Research and Development Activity of Marine Environment Assessment Technology for CCS in RITE

RITE CO₂ Storage Research Group
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1. CCS Technology in RITE
2. Ocean Sequestration Project
   1. Overview
   2. Natural Analogue Study
   3. Prediction Models
   4. Biological Impact Assessment
3. Application for Sub-Seabed CO₂ Geological Storage
1. CCS Technology in RITE

Roadmap of CCS technology development
From reference of Council for Science and Technology (2008.10.14.)

G8 Toyako Summit expressed needs of starting large scale CCS projects. Cabinet decided start of CCS project early after 2009.

|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|

**CCS pilot test**
- large scale experiment (100Kton/yr)
- geological storage near emission source

**R&D of Geological Storage (RITE)**
1) CO2 injection (10Kton)
3) Basic research

**R&D on Environmental Impact Assessment Technology for CO2 Ocean Sequestration**
Phase I: 1996 – 2001
Phase II: 2002 – 2006
Phase II - extension: 2007-2008

**Target of CO2 capture cost: 2000JPY/t-CO2**

**Target of CCS implementation decided by cabinet**
Image of Safety Assessment for CO₂ geological storage

1. CCS Technology in RITE

Ⅰ. Evaluation of CO₂ storage performance

Ⅱ. Long term monitoring system

Ⅲ. Monitoring & analysis technology for CO₂ behaviour in reservoir

Ⅳ. Monitoring & analysis technology for CO₂ behaviour in shallow subsurface

Ⅴ. Confidential building of CCS

→ [Drafting CCS technical guideline]
CO₂ Ocean Sequestration Project

Official Name: Study of Environmental Assessment for CO₂ Ocean Sequestration for Mitigation of Climate Change

**Phase I:** (FY1996 to 2001)  
NEDO → RITE & KANSO  
PICHTR (International Collaboration)

**Phase II:** (FY2002 to 2006, 1st stage)  
METI → RITE

**Phase II-extension:** (FY2007 to 2011, 2nd stage)  
METI → RITE  -- FY2008 finished

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**Biological Impact Assessment Technology**

**CO₂ Dilution Technology**

**Technical Evaluation of OS and Public Acceptance activity**
2. Ocean Sequestration Project  1. Overview

Application from Ocean Storage to Geological Storage

Prediction of CO₂ behavior in the ocean, and technical feasibility study of CO₂ Ocean Sequestration

**Dilution Technology**
- MHI & Tokyo Univ. & TIT Univ. & AIST

**Observation System**
- CRIEPI

**CO₂ behavior prediction Technology**

- **CO₂ Droplet Dilution Model**
  - Two Phase Model
  - AIST & Tokyo Univ.

- **Meso-Scale Model**
  - Meso Scale model
  - Tokyo Univ. & AIST

- **Large Scale Model**
  - High Resolution Model (OFES)
  - Hokkaido Univ.

- **Global Ocean Circulation Model**
  - BOX Model
  - Low resolution Model
  - RITE

**Biological Impact Assessment on CO₂ Ocean Sequestration Technology**

- **Observation**
  - Research Vessel (397t)
  - Current meter
  - RMS-CTD

- **Analysis of Abyssal food chains**
  - Condensation of sedimenting particle
  - DNA analysis etc.

- **Laboratory Experiment**
  - Laboratory Chamber

- **Field Experiment**
  - Benthic Chamber
  - Pelagic Chamber

- **Deep-sea Ecosystem Model**

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Observation of Natural CO$_2$ Analogue Site

2. Ocean Sequestration Project  2. Natural Analogue Study

**Dissolution Process of CO$_2$ Droplets**

- Hatoma Knoll & Yonaguni Knol in Okinawa Trough (FY2002)
- CO2 Leakage & CO2 Droplets & Gas Analysis
- ROV Hyper Dolphin by JAMSTEC

- Hatoma Knoll in Okinawa Trough (FY2004-2005)
- CO2 Leakage & CO2 Droplets & pH distribution
- ROV Hakuyo2000

**Behavior of Dissolved CO$_2$**

- Wakamiko Caldera in Kagoshima Bay FY2007
- CO2 Leakage & pH distribution
- R/V Hakuyo

- Wakamiko Caldera in Kagoshima Bay FY2007
- pH Distribution
- AUV REMUS by CRIEPI

**CO$_2$ Leakage Process**

- NW Eihuku SM in Mariana Arc FY2006
- pH Distribution by CREPI

- (KAGOSHIMA Bay)

- (OKINAWA Trough)

- (MARIANA ARC)
Observation of Natural Analogue

Observation at the Kagoshima Bay for CO2 bubble and low pH region

Dive boat Hakuyo

movie of CO2 bubble
R&D of Models and Experiments

2. Ocean Sequestration Project
3. Prediction Models

CO₂ Behavior, Case Study, Biological Impact

- Global Ocean
- Around Japan
- Sequestration Site
- With of CO₂ Plume
- Pipe Length
- Injection Layer
- Small Ocean Experiment
- Large scale Global Carbon Cycle Model
- CO₂ behavior in the Global Ocean

Large scale Global Carbon Cycle Model
Diffusion Model
BOX Model

Meso-Scale CO₂ Behavior Model

CO₂ Droplet Dilution Model

Case Study for 50 million ton CO₂/yr

Temporal Scale (10^t year)
Special Scale (10^L km)

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R&D of Biological Impact Assessment Technology

2. Ocean Sequestration Project  4. Biological Impact Assessment

- Physiological Research (pressure chamber) (Fish)
- Acute Effect Experiment
- Acute Effect Model
- In Situ Exposure Experiment
- Method of CO2 Influence assessment
- Deep-sea Ecosystem Model

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**Individual**  **Population**  **Species**  **Community**  **Ecosystem**

**Physiological Research**

**Acute Effect Model**

**Acute Effect Experiment**

**Chronic Effect Experiment**

**In situ Exposure Experiment**
- Benthic Chamber
- Pelagic Chamber

**Mesocosm Experiment**

**(Background survey of Practical Area)**

**Reproduction Effect Research**

**Ecosystem Model**

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**Future Plan**

**Model**

**In action**

**Shoert Days**

- 10 Years
- 100 Years

**Long**

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Objective: The understanding of the environmental impact of CO$_2$ to the marine ecosystem

Period: FY2004-2006
- FY2004: experiment planning
- FY2005: experiment, symposium
- FY2006: analysis and report

Field: Strofjorden (Alesund Norway)
Pelagic Chamber System

We are developing the experiment system to measure the CO$_2$ impact on the marine biological community in the sea water. The final operation examination is executed at last year. However, The deep-ocean impact experiment is not carried out.
Impacts of CO₂ on Marine Organisms

I. Impact of high $p$CO₂
Marine organisms are more sensitive than terrestrial organisms due to lower $p$CO₂ of body fluid.

Case Studies:
- Egg and larva of fish
- Fish growth
- Copepods

II. Impact of low pH
Species with calcium carbonate (CaCO₃) exoskeleton are more sensitive.

Calcite: Coccolithophorid, Echinoderm (sea urchin etc.), Arthropod (shrimp, crab etc.)
Aragonite: Corals, Pteropod
Calcite + Aragonite: mollusk (shellfish)

Case Studies:
- Coccolithophorid
- Sea urchin larvae
- Sea urchin growth
Setting the PNEC for CO$_2$

Predicted No Effect Concentration (PNEC) can be set by applying Assessment Factor (AF) to the values of No Observed Effect Concentration (NOEC) resulted from acute toxicity tests of CO$_2$ on test species.
3. Application for Sub-Seabed CO2 Geological Storage

Research & Development of Environmental Assessment for CCS

The Ministry of Environment revised the Sea Pollution Prevention Act in 2006 for CCS.

Contents required for the application of CCS (Sub-seabed Geological CO2 storage)

1) Enforcement of environmental Assessment
   - biological impact of CO2
     (in-situ ecosystem)
   - prediction CO2 leakage and seepage (pH change in sea water)

2) Planning of Monitoring system for CO2 leakage and seepage.
   (practical instilments and systems)
3. Application for Sub-Seabed CO2 Geological Storage

Development of Monitoring system for water column and sediment

- Research of CO2 Seepage process
  1. Field Observation
     - Sonic Prospecting
  2. Laboratory Experiments

- Development of CO2 Biological Impact
  Existing System
  - DPC
  - DBC ~ 2000m
  - SPC ~ 400m
  Future Plan
  - DPC
  - SPC
  - SBC ~ 30m

- Development of Models for CO2 distribution and biological impact
  - Prediction Model for CO2 behavior
  - Model parameter for CO2 influence

Development of CO2 Monitoring System

1. Usual System
   a. Permanent System
      - Based on Buoy System
      - Based on Cable System
   b. Periodic System
2. Unusual System
   a. Concern of Leakage
   b. Confirmation of Leakage

Draft Image
- Sonic Prospecting
- Water Sampling
- Mud Sampling
- AUV
- Buoy
- Bottom pH Sensor System
- Bottom pH Seismograph

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3. Application for Sub-Seabed CO2 Geological Storage

Technical Combination for Risk assessment of CO2

Laboratory CO2 exposure experiment for benthic ecosystem

- Sampling
- CO2 experiment
- Analysis

In-situ CO2 exposure experiment for benthic ecosystem

Setting of field test condition

Setting of Results of Laboratory experiment

Results of Laboratory experiment

Numerical Simulation for Benthic ecosystem

BC for Shallow ocean

Setting of Results of CO2 influence component

Results of In-situ experiment

Risk assessment of CO2 Leakage and Seepage

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Thank you for your attention

Research Institute
of
Innovative Technology for the Earth
1. CCS Technology in RITE

The Role of RITE

Toward Economic Development and Global Environment Protection Compatible with Each Other

Global warming is one of the most serious issues faced by mankind, and as such must be addressed on a global scale. In 1990, Japan announced "New Earth 21", a 100-year plan to clean up our natural environment which has been degraded by human industry over the past 200 years.

- Development of Innovative Environmental Technologies
- Expansion of CO2 Sinks