Carbon Sequestration by Aquatic Microalgae in India—A State of the Art Review

R. Saravanane1*, T. Sundararajan2 and N. Madhivanan3
1,2Professor, Environmental Engineering Lab, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry–14, India
3Junior Research Fellow (JRF), Environmental Engineering Lab, Department of Civil Engineering, Pondicherry Engineering College, Pondicherry–14, India
E-mail: *vanan.madhi4@gmail.com

ABSTRACT

Carbon dioxide sequestration by aquatic microalgae appears to be the most promising, environmental friendly and cost effective means of reducing carbon dioxide emission in the energy sector. Carbon sequestering—capturing and storing carbon emitted from the global energy system by such photo-bioreactors could be a major tool for reducing atmospheric CO₂ emissions. Such carbon sequestration technologies could be ideally incorporated and best applied in connection with large-scale energy conversion plants such as coal power plants and oil refineries. Carbon sequestration offers the possibility for new industrial applications such as the production of hydrogen, together with electricity, from fossil fuels. This paper provides a state of the art review on this subject.

Keywords: Carbon dioxide, Microalgae, Bubbling Reactor, Photo Bio-reactor

INTRODUCTION

Carbon dioxide is a naturally occurring chemical compound composed of two oxygen atoms each covalently double bonded to a single atom. It is a gas at standard temperature and pressure and exists in the earth’s atmosphere in this state, as a trace gas at a concentration of 0.039 per cent by volume. As part of the carbon cycle, plants, algae and cyanobacteria use light energy to photosynthesize carbohydrate from carbon dioxide and water, with oxygen produced as a waste product. Carbon dioxide produced by combustion of coal or hydrocarbons. CO₂ is also found in lakes, at depth under the sea and commingled with oil and gas deposits.

The environmental effects of carbon dioxide are of significance interest. Carbon dioxide is an important greenhouse gas, absorbing heat radiation from Earth’s surface which otherwise would have left the atmosphere. Burning of carbon-based fuels since the industrial evolution has rapidly increased concentrations of atmospheric carbon dioxide increasing the rate of global warming and causing anthropogenic climate change. CO₂ emissions are expected to increase at an annual rate of 3%. The potential effects of global warming on India vary from the submergence of low lying islands and coastal lands to the melting of glaciers in the Indian Himalayas, threatening the volumetric flow rate many of important rivers of India and south Asia.

Records show that 0.6 °C increase in global average temperature over the past century mainly due to increase in atmospheric CO₂. The best scientific
estimate is that global mean temperature will increase between 1.4 and 5.8 °C over the next century as a result of increase in atmospheric CO$_2$ and other GHG. This type of phenomena cause the increase in global temperature would cause significant rise in average sea level. Without substantive changes in global patterns of fossil fuel consumption and deforestation, warming trends are likely to continue for environmental safe aspects.

Carbon sequestering—capturing and storing carbon emitted from the global energy system could be a major tool for reducing atmospheric CO$_2$ emissions. Carbon sequestration technologies could be incorporated and best applied in connection with large-scale energy conversion plants such as coal power plants and oil refineries. Carbon sequestration offers the possibility for new industrial applications such as the production of hydrogen, together with electricity, from fossil fuels.

Photosynthesis has long been recognized as a means, at least theory, to capture anthropogenic carbon dioxide. Photosynthesis is the original process that created the fixed carbon present in today’s fossil fuels. Aquatic microalgae are among the fastest growing photosynthetic organisms, having carbon fixation rates an order of magnitude higher than those of land plants. Microalgae utilize CO$_2$ as one of their main building blocks and we propose that algal photosynthesis may be viable option for anthropogenic CO$_2$ capture and sequestration. While microalgal culturing is expensive, microalgae can also produce a variety of high value compounds that can be used to generate revenues. Those revenues could pay for the cost of carbon capture and sequestration. Microalgal photosynthesis can also result in the precipitation of calcium carbonate, a potentially long term sink of carbon. The advantages of using a microalgal-based system are that:

- High purity CO$_2$ gas in not required for algal culture. Flue gas containing varying amounts of CO$_2$ can be fed directly to the microalgal culture. This will simplify CO$_2$ separation from flue gas significantly.
- Some combustion products such as NOx or SOx can be effectively used as nutrients for microalgae. This could simplify flue gas scrubbing for the combustion system.
- Microalgae culturing may yield high value commercial products. Sale of these high value products can offset the capital and the operation costs of the process.
- The envisioned process is a renewable cycle with minimal negative impacts on environment.

In this study we have used bubbling reactor and photobioreactor for the growth of microalgae, CO$_2$ can be effectively fixed by microalgae and the final product used for commercial purposes. Fig 1. in materials and methods shows you the experimental setup used for the study.
MATERIALS AND METHODS

A small experimental setup (Fig. 1.) could be viable solution to study the effect of CO₂ sequestration.

Aquaculture systems involving microalgae production and wastewater treatment (e.g., of amino acids, enzymes or food industries wastewaters) seems to be quite promising for microalgae growth combined with biological cleaning. This allows nutrition of microalgae by using organic compounds (nitrogen and phosphorous) available in some manufactures wastewater, not containing heavy metals and radioisotopes. Additionally, microalgae can mitigate the effects of effluent and industrial sources of nitrogenous waste as those originating from treatment of fish aquaculture and at the same time contributing to biodiversity. Moreover, removing nitrogen and carbon from water, microalgae can help reduce the eutrophication in the aquatic environment.

Mode of cultivation of algae:

1. Open pond system.
2. Closed photo bioreactors.

A comparison of open and closed large scale culture system for micro algae.

<table>
<thead>
<tr>
<th>Culture System for Algae</th>
<th>Closed System (PBRs)</th>
<th>Open Systems (Ponds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination control</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Contamination risk</td>
<td>Reduced</td>
<td>High</td>
</tr>
<tr>
<td>Sterility</td>
<td>Easy</td>
<td>None</td>
</tr>
<tr>
<td>Process control</td>
<td>Easy</td>
<td>Difficult</td>
</tr>
<tr>
<td>Species control</td>
<td>Easy</td>
<td>None</td>
</tr>
<tr>
<td>Mixing</td>
<td>Uniform</td>
<td>Very poor</td>
</tr>
<tr>
<td>Operating regime</td>
<td>Batch/Semi-continuous</td>
<td>Batch/Semi-continuous</td>
</tr>
<tr>
<td>Area/ Volume ratio</td>
<td>High (20,200/m²)</td>
<td>Low (5-10/m²)</td>
</tr>
<tr>
<td>Population density</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Investment</td>
<td>High</td>
<td>Poor</td>
</tr>
<tr>
<td>Operation costs</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Capital / operating costs</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Low utilization efficiency</td>
<td>High</td>
<td>Poor</td>
</tr>
<tr>
<td>Temperature control</td>
<td>More uniform temperature</td>
<td>Difficult</td>
</tr>
<tr>
<td>Productivity</td>
<td>3-5 times more</td>
<td>Low</td>
</tr>
<tr>
<td>Water losses</td>
<td>Depend upon cooling design</td>
<td>Equal</td>
</tr>
<tr>
<td>Evaporation on growth medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Gas transfer control</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>CO₂ losses</td>
<td>Depend on pH, alakalinity etc</td>
<td>Same.</td>
</tr>
</tbody>
</table>
There are different types of photo bioreactors available in the market:

- Vertical tubular photo bioreactor.
- Flat panel photo bioreactor.
- Horizontal tubular photo bioreactor.
- Helical type photo bioreactor.
- Stirred tank photo bioreactor.
- Hybrid type photo bioreactor.

CONCLUSIONS

CO₂ sequestration is very essential to prevent earth from global warming. As CO₂ plays a major role in green house effect. We must take care of increasing atmospheric CO₂ level. The most economic way of reducing CO₂ is by Biological method by using Microalgae. The suitable method of growing microalgae is discussd above. Microalgae not only plays vital role in CO₂ reduction it also used as alternative source for fuel. Microalgae on further processing used as Biodiesel.

Algae Biomass to Biodiesel

Biodiesel is a mixture of mono alkyl esters of long chain fatty acids (FAME) derived from a renewable lipid feedstock such as algal oil. After the extraction process, the resulting product algal oil can be converted into biodiesel through a process called trans esterification. Trans-esterification is a chemical reaction between triglycerides and alcohol in the presence of a catalyst to mono-esters that are termed as biodiesel.

Algal biodiesel has several advantages over petroleum diesel in that:

- It is derived from biomass and therefore is renewable, biodegradable and quasi-carbon neutral under sustainable production.
- It is non-toxic and contains reduced levels of particulates, carbon monoxide, soot, hydrocarbons and SOx.

REFERENCES


