Characterization of Natural Surface CO₂ Flux: Implication for Leakage Detection Monitoring at CO₂ Geological Sites

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Abstract

Global temperature has been rising due to the increasing greenhouse gases released to the atmosphere. The impacts to the environments and human beings have driven the experts to find the way to reduce it. Carbon capture and storage (CCS) technology is believed to be an effective, and proven, alternative to mitigate this phenomenon. However, this technology is challenged primarily by the leakage of the sequestered gas, which should be monitored in principle to ensure proper health, safety and environment conditions. Besides, a controlled gas leakage is one of the standards to measure the success of a typical CCS project. In other words, detecting a gas leakage, at CCS sites, suggests that the technology has failed its primary purpose. On the other hand, natural gas fluctuations above sampling layer (herein soil surface) complicate seemingly the detection and/or the identification of gas leakage from the sequestered matrix. Thus, it is imperative to understand and to draw out the baseline of natural soil surface gas flux at CCS sites as the soil layer connects the deep layers underground and atmosphere. With the knowledge that the natural soil surface gas flux defines the produced gas (greenhouse gases) in the soil layer transported to surface and emitted to the atmosphere, it should be noted that any additional flux from below could increase the gas concentration above the baseline threshold. Giving these considerations, this study analysed the characteristics of surface CO₂ flux and its implication for determining the baseline threshold to identify the gas leakage at CCS sites. CO₂ was selected as efflux gas primarily because of its relative abundance among the different greenhouse gases in soil.

In this work, natural surface CO₂ flux was measured at CO₂ storage test field (Ito Natural Analogue Site or INAS) located in Japan. The measurements were carried out using a simple-modified device which followed/adopted the basic principal of close-chamber method, in which emitted CO₂ is trapped and accumulated in the chamber and the increase in its concentration over time is analysed subsequently. Not only we measured the surface CO₂ flux, but also we monitored both the soil temperature and soil moisture content. Both parameters are reported to influence the surface gas flux. Soil physical properties (porosity and soil density) were analysed equally to estimate the gas diffusion coefficient using available model of diffusion rate. Therefrom, the natural surface CO₂ flux showed a better agreement with soil temperature compared to that of the moisture content. It was found to increase exponentially with the soil temperature. However, after raining period after what the soil was nearly saturated, surface CO₂ flux reduced by more than half compared to that obtained in dry conditions. Based on field measurement results and some defined conditions, an equation for natural soil CO₂ flux was proposed. The model considered as variable as soil temperature, porosity, moisture, and constants that characterize the effect of various soil properties on CO₂ emission. Subsequently, a maximum baseline threshold equation of natural surface CO₂ flux was proposed as an indicator for leakage detection monitoring at above layer of CCS sites.