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Non-invasive geo-electrical monitoring of nitrogen transformation processes across a dynamic capillary fringe

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The capillary fringe (CF) is characterized by steep redox gradient, that is thought to be a hot spot for biogeochemical processes. Understanding chemical fate and transport in the CF is significant, however, biogeochemical dynamics here are poorly understood due to the transient nature of chemical and hydrologic conditions, and the difficulty to measure at great depth. The inspiration of this research is from the operation of the soil aquifer treatment (SAT) system of the Shafdan plant, Israel, where the hydrological regime is intense. Outside the Shafdan SAT system, the water table is at 30 to 40 m depth. Hydrogeophysics is a developing field which use minimally intrusive and quick response methods to monitor hydrological properties. Of special interests are the spectral induced polarization (SIP) and self-potential (SP) methods, as they are more sensitive to the interface between the solid and aqueous phases. The challenge lies on linking the geo-electrical response with biogeochemical processes.

We conducted continuous soil column experiment (size: 19.3 $\times$ 9.9 $\times$ 90 cm^3) with the Shafdan soil to study nitrogen cycle under hydrologic dynamics (groundwater fluctuation versus local infiltration) across the CF. We consider static experiment (static groundwater table), periodic pulse experiment (constant groundwater table with intermittent infiltration), and several dynamic experiments (fluctuating groundwater table subjected to drying-rewetting cycles). Preliminary results of SIP signals showed a good response to nitrogen species (NO_3^- and NH_4^+), dissolved organic carbon, CO_2 emission, and major dissolved ions (Na, K, Ba, Ca, S, Mg, Fe, Mn, P), water content, matrix potential and Eh. They are likely induced by (1) biogeochemical processes of the water chemistry under different redox states (that are primarily related to water saturation); and (2) adsorption and desorption of cations to the soil surface and cation exchange between the soil surface and aqueous phase. SP signals are shown to be effective to locate the hot zone of biogeochemical processes.

The outcome of this research will not only increase the potential use of SIP and SP methods across the CF, but also afford suggestions for efficient operation of the Shafdan SAT system.