A 10-year record of geochemical and isotopic monitoring at the IEA Weyburn-Midale CO₂ Monitoring and Storage Project (Saskatchewan, Canada)

Bernhard Mayer, Maurice Shevalier, Michael Nightingale, Jang-Soon Kwon, and Ian Hutcheon
University of Calgary, Department of Geoscience, Calgary, Canada (bmayer@ucalgary.ca)

Carbon capture and storage is a promising technology to reduce CO₂ emissions into the atmosphere. Monitoring of CO₂ storage sites is required by many of the emerging regulations with specific interest in verification of injected CO₂ in various target reservoirs. The objective of this study was to use geochemical and isotopic techniques to trace the fate of CO₂ injected over a 10-year period at the IEA Weyburn-Midale CO₂ 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-CO₂ reactions resulting from CO₂ 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 CO₂ were constant at -20.4‰ throughout the 10-year study period and were markedly different from baseline δ¹³C values of dissolved CO₂ in the reservoir brines. Therefore, carbon isotope ratio measurements constitute an elegant tool for tracing the movement and the geochemical fate of injected CO₂ in the reservoir.

Gas samples obtained from the observation wells at baseline had a median CO₂ concentration of 4 mole%. After 7 to 10 years of CO₂ injection, a significant increase in the median CO₂ concentration was observed yielding values ranging from 64 to 75 mole%. This increase in CO₂ concentrations was accompanied by a decrease in the δ¹³C values of CO₂ 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 CO₂ concentrations are caused by injected CO₂ arriving at numerous observation wells.

Analyses of fluid samples revealed that the median total alkalinity increased from ~400 mg/L at baseline (2000) to circa 2200 mg/L ten years after commencement of CO₂ 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 CO₂ in the reservoir brines. However, dissolution of carbonates with δ¹³C values of +3 to +5‰ generated additional HCO₃⁻ resulting in higher δ¹³C values of DIC than expected from CO₂ dissolution alone. Increases in the median calcium concentrations from 1400 mg/L at baseline (2000) to 2100 mg/L ten years after commencement of CO₂ injection confirmed that ionic trapping of injected CO₂, 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 CO₂ injection sites have the potential to reveal not only the movement of injected CO₂ in reservoirs, but also the trapping mechanisms of injected CO₂ in the target formation, provided that a sufficient number of observation wells are accessible.