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Potential impact of CO2 storage on subsurface microbial ecosystems and implications for groundwater quality

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The success of carbon capture and storage (CCS) projects depends on the ability of storage sites to contain CO2 without leakage; and to demonstrate to regulators and the general public the safety of the technology. If leakage were to occur after formal closure of the injection site, this could be over small areas from discrete point sources, such as abandoned wells, resulting in localised high concentrations of CO2 in near-surface ecosystems. Consequently, studies of the potential environmental consequences of CCS have focused on near-surface ecosystems and, as a result, environmental impacts of localised elevated CO2 on terrestrial and marine ecosystems are areas of active research. However, a CO2 storage site, in itself, could also impact on deep subsurface microbial ecosystem and biogeochemical processes. An example would be the impacts of CO2 acting as an energy source by a range of different methanogenic organisms in strongly reducing environments either in terms of behaviour of resultant methane or associated oxidation of reactive minerals, such as sulphides. The latter process could lead to the mobilisation of trace metals. This may have the potential to impact groundwater quality in situations where potable water supplies overlie sites of deep CO2 storage. It is also important to consider the impact resulting from impurities (such as H2S, SOX and NOX) that may be present in the stored CO2. These could, if they were co-transported within a leaking CO2 plume, also alter pH and redox conditions in the subsurface environment with possible associated degradation of water quality.

Using a microbial energetics approach, the significance of these impacts can be scoped with a simple evaluation tool. For example, in order to examine the feasibility of microbes utilising CO2 as an energy source, the fundamental chemical thermodynamic constraints on this process can be considered. Lithotrophic microorganisms utilise the energy of redox reactions for their life processes and hence a key issue is what potential oxidation reactions can be coupled to the reduction of CO2. In many deep environments, sulphide minerals are likely reductants that have been shown to commonly participate in microbial redox reactions. However, the nature and scale of the geochemical impacts from microbially catalysed redox reactions will be heavily dependent on the characteristics of the geological setting. Although the consequences of slow seepage into aquifers may be of more general concern, in some cases the redox front could just develop throughout the cap rock overlying the CO2 store. The extent of the redox front would be controlled by the available nutrients and also the amount of energy available to the microorganism from the utilised redox reactions. The resulting impacts of microbial activity from these reactions could be both physical (e.g. altering porosity through the production of biofilms) and chemical (e.g. changing pH, redox conditions) and may result in intracellular or extracellular mineral formation or degradation. These processes could all directly impact on the physical transport of CO2 (as a gas or dissolved in fluid) through fractures and porous media. Although it is unlikely that such processes could cause failure of containment, they should, at least, be assessed.