Continuous monitoring of natural CO_2 emissions near Rome – lessons for low-level CO_2 leakage detection

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Abstract

Regulations for geological storage of CO_2 (such as the EU Directive on Geological Storage of CO_2 and that covering the Emissions Trading Scheme) require monitoring for leakage detection and quantification of any emissions to the atmosphere or marine water column. Whilst early indications of migration within the storage reservoir and storage complex, and leakage from the storage complex, may be provided by deep-focussed monitoring, the ultimate detection of surface emissions and their quantification will need to be made by near-surface measurements.

There have been no significant leaks from CO_2 storage sites operated to date at pilot, demonstration or larger scales that range up to more than 1 Mt of CO_2 injected per year and totals stored in excess of 20 Mt. In the absence of such leaks, assessment of leakage detection technologies has been undertaken at controlled injection and release sites, such as the ZERT site in Montana, Ginninderra in Australia or the CO_2 Field Lab in Norway, or at sites of natural CO_2 emission. At many of such sites the gas emissions occur at clear seepage points, restricted in areal extent (a few metres to tens of metres across) and with CO_2 concentrations in the soil, fluxes across the soil-to-atmosphere interface and concentrations in the near surface atmospheric boundary layer that are readily distinguishable from background values. However, there is also some evidence for more subtle emissions, from isotopic data or gas ratios, that can fall within normal baseline ranges and are therefore more difficult to detect. Also there exists the possibility that such low-level emissions could lead to significant loss of stored CO_2 if they occurred over large areas.

We report here investigations carried out at a natural CO_2 emission site near the main Rome airport at Fiumicino. The CO_2 concentrations in the soil and fluxes from the soil are generally at much lower levels than those at many previously studied sites. At Latera in Italy, Laacher See in Germany and Florina in Greece, for example, there are obvious gas vents in the centre of which CO_2 concentrations in the soil gas are close to 100% and fluxes range up to several kg m^{-2} d^{-1}. In contrast the maximum concentrations and fluxes measured during characterization of the Fiumicino

site were 68% and 124 g m^{-2} d^{-1} but were mostly less than 35% and 70 g m^{-2} d^{-1}. Stable carbon isotope and fixed gas ratios for the site indicate a likely deep origin for the escaping CO_2 ($\delta^{13}C$ close to zero) and clearly distinguish between the deep gas and near-surface biogenic CO_2 even when CO_2 concentrations and fluxes are within the anticipated background range of shallow biological gas production.

Continuous measurements of gas concentrations and fluxes have been made at Fiumicino over a total period of more than a year, although not all instruments functioned correctly for the full duration. Monitoring included soil gas concentrations using GasPro buried probes, flux measurements by multiple automated accumulation chambers, and flux and atmospheric CO_2 (along with meteorological data) by eddy covariance.

Data show the variability of gas concentrations and fluxes over differing timescales (diurnal to seasonal) and the response to changing meteorological and soil conditions. They also allow the detection of low level leakage to be evaluated using process-based (gas ratio) and isotopic methods.

Statistical analysis has been used to examine the cross correlation between CO_2 concentration and flux and a range of other parameters including temperature (in the soil and atmosphere), pressure, rainfall, soil moisture and wind speed and direction. These reveal whether there is a significant positive or negative correlation, the strength of the interrelationship and any lag between changes in environmental factors and CO_2. Seasonal variability has been investigated by comparing cross correlations at different times of year. Results illustrate the subtle nature of low-level leakage and how its signature can vary as a function of near-surface processes, being more or less evident depending on meteorological and soil conditions. The goal of this work is to highlight sampling periods and monitoring methods that will maximize the potential for success in finding and quantifying a low-level CO_2 leak.