

Spatial variation of carbon isotope compositions of soil CO₂ around CO₂-rich spring: implications for soil gas monitoring to detect CO₂ leakage

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Natural CO₂-rich springs are the natural analogue of the seepage of sequestered CO₂ from a geologic carbon storage site. In this study, we examined the spatial variation of the flux and carbon isotopic composition of soil CO₂ around the CO₂-rich spring (Chosukgol) in the Gyeongsang sedimentary basin, South Korea, in order to evaluate the usefulness and limitations of soil gas monitoring to delineate the leakage of CO₂. From 61 spots around the spring, the measured soil CO₂ flux values ranged widely from 2.02 to 48.02 g/m²/day. The δ¹³C values of soil CO₂ also widely ranged from -26.8 to -10.7‰. These data indicate the mixing of CO₂ from three different sources in the study area: i) atmospheric CO₂ (CO_{2atm}), ii) soil CO₂ (CO_{2soil}), mainly derived from soil respiration, and iii) ascending, deep-seated CO₂ (CO_{2deep}) of a magmatic origin. The spots with relatively high δ¹³C_{CO2} values tend to be located along an N-S-trending lineament, together with the location of CO₂-rich springs. The CO₂-rich springs have very high P_{CO2} and δ¹³C_{DIC} values, indicating that the aquifer have been strongly affected by CO_{2deep}. However, the zone with depleted CO₂ flux values occurs preferentially around CO₂-rich springs; this is likely due to the dissolution of uprising CO_{2deep} into shallow groundwater. Our study indicates that subsurface processes such as dissolution of CO_{2deep} into water and the mixing with other sources such as CO_{2soil} and CO_{2atm} can make it difficult to detect and discriminate spatially the leakage of CO_{2deep} by monitoring soil gas concentration and/or CO₂ flux. The leakage of CO_{2deep} can be identified by distinctly higher δ¹³C_{CO2} values of soil gas, even though CO₂ flux are lowered by dissolution into water. This study implies that the combined interpretation of CO₂ flux data with δ¹³C_{CO2} values of soil gas is crucial to precisely detect the leakage of CO₂ from a carbon storage site.

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