Development of Conceptual Hazard Event Tree of CO2 Geological Storage R&D

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INTRODUCTION

To maintain sustainable carbon consumption in the world, carbon capture and sequestration (CCS) is one of essential technologies that have to be utilized in the near future. The CO2 geological storage technology aims to store Carbon dioxide into underground oil or gas reservoirs, coal beds, or aquifers. To utilize the technology, three categories of research and development issues have to be broken through: (1) monitoring and verification; (2) evaluation capacity of various types of CO2 storage reservoir capacity; (3) safety and risk assessment for practical realization in the near future. In this paper, the authors report about our development of conceptual hazard event tree of CO2 geological storage R&D, as an effort of (3) category of above.

The state of art of CO2 geological storage R&D in Japan

Concerning to R&D of CO2 geologic storage, weight has been put on verification of reality of this new technology especially from geosciences and energy-economical side of view.

In Japan, under the contract with Ministry of Economy, Trade and Industry, some of institutes are contributing to the project. AIST GSJ is in charge of geo-technological side of R&D: evaluation of capacity of geological CO2 storage, laboratory experiments, modeling and simulations, research and evaluation of potential storage capacity of major aquifers. Getting preferable results of a few years in-site experiments and monitoring, the R&D is going to enter verification for realization stage: basic verification test of injection and monitoring, development of advanced model of storage, and preliminary safety assessment methodology.

Side by side with geo-technological R&D, Japanese legislative sector start to consider on legislations about this new technology. For realization of the CO2 geological storage technology safely and effectively, efforts on preliminary safety and risk evaluation is essential in this stage.

As for safety and risk evaluation of CO2 geological storage, huge contributions have been made with geo-technical perspective. To accomplish total safety and risk evaluation for whole CO2 geological storage technology, considerations from safety engineering side point of view shall contribute in some extent.

Conceptual hazard event tree and scenarios for risk analysis

To utilize the CO2 geological storage technology, there are three categories of research and development issues those have to be verified: (1) monitoring and verification; (2) evaluation capacity of various types of CO2 storage reservoirs capacity; (3) safety and risk assessment.

As regard with (3) safety and risk assessment of the CO2 geological storage, those include consideration of operation errors within the geologic storage systems in the future and/or risks of carbon dioxide release from geologic storage sites. It requires identification of hazards and
evaluation of consequences and frequencies of inherent hazards within the new technologies.

To avoid any oversight in risk assessment framework of the new technology, the assessment of the risks associated with CO2 geological storage has to be simultaneously processed with (1) and (2) above. Results of the assessment will be feed back to newer results of monitoring and verification researches, and evaluation of capacities of various types of CO2 storage reservoirs researches.

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**Fig. 1: Conceptual hazard event tree of CO2 geological storage R&D**

IPCC 2005 report on CO2 geological storage pointed out the lack of referable hazard data and importance of gathering hazard scenarios by way of FEP (Features, events and processes) data. IEA GHG is developing a FEP database, which has 178 qualitative scenarios of seven categories of risks. To evaluate total risk and establish management system of CO2 geological storage, further quantization efforts should be made. One example of engineering side of risk evaluation is shown in EN draft of legislation 2008: some estimation of number of fatalities due to CO2 leakage. Nevertheless, risks of all hazard scenarios are not estimated yet in overview. Therefore, estimation of hazard from related fields is essential for advancement of the risk evaluation.

To prepare wide ranged risk assessment framework of CO2 geological storage, we are developing a conceptual hazard event tree of technical problems that should be solved within R&D stage. We constructed the tree using factors that were gathered in interviews to geologists and mining engineers and a survey of the literatures (Figure 1). This is preliminary step of risk assessment.
of CO2 geological storage. The tree will assist decision-making of range and depth of safety and risk assessment of this problem.

<table>
<thead>
<tr>
<th>Hazards</th>
<th>CO2 Injection plant</th>
<th>Well</th>
<th>Storage Aquifer</th>
<th>Frequency / Consequence</th>
<th>Mitigating / Recovery Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural disasters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volcanic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earthquake</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind and flood</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leakage</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Accidents             |                      |               |                |                         |                              |
| Leaks                |                      | X             |                |                         |                              |
| Corrosion            |                      | X             |                |                         |                              |
| Errors               |                      | X             |                |                         |                              |

| Referable technology/ | Geothermal power plant, Oil & natural gas extraction (especially in air or water induced production), Underground mining, Natural gas storage and supply, Nuke geological disposal |
| engineering          |                                                                 |

Table 1: Extraction of short and long term hazard preliminary analysis

Along with the conceptual hazard event tree, we are developing short and long-term hazard preliminary analysis also to prepare total preliminary risk analysis (Table 1). To accomplish table 1 and evaluate risks, the authors are extending investigation and gathering data not only hazard scenario but possible mitigating measures. The result of the study is expected to contribute both risk management and legislation in realization stage of this technology in near future.

CONCLUSIONS
To prepare wide ranged risk assessment framework of CO2 geological storage, we developed a conceptual hazard event tree of technical problems those have to be solved, based on interviews of geologists and mining engineers and a survey of the literatures. Along with the conceptual hazard event tree, we are developing short and long-term hazard preliminary analysis also to prepare total preliminary risk analysis. The authors are extending investigation and gathering data not only hazard scenario but possible mitigating measures. The result of the study is expected to contribute both risk management and legislation in realization stage of this technology in near future.

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**An Improved Research Method of Regional Economic Resilience of Disasters Model**

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**BACKGROUND**

Entering the new century, a number of devastating disasters throughout the world, such as "September 11" terrorist attack, a series of explosions in the London subway, the tsunami in South-east Asia and eastern Africa, Hurricane Katrina, WenChuan China huge earthquake made tremendous huge losses in many countries. Therefore, more and more scholars in the field of disaster risk management focus on the rapid recovery of living and producing after the huge shock. Taking 5.12 WenChuan China huge earthquake as an example, the government also attaches importance to the recovery of production in the hit enterprise and comeback of the living conditions except for focusing on rescuing and helping casualties. To some extent, resilience of disasters plays an important role in the recovery of the region after events.

Resilience refers to the adaptive ability of rapid response of an entity itself following a disaster shock that enables the region to decrease potential losses in a very short time after the occurrence of a hazardous event (Shaoyu Wang, 2007). Nowadays, more and more organizations emphasize the study of resilience. Most of them focus on the definition, composing factors and influencing factors of regional resilience. However, the discussion of these parts is absolutely not the destination. The aim is to find a way to recover to the original state after the huge disaster through the study of definition and factors. So the most important meaning of studying regional resilience of disasters lies that we can find the equilibrium point between expense of reducing disasters and benefits of restarting business activities after disaster.

In the field of equilibrium analysis, for many years, input-output (I-O) analysis was used most widely modeling approach. However, I-O is featured by a linear and rigid response, almost devoid of behavioral content. In this approach, for example, it is extremely difficult to incorporate input substitution or conservation. In essence, basic I-O analysis provides only an upper bound estimate of the direct and indirect responses to a supply shortage. Some progress has been made with regard to the shortcomings of this approach for application to hazard situations, but only in a limited manner that has not altered its general liabilities. This approach is severely limited in modeling most aspects of resilience to hazards at either the level of the firm, the market, or the regional economy. Therefore, there is coming a alternative model approach ---- computable
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