Gas source attribution techniques for assessing leakage at geologic CO_2 storage sites: Evaluating a CO_2 and CH_4 soil gas anomaly at the Cranfield CO_2-EOR site

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Abstract

At the Cranfield CO_2 enhanced oil recovery (CO_2-EOR) site, a localized area of high concentrations of CO_2 (up to 44%) and CH_4 (up to 47%) in soil gas was detected near a plugged and abandoned well. The complexity of attributing this anomaly, especially in a CO_2-EOR setting, underscores the need for careful attribution techniques and provides rare and valuable experiential knowledge on attributing blind anomalies. An extensive geochemical monitoring program utilizing process-based soil gas ratios, stable and radioactive isotopes of CO_2 and CH_4, light hydrocarbon concentrations, noble gases, and perfluorocarbon and sulfur hexafluoride tracers was undertaken from 2009 through 2014. The goals were to attribute source, assess the usefulness of various attribution techniques, and begin to develop a framework for attribution in complex CO_2-EOR settings. Initial process-based assessment indicated an "exogenous" source meaning that it was not the result of natural in-situ processes (Romanak et al., 2012). We report on the additional analyses used to determine the degree to which the anomaly was related to CO_2 injection. This work included characterization of potential non-reservoir gas sources within the overburden using mud-gas samples collected during a new drill and downhole fluids collected from wells within the field. Two hydrocarbon gas sources, one within the reservoir (Tuscaloosa) and one in the above-zone (Wilcox) were geochemically distinct. Stable carbon isotopes (δ13C) of CH_4 in the anomaly were similar to those of the reservoir, but stable hydrogen isotopes (δD) indicated that anomalous gases originate from an undetermined microbial source rather than either of the subsurface gas reservoirs. Hydrocarbon geochemical parameters were therefore not only useful for attribution, but were also found to have a high potential for leading to inaccurate conclusions because of alteration via CH_4 oxidation. Noble gases and introduced tracers proved least effective for attribution in this case. The most useful indicator was radioactive isotopes of CO_2 and CH_4, which contained > 100% modern carbon indicating a negligible input, if any, from the reservoir.