Microbial metabolic activities shaping pelagic iron-rich aggregates (iron snow)

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Pelagic iron-rich macroscopic aggregates (iron snow) are formed by iron oxidizers at opposing gradients of oxygen and Fe(II) in the redoxcline of acidic lignite mine lakes. Precipitation of the iron snow links the redoxcline with the sediment, where the reduction of Fe(III) is the terminal electron-accepting process. To elucidate the chemical structure of iron snow and the diverse metabolic activities involved in aggregate formation we applied a combination of metatranscriptomics and microscopic analyses of iron snow collected at different time points below the redoxcline.

The iron oxidizers *Ferrovum* and *Acidithrix*, and the reducers *Acidiphilium, Acidobacterium* and *Acidisphaera* exhibited high transcriptional activities. Metatranscriptomic analysis showed that microorganisms adapted to the acidic environmental condition by regulating the expression of genes involved in low-pH adaptation, oxidation and reduction of iron, carbon assimilation and biofilm formation. To identify potential glycoconjugates of extracellular polymeric substances (EPS), we stained iron snow with 75 different fluorescently labeled lectins and used confocal laser scanning microscopy (CLSM). Globular capsule- and cloud-like EPS patterns were observed in the iron snow and EPS glycoconjugates were dominated by sialic acid, amino sugars, fucose, mannose and galactose. Scanning transmission X-ray microscopy (STXM) analyses at the Fe $L_{2,3}$-edges revealed strong redox heterogeneities of Fe redox state at the sub-micrometer scale. X-ray absorption near edge structure spectra revealed spots exhibiting up to 60% Fe(II) in iron snow particles from the anoxic 6 m deep water layer. This local increase of the Fe(II)/Fe_{Total} ratio in iron snow aggregates suggests active microbial Fe(III) reduction in the anoxic water column. Our results provide insights into the highly active and specific metabolic processes that characterize the formation and activities of pelagic aggregates in acidic lakes.