other design variable noted in Chapter 1, we have made the following observations:

Microalgae selection. Our selection of Chlorella as the microalgae for our biofilter proved fruitful. The microalgae successfully consumed carbon dioxide in the biofilter. However, Chlorella's low growth rate at low pH levels has proved to be a constraint.









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