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Harnessing microbial processes for hydrogen consumption in radioactive waste repositories

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Hydrogen gas production will result from anoxic steel corrosion in deep geological repositories (DGRs). Engineered barriers are designed to limit transport of radionuclides to diffusion and to allow gas redistributing within the underground structure. In Switzerland clay was selected both as the host rock and as the main material for engineered barriers, in order to achieve the desired combination of low hydraulic conductivity and sufficient gas permeability. Indeed, the transport of gases (produced in the disposal caverns) to the operational tunnel limits overpressure, and prevents the formation of fractures in the barriers and in the host rock. As an additional safety parameter, the capacity of microorganisms to act as a hydrogen sink is being considered. However, the small pore space and low water activity in undisturbed clay rocks limit microbial metabolism and growth. Thus, the proposed strategy is to backfill the operational tunnels with porous material to allow microbial growth and the concomitant consumption of H_2 through sulfate reduction, methanogenesis, and/or homoacetogenesis.

Here, we present an *in-situ* experiment in the Mont Terri Underground Rock Laboratory (Switzerland), that consists of a borehole drilled in Opalinus Clay rock, feeding porewater to gas-tight reactors packed with porous medium. The latter corresponds to material being considered for gallery backfill. The experiment aims at quantifying the microbial hydrogen consumption rate in backfill porous material, and deconvoluting the underlying microbial processes and their dynamics.

To reconstruct expected repository conditions, porous medium is only partially saturated with Opalinus Clay porewater and pulse injections of hydrogen are applied to the reactor, establishing a gas overpressure. The gas pressure and composition are monitored daily, allowing the determination of microbial hydrogen consumption and methane production rates and porewater chemistry reveals the rates of sulfate consumption and acetate production. Finally, the microbial community distribution and the speciation of redox-sensitive elements (Fe, S) are characterized in a spatially-resolved manner.

This study will provide an accurate rate of hydrogen consumption in a porous repository backfill and will help inform the safety case with respect to the potentially beneficial impact of microbial hydrogen oxidation in DGRs.