Surface Monitoring for CO2 Geological Storage with H2 Tracer

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論 文 名　：Surface Monitoring for CO_2 Geological Storage with H_2 Tracer
（CO_2 地中貯留に対する H_2 トレーサを用いた地表でのモニタリング）

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論　文　内　容　の　要　旨

The CO_2 capture and geological storage (CCS) would be an effective method for offsetting human-induced climate change provided that the captured CO_2 can be safely stored in underground formations for long-term, i.e. for hundreds or thousands of years. In order to make CCS widely accepted by policy makers and the general public, particularly the residents living in the vicinity of the storage sites, the storage will have to be safe and demonstrate no leakage of CO_2 gas from a deep reservoir. Those sites, therefore, need to be evaluated using appropriate CO_2 leakage monitoring procedure and a comprehensive monitoring system.

The greenhouse gas emission control will be more effective if it is supplemented by reducing the carbon-based energy consumption and using lower- or zero-carbon energy sources, such as hydrogen (H_2). Currently, some industries are producing H_2 extensively, however H_2 production plants from hydro-carbon resources are also emitting CO_2 and CCS can be embedded into their system to reduce net carbon emissions. The CO_2 captured from H_2 plants contains slight quantities of H_2 that would be injected along with CO_2 into deep geological formations. In addition, natural H_2 may also be produced in the deep subsurface area around the geological storage. On the other hand many studies have considered a wide range of gases to be utilized as tracers for CCS monitoring, and H_2 if being injected into the reservoir can be a suitable gas for this purpose. In this study, a new monitoring approach has been proposed to be used for CO_2 leakage detection by utilizing H_2 gas as a tracer.

This dissertation consists of six chapters.

Chapter 1 describes the background, objectives and the importance of the research to provide the fundamental insights into the study.

Chapter 2 presents a literature review of some basic concepts related to CCS and CO_2 leakage monitoring.

Chapter 3 describes a field characterization and experimental design. This study was carried out at Ito Natural Analog Site (INAS) field in Fukuoka, Japan. The test field is administratively belonged to Itoshima City, and has a humid subtropical or temperate climate. Two wellbores for the gas injection, 24 m apart from each other, were drilled in the test field with depths of 100.5 m and 113.0 m. The property of rock fractures and underground water at the test field were investigated. The geology of study site is composed of Itoshima granodiorite,

commonly classified in unfractured to moderate fractured, except in 62 m, 79 m, 81 to-89m, and 88 to 95 m depths where intensive discontinuity has occurred. Fracture dip orientation is mostly in SE direction. The hydrogeology of the area is very complex. Both of the boreholes have different groundwater level and groundwater flow only in 24 meters: 19 and 15 m depth of water level, NNE, and EES direction, and 0.67 cm/s and 1.06 cm/s, respectively. The total of 95 monitoring pipes (initially, 65 monitoring points) were set at intervals of 1.25 or 2.5 m, forming a rectangular grid, to provide an accurate spatial setting for monitoring and measuring the CO_2 release above the test field. Also, another three boreholes approximately 19.5 m in depth were developed for carrying out the field tests for CO_2 leakage monitoring.

Chapter 4 presents the description of the near-surface gas leakage monitoring after CO_2 released at INAS site. The first injection experiment showed a significant increase of CO_2 concentrations as an anomaly in 4 points, identified Y-E4, Y-F4, Y-F5 and Y-F6, in 64 points installed the monitoring pipes, i.e., 1.2, 3.1, 3.6 and 0.62 %, respectively. However, the same trend was not observed in the second and third experiment. In this study, the direct CO_2 measurement was considerably influenced by seasonal and rainfall intensity and CO_2 concentration tended to decrease after the rainfall. This study also demonstrated that CO_2 concentration measured by pipes gas method occasionally gives low confident result due to the noise of external factor such as the natural CO_2. Considering that the quantity of natural CO_2 flux produced from soil carbon was larger than that of CO_2 flux produced from the storage site, the anomaly level of CO_2 flux could have been hindered on direct surface monitoring. To increase the reliability of leakage detection, a new monitoring approach that utilizes H_2 gas as a CO_2 tracer has been proposed in this study.

Chapter 5 presents another field test for surface monitoring with H_2 as a tracer to detect and predict potential CO_2 leakage from geological storage sites. The mixed gas (CO_2: H_2 = 99:1) was released through the injector well-b into 20 m depth of shallow aquifer. Gas pipe measurements showed that H_2 was detected immediately in 15 ppm at the monitoring point just after mixed gas was released to the water saturated zone. Repeated measurements were then conducted at some monitoring points and recorded the elevation of H_2 continuously between 15 – 65 ppm for two weeks. Meanwhile, pipe gas measurement only showed CO_2 elevation at one monitoring point a day after mixed gas was released. The field result was confirmed by laboratory experiments of mixed gas release which suggests that H_2 was detected earlier than CO_2.

Chapter 6 presents the conclusions of the study together with suggestions for future research. The elapsed time between H_2 and CO_2 surface detection after the release of mixed gas was observed in this study suggesting that H_2 has the potential to be an early signal precursor for CO_2 leakage. It would be very useful for early detection of a potential leakage of CO_2 in advance, so that mitigation actions can be implemented. However, it is necessary to investigate the applicability of H_2 as an effective monitoring methodology at CO_2 storage sites in various scales. More research is also required to not only test the sutability of H_2 for CO_2 leakage detection, but also using it for quantifying the potential leakages.