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A natural analogue study of soil gas monitoring for CO_2 geological storage

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Monitoring of soil gas in the near-surface environment is important for risk management of geological CO_2 storage projects. In order to evaluate the effectiveness of conventional soil gas monitoring methods for CO_2 leakage detection, we measured soil gas composition, carbon isotope ($\delta^{13}C_{CO2}$) and CO_2 flux in a site where the CO_2-rich waters are observed. The research site, Daepyeong area, is located in the southeastern Sejong City, South Korea. Springs and wells of CO_2-rich waters are located along the boundary between gneiss and granite. Soil gas samples were densely collected on a grid spacing of about 50 m (near CO_2-rich water springs and wells) and 100 m (far from CO_2-rich water). The soil gas samples were taken from about 60 cm depth and stored in a multi-layered gas bag with a peristaltic pump. The CO_2 flux was measured near the soil gas sampling sites by Li-COR 8100A. Gas composition and $\delta^{13}C_{CO2}$ of soil gas samples were analyzed by GC (Aglient 490 Micro GC) and CRDS (Picarro G2121-i) at KIGAM, respectively. Five soil gas samples were analyzed in Isotope Science Laboratory at University of Calgary for cross check. In result, the soil CO_2 concentration of the samples ranged 0.04 $\sim$ 2.8 % (mean = 0.6 %) except M17 (36 %) near a CO_2-rich water well. The O_2-CO_2 relationship of soil gas showed that most of the soil gas samples are on the biological respiration line, indicating that CO_2 in the study area originates from the oxidation of organic matter and its mixing with the atmosphere. On the other hand, the M17 sample was plotted on the right side of the biological respiration line, which is probably attributed to exogenous CO_2 inflow other than biological activity. M17 also showed the highest CO_2 flux (about 440 g/m^2/d). The CO_2 flux was relatively high around M17. $\delta^{13}C_{CO2}$ of M17 (-5.7 ‰) could be explained as a deep-sourced CO_2 intruding the vadose zone given that $\delta^{13}C_{CO2}$ from decomposition of C3 plants is known to be lower than -23 ‰ and $\delta^{13}C_{CO2}$ of most soil gas samples in this study area (samples without mixing with atmospheric air) were -32 $\sim$ -19 ‰. In this study, the location (i.e., M17) of naturally released CO_2 through soil was successfully detected by using conventional soil gas monitoring methods. Even in the CO_2-rich water area, leaks appeared near the well. As many researchers have pointed out, this is another example of the highest risk of CO_2 leakage around wells. Therefore, we suggest that monitoring soil gas around wells in a CO_2 storage site must be prioritized when constructing a soil monitoring strategy.