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A 10-year record of geochemical and isotopic monitoring at the IEA Weyburn-Midale CO_2 Monitoring and Storage Project (Saskatchewan, Canada)

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Carbon capture and storage is a promising technology to reduce CO_2 emissions into the atmosphere. Monitoring of CO_2 storage sites is required by many of the emerging regulations with specific interest in verification of injected CO_2 in various target reservoirs. The objective of this study was to use geochemical and isotopic techniques to trace the fate of CO_2 injected over a 10-year period at the IEA Weyburn-Midale CO_2 Monitoring and Storage Project (Saskatchewan, Canada).

Geochemical monitoring measures changes in chemical and isotopic parameters of fluid and gas samples in a storage reservoir due to brine-mineral-CO_2 reactions resulting from CO_2 injection. Seventeen sampling events were conducted over a 10-year period, including one pre-injection (baseline in the year 2000) and 16 post-injection surveys between 2001 and 2010. Fluid and gas samples were obtained from circa 50 observation wells per sampling event followed by chemical and isotope analyses.

Carbon isotope ratios (δ13C) of injected CO_2 were constant at -20.4 ‰ throughout the 10-year study period and were markedly different from baseline δ13C values of dissolved CO_2 in the reservoir brines. Therefore, carbon isotope ratio measurements constitute an elegant tool for tracing the movement and the geochemical fate of injected CO_2 in the reservoir.

Gas samples obtained from the observation wells at baseline had a median CO_2 concentration of 4 mole%. After 7 to 10 years of CO_2 injection, a significant increase in the median CO_2 concentration was observed yielding values ranging from 64 to 75 mole%. This increase in CO_2 concentrations was accompanied by a decrease in the δ13C values of CO_2 from a median value of -12.7 ‰ at baseline in the year 2000 to values near -18 ‰ between 2008 and 2010. This is evidence that elevated CO_2 concentrations are caused by injected CO_2 arriving at numerous observation wells.

Analyses of fluid samples revealed that the median total alkalinity increased from $\sim$400 mg/L at baseline (2000) to circa 2200 mg/L ten years after commencement of CO_2 injection (2010). Carbon isotope ratio measurements on dissolved inorganic carbon (DIC) in the fluids revealed a decrease from δ13CDIC values of -1.8 ‰ at baseline to circa -12.0 ‰ between 2008 and 2010. This significant decrease indicates that there was considerable solubility trapping of injected CO_2 in the reservoir brines. However, dissolution of carbonates with δ13C values of +3 to +5‰ generated additional HCO_3- resulting in higher δ13C values of DIC than expected from CO_2 dissolution alone. Increases in the median calcium concentrations from 1400 mg/L at baseline (2000) to 2100 mg/L ten years after commencement of CO_2 injection confirmed that ionic trapping of injected CO_2, caused by carbonic acid enhanced carbonate dissolution, occurred in the reservoir brines.

We conclude that combined chemical and isotopic analyses of gases and fluids from observation wells at CO_2 injection sites have the potential to reveal not only the movement of injected CO_2 in reservoirs, but also the trapping mechanisms of injected CO_2 in the target formation, provided that a sufficient number of observation wells are accessible.