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Field test study on leakage monitoring at a geological CO_2 storage site using hydrogen as a tracer

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ABSTRACT

In this study, a new monitoring approach for detecting CO_2 leakage is proposed that utilizes hydrogen gas as a tracer for CO_2 geological storage. The gas leakage from a shallow formation is studied using 20–100-m deep boreholes at the Ito Natural Analog Site field testing facility in Fukuoka, Japan. Direct measurements of CO_2 concentrations may yield unreliable results, particularly in summer when high levels of CO_2 flux are produced from soil respiration. A gas mixture (CO_2:H_2/99:1) was injected through a well to the subsurface. The concentrations of gas emitted from the soil were measured in pipes where the gas was trapped; hydrogen was detected at 15 ppm immediately in less than 30 min after the mixed gas was released to the water-saturated zone. Repeated measurements were conducted in the area and elevated H_2 levels of 15–65 ppm were recorded for 2 weeks. CO_2 measurements in the pipes showed elevated levels at one monitoring point a day after the mixed gas was released. The field result was confirmed by laboratory experiments of the mixed gas, verifying that H_2 is detected earlier than CO_2. The elapsed time between H_2 and CO_2 after the mixed gas released was observed in this study suggesting that H_2 has a potential as signal precursor for a future of CO_2 arrival. However, further experiment should be conducted to demonstrate the applicability of H_2 as a monitoring tool in CCS.

1. Introduction

The balance of the carbon budget in the earth's natural reservoirs (the atmosphere, soil, and ocean) plays a significant role in maintaining the temperature stability of the earth. The carbon balance of earth's carbon cycle was disrupted by the industrial revolution that led to the large-scale extraction of carbon from the reservoir rock. The production of fossil fuel is currently emitting about 9 GtC every year, of which about 66% remains in the atmosphere, resulting in an increase of 2 ppm/year of carbon dioxide (Sabine et al., 2004; Schlesinger and Bernhardt, 2013). Slight changes in the carbon budget in the atmosphere can have a dramatic effect on the earth's climate (Schlesiner and Bernhardt, 2013). Hundreds of years, if not thousand years, is required to removes excess CO_2 from earth's atmospheres to meet climate stabilization (Gunter et al., 1998). Carbon capture storage (CCS) is technology that allows us to mitigate climate change by reducing carbon emission from fossil fuel-burning and other anthropogenic sources escapes to the atmosphere with sequestering greenhouse gas, particularly CO_2, to another carbon reservoir (Gale, 2004; Baines and Worden, 2004; Benson and Cook, 2005; Selma et al., 2014).

One of the main concerns for CCS application at geological storage is how to make the injected CO_2 is permanently retained within the planned storage formation. The success of CCS project will be determined by its environmentally safe storage without significant leakage into the surrounding environments, contamination of underground sources of drinking water and ecosystems threatened (NETL, 2011). CO_2 geological storage in Canada and Norway has injected over 5 and 10 million tons of CO_2 respectively, without detectable leakage (IEA GHG, 2008). However, Klusman (2003, 2005) showed that micro-seepage of deep CO_2 has been observed at Rangely Oilfield which has been operating a CO_2-EOR since 1986. Discontinuities in the seal, faults, fractures, corrosion and failure of annular cement may allow the rapid vertical migration of injected CO_2 which can be detected as leakage at the surface area (Klusman, 2011). Therefore to ensure that the health, safety, and environmental parameters of CO_2 geological storage facilities are monitored

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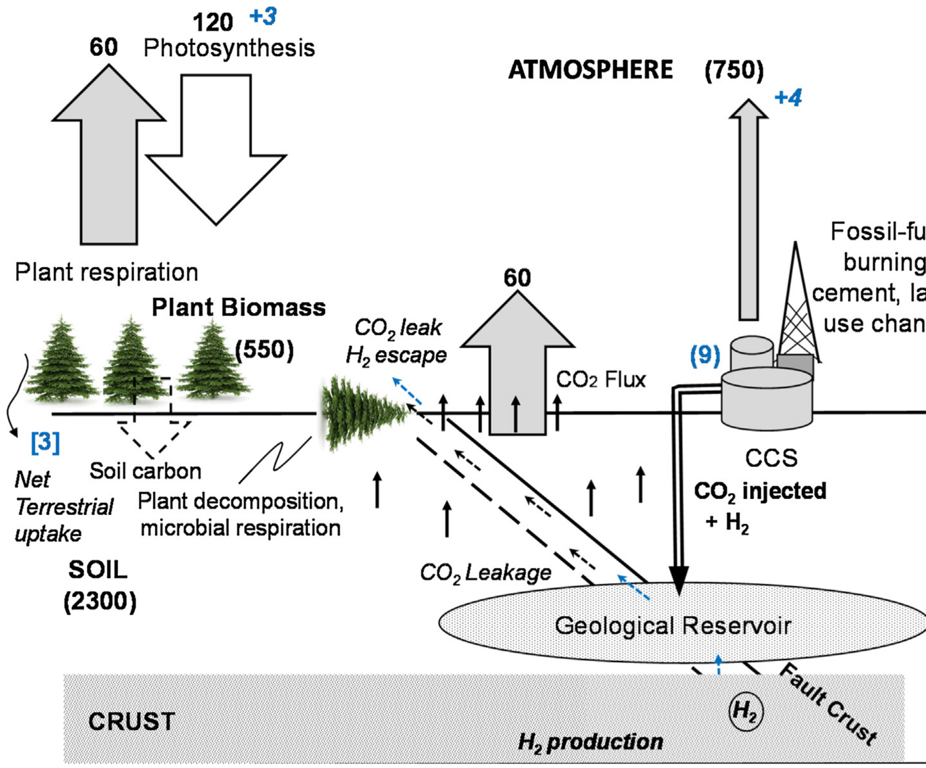

Fig. 1. The illustration of CO_2 leakage of geological storage among natural CO_2 flux, H_2 discharge, and other carbon cycle component. The quantity of emission or gas discharge is represented by arrow sizes. All quantity expressed in Gigatons of Carbon per year, GtC/y (Post et al., 1990; Gruber et al., 2004; Schlesiner and Bernhardt, 2013). Natural carbon fluxes and stock are in black, blue color indicates carbon from anthropogenic emission. The migration of H_2 injected or natural H_2 from deep-seated to the surface, represented by a blue arrow, might be reliable as a tracer for CO_2 leakage. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

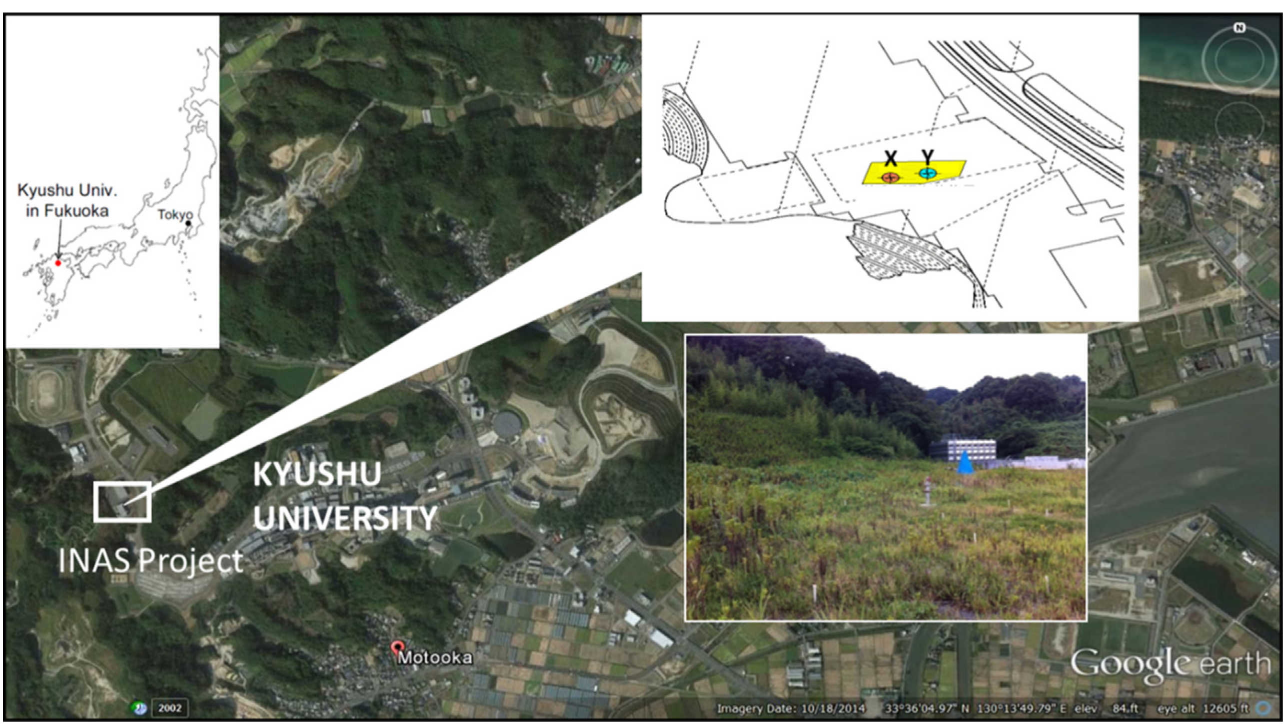

Fig. 2. Location of the Ito Natural Analogue Site (INAS) projects study area in Fukuoka Prefecture, Japan.

and managed effectively, it is essential to carry out measuring, monitoring, and verification (MMV) particularly the monitoring of potential CO_2 leakage. In addition, the development of efficient and sensitive monitoring technology could be significant as an early warning signal that allows improvement in injection strategy to