PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

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International Collaboration on CO_2 Sequestration

CONTACTS

Sean Plasynski
Sequestration Technology Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4867
sean.plasynski@netl.doe.gov

Heino Beckert
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-4132
heino.beckert@netl.doe.gov

E. Eric Adams
Principal Investigator
Massachusetts Institute of Technology, Department of Civil and Environmental Engineering
Room 48-216b
Cambridge, MA 02139
617-253-6595
eeadams@mit.edu

Background

Research has shown that the concentration of carbon dioxide (CO_2) in the atmosphere has been increasing since the start of the Industrial Revolution, possibly due, in large part, to increased fossil fuel combustion. Because CO_2 is a greenhouse gas, its increased atmospheric concentration has generated concern about global climate change. One suggestion to address this issue is to capture CO_2 from stationary power sources and introduce it directly into the oceans, thus bypassing the slower biological and solubility cycles by which approximately 80 percent of the CO_2 that we currently emit will ultimately be absorbed by the oceans.

Among the issues requiring consideration before sequestering CO_2 in the oceans would become feasible is the need to obtain high initial dilution of CO_2 in ocean water in order to minimize the excess concentration of dissolved inorganic carbon and, hence, the associated increase in pCO_2 and decrease in pH to which the aquatic biota would be exposed.

Description

Although the overall project involved eleven tasks, the emphasis at the Massachusetts Institute of Technology (MIT) was on the following four tasks: (1) preparation and testing of equipment for measurement and monitoring; (2) observing the performance of ocean field experiments; (3) analysis of data acquired during the experiments; and (4) collation of overall results obtained in the field experiments. This international effort involved five nations (the United States, Japan, Norway, Canada, and Australia) and one private corporation (ABB of Switzerland). In the project agreement, MIT was designated as the Implementing Research Organization for the Department of Energy (DOE).

Two-phase plumes play an important role in various scenarios for ocean sequestration, i.e., dispersing CO_2 as a buoyant liquid from either a bottom-mounted or ship-towed pipeline or as a negatively buoyant hydrate from a ship. Despite much research on related applications, understanding of these CO_2 flows is incomplete, especially concerning the phenomenon of plume peeling in a stratified ambient environment. To address this deficiency, a laboratory facility was built to obtain fundamental measurements of CO_2 plume behavior in the ocean.

PARTNERS

Massachusetts Institute of Technology

Research Laboratories in Japan, Norway, Canada, and Australia

PERFORMANCE PERIOD

08/24/1998 to 06/30/2007

COST

Total Project Value
$1,100,000

DOE/Non-DOE Share
$1,100,000 / $0

An additional task was added to update the assessment of the environmental impacts of direct ocean sequestration to reflect the substantial body of research that has taken place over the past eight years. This effort included a substantial portion conducted by researchers associated with this project. This update represents a valuable summary of the current research in ocean sequestration of CO_2.

Primary Project Goal

The overall goal of this international effort toward reduction of greenhouse gases via ocean sequestration of CO_2 was to (1) investigate the technical feasibility of this approach to carbon management, (2) improve our understanding of the potential environmental impacts of ocean sequestration of CO_2, and (3) to minimize impacts associated with this sequestration technology on the marine biota.

MIT's primary activity, as part of this overall effort, was to conduct a series of laboratory experiments and to develop a mathematical model to describe a plume of liquid CO_2 dispersed from a nozzle in the deep ocean (greater than 2000 meters).

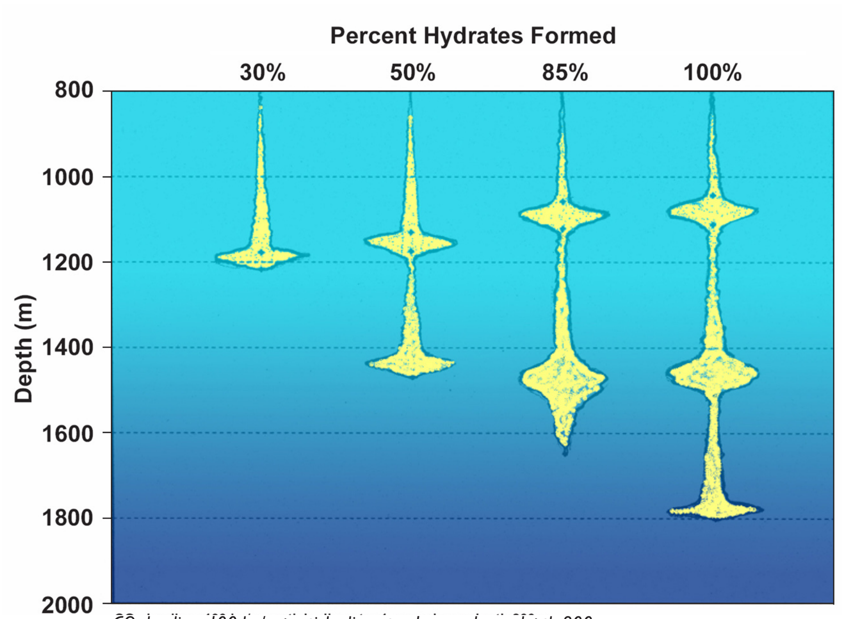
Objectives

The objectives of this international research effort were to:

- Prepare and test instrumentation for the measurement and monitoring of CO_2 injection into the oceans.
- Better understand the phenomena occurring in two-phase plumes.
- Observe the performance of ocean field experiments.
- Analyze data acquired during field experiments.
- Collate overall results obtained from field experiments.
- Develop and validate a model of the behavior of CO_2 injected into the ocean.
- Participate in project management as a member of the Technical Committee.
- Update the assessment of environmental impacts associated with direct ocean sequestration.

Benefits

The consequences from global climate change are potentially severe. Therefore, it is important to explore all options for mitigating the buildup of greenhouse gases in the atmosphere. One possibility is sequestration in the oceans. However, much more complete understanding of the environmental effects of this option needs to be developed before ocean sequestration of CO_2 can be implemented. This project is aimed at providing that understanding.



CO_2 loading: 100 kg/s; particle diameter 1 cm; release depth 800 m.

A schematic depicting plume model results for sinking plumes of different hydrate composition.

Accomplishments

Quantitative data were compared with a new analytical model which treated the CO_2 flow as an upward-moving inner plume, coupled with an annular, downward flowing outer plume. The model included CO_2-specific features, such as bubble/droplet mass transfer, solute dissolution effects on plume buoyancy, and change in total CO_2 concentration and pH. This double plume model was used to explore the fate of solid CO_2 hydrate particles released into the ocean for the purpose of CO_2 sequestration. Previous modeling results have been compared with those of researchers from Japan and Norway.

Mathematical models were used to examine three CO_2 dilution strategies that promote mixing in the longitudinal, lateral, and vertical directions. A point release of negatively buoyant solid CO_2 hydrate particles from a moving ship would achieve acceptable dilution near the source, while subsequent concentrations would be very low due to longitudinal mixing afforded by the ship's speed. A long, bottom-mounted diffuser, discharging buoyant liquid CO_2 droplets, can be designed for high

ADDRESS

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South
Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street,
Suite 1400
Tulsa, OK 74103-3519
918-699-2000

CUSTOMER SERVICE

1-800-553-7681

WEBSITE

www.netl.doe.gov

lateral mixing, resulting in arbitrarily small near-source concentrations but, because the resulting near field plume would be very wide, subsequent dilution would be slow. A stationary point release of CO_2 hydrate particles would achieve good vertical mixing due to the negatively buoyant plume effect, resulting in intermediate local and subsequent concentrations.

An assessment of environmental impacts associated with direct ocean sequestration was completed as an add-on task. The assessment reviewed available literature on both acute and chronic effects of CO_2 on deep-sea aquatic organisms. The researchers concluded that ocean discharge scenarios can likely be designed to largely avoid acute (short-term) impacts, but that more information is needed to fully address chronic (long-term) impacts. The researchers concluded that although the potential for impacts is a controversial subject, ocean sequestration should not be dismissed at this time from future consideration as a mitigation option for CO_2 reduction.