The effect of free-phase NAPL on the spectral induced polarization signature of variably saturated soil

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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 two treatments: clean soil and decane contaminated soil. The water content of the two treatments was nearly the same, while for the contaminated treatment 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 processes. Complementary chemical analyses were conducted, alongside temporal measurements of the electrical response of the different treatments.

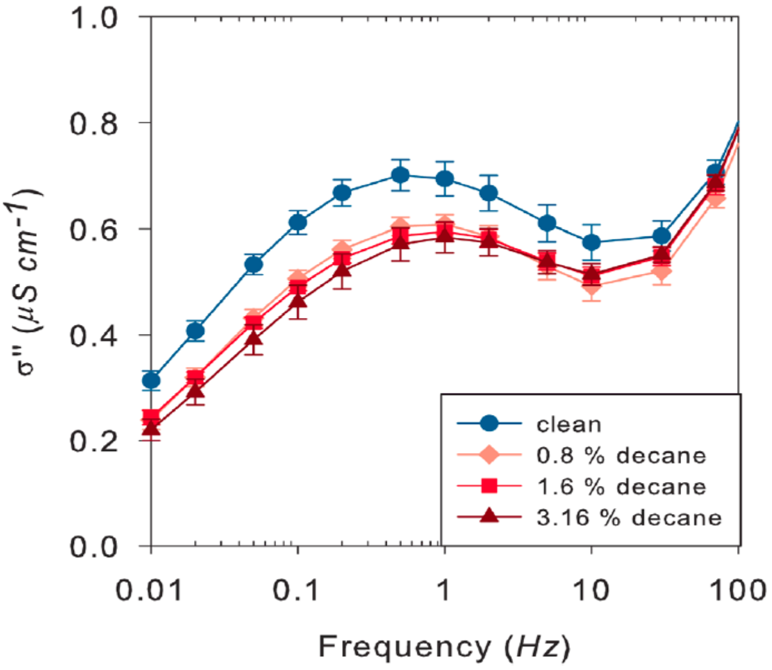

Fig. 1: The imaginary part of the complex conductivity for clean and decane contaminated are treatments. The error bars are the standard deviation values of replicates at each treatment.

The results show a clear decrease in the imaginary part of the complex conductivity for the decane contaminated soil. Moreover, a shift (reduction) of the relaxation frequency was observed for the contaminated soil (see Fig. 1). Furthermore, the amount of added decane virtually did not change the effect on the soil's polarization. These results are attributed to the membrane polarization mechanism, and specifically to its geometrical aspects. Chemical evidences support this argument and assure that the alternative mechanism of Stern layer polarization cannot explain our observations. 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). Figure 2 depicts a solution of the

Young-Laplace equation for the interfaces created in our four-phase system, and shows a clear geometrical influence as a result of the decane addition. 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 significantly alter this distribution. Furthermore, we associate the time required for this liquid phase arrangement with the temporal changes of the soil's electrical signature. A clearer understanding of the SIP signature for soils contaminated with free-phase organic compounds can be achieved with this study's findings.

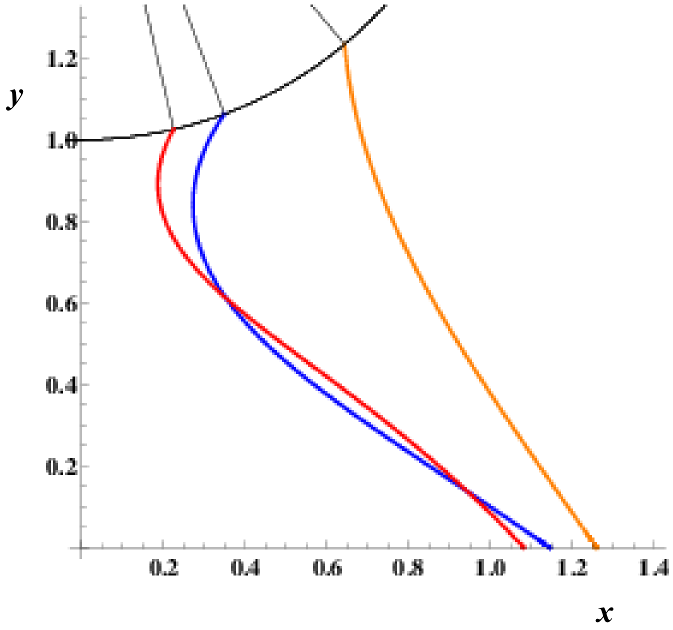

Fig. 2: Solution of the Young-Laplace equation for the described multiphase system.
Blue: the clean soil- water air interface; red: the water decane interface; orange: the decane-air interface.