

UNDERGROUND SEQUESTRATION OF CARBON DIOXIDE IN TECTONICALLY ACTIVE AREA

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ABSTRACT

An outline of a newly-launched Japanese R&D program on the underground sequestration of carbon dioxide (CO₂) is presented. The main target of the 5-year program is to assemble sufficient information to assure the safety of underground storage of CO₂, through a small-scale injection test in the field, and laboratory experiments. A study of the social and economic aspects of the technology is also included. The existing estimates show 73.5 billion tons of CO₂ potential capacity in offshore aquifers near Japan Islands. For implementation of the technology, site identification will be a key issue.

INTRODUCTION

The technical feasibility of the underground storage of carbon dioxide (CO₂) is provided by experience with underground natural gas storage schemes and the enhanced oil recovery. On the basis of the first commercial scale CO₂ storage project in the Utsira aquifer formation associated with Sleipner Vest gas field, we have confidence in the aquifer storage concept in a large-scale geological unit. Japan Islands are located in a tectonically active region on our planet and its geological units are relatively small in space: The small-scale disseminated gaseous emanation in a variety of natural forms, such as hot springs with a high content of gases like H₂S, CH₄ and CO₂, and direct gas emissions associated with volcanic activities, are familiar to the people in Japan. Although Japan's target site for underground storage of CO₂ is offshore, people's perception on safety issues will be a large factor in the economics of the sequestration, through the required distance of the site from the shoreline for avoidance of human deaths caused by leaks. Comprehensive analyses, in a "worst case scenario", of the possible migration paths based on the reliable geochemical reaction rates are necessary.

Japan will launch a new national R&D program of "Underground Storage of Carbon Dioxide" in the fall of 2000, and RITE is now applying for the Project. The outline of the project, its target and approach are described in this report. Our efforts in persuading the Japanese government to undertake this R&D program is based on the capacity estimation of CO₂ underground sequestration by Tanaka et al. (1995). These authors estimated the potential CO₂ capacities in the offshore aquifers with anticlinal and monoclinical structures to be 1.5 and 72 billion tons, respectively.

ONSHORE SMALL-SCALE INJECTION TEST

With cooperation of the Safety & Environmental Center for Petroleum Development (SEC) in Japan, we will conduct a small-scale field test of liquid CO₂ injection at an onshore gas/oil field site until 2004. Our target aquifer will be selected in the viewpoint of continuity and sealing capacity of its roof rock. An injection well will be drilled within FY 2000, and three observation wells are to be installed in FY 2001. The planned total volume of CO₂ during an 18-month injection period is approximately 20,000 metric tons in weight. This volume is a practical upper limit of available CO₂, if purchased in the commercial market. The observation wells will be used to monitor the response of an aquifer; for geophysical logs, the passage of fluid is monitored due to changing saturations and small samples are taken of the fluids. Between the injection and observation wells, the inter-well seismic tomographic profiling will be conducted in multiple times during the injection period.

A simulator for the prediction of CO₂ behavior underground will be developed on the basis of the existing simulation code used in the “underground gas storage” project in Japan. To this compositional-type simulator, fundamental data will be added, obtained in the laboratory study within this project on solubility of CO₂ in the saline water coexisting with small amounts of CH₄, and the mineral dissolution rates with CO₂-enriched saline water.

SYSTEM ANALYSIS STUDY

System Analysis for Global Environment Laboratory (SAGE) of RITE will conduct the following studies:

- Large-scale emission sources, such as fossil fuel fired power plants, steel mills and cement manufacturing factories in Japan are identified and the total system from flue gas sources to target aquifers, comprising CO₂ stripping, compression, transportation, and injection is analyzed in view of life cycle assessment. The results will be compared with those of the other mitigation options.
- Since no comprehensive study has been conducted yet on the actual implementation of CO₂ underground sequestration inside Japanese territory, the construction of the realistic scenarios are to be included in the above system study. The scenarios from economical and safety viewpoints will be proposed on time horizons such as the year 2010 and 2020 for CO₂ sequestration with parameters of the implementation scale (i.e., the annual amount of CO₂ storage and its duration), and the locations of both emission sources and target aquifers.
- Social aspects of the implementation of the technology will also be examined by SAGE of RITE.

SITE SURVEY

The most difficult task in this 5-year new program “Underground Storage of Carbon Dioxide” under the auspices of New Energy and Industrial Technology Development Organization (NEDO) includes the site survey part. With the limited budget allocation in this part, re-examination of the existing off-shore seismic survey data in these 30 years will be followed by the dedicated surveys on the promising areas, preferably on the Pacific side continental shelf and slope. The candidate aquifer for the full implementation of this technology should be one with a structural roof rock; the precise analysis on anticline structure and lithology of the target aquifer is essential.

LABORATORY STUDY

In April, 2000, RITE established its CO₂ Storage Laboratory. This new section of RITE will take care of the fundamental aspects of the Project by the laboratory experimental approaches.

Since the reaction between aqueous CO₂ and minerals in the pressure and temperature conditions we encounter in the underground sequestration (under 50 degree C and 100MPa) is largely slow, the change in the solution composition is too small to detect. We plan to introduce the real-time phase-shift interferometric method to tackle the mineral surface *in-situ* observation with a precision of the surface retreat rate of a few nanometer per second. Combining with the autoclave-type laboratory results such as shown in Hitchon (1996), we can provide the scientific basis for the mineral trapping mechanism of the CO₂ aquifer disposal.

We will also employ the laboratory scale model aquifer approach; since the long-term migration of CO₂ from the target aquifer can be envisaged by this technique. The influence of cap-rock mechanical imperfection and the long-term change of integrity of sealing capability due to the mineral-CO₂ reactions will be examined on the basis of the model experiments in laboratory.

In Japan, we suffer gas hazard associated with volcanic activity. In other words, we have many natural analogs in a sense. In the early stage of the Project, we will survey the literature from this

point of view on the domestic natural analogs, and then try to establish a natural analog test field of the Project for an intensive and purpose-oriented fieldwork.

CONCLUSION

Japan took the first step for the implementation of underground sequestration of CO₂. As many authors such as Holloway (1997) pointed out, the major barrier to implementation of the underground sequestration of CO₂ is cost. Besides cost, the safety issues are the key and the site-specificity of the safety assurance makes a significant difference of the underground sequestration from the ocean sequestration.

ACKNOWLEDGMENTS

In the process of drafting and finalizing our proposal to NEDO, RITE owed much to the SEC staff members, particularly to Mr. Sasagawa, for their enthusiastic involvement and assistance. One of the authors (T.O.) would like to express his sincere gratitude to the continuous encouragement provided by Professor S. Tanaka.

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