

Microbial energetics, carbon, and the progression of redox reactions in flooded soils

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Frequently flooded soils (*e.g.* floodplains, rice paddies) are important repositories for carbon, nutrients, and metals, and they are major contributors to global greenhouse gas emissions. Hydric soils exhibit heterogeneously distributed, poorly crystalline iron oxides/sulfides (redoxomorphic features), plant residues, and highly diverse microbial communities equipped with a wide-range of metabolic pathways. Accordingly, a complex web of reaction trajectories likely follow a re-flooding event, posing a major challenge for modeling the biogeochemical network and resulting element fates. The rates, directions, and reaction sequence dictate carbon, nutrients, and contaminant export to groundwater, surface water, and the atmosphere.

Here we follow energy and element fluxes during the transition from oxygenated to anoxic conditions in flooded soils within microcosms. Distinct transitions in microbial metabolic strategies are identified by determining heat dissipation using isothermal microcalorimetry. Monitoring the heat output of microbial metabolism in natural soil allows for targeted sampling of gas, solution, and soluble phases. In combination, we are able to determine redox reaction kinetics and to identify and quantify (bio)geochemical conditions (thermodynamics) that trigger the onset of specific reaction pathways. Further, we can target microbial analyses (*e.g.*, genomics and transcriptomics) combined with metabolites at each stage of the transitions, enabling metabolic profiling. Numerical information about the kinetics and thermodynamics for redox reactions in soils is essential for developing the process representations in computational models. Equally important is the identification of key reactions and how they are coupled, so that simplified reaction networks can be developed without losing predictive capability. Our work provides such critically needed data to support efforts in reactive transport modeling.