



## The electrical signature of free-phase NAPL

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The SIP signature of an unsaturated soil contaminated with a free- phase non-aqueous phase liquid (NAPL), decane, was experimentally investigated. Using an accurate SIP measurement system, the soil's complex electrical conductivity was measured for four treatments: clean soil, and three levels of decane contamination. The water content for all treatments was kept constant between treatments, while for the contaminated treatments decane was added and mixed to the soil, thus replacing air and creating a four-phase system. This procedure was used to isolate the effect of the free phase NAPL from other related processes such as cation exchange. Complementary chemical analysis was conducted, alongside temporal measurements of the electrical response of the different treatments. The results show a clear decrease in the imaginary part of the complex conductivity for the decane contaminated soil. Moreover, a shift of the relaxation frequency was observed for the contaminated soil. Furthermore, the amount of added decane virtually did not change the effect on the soil's polarization. By exclusion of other possible mechanisms, we attribute these results to membrane polarization. Since no change in the solutions major ion composition was observed, we concluded that no ion exchange processes took place and there was no change in the Stern layer ion composition. Clearly, there was no change in the grain size distribution as the same soil was used for both treatments. Hence, the Stern layer model that depends primarily on the chemical composition of the Stern layer and on grain size distribution could not explain our results. We suggest that the addition of decane to the unsaturated porous media changes the distribution of liquid phase in the pore scale, thus affecting membrane polarization through its pore-scale geometrical component (while its chemical component is not being affected). Moreover, once the addition of the free-phase fluid alters the geometrical distribution of the water in the pore throats, a supplementary amount does not affect this distribution. This is also supported qualitatively by solution of the pore-scale liquid distribution for three and four phase systems. A clearer understanding of the SIP signature for soils contaminated with free-phase organic compounds can be achieved with this study's findings.