Geophysical characterization of iron oxide precipitation in anoxic groundwater discharge zones

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Project Abstract:

The precipitation of iron(III) oxides and/or hydroxides (Fe oxides) often occurs in streams and wetlands when low oxygen groundwater containing Fe(II) ions discharges into shallow oxygenated sediments and surface water. Efficient characterization of Fe oxide spatial distributions would permit identification of low oxygen groundwater discharge zones associated with contamination and enhanced biogeochemical reactions. Additionally, it would generate a better understanding of contaminant transport through river corridors as high surface area Fe oxides function as a sorption sink for dissolved contaminants (e.g., As, U). We aim to assess the spectral induced polarization (SIP) electrical geophysical technique for in situ and efficient characterization of Fe oxide precipitation in streambed sediments. We used laboratory experiments to show that the imaginary conductivity has a strong linear relationship (R^2=0.87) with sediment specific surface area, which in this case, is controlled by the concentration of fine-grained Fe oxides (up to 24.1 mg g^{-1}). We developed a specialized field measurement probe applied underwater to sense in situ the shallow streambed at up to 10 cm depth. We used a 1D analytical model to demonstrate the low sensitivity of the imaginary conductivity measurement to the electrically conductive stream water layer, a factor often complicating more typical electrical resistivity and electromagnetic measurements. We applied streambed SIP measurements along a coastal stream (Mashpee River, MA) and an alluvial river (East River, CO), where Fe oxide precipitates are formed by anoxic groundwater discharges resulting from a prior landfill leachate and beaver activities, respectively. We observed distinctly higher imaginary conductivity responses in the Fe oxide precipitation zones (up to 3 μS cm^{-1}) than the controlling background areas (generally less than 0.1 μS cm^{-1}). This study provides a new methodology for geolocating anoxic groundwater discharge zones and mapping spatial variations of sediment physicochemical properties.