# High methane oxidation rates in ferruginous lake Matano

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Lake Matano is the 8th deepest lake on the planet and is the world's largest known ferruginous basin [1]. This ancient lake is persistently stratified, and beyond its high Fe content, it is characterized by extremely low $SO_4{}^{2-}$ and very high $CH_4$ concentrations. It has been proposed that $CH_4$ consumption in the lake occurs via a novel pathway in which $CH_4$ oxidation is coupled to the reduction of Fe and Mn (hydr)oxides [1]. To investigate the pathways of $CH_4$ consumption, we monitored methane oxidation rates with a $^{14}C$-$CH_4$ tracer, both with and without the addition of a suite of electron acceptors including Fe and Mn (hydr)oxides. Our initial measurements yield volume specific rates as high as 0.8 $\mu$mol $l^{-1}$ $d^{-1}$, comparable to modelled rates from C isotope and $CH_4$ concentration profiles [1]. Our measured rates, without added electron donor, are 7 orders of magnitude higher than those reported for the Cariaco Basin [2] and approximately 10 to 50 times higher than in Big Soda Lake, Nevada [3]. Considering the ultra-oligotrophic nature of Lake Matano, these are remarkably high rates. Electron acceptor addition experiments are in progress and these results will be discussed. Our results to date clearly show that $CH_4$ is an important component of the C cycle in Lake Matano and by extension ferruginous systems in general.

[1] Crowe *et al.* (2011) *Geobiology* **9**, 61–78. [2] Ward *et al.* (1987) *Nature* **327**, 226–229. [3] Iversen, Oremland & Klug (1987*) Limnol Oceanogr.* **32**, 804–814.

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# Laboratory experiments and modeling of $CO_2$ dissolution in water for carbon sequestration

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The injection of $CO_2$ gas in the dissolved phase is an alternative to that of supercritical $CO_2$ if the depth of the formation is <800m, or where immediate solution trapping is desired because of safety concerns. The most efficient way to dissolve $CO_2$ in water is downhole in order to take advantage of the increased hydrostatic pressure. We conducted experiments in a 100m long 'well' set up in the staircase of a Manhattan building to study the dynamics of the dissolution process. $CO_2$ was added at the top of the well with a sparger and the dissolution process was monitored downstream by image processing technology.

The experimental results reveal that bubble size and density decrease along the flow path as expected. However, the rate of dissolution decreased along the flow path with bubbles dissolving rapidly initially and extremely slowly afterwards. As the bubbles decrease in size, they became harder to dissolve, due to effects of rigidity of the gas-liquid interface and the presence of low solubility gases in the water and gas. The degree of dissolution could be considerably enhanced by using a passive mixer or an active downhole submersible pump. The dissolution process was simulated using the Darcy-Weisbach equation and a one-dimensional multi-gas numerical gas exchange model. Besides $CO_2$, common impurities such as $N_2$, $O_2$, noble gases, $H_2$, $H_2S$ and gas tracers ($SF_6$ and $SF_5CF_3$) were included in the model. Extrapolation of the model parameters to real-world injection scenarios (e.g. the Carbfix pilot project in Iceland [1]) illuminate the role that the dissolved gas composition, the purity of the $CO_2$, and temperature play in controlling the efficiency of $CO_2$ dissolution for storage in geologic formations.

[1] Gislason *et al.* (2010*) Int. J. Greenh. Gas Con.* **4**.