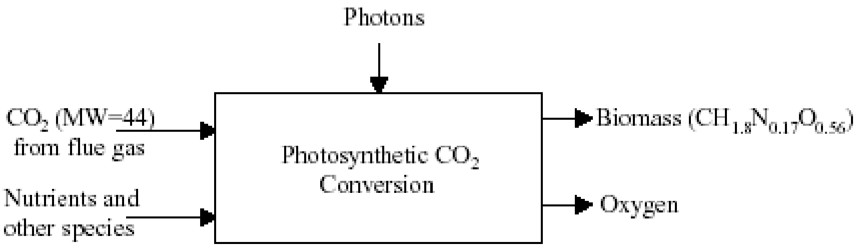
Blue-Green and Red Hot

The phrase “global warming” has for years elicited feelings of futility and apprehension from scientists and civilians alike. The term itself conjures up images of virulent noxious gasses ravaging the earth’s atmosphere. Against such an immense and unstoppable force, it is difficult to imagine any combative measures that might be taken. But sometimes, when faced with an immeasurable phenomenon, the solution at hand might be very small. Microscopic in fact. Cyanobacteria, better known as blue green algae, directly utilize carbon dioxide (CO2) in the process of photosynthesis. Carbon dioxide is one of the green house gasses responsible for global warming, and a main component of emissions from power-plants sustained by fossil fuels. Dr. David Bayless and his team at the Ohio Coal Research Center have developed a system incorporating artificial elements and the tiny organisms which convert the waste gasses into complex sugars, with the byproducts of untainted oxygen and water.

Structure of the Bioreactor

The system which the team proposes consists of a bioreactor: a black metallic box filled with compact mesh screens on which the algae are grown. With the use of these growth substrates, Dr. Bayless explains that”…you get a lot of surface area for growth, but you don’t need a lot of water.” (DiJusto). The boxes are therefore efficient in the consumption of water and space. The bacteria adhere to mesh film, which have been likened to window screens, and are supplied with the gaseous wastes of the smoke stack’ exhaust (Dye). Ducts deliver the fumes to the boxes located nearby, in which the bacteria begin to utilize Carbon dioxide.

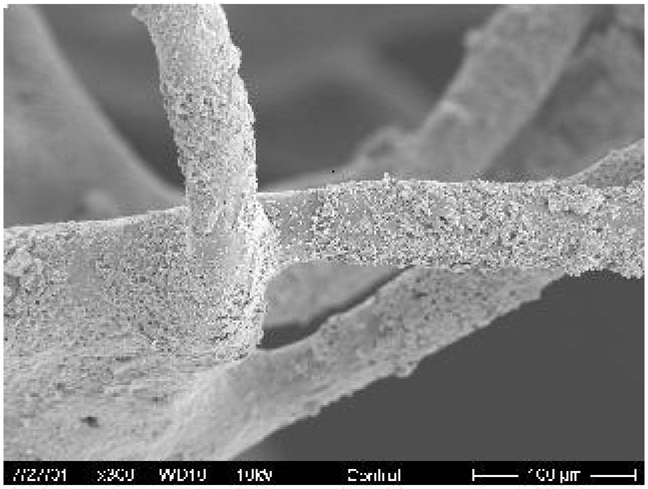


Applied conversion using photosynthesis (Kremer, et al)

Bacteria grow best and photosynthesize the most when exposed to natural sunlight, a characteristic taken into account in the engineering of the contraption. By passively collecting sunlight, researchers have modified a technique developed at the nearby Oak Ridge Laboratory (Walli). to provide the bacteria with illumination. The machinery utilized incorporates fiber optic cables, parabolic mirrors, and roof mounted dishes (Kremer, et al). The lighting cycle required for maximum growth of the bacteria has yet to be determined, but estimates include a period of about sixteen hours. The use of solar energy greatly reduces the amount of energy needed to sustain the system.

The main function of the cyanobacteria in this arrangement is the natural process of photosynthesis. The bacteria provide a natural sink which converts the harmful gas into potentially applicable biomass. Possible uses for the product include “fuel, fertilizer, [or] feedstock” (Kremer, et al). The organic compound is ecologically harmless, as a natural byproduct of photosynthesis.

<u>Chroogloeocystis Siderophila</u>



A biofilm of Yellowstone cyanobacteria (Bayless)

In order to find a species of bacteria suited for the harsh conditions of the bioreactors, Dr. Bayless elicited the help of Dr. Keith Cooksey of the microbiology department at Montana State University. The ideal specimen would possess an affinity for both high temperatures and carbon dioxide. Dr. Cooksey at the time had been continuing his research at Yellowstone National Park in the life present in hot springs and geysers \ (Farquhar) . His work predominately concerned diatoms, tiny microbes of brown algae with cells walls composed of silicon dioxide. The newly discovered Chroogloeocystis siderophila seemed to be the likeliest contender.

The thermophillic (heat-loving) bacteria adhere to moist surfaces, forming colonial biofilms which common machines of fast moving water cannot easily strip off (Bayless).In nature, “Diatoms and their extra cellular polymers are also responsible for the stabilization of near-shore marine sediments and thus they protect coastal areas form erosion." (Cooksey "Research…"). The adhesion of the organisms to the vertical plates is extremely important to ensure as little pressure drop of the flue gas as possible. Chroogloeocystis can survive at temperatures of 50 to 75 degrees Celsius (131 degrees Fahrenheit), temperatures similar to those of flue gas (Kremer, et al).

The chemical makeup of the cyan bacteria includes the ration $CH_{1.8}N_{0.17}O_{0.56}$. One mole of CO2 is necessary for the development of the respective amount of cyanobacteria (Kremer, et al). The gaseous emissions of the flues possess a high percentage of carbon dioxide (14%) in contrast to the normal atmosphere' 350 parts per million. (Kremer, et al). The ideal mixture of nutritious compounds on which the bacteria will be fed has yet to be determined, though scientists believe some combination of nitrates (NO4) and bi-carbonates (HCO3) would be best (Bayless). A routine harvesting of dead and mature bacteria maximizes carbon sequestration and promotes the multiplication of growing bacteria in the free space. The maturing bacteria convert the most carbon as it is necessary to maintain growth.

Lighting and Pipes

Of the wide spectra of light, cyanobacteria only employs a small portion for photosynthesis. The process itself uses light with a wavelength, or photon flux, of 400-700 nanometers (Kremer, et al). When deciding on how to illuminate the growth substrates, a student of Dr. Bayless, Ben Cipiti, suggested modifying the system used at Oak Ridge Laboratory. The main energy resource of the structure is solar photons from passively collected sunlight (Bayless). However, the particles from the flue gas would cause the light to vary and shift in unpredictable ways, leading to unequal illumination of the cyan bacteria, and thus, uneven growth. The Oak Ridge system accounts for this. The structure contains the "scattering properties of the large core

Illuminated panels within the bioreactor (Bayless)

optical fibers so that a maximum amount of visible light emerges radially [like wheel spokes] from the fibers." (Kremer, et al). Because the bacteria are able to survive using one tenth of the light's energy at full power, one meter's worth of sunshine is enough to power ten "glow plates", the plastic squares placed adjacent to the mesh screens on which the algae are grown (DiJusto). The plates light all areas of the substrate with equal intensity, using light collected by solar dishes on the roof.

Though the bacteria can withstand extreme temperatures, it is still necessary to decrease those of liquid and gas once they have flowed through the ducts.

The system incorporates translating flow technology, which cools both the water and waste gas flowing through the pipes. It was created at the Ohio University's Institute for Corrosion and Multiphase Processes. In addition to reducing the heat of the emissions, translated slug flow technology has the additional benefit of allowing greater amounts of carbon dioxide to dissolve in water. The algae can better convert this alternate form of the compound through photosynthesis (Bayless).

Roof mounted "solar collector" (Bayless)

Environmental Considerations

One of the chief concerns of the research team was the possible ecological effect of the bacteria. It was a possibility to augment the yields of photosynthesis by the manipulation of genes or the use of catalysts on the bacteria. However, the altered beings often demonstrate widely varied results when bred in great amounts. Also, the scientists considered the environmental impact if the bacteria of the plant were loosed, an introduction of a foreign species on a new habitat. Bayless was disinclined to genetically engineer any species, because of the ecological ramifications of releasing large amounts of altered organisms into the natural environment. The nature of the hemophilic organism counters this though, as lower temperatures decrease its rate of growth and chances of survival in colder habitats (which, relative to the hot springs, is almost anywhere in Ohio).

The Present and Future Developments

Scientists discussed many courses of action for the successful alleviation of carbon dioxide. A tax based on carbon emissions was suggested, but that plan would financially ruin many workers in the fossil fuel industry. That proposal offered no recourse, especially to those employed at coal based power-plants.

Another solution was to pump the excess chemicals into an ocean nearby, but researchers believe this could have extreme environmental consequences. The ocean could not incorporate the carbon into its biology unless great quantities of iron were supplemented. The only organisms expected to benefit from this strategy are invasive species of plankton , malign to the native creatures. Stowing pools of the compound at the bottom of large bodies of water present great risks and effects that currently are not altogether understood. (Kremer, et al). Altered organic sinks are an option that is both ecologically friendly and cost efficient.

Thus far, the model introduced by Dr. David Bayless and his team offers the most practical solution to fighting the harmful emissions produced by power plants all over the United States. Bayless is currently still conducting tests of his reactors at the Tennessee Valley Authority power-plants. If they are successful, he may have a complete complement of these boxes able to manage the emissions of a full-size power plant built by 2010. By integrating manmade machinery with a natural process, a symbiosis of the two is possible which will benefit mankind and nature and combat the effects of global warming.

Works Cited

Bayless, David J., et al. “Enhanced Practical Photosynthetic CO2 Mitigation.” Session: “Advanced Conversion/Capture Concepts- Biological/Chemical Processes.” Ohio Coal Research Center, Ohio University. 2005.

Cooksey, Keith E., Brown, Igor. “Enhanced Practical CO2 Mitigation.” Department of Microbiology, Montana State University. Bozeman, MT. 2005.

Cooksey Ph.D., Keith. “Research Interests.” http://www.montana.edu/wwwmb/homepages/kcooksey.htm. 10/31/05.

DiJusto, Patrick. “Blue-Green Acres, Fighting factory CO2 emissions with cyanobacteria.” Scientific American Online. 8/29/05. 10/17/05.

Dye, Lee. “In Search of Pollution-Eating Bugs- Researcher Hunts For Bacteria That Can Fix Global Warming.” ABC News Internet Ventures. 2/15/05. 10/17/05.

Farquhar, Brodie. “Some like it hot: rare microbes in Yellowstone National Park geysers and hot springs.” Yellowstone Journal, News and Stories. http://www.yellowstonepark.com/news/archive/2004/Geyser-microbes.asp 10/31/05.

Kremer, G.; Vis, M.; Prudich, M.; Bayless, D. “Practical Photosynthetic Carbon Dioxide Mitigation.” Ohio Coal Research Center. www.ent.ohiou.edu/~ohiocoal. 10/30/05

Walli, Ron. “New Oak Ridge company putting hybrid solar lighting on map.” Communications and External Relations of the Oak Ridge National Laboratory. 8/30/05.http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20050830-00. 10/27/05.