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Principal Authors: Dr. Gregory Kremer
Dr. David J. Bayless
Dr. Morgan Vis
Dr. Michael Prudich
Dr. Keith Cooksey, Montana State University
Dr. Jeff Muhs, Oak Ridge National Laboratories

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Organization:	Ohio Coal Research Center 248 Stocker Center Athens, OH 45701-2979 bayless@ohio.edu (740) 593 0264 <i>voice</i> (740) 593 0476 <i>fax</i>	Department of Microbiology LW-113B Montana State University Bozeman, Montana 59717 umbkc@gemini.oscs.montana.edu	Division of Photonics Oak Ridge National Laboratory P.O. Box 2009, MS-8058 Oak Ridge, TN 32831 um4@ornl.gov
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Abstract

This quarterly report documents significant achievements in the Enhanced Practical Photosynthetic CO₂ Mitigation project during the period from 1/2/2004 through 4/1/2004.

Specific results and accomplishments for the first quarter of 2004 include:

- **CRF-2 test system:** After the recent successful test results were achieved, the system was taken off-line for re-sealing and other operational improvements to prepare for the next level of testing, which will include direct measurement of carbon uptake in addition to organism mass measurements.
- 15 biomass slurry samples are currently being analyzed with carbon dating techniques at Galbraith Labs, and statistical analysis of the results will determine if pre and post test carbon analysis is an acceptable means for carbon uptake estimation.
- **Pilot Scale:** Quantitative organism growth testing is underway in the pilot scale bioreactor. Problems with uniformity of organism loading delayed the start of quantitative testing, and it remains as a continuing issue that has not been completely resolved.
- The sustainability test was begun with approximately 30 gallons of algae and 2 Omnisil membranes. The initial mass determination procedure was completed, and the biomass growth over the course of the experiment has been preliminarily quantified.

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Executive Summary

During the first quarter of 2004 we continued our test plan and moved closer to obtaining the pilot scale quantitative test results necessary for project completion.

Improvements to the Pilot Scale bioreactor test rig were completed, and a sustainability test which includes quantitative measurement of organism growth was initiated. The test was begun with approximately 30 gallons of algae and 2 Omnisil membranes, and the initial mass determination procedure was successfully completed. The test will be run for a minimum of two weeks, and biomass growth over the course of the experiment will be quantified.

Test are also continuing with the CRF-2 test system. After the recent successful long term tests which included harvesting and regrowth, the system was taken off-line for re-sealing and other operational improvements to prepare for the next level of testing, which will include direct measurement of carbon uptake in addition to organism mass measurements. To obtain the data necessary to determine if pre and post test carbon analysis is an acceptable means for carbon uptake, 15 biomass slurry samples were sent to Galbraith Labs for carbon dating analysis.

Productivity experiments were performed, with growth measured as the quantity of organism recovered from nightly harvesting. The results indicate that growth is proportional to daily solar photon flux averages.

Results and Discussion

Task 1.0. Evaluate and rank component and subsystem level alternative design concepts

Subtask 1.1 Investigate critical properties of alternative photosynthetic agents (cyanobacteria)

No Report - the researchers at Montana State have completed their subcontract.

Subtask 1.2 Design deep-penetration light delivery subsystem)

No report - the new solar collector is operating well and has survived the winter weather.

Subtask 1.3 Investigate growth surface subsystem design

No new material tests have been run. We are focusing our efforts on Omnisil fabric since it has excellent wetting and rewetting properties, organisms adhere well to it, and it has properties that are appropriate for the bioreactor environment.

Subtask 1.4 Investigate the use of a hydraulic jump to improve the system's overall CO₂ conversion efficiency

Based on the results collected and reported in previous reports, the experiments in this area have been discontinued. The Phase I experimental evaluation of the hydraulic jump is complete.

Subtask 1.5 Design harvesting subsystem

Design improvement work continues on the header pipe / shim insert flow control system to improve flow uniformity over the entire membrane surface, but the basic harvesting system design is functioning well and is adequate for the planned tests.

Subtask 1.6 Quantify properties (higher heating value, elemental composition, volatile content) of dried biomass for potential end-uses.

We continue to search the literature and search for potential end uses for the biomass, but experiments in this area are on hold until we get closer to making a final decision for the organism.

Task 2.0. Evaluate subsystem combinations and select an “optimum” system design

The CRF-2 is the primary test facility for evaluating the subsystem combinations. Long-term quantitative tests in the CRF-2 bioreactor have been successfully completed, including harvesting and regrowth phases. The results of the CRFII tests were used to set pilot scale tests.

After the recent successful test results were achieved, the system was taken off-line for re-sealing and other operational improvements to prepare for the next level of testing, which will include direct measurement of carbon uptake in addition to organism mass measurements. To prepare for that testing, 15 biomass slurry samples were sent to Galbraith Labs and are currently being analyzed with carbon dating techniques. The results are shown in Table 1.

Table 1. Carbon and Hydrogen content of Algal Samples

Sample ID	Carbon			Hydrogen		
	Mass %	Average	Std Dev	Mass %	Average	Std Dev
T-8-1	45.25			6.54		
T-8-2	46.67			6.71		
T-8-3	47.22			6.77		
T-8-4	46.91			6.85		
T-8-5	46.82	46.57	0.77	6.57	6.69	0.13
T-9-1	48.67			7.09		
T-9-2	46.20			6.73		
T-9-3	47.57			7.03		
T-9-4	47.63			6.79		
T-9-5	46.17	47.25	1.06	6.83	6.89	0.16
T10-1	47.97			7.04		
T-10-2	46.15			6.95		
T-10-3	46.18			6.79		
T-10-4	47.03			6.95		
T-10-5	46.92	46.85	0.75	6.89	6.92	0.09
Total		46.89	0.86		6.84	0.16

A comparison of the standard deviations and averages of the clusters (Group 8, 9, and 10) and the total population appear to be statistically similar to a very high confidence interval. As a result, it appears that sampling of a small mass from the bioreactor (population) should yield a result that is representative of the overall biomass in the bioreactor.

Task 3.0. Implement the optimum system in scaled model

Quantitative tests have begun in the pilot scale bioreactor. A discussion of accomplishments and actions items from the pilot scale bioreactor team is copied below.

Group Accomplishments:

We performed maintenance of the entire bioreactor including the resealing of the entire bioreactor and sealing and epoxy coating of the transitions to avoid rusting. We observed a considerable loss (up to 3 gallons per day) of the growth solution due to evaporation,

condensation, and also a few leaks. We linked a majority of the loss to the top of the bioreactor, which needed to be sealed off completely. To be able to access the inside of the chamber access panels were cut into the sides of the chamber.

A system level test was performed after the maintenance to test for leaks and other losses of the growth solution. It was seen that the losses were greatly reduced to much less than 0.5 gallons per day.

Considerable attention was given to the flow patterns of the membranes and we discovered that the header pipe insert and the shim were the most important factors for even flow. We performed a series of offline tests with 6 header pipes to study the flow characteristics of each one.

We have experienced some problems with respect to sustaining the burner flame and are investigating the possible solutions. In the meantime, we have installed and connected carbon dioxide gas bottles to continue with our testing. We have purchased a new air compressor and are confident that it will provide a solution to the burner flame problem.

Productivity Testing

We have initiated a sustainability test with approximately 30 gallons of algae and 2 Omnisil membranes. We have completed the initial mass determination procedure, which enabled us to quantify the algae growth over the course of the experiment. The daily yield of organism was determined, after harvesting each night. The results are not considered significant, as they have not been repeated. However, they are presented here because of the trend.

Figure 1. Preliminary Productivity Data

We noted that the productivity for the following day tracked the average solar flux for the previous day's growth very well (correlating to over 98%). It is hoped that these experiments can be repeated soon to confirm this. However, it seems intuitive that if the solar collector/distributor system is tuned to produce an optimal photon flux ($100\text{-}200\ \mu\text{molm}^{-2}\text{s}^{-1}$) that reducing the daily photon exposure would correspondingly reduce biomass productivity.

Webpage

The web page is running at <http://132.235.19.45/DOE>.

Conclusions

As we continue the fourth year of this project we can report that we have made significant progress towards achieving our overall project goals and are working hard to complete all of our deliverables. All of our test facilities are developed and our test plans and procedures are in place and the important pilot scale bioreactor tests are in process. We will proceed with the tests needed to meet our project goals and will report the results as soon as possible.