Analog Studies: "Process-Based" Approach

Project Description

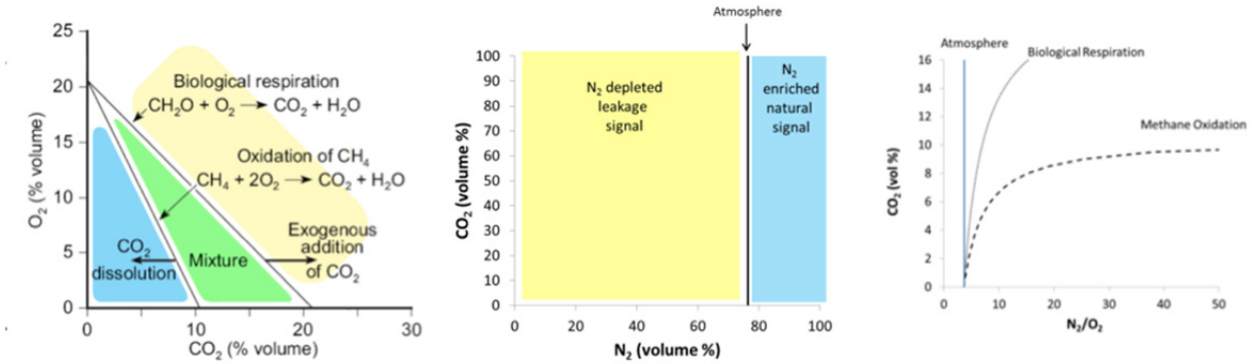
Leakage detection in the near-surface vadose zone is important for (1) responding to landowner/public concerns; (2) assessing environmental impacts; and (3) measuring release to the atmosphere for accounting purposes in the event of a leak. Current "concentration-based" near-surface monitoring protocols rely on comparing pre- and post-injection CO_2 soil gas concentrations for discriminating leakage. Any statistically significant increase in CO_2 concentrations above the preinjection baseline during a project could signal a storage formation leak. Soil gas measurements and supporting weather data (rainfall, temperature, and barometric pressure) must be collected one to three years before injection and assessed using complex statistical analysis to understand and rule out environmental variability as the cause of changes in CO_2 concentration. This project developed an approach to detecting leakage using relationships that naturally exist among soil gases.

The Challenge

Current methods are lengthy, complex, and inaccurate. Challenges are (1) High variability of CO_2 generated in situ can mask a moderate leakage signal. (2) Background characterization cannot account for complete CO_2 variability from climatic, land use, and ecosystem variations expected over the lifetime of a storage project. (3) Background measurements require a long lead time, potentially hindering a project's progress. (4) Background CO_2 cannot be measured across all potential small-diameter leak points within the area of review. Therefore, if concerns arise in an area lacking local background measurements, no baseline data exist with which to compare monitored CO_2 concentrations.

Our Solution

To address the complexities and uncertainties of current concentration-based methods, we have developed a process-based approach. This is a powerful yet simple method that can promptly identify a leakage signal using three simple relationships among coexisting gases (CO_2, N_2, O_2, and CH_4) to distinguish processes acting in the near surface. Processes that can be identified using the method are (1) biologic respiration, (2) CO_2 dissolution and reaction with soil carbonate, (3) CH_4 oxidation (important at carbon capture use and storage [CCUS] sites), (4) atmospheric mixing, and (5) leakage signal.



Fundamental relationships between gasses in the soil allow for determination of the processes that produced the signal

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How the Solution is Working

This approach was developed at a natural CO_2-rich playa lake in West Texas, United States (under U.S. Department of Energy funding from the high-level nuclear program) and tested at the RCSP SECARB Phase III "Early" site. Before CO_2 injection, the method identified a gas migration pathway from reservoir to surface and showed that CH_4 had migrated into the near surface from depth and oxidized to CO_2. Postinjection, the method appears to differentiate a small CO_2 injectate signal on top of the complex hydrocarbon-induced anomaly. The method was also demonstrated at the ZERT controlled-release site, where process-based ratios indicating leakage signals were validated. The process-based approach was also applied at the high-profile Kerr farm in Saskatchewan, Canada, where landowners claimed CO_2 leakage affected their property. Here, the method showed that CO_2 at the farm was of natural origin.

Summary

The process-based method is providing the basis for a paradigm shift for environmental assessment at carbon capture and storage (CCS) sites. A surface monitoring method that is quick and reliable and does not require years of background monitoring has profound implications. This powerful tool is not limited to onshore CCS sites and has gained the attention of stakeholders who want to test the application of this method to dissolved gases in marine sediments at offshore CCS sites and also for environmental assessment at unconventional shale gas and coalbed methane operations. In addition, research is ongoing to develop a smart data collection technology for a process-based approach. This technology will provide continuous, in situ measurement of all the gases of interest for a process-based analysis. Devices will be compact, economical, and reliable, thereby enhancing the accuracy and ease of near-surface monitoring at industrial sites.

Selected Citations

Romanak, K. D., 2013, Potential for a process-based monitoring method above geologic carbon storage sites using dissolved gases in freshwater aquifers: Procedia Earth and Planetary Science, v. 7, p. 746–749.

Romanak, K. D., Bennett, P. C., Yang, C., and Hovorka, S. D., 2012, Process-based approach to CO_2 leakage detection by vadose zone gas monitoring at geologic CO_2 storage sites: Geophysical Research Letters, v. 39, L15405, doi:10.1029/2012GL052426.

Romanak, K. D., Wolaver, B., Yang, C., Sherk, G. W., Dale, J., Dobeck, L., Spangler, L., in press, Process-based soil gas leakage assessment at the Kerr farm: comparison of results to leakage proxies at ZERT and Mt. Etna: International Journal of Greenhouse Gas Control.

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