PROGRAM facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

10/2006

SEQUESTRATION OF CARBON DIOXIDE EMISSIONS IN THE OCEAN

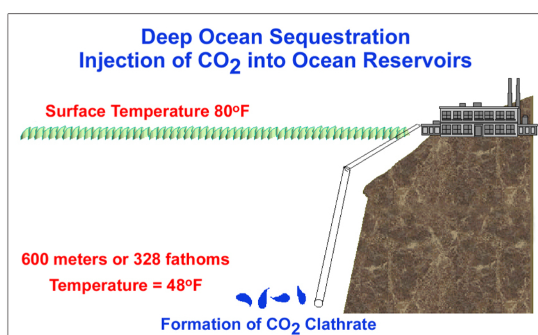
Background

The world's oceans represent the largest potential sink for the carbon dioxide (CO_2) produced by human activities (anthropogenic CO_2). Already oceans contain the equivalent of an estimated 140,000 gigatons of CO_2. The ocean's natural carbon transfer processes span of thousands of years and will eventually transfer 80-90 percent of today's man-made CO_2 emissions to the deep ocean. This natural CO_2 transfer may already be adversely affecting marine life near the ocean surface and could also alter deep ocean circulation patterns. The effectiveness of ocean storage techniques depends largely on how long the CO_2 would remain in the deep ocean. Most studies indicate that if CO_2 can be injected into regions of deep oceanic water circulation, it will remain there for approximately 1,000 years. Direct injection of CO_2 into the ocean would reduce both atmospheric CO_2 concentrations and their sharp rate of increase. The purpose of this program is to investigate the technical, economic and environmental feasibility of CO_2 sequestration by injection of liquid CO_2 in the deep ocean.

Description of Program and Future

The purpose of R&D in ocean sequestration is to gain a better understanding of marine ecosystem dynamics at elevated CO_2 concentrations. Ocean sequestration is the injection of liquid CO_2 into the deep oceans for long-term storage. Key concerns about such an approach include the cost of delivering CO_2 500 meters or deeper below the ocean surface, the permanence of injected CO_2, and possible negative effects on the deep ocean ecosystem. The advantage of this approach is the enormous potential storage capacity of the deep oceans. Although this extensive CO_2 storage capacity represents a considerable advantage compared to other CO_2 sequestration technologies, this approach to long-term CO_2 storage is not considered to be a viable option. Cost of transportation and compression of large amounts of CO_2, together with the as yet to be determined impacts on the ocean ecosystems mitigate against a wide application of this CO_2 sequestration technology at this time. Therefore, the DOE will no longer sponsor research and development projects looking at carbon sequestration in the ocean once the existing projects are completed

This figure illustrates the basic concept of Ocean Sequestration. Liquid CO_2 is injected into the Ocean at a depth of 500+ meters. At this depth and temperature, the CO_2 remains as a liquid or a hydrate.



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PARTNERS

Massachusetts Institute of Technology

Monterey Bay Aquarium Research Institute

National Energy Technology Laboratory

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University of Washington at St. Louis

Projects

Feasibility of Large Scale Ocean Sequestration: Experiments on the Ocean Disposal of CO_2 from Fossil Fuels

<u>Principal Investigator</u>: Dr. Peter Brewer, 831-775-1706 **<u>Partner</u>: Monterey Bay Aquarium Research Institute**

Monterey Bay Aquarium Research Institute will use the Remotely Operated Vehicle (ROV) to carry out pilot experiments involving the deployment of small quantities of liquid CO_2 in the deep ocean for the purposes of investigating the fundamental science underlying concepts of ocean CO_2 sequestration. Below a depth of about 3,000m the density of liquid CO_2 exceeds that of seawater, and the liquid CO_2 is quickly converted into a solid hydrate by reacting with the surrounding water.

Feasibility of Large-Scale Ocean Sequestration: Optimized In Site Raman Spectroscopy on the Sea Floor and Effects of Clathrate Hydrates on Sediment

<u>Principal Investigator</u>: Prof. Jill Pasteris, 316-935-5889 **<u>Partner</u>: University of Washington at St. Louis**

The research group at Washington University in St. Louis will work with MBARI to carry out the first direct in situ analysis on the seafloor of CO_2 clathrate hydrates, their entrained and surrounding fluids, along with sediments adjacent to the clathrate hydrates, using a Raman spectrometer. This information on the physical chemical of clathrate hydrates and clathrate sediment interaction is essential for the evaluation of CO_2 ocean sequestration.

International Collaboration on CO_2 Sequestration

<u>Principal Investigator</u>: Eric Adams, 617-253-6595 **<u>Partner</u>: Massachusetts Institute of Technology**

MIT is conducting a review of recent and ongoing engineering studies concerning techniques for injecting CO_2 into the ocean; a review of experimental studies of the rates of formation and dissolution of CO_2 hydrates; and a review recent and ongoing biological studies concerning organism response to reduced pH and increased CO_2 concentrations.

Laboratory Investigations in Support of Carbon Dioxide-Limestone Sequestration in the Ocean

<u>Principal Investigator</u>: Dr. Dan Golomb, 978-934-2274 **<u>Partner</u>: University of Massachusetts at Lowell, MA**

The University of Massachusetts will establish a data base for the improvement of deep water ocean sequestration using a CO_2-H_2O limestone emulsion. The work will take place over 5 years. The first phase will research the equilibrium characteristics of $CO_2/H_2O/CaCO_3$ emulsions by conducting experiments to quantify the physical characteristics of the liquid and solid phases in emulsion, measure bulk density of emulsion, chemical species concentrations, and the dependence of equilibrium emulsion properties on initial conditions. The second phase will focus on understanding the kinetics of $CaCO_3$ and CO_2 dissolution and reaction. Data collected during this phase will facilitate the development of modeling for future scale up work. Laboratory tests for creating the slurry have been conducted at NETL's Pittsburgh, PA site and at Lowell, MA.

Accomplishments/Benefits of the Research to Date

In cooperation with U.S. DOE's Office of Science and the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), the Core R&D effort is funding research to assess the effects of injected CO_2 on aquatic organisms near the injection zone. A large part of the work has been devoted to prerequisite efforts of developing the instrumentation and remotely-operated vehicles needed to conduct experiments in the deep ocean. Experiments have shown that some fish are able to detect and avoid a CO_2 plume. Other experiments have shown that sessile marine organisms contacted by a CO_2 plume experience high mortality rates. Further research efforts are focused on the boundary layer between the CO_2 plume and the surrounding ocean and in measuring the pH gradient from the injection point outward. Other ongoing research is aimed at developing models for the description of impacts of injected CO_2 on the marine biota; a review of experiments on CO_2 hydrate formation and dissolution; and a study of the fate and effects of liquid CO_2 emulsified in calcium carbonate and released in the deep ocean as a "globulsion". This latter approach has the advantage of coating tiny CO_2 droplets with an alkaline coating which prevents immediate acidification of the surrounding water column.

CUSTOMER SERVICE

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WEBSITE

www.netl.doe.gov