CO₂ Storage Research Group

Development of CO_2 Geological Storage Technology for Practical Use

1. CO_2 geological storage project

CO_2 geological storage is a technology to safely contain CO_2 into deep underground formations to prevent the greenhouse gas from being released into the atmosphere. The technology involves: enhancing oil recovery (EOR) by injecting CO_2 into oil reservoirs; enhancing coal-bed methane recovery (ECBM) by injecting CO_2 into coal seams; geological sequestration of CO_2 into depleted gas fields; and storing CO_2 in deep saline aquifer. RITE has been working on storing CO_2 in deep saline aquifer, where caprock (mudstone) formation overlies sandstone formation and blocks migration of gases and fluids with high sealing properties, so that CO_2 is safely stored underground for years.

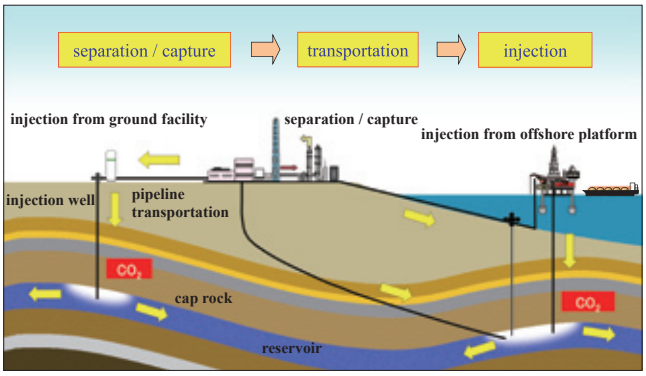


Figure 1 Concept of CO_2 geological storage

RITE has been proceeding with basic research on geological characterization (geological modeling), CO_2 behavior analysis (monitoring and long-term prediction of CO_2 behavior) and CO_2 migration analysis (safety assessment):

(1) Developing techniques of geological characterization

Based on results of cross-hole seismic tomography, physical loggings, physical property measurements of core samples, etc. obtained in the field of Nagaoka demonstration site, RITE closely studies reservoir structures to design better geological modeling that reflects Japan-specific complex geology, such as sand-and-clay formations and gravel formation, and develops methods for geological characterization of reservoir.

(2) CO_2 behavior analysis in reservoir

Through a thorough analysis of physical logging data obtained in Nagaoka demonstration site this year and in the past, RITE further clarifies CO_2 storage mechanism and simulates long-term CO_2 behavior with increased accuracy.

(3) CO_2 migration analysis from reservoir

CO_2 migrates from reservoir mainly through faults and abandoned wells after well or site closure. RITE studies methods of modeling CO_2 migration and develops techniques to monitor and assess environmental impacts on ocean.

RITE applies the above-stated technologies to a proposed CCS large-scale demonstration project and helps accelerate CCS projects in Japan. The CO_2 Storage Research Group achieved the following results in FY2011:

- CO_2 behavior analysis in Nagaoka site

From July 2003 to January 2005, RITE injected about 10,400 tons of CO_2 into saline aquifer 1,000 meters below the ground surface of Iwanohara field, Nagaoka, Niigata Prefecture (owned by Inpex Corporation). To grasp CO_2 behavior after the injection, RITE keeps taking field data regularly by using the wells there. In FY2011, RITE conducted physical well logging, VSP measurement, and analysis of fluids samples of reservoir to study post-injection CO_2 status. Based on the data obtained, RITE carried out history matching and improved long-term simulation analysis of CO_2 behavior. Among many demonstration projects worldwide, only Nagaoka project continues monitoring CO_2 behavior even after the end of injection, thus the observed monitoring results have

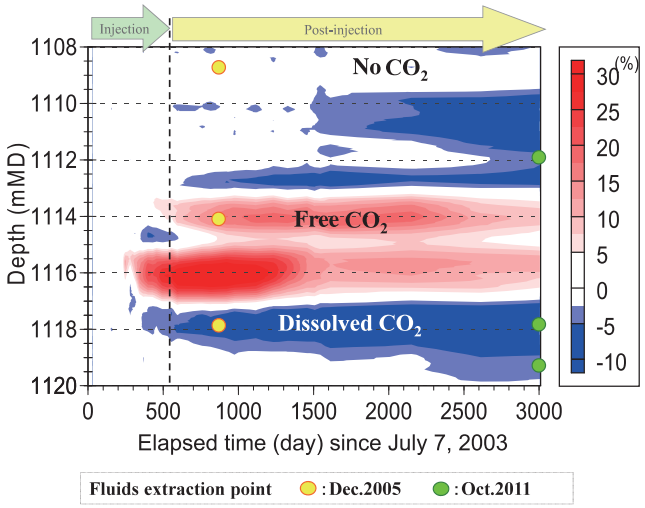


Figure 2 Detection of dissolved CO_2 by resistivity logging (Observation well OB-2)

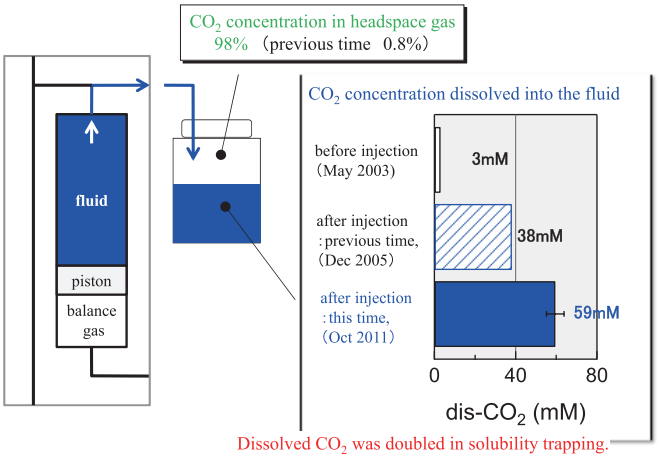


Figure 3 CO_2 concentrations dissolved into formation water

drawn great attention from the world.

- Visualization of CO_2 flow using X-ray CT scanner

RITE introduced a state-of-the-art X-ray CT scanner to understand CO_2 behavior injected into porous sandstone formations of saline aquifer and successfully visualized supercritical CO_2 flows in the pore-space structure of the sandstone. RITE plans to characterize rock porosity and CO_2 saturation in terms of seismic wave velocity and to further advance CO_2 monitoring technology.

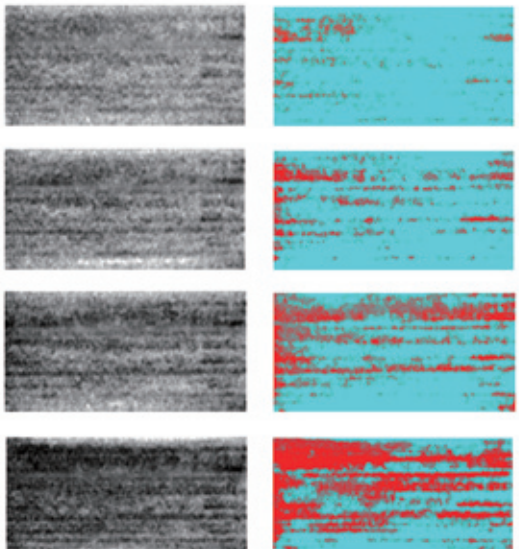


Figure 4 Visualized images of CO_2 flow in sandstone (left: CT images, right: CT images of injected CO_2 (in red))

- Long-term field observation by permanent OBC

As a technique to monitor offshore CO_2 geological storage, RITE adopted a permanent OBC (Ocean Bottom Cable) system and has been evaluating the system since FY2007. First a 16-module (800 meters) OBC was tested in inland water reservoir to evaluate its performance, and then a 24-module (1,200 meters) OBC was tested in real waters for a short time to demonstrate the performance and effectiveness in FY 2010. In FY 2011, RITE further added a 24-module (1,200 meters) OBC to the system and started long-term consecutive observation offshore of Hiratsuka coast in Sagami Bay. In view of application of the system to large-scale CCS demonstration projects, RITE plans to proceed with development of CO_2 monitoring techniques using the permanent OBC.

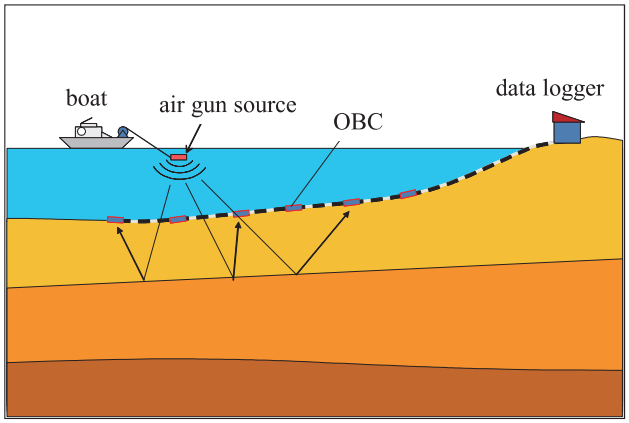


Figure 5 Concept of permanent OBC observation system

Figure 6 Laying permanent OBC observation system

- Research on CO_2 injection impact on geological formation

To observe microseismicities caused by CO_2 injection, RITE installed six 3-C geophones in a CO_2 injection site (Cranfield oil field, Mississippi) of the US carbon sequestration regional partnership under collaboration with the Lawrence Berkeley National Laboratory and the Bureau of Economic Geology of the University of Texas. Observation started in December, 2011. RITE will develop techniques of observing microseismicities to ensure safe injection of CO_2 at the proposed large-scale CCS demonstration project and commercial implementation.

- Environmental impact assessment

Under the project to develop a safety assessment technique of CO_2 migration, RITE selected a baseline model for CO_2 migration simulation in marine sediment and started modeling of CO_2 migration. Under the project to develop a marine environment monitoring, RITE has

studied a technique using microbial activity for CO_2 monitoring. Under the project to develop a technique to assess CO_2 impact on benthic ecosystem, RITE started building a database of CO_2 impact on benthic organisms and collecting information on research and development in the UK. RITE is considering: studying survey methods for physical, chemical and biological baselines of marine environment; building a CO_2 behavior prediction model such that CO_2 takes potential migration paths to reach the bottom of ocean and disperse in the ocean water; and developing methods for evaluating CO_2 impact on benthic ecosystem, in future.

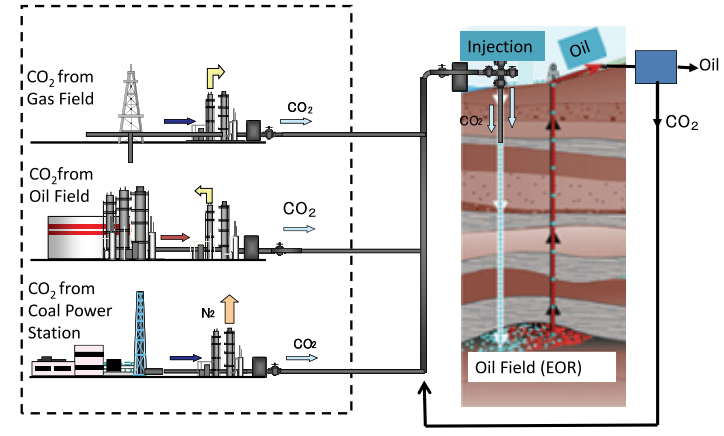
2. Japan-China CCS-EOR project

CCS is a technology to capture and store CO_2 emissions from fossil fuels burning, which is believed to remain essential countermeasures against global warming before 2100. CCS-EOR combining CCS with EOR (Enhanced Oil Recovery) makes profits through the operation so that it is expected to be deployed much earlier. In the United States, CCS-EOR utilizing natural CO_2 has been already implemented in a scale of 60 million tons per year. It is highly expected that the CCS-EOR will move forward to utilizing CO_2 emissions from coal-fired power station in the near future. Its emissions are comparatively large in generating electricity of a specific energy basic unit (1kWh).

Along with the high economic growth in recent years, China increased CO_2 emissions year by year and became the world's largest emitter in 2007. Japan ranks the fifth largest CO_2 emitter in the world. Therefore, CCS-EOR joint study of Japan and China has a significant meaning from the perspective of preventing global warming.

RITE has deepened knowledge sharing on technologies with China National Petroleum Corporation (CNPC) through CCS-EOR workshops (in 2009 and 2010), Saving Energy, Environmental Protection, GHG reduction Workshop (2011) co-organized by RITE and CNPC, and mutual visits to CCS/CCS-EOR related facilities and sites in Japan and China. The technology knowledge sharing resulted in three selected themes for Japan-China collaboration: (1) research on entire CCS-EOR (CCUS) system, (2) research on reservoir characterization techniques, (3) research on microbial restoration of methane deposits with subsurface CO_2 sequestration into depleted oil fields. RITE and CNPC signed "the Memorandum of Understanding on Japan-China collaboration themes" in Beijing on September 28, 2011.

In 2012, the collaboration with CNPC will be focused on "research on reservoir characterization techniques", in which applicability of RITE's reservoir characterization techniques to oil fields in China is scheduled to be studied in detail.



CCS-EOR: Achievement of both Huge CO_2 Storage and Increasing Oil Production

Figure 7 CCS-EOR Overview

Figure 8 Signing ceremony for MoU on CCS-EOR Japan-China collaboration themes