Characterization of Iron Oxide Biofilms from Arctic Tundra Air-Water Interfaces

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Large amounts of organic matter has accumulated in the Arctic permafrost due to freezing temperatures and saturating water that creates suboxic conditions and limits aerobic respiration. Alternative electron acceptors are thus required for microbes to degrade organic carbon in these soils. Iron or iron oxides have been recognized to play an important role in carbon cycle processes in Arctic soils, although the exact form and role as an electron acceptor or donor remain poorly understood, particularly in tundra surface waters where iron reduction and oxidation can occur concurrently.

Here we have characterized Arctic biofilms collected during the summers of 2016 and 2017 from the air-water interface of tundra surface waters on the Seward Peninsula of western Alaska using a suite of microscopic and spectroscopic methods. We hypothesize that: (i) these biofilms consist of iron-oxide nanoparticles formed by oxidation of microbially reduced Fe(II) at the natural redox transition zone at the water surface, and (ii) they could contribute to organic matter degradation in these anoxic environments by acting as electron donors or acceptors. The major components of the films were found to be aggregates of iron oxide nanoparticles closely associated with extracellular polymeric substances. The observed mineral phases varied between films collected in different years with magnetite nanoparticles present in the 2016 films, while only ferrihydrite-like amorphous iron oxyhydroxides were observed for films collected in 2017. Although the exact formation mechanism of these Artic iron oxide films remains to be explored, the presence of magnetite and other iron oxide/oxyhydroxide nanoparticles at the air–water interface may represent a previously uncharacterized source of electron acceptors for continual anaerobic microbial respiration of organic carbon within poorly drained Arctic tundra.