Improving CO$_2$ Capture Using Porous Membranes for Commercial Algae Farm Cultivations

Bridget Ediger, Dr. Kenneth Reardon, Dr. Jaclyn Adkins

Department of Chemical and Biological Engineering
Colorado State University, Fort Collins, CO, USA
Commercial Algae Cultivations

- Performed in open ponds (i.e., for biofuel)
- Algae consume CO$_2$ in the form of bicarbonate
- Currently, CO$_2$ gas is bubbled up into ponds
  - Very inefficient (85% loss)
- Goal: Develop a more efficient, nonbubbling, method of adding CO$_2$ gas to ponds via a porous membrane

**Figure 1.** Dissolved CO$_2$ in ocean; image courtesy rwu.pressbooks.pub

**Figure 2.** Qualitas Health algae cultivation site in Imperial, Texas; photo courtesy Qualitas Health.
Proposed Algae Pond Carbonation System

- Project focused on two areas of system
  - (1) Storage tank use and solution stability
  - (2) Membrane module carbonation used to interface feed solution with carbon source

Figure 3. Schematic of carbonation system. Courtesy of Dr. Reardon.
Storage Tank (1)

- Determine if storing water with dissolved bicarbonate is stable (minimal loss to atmosphere)
- Two sodium bicarbonate solutions with sodium chloride, each tested with a covered vs. uncovered opening (~1 L each)
  - Sodium chloride (salt) at 18 ppt
  - Sodium bicarbonate at two concentrations, 10 and 100 mM
- Measured change in pH and carbon concentration

**Figure 4.** Close-up of experimental set-up. From left to right: 100 mM NaHCO₃, covered; 100 mM, uncovered; 10 mM, covered; 10 mM, uncovered.

**Figure 5.** Overview of experimental set-up. Student ID for scale.
Membrane Module (2)

- Rate of CO₂ transfer to water through membrane
  - Carbonic anhydrase catalyzes dissolution of CO₂ into bicarbonate
- Experimental set-up designed by Dr. Adkins
- Measured pH changes to estimate dissolution of CO₂ gas

Figure 5. Close-up of membrane module and schematic of components. Image courtesy of Dr. Adkins.

Figure 6. Overview of experimental set-up.

Figure 7. Close-up of alternate membrane module with hollow fibers.

Figure 8. Close-up of sample with pH probe.
Storage Tank Results

- Storage tank at pH 8 and low (10 mM) to high (100 mM) bicarbonate concentration
  - No loss in carbon was measured
  - Slight increase in carbon and pH likely due to evaporation and equilibration of species in solution (Bicarbonate equilibrium pH is 8.4)

**Figure 9.** pH (x-axis) vs. mM IC (inorganic carbon, y-axis; photo courtesy of NREL.

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Open Surface Area:Volume</th>
<th>ΔpH</th>
<th>ΔC (%mg/L)</th>
<th>ΔpH</th>
<th>ΔC (%mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sealed</td>
<td></td>
<td>0</td>
<td>&lt;1%</td>
<td>0.00</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>vial</td>
<td>10</td>
<td>0.21</td>
<td>&lt;1%</td>
<td>0.20</td>
<td>1%</td>
</tr>
<tr>
<td>beaker</td>
<td>24</td>
<td>0.18</td>
<td>ND</td>
<td>0.25</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Figure 10.** Measured pH over time for experiment.
Conclusions

No carbon loss was measured during the first experiment simulating CO$_2$ storage tanks. This is important for capturing and storing carbon dioxide for use in commercial algae farm cultivations.

**Used and learned new equipment/techniques in a research setting**

- pH probe
- Pipetting
- Prepare chemical solutions
- Shimadzu Carbon Analyzer (Setup calibration and dilute samples for analysis)
- Pump flow rate calibration
- UV cured hydrogel fabrication
- Membrane module assembly

Aside from the bicarbonate equilibrium pH being 8.4, it is not clear why the pH increased in the open samples and not the sealed samples. Further research is needed to understand this system and the results of this experiment, by testing carbonated solutions at different pH and monitoring pH and carbon concentration over time.

Membrane manufacturing and setup was conducted; however, more time was needed in order to complete the experiments. This includes conducting experiments with the membrane, hydrogel, and enzyme carbonic anhydrase and isolating each component.
What benefits did you get from your SURE experience?

Through the SURE program, I was able to experience the day-to-day reality of a researcher at CSU. Before participating in this program, “research” seemed like a vague description for a possible career path, one which I had no real understanding of. Now, I have a much better understanding of what “research” entails on a daily basis, from both experiencing it myself and speaking with my research mentor. This will help me in the future, when deciding what career path I would like to pursue and considering the various options. In addition, the SURE program allowed me to participate in and contribute to scientific and engineering research, which is incredibly exciting for me. I greatly appreciate the opportunity to contribute to meaningful research on campus that will have a measurable effect on the world, particularly on renewable energy resources, a topic which is very important to me.

References & Acknowledgements

This research was made possible by the Department of Energy.

Thank you to Dr. Kenneth Reardon and Dr. Jaclyn Adkins for making this research possible.

Thank you to the Suzanne and Walter Scott Foundation, Tointon Family Foundation, The Filsinger Family, Caterpillar Inc., and Contributors to the Dean’s Innovation fund for making the SURE program possible.
Thank you