Quantifying CO₂ leak rates in aquatic environments

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Abstract

It is important to demonstrate storage site monitoring capability to assure regulatory bodies and the public of CO₂ storage integrity. This includes the capability to identify and quantify potential CO₂ leakage. A significant proportion of global CO₂ storage capacity is located offshore, with some regions of the world having no onshore storage (IEAGHG, 2008). In the case of CO₂ migration from offshore stores, should the leaked CO₂ migrate to the seabed it will emerge as bubble plumes that dissolve into the water column (Caramanna et al., 2011; Blackford et al., 2014). Recent work has identified that the current ability to quantify CO₂ leakage in marine settings is limited due to a number of reasons, including sampling challenges (Roberts et al., 2017). In the case of CO₂ migration from engineered stores onshore, if the leaked CO₂ migrates to the near surface it could dissolve into groundwater (and perhaps emerge as a dissolved constituent of natural springs), seep to the atmosphere as a dry gas, or seep into water bodies such as lakes or rivers. Indeed, studies of onshore natural analogues and field sites find that CO₂ seeps are more likely to emerge in topographic low points (Roberts et al., 2014; Roberts and Stalker, 2017), where there may be rivers or lakes.

Here, we studied natural CO₂ seeps in the Daylesford region in the Central Highlands of Victoria (Australia), to investigate how well CO₂ seepage can be quantified at these sites. In the Daylesford region over sixty mineral springs rich in dissolved CO₂ have been documented (Cartwright et al., 2000). These seeps largely occur as bubble streams in creeks or water bodies close to mineral springs with high CO₂-content. We surveyed degassing characteristics and flux during two field seasons; in June 2016 and March 2017 (wet season and dry season respectively, to compare seasonal effects on CO₂ leak rates) at three locations where CO₂ bubbles through ponded springwater discharge; Wombat Flat, Taradale, and Tipperary springs. To measure bubbling point flux we used a portable fluxmeter (West Systems) and accumulation chamber augmented with a floatation device to position the chamber at the water surface. Bubble distributions were accurately mapped using real time kinematic (RTK) GPS equipment, and we observed bubbling characteristics, such as the energy of the bubbling (weak, vigorous), their temporal consistency (constant, intermittent, irregular, infrequent, regular, frequent), and the size and number of the bubbles (small, large, distributed, dense).

Bubbling behaviour varied between sites. Bubbling points could be contained (< 1m² at Wombat Flat) or more widespread (> 60m² at Tipperary) and few (<20 points at Wombat Flat and Taradale) or numerous (>60 points at Tipperary). Some bubble streams were continuous, others were
intermittent – usually short bubbling periods were followed by irregular periods of dormancy (from many minutes to half an hour, depending on the site), though some bubbling points exhibited regular, cyclical activity. The site of bubble emergence was fixed for some bubble streams, whereas for others they were variable with seemingly random changes in bubbling location. The bubble size also ranged from millimetre to centimetre scale. The measured individual bubble stream rates from all three sites and across seasons ranged in value from 2 to 530 g(CO$_2$)d$^{-1}$. There were fewer bubble streams in the wet season. These variations introduce complexities when attempting to measure fluxes and to estimate leakage rates at these sites. The approach used to integrate individual bubbles stream flux to calculate total emission rate presents a key quantification challenge; if bubbling intermittency (in time and location) is not accounted for, the flux will be overestimated. Importantly, regardless of the approach used to estimate total CO$_2$ flux, we find that flux is not indicated by bubble stream density nor total number of bubble streams. Further, we find that fluxes vary with the season.

Dynamic CO$_2$ bubble streams have been observed at natural CO$_2$ seeps, including Laacher See (Germany - CO$_2$ bubbling is observed from the floor of a crater lake), Panarea (Italy - submarine geothermal region) and at the QICS project (Scotland - simulated CO$_2$ leak to the marine environment; Blackford et al., 2014). These observations, and the subsequent leak quantification challenges have implications of dynamic seepage on leak monitoring and quantification at engineered CO$_2$ storage sites. We discuss the different approaches for estimating the emission rates and the challenges in balancing practicality versus accuracy. We propose that these uncertainties may be insignificant at such small seeps, and that a simple order of magnitude emission rate classification of a leakage feature could be sufficient (e.g. <0.01 t/d, <0.1 t/d and <1 t/d) when using flux chamber techniques. At higher flux seeps (> 1 t/d) it may be possible to estimate leakage rates more accurately using atmospheric monitoring techniques, which are able to average out variability and better integrate emissions (Feitz et al., 2017).

**References:**