Quantifying Microbial Roles in Environmental Iron Oxidation Via an Integrated Kinetics, 'Omics and Metabolic Modeling Study

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Project Abstract:

Iron oxyhydroxides are extremely reactive environmental components and thus strongly influence biogeochemical cycles. Microorganisms catalyze iron oxidation to form iron minerals, but it is unknown how much environmental iron oxidation is biologically-mediated. We aim to quantify microbial iron oxidation rates and gain insight into the controls, toward an ultimate goal of integrating biotic iron oxidation into reactive transport models. Our work focuses on the Savannah River Site (SRS) in South Carolina. At Tims Branch, part of the Argonne National Laboratory Wetland Hydrobiogeochemistry SFA, where groundwater discharges into the stream, extensive iron-oxidizing microbial mats form and appear to be a major sink of uranium. Pond B, part of the Lawrence Livermore National Laboratory BioGeoChemistry of Actinides SFA, is an actinide-impacted seasonally-stratified pond with iron oxidation at the chemocline, which may be due to Fe-oxidizers.

Our approach combines field work, kinetics experiments, and metagenomics/metatranscriptomics coupled to metabolic modeling. Our objectives are to:

1. **Quantify biotic iron oxidation rates** in the field and in iron microbial mat incubations. We will compare these rates to abiotic rates to determine the relative contributions of microbes.
2. **Identify and quantify dominant iron-oxidizing microorganisms** and flanking community members at both SRS sites using genome-resolved metagenomics and metatranscriptomics and integrate the results to identify trophic status and carbon utilization of dominant iron oxidizers.
3. **Construct metabolic models of a well-studied iron-oxidizer and the most abundant and active iron-oxidizers and flanking organisms** to establish linkages between microbial Fe oxidation and C cycling.

The collaborations between UD, Argonne and LLNL SFAs, and the University of Minnesota-led project allow us to take advantage of field operations and hydrogeochemical observations from the locations that we plan to sample. Initial fieldwork (May 2021) included site scouting and sample collection for Objectives 1 and 2. A major project outcome will be iron oxidation rates and better protocols for obtaining reliable, replicable biotic iron oxidation rates for use in modeling, and an understanding of controls on iron oxidation. Our initial kinetics experiments on SRS mats have yielded promising results.

We will be generating a new library of Fe-oxidizer genomes from both SRS sites, and with transcriptomic results, we will characterize the trophic status of major Fe-oxidizers and ecological linkages that connect Fe and C cycling. This work sets the stage for our longer-term goal to link iron-oxidizer metabolic models and kinetics to biogeochemical/hydrological models to predict Fe, C, nutrient and contaminant metal cycling effects.