MR13A-3183: Microbial and Geochemical Characterization of Groundwater: Implications for Underground Hydrogen Storage Leakage

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ABSTRACT

Underground hydrogen storage (UHS) in geological formations is a key element of the clean energy transition as it enables the decarbonization of the transportation and industrial sectors by decoupling hydrogen production and storage. UHS has many benefits, including low cost, much wider availability, large storage capacity, well-established infrastructure, and increased safety because of geological sealing capabilities. However, the impact of hydrogen (H_2) biogeochemical interactions in the presence of subsurface microorganisms is largely neglected from UHS perspectives. These interactions might affect the effectiveness of storage and can even cause H_2 to leak into the shallow aquifers through storage reservoirs. Leakage of H_2 into groundwater can change the geochemistry and induce several microbial-driven processes. Microorganisms, such as sulfate-reducers, are naturally abundant in groundwater and consume H_2 to produce hydrogen sulfide (H_2S), which can contaminate the freshwater drinking groundwater and cause damage to infrastructure. Hydrogen leakage can also trigger microbial reactions responsible for metal mobility, which can impact the water quality. However, the kinetics of these reactions and the temporal impact of hydrogen leakage in groundwater are still unknown. Therefore, a time series hydrogen-groundwater interaction experiment was conducted, and the changes in fluid chemistry and headspace gas composition will be analyzed along with DNA sequencing results to understand the extent and kinetics of biogeochemical reactions that occur if hydrogen leaks into groundwater. In the experiments, Ultra High Purity (UHP) hydrogen gas will be injected into glass vials with groundwater samples, for a designated time period. For each glass-sealed vial, 16S rRNA gene sequencing, IC, ICP-MS, and GC-TCD will be performed. The experiments provide insights into plausible impacts of hydrogen leakage into shallow drinking water aquifers.

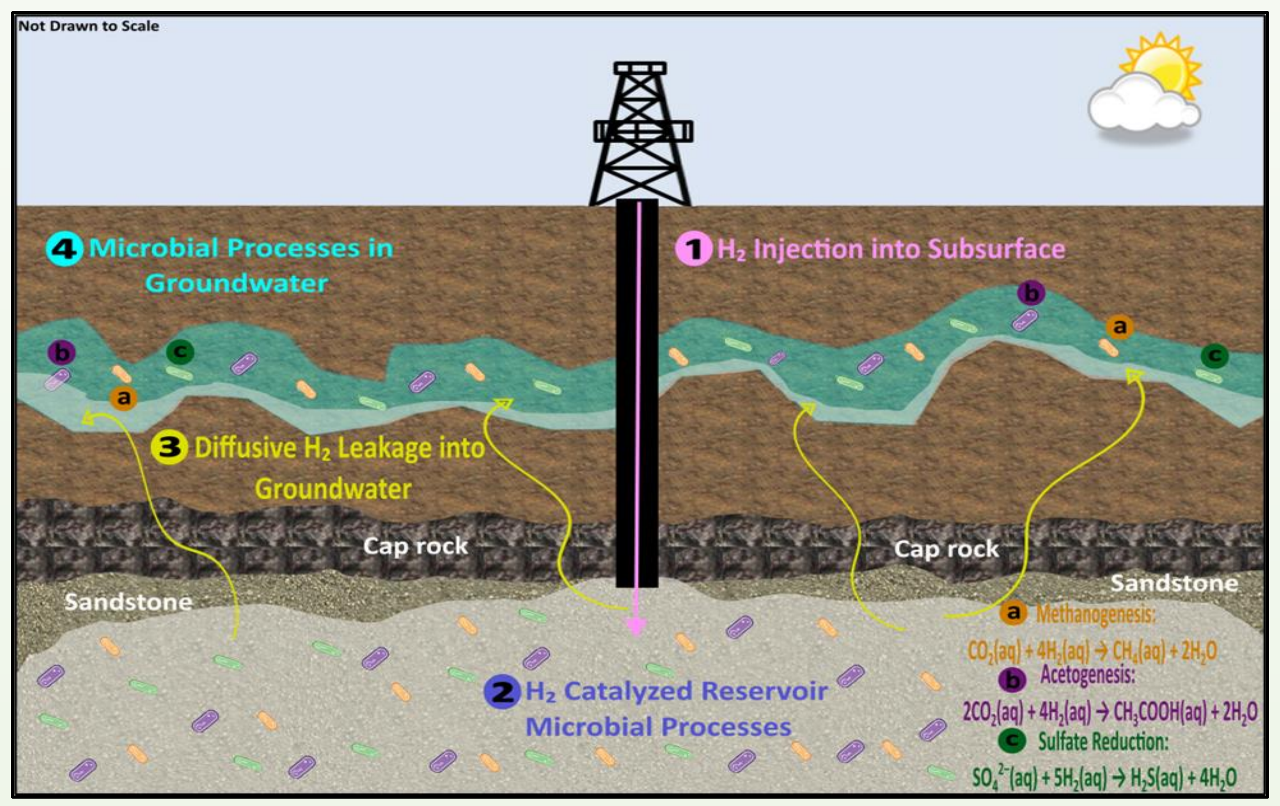


Fig 1: Overview of interactions between microorganisms and stored H_2 in the subsurface. Microbial processes in reservoirs consume H_2. Diffusion can lead to increased concentration of H_2 in groundwater. Microbial processes in groundwater consume H_2 leading to possible contamination of groundwater.

Key Microbial Processes

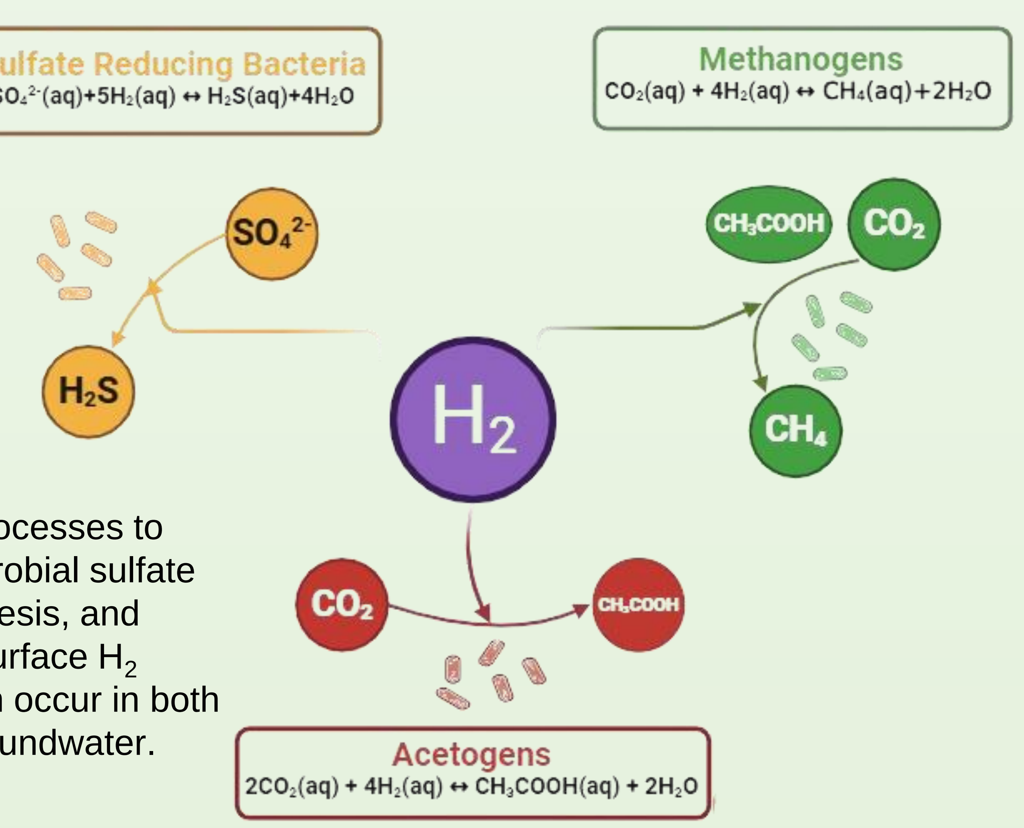


Fig 2: Key microbial processes to consider including, microbial sulfate reduction, methanogenesis, and acetogenesis, for subsurface H_2 storage. Processes can occur in both the reservoir and in groundwater.

EXPERIMENTAL APPROACH

Experimental Setup

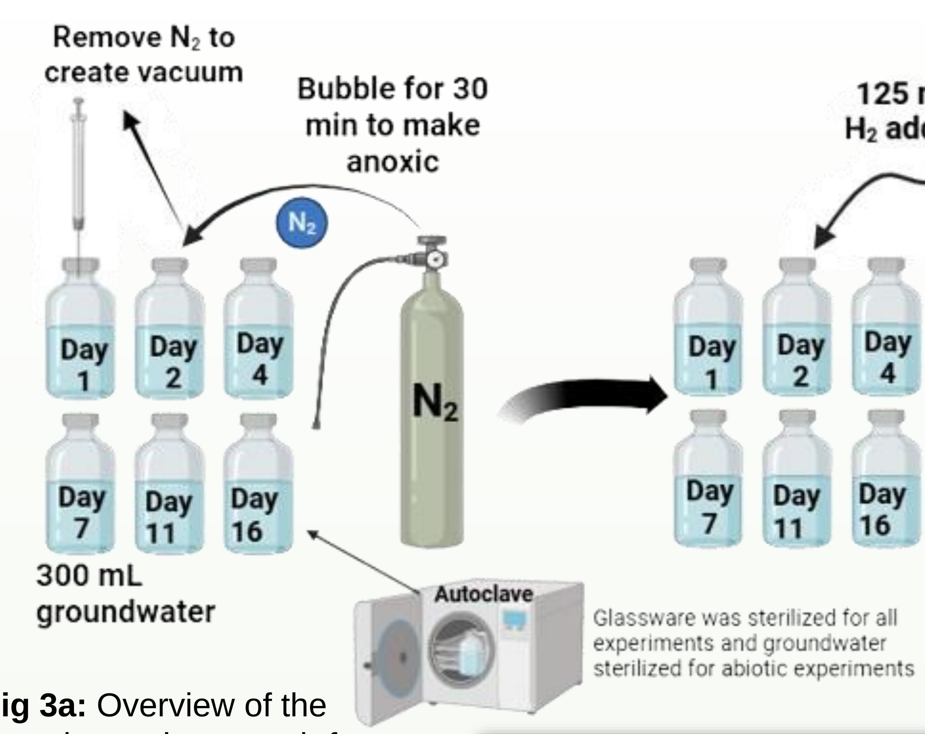
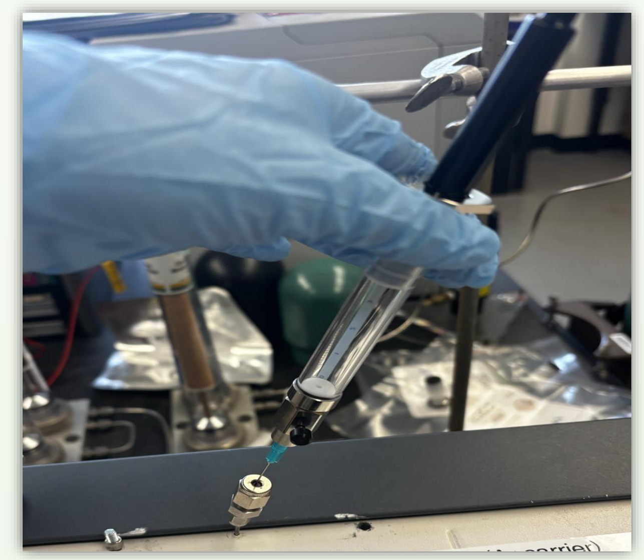
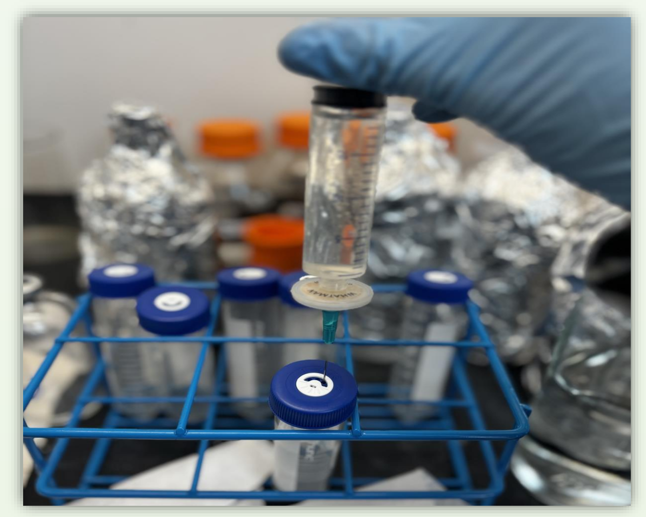


Fig 3a: Overview of the experimental approach for determining the hydrogen consumption rates due to microbes in groundwater under near ambient conditions.





Gas and Fluid Sampling

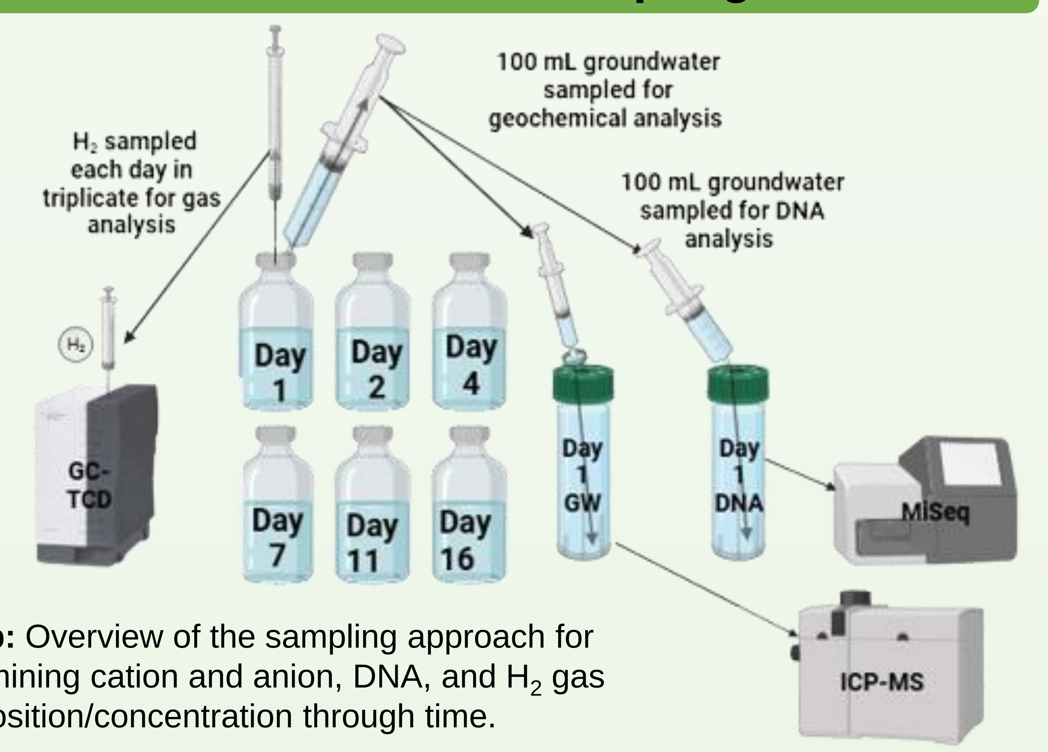


Fig 3b: Overview of the sampling approach for determining cation and anion, DNA, and H_2 gas composition/concentration through time.

PRELIMINARY GEOCHEMICAL RESULTS

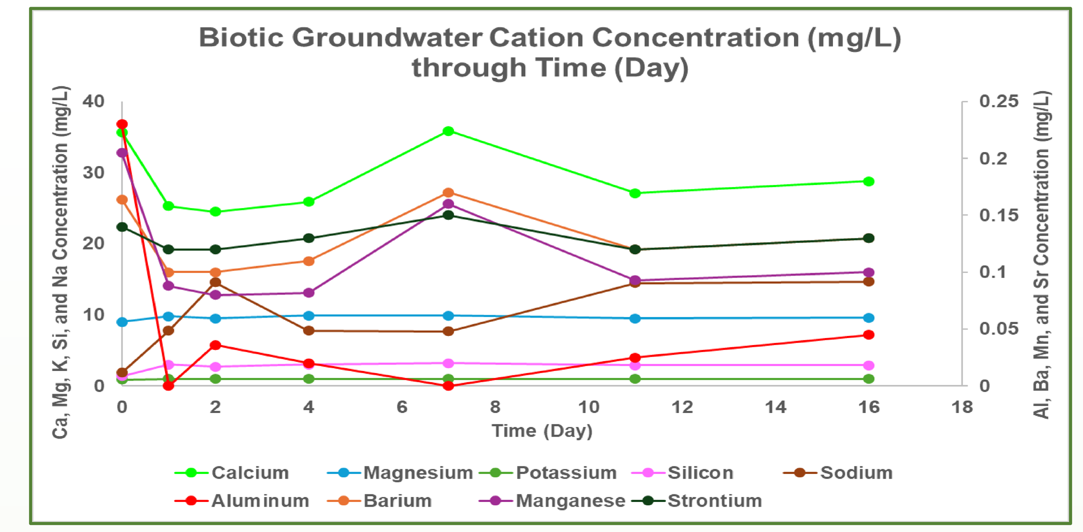


Fig 5a: Comparison of cation concentration (mg/L) of biotic groundwater subjected to UHP grade H_2 (ppm) through time (Day). Day 0 groundwater had no exposure to H_2.

Aluminum has significant decrease in concentration from Day 0 to Day 1. Magnesium, silicon, and potassium remain constant

Barium, calcium, manganese, strontium follow a similar trend with a decrease from Day 0 to Day 1 and a peak at Day 7

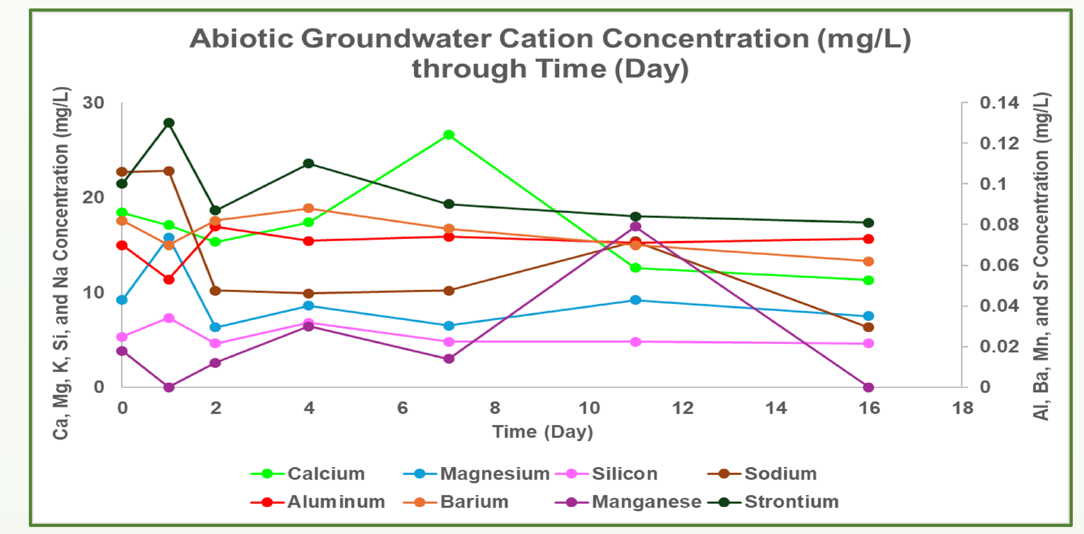


Fig 5b: Comparison of cation concentration (mg/L) of abiotic groundwater subjected to UHP grade H_2 (ppm) through time (Day). Day 0 groundwater had no exposure to H_2.

Calcium, magnesium, barium, and silicon show similar trend to biotic groundwater cation concentrations

Compared to biotic aluminum does not decrease from Day 0 to Day 1. Unlike biotic sodium decreases from Day 1 to Day 2 in abiotic

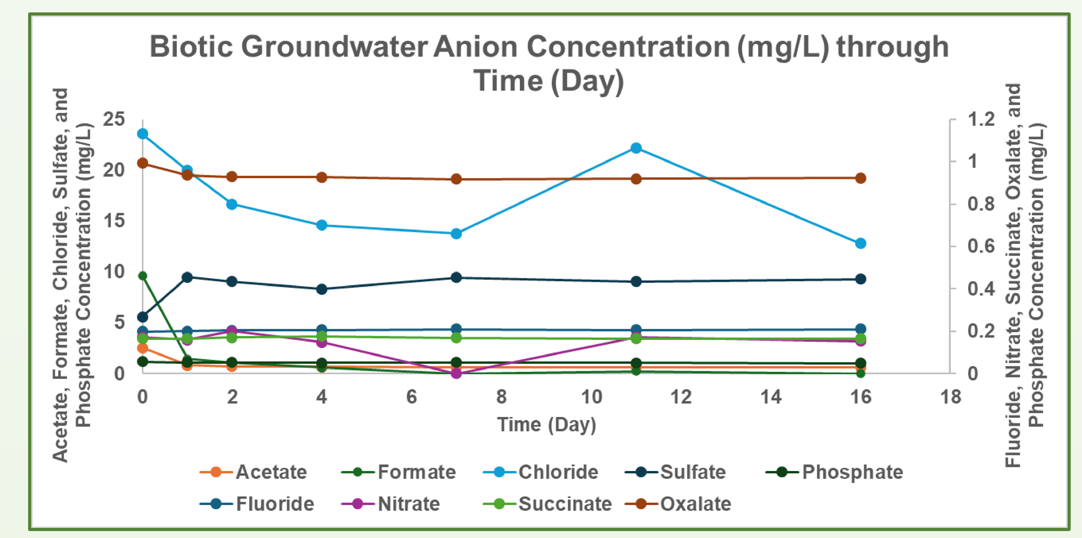


Fig 5c: Comparison of anion concentration (mg/L) of biotic groundwater subjected to UHP grade H_2 (ppm) through time (Day). Day 0 groundwater had no exposure to H_2.

Oxalate, phosphate, sulfate, succinate, fluoride, nitrate, and acetate remain constant. Chloride decreases through time and peak at Day 11

Need to complete abiotic anion analysis to make comparisons. Geochem analysis for DI water also needs to be completed

GAS RESULTS

Linear decrease in H_2 concentration through time suggesting biotic consumption

Both abiotic groundwater and DI water H_2 concentration remains relatively constant through time

DNA analysis needs to be conducted for biotic, abiotic, and DI water to make conclusions

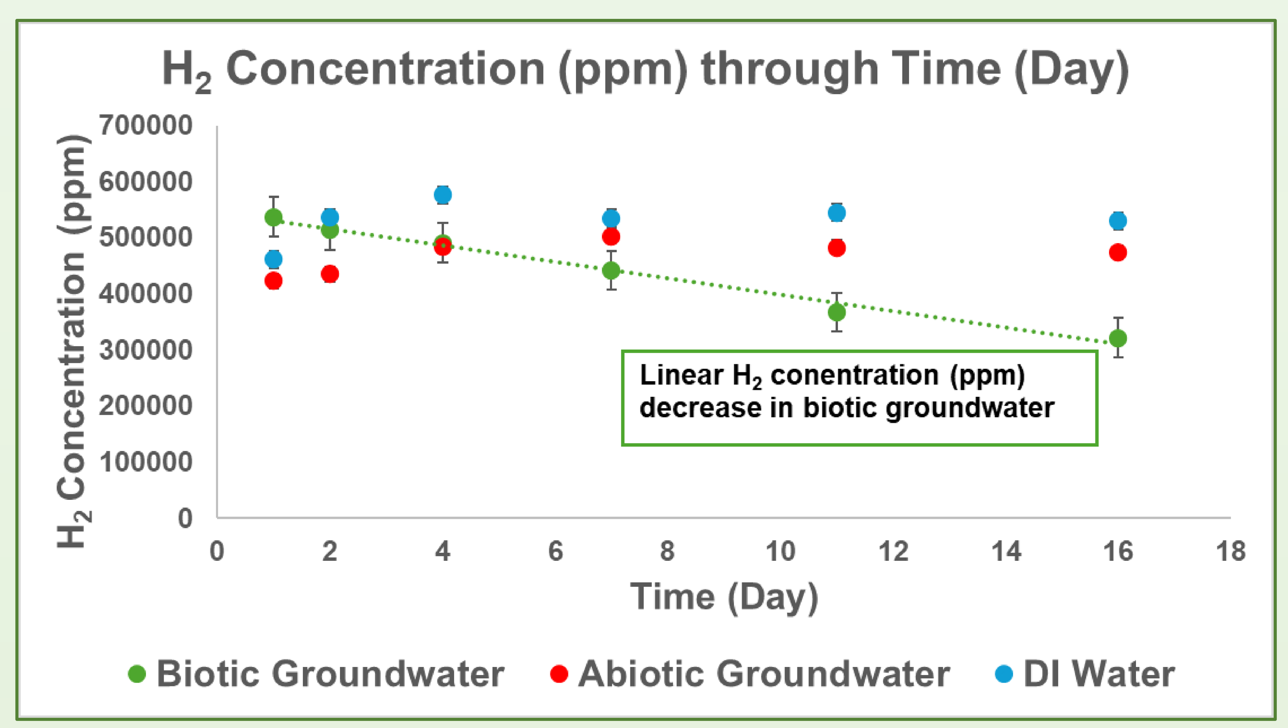


Fig 4: H_2 gas concentration (ppm) through time (day) for biotic and abiotic batch reactions containing groundwater and UHP H_2 gas headspace. DI water batch reaction conducted as blank. H_2 concentration adjusted to 4 mL of sample injected into GC-TCD.

FUTURE WORK

Collect the rest of the geochemical data for the biotic, abiotic, and DI water blank experiments

Complete DNA analysis for biotic and DI water samples

Repeat groundwater experiments with added clay minerals to explore clay mineral-H_2 microbe interactions

Acknowledgements

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