

Spectral induced polarization as a tool to map subsurface biogeochemical hot spots: a first laboratory evaluation in the Fe-S system

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Zones of intense biogeochemical reactivity (hot spots) arise in the saturated subsurface at the interface between regions with oxidizing and reducing conditions. Hot spots are both sinks and sources of different chemical compounds, thus they are of particular importance for element cycling in the subsurface. However, the investigation of hot spot structures is difficult, because they are not directly identifiable from the surface and can only be investigated by invasive methods in the subsurface. Additionally, they often form in sensitive wetland ecosystems where only non-destructive measurements are applicable to avoid significant degradation of these sensitive environments. Under these circumstances, geophysical methods may provide useful tools to identify biogeochemically active regions. One of the most important biogeochemical reactions in wetlands is the reduction of sulphate and formation and accumulation of Fe_xS_y minerals (where x and y delineate mineral stoichiometry). These reactions only occur in specific hot spots where specific chemical and microbial conditions are met.

Within a research project concerning biogeochemical transformations and turnover in wetlands, we investigate the applicability of the geoelectrical method of spectral induced polarization (SIP) to locate and monitor regions containing polarizing Fe_xS_y particles as indicator for biogeochemical hot spots. After developing and testing a sample holder and a set of non-polarizing electrodes for laboratory SIP measurements, we performed experiments on natural soil samples taken from the hyporheic zone of a local river channel. The collected material originates from a location known for biogeochemical activity. The sample contains a high percentage of dark grayish/black sediment interpreted as Fe_xS_y , and possibly pyrite (FeS_2). The material was homogenized and split into four samples. The Fe_xS_y concentration was adjusted to three different levels by oxidation using H_2O_2 . For all samples we recorded the SIP spectra in the frequency range between 0.26 Hz and 25 Hz repeatedly.

The sensitivity of SIP measurements to the Fe_xS_y content is promising. For a sample of the sediment saturated with its natural fluid (conductivity $> 600 \mu\text{S}/\text{cm}$), we observed phase shifts of more than 7 mrad at frequencies between 1 and 10 Hz. We expect a lower fluid conductivity and thus a larger maximum phase shift for measurements in wetlands. The application of the SIP method in field surveys at places with biogeochemical activity will be the next step in our study.