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Groundwater - lake water exchange affects biogeochemistry: Results from a multivariate analysis of sediment properties in an acid mine lake

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Lake sediments are a biogeochemically highly active interface. This zone is often characterized by strong chemical gradients especially if the adjacent water bodies are chemically very different such as in acidic mine lake (AML) systems. AMLs are characterized by high loads of iron and sulfur and a low pH. Diffusive and advective mixing of such waters with groundwater at the sediment-water-interface influences the distribution of sulfate and iron, and the pore-water pH and thus redox processes within such sediments. To study interactions between groundwater flow and biogeochemistry, we measured flow rates along with pore-water and sediment composition at 19 sites at an anthropogenic AML near Lauchhammer, Germany, and analyzed our findings by multivariate statistical analysis.

The hydrological flow pattern at the AML was heterogenous with mainly groundwater inflow in the northern part of the lake and lake water outflow in the south (-3 to +7 L m^{-2} d^{-1}), except for some hotspot locations. Pore-water composition was influenced by groundwater-lake water exchange and resulted in higher concentrations of iron(II) and sulfate ($>$ 10 mmol L^{-1}) at the groundwater inflow sites. Furthermore, the pore-water pH, which is an essential driver for biogeochemical processes, reflected the inflow-outflow pattern with a higher pH at the outflow sites (above 3.5 to 4). To analyze the influence of groundwater flow on the sediment characteristica (e.g. iron and sulfur reduction rates, mineral composition) and to group sediment samples with similar characteristics, we conducted a multivariate cluster analysis. Five clusters were found which could be partly related to the observed hydrological pattern but also reflected the general sediment heterogeneity at the anthropogenic lake. For example, clusters which combine samples with high pH, high reductive turnover, and high contents of reduced sulfur species are found in the northern part of the lake where mainly groundwater inflow occurred. Our results indicate that biogeochemical processes in the AML sediments are driven by groundwater flow.