Using SIP as a tool for identifying inorganic cations in a variably saturated soil

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In this work the potential of SIP as a tool for identifying and distinguishing between different inorganic cations in the soil's adsorbed phase is experimentally tested. A red sandy loam ('Hamra') had undergone five types of treatments with particular brine solutions: sodium, calcium, magnesium, potassium and ammonium chlorides. In order to achieve near homo-ionic conditions for each treatment, the soils were prewashed with the proper concentrated brine. The soil in each treatment was washed in the ratio of 1:2 soil to solution weight, seven times with descending concentrations until reaching salinity in the same order of magnitude as tap water (~ 1 mS cm^{-1}). Samples of the washing solutions were chemically tested to make sure the dominant cation is the one we are interested in. Following drying of the soils, 10 % (by weight) distilled water were added, mixed, and packed in sealed glass boxes (five replicates each). The electrical SIP measurements were taken five days after packing and complementary chemical measurements were conducted to measure the adsorbed and the solution's cations composition.

Preliminary results of the electrical SIP measurements are presented in Fig. 1, for the real and the imaginary part of the complex conductivity.

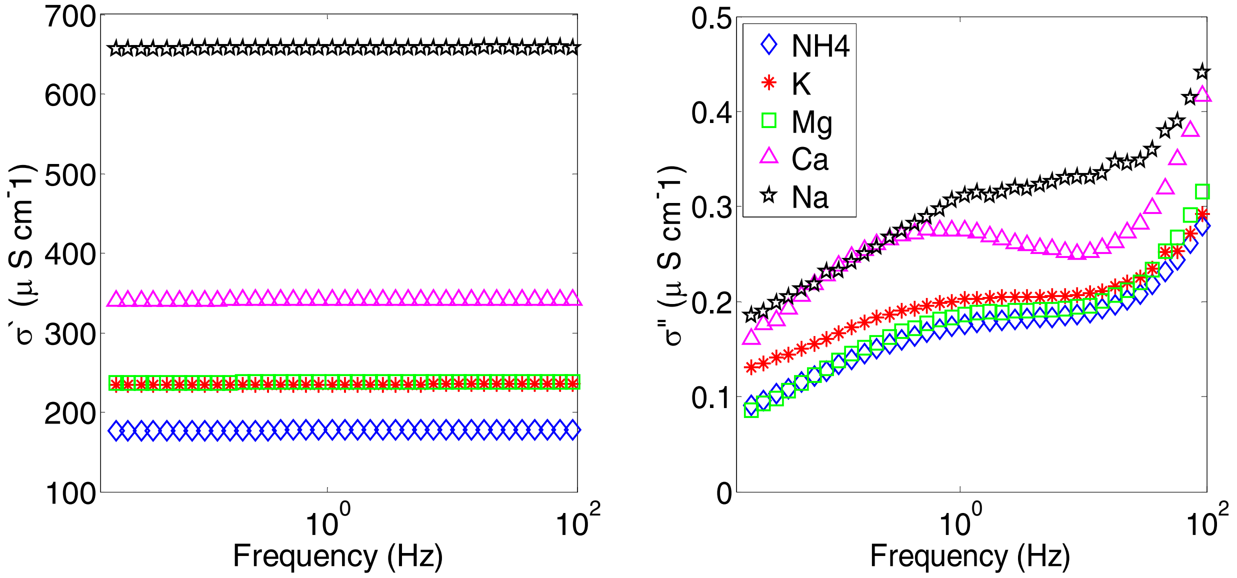

Fig. 1: mean values of the real part complex conductivity (left) and mean values of the imaginary conductivity (right) for the different treatments as a function of frequency. Error bars of the standard deviation are the same order of magnitude as the curves markers, therefore not presented.

A clear distinction can be made between the sodium treatment, the calcium treatment and the other three cations (K, Mg, and Na) by looking at the imaginary conductivity values. The magnesium's lower polarization effect compared to the calcium effect is somewhat surprising due to its lower adsorption selectivity to the solid surface (weaker binding) that allows greater mobility at the EDL. Moreover, its SIP signature greatly resembles the potassium's behaviour. The sodium's signature, though a bit noisy, has a very broad σ'' signature, while the calcium treated soil has clearer relaxation time. Although K and NH_4 are monovalent ions, they create strong bindings with the mineral surface which decreases their mobility and by that, apparently, their polarization decreases. As can be seen from the real part, Fig. 1 (left), the sodium's conductivity is prominently higher from the other treatments. This is a result of the difficulty to dry the sodium treated soil without losing the material. Nonetheless, the sodium's high salinity did not diminish its polarization effect as seen from Fig. 1 (right).

The electrical measurements results were fitted to a double Cole-Cole model (with the method presented by Chen et al. (2008). The relaxation time parameter τ_1 (s) is depicted in Table 1. As prominent from this table, the calcium treatment relaxation time is longest, corresponding to its stronger surface interactions, while the sodium on the other hand, has the shortest time constant. Potassium, ammonium and magnesium have similar time constants. These time constants match the apparent peak frequencies obtained from Fig. 1 (left), with Na as an exception. Combining these constants with the σ'' signatures of the different treatments enables the characterization of each cation's effect.

	Ca	K	NH_4	Mg	Na
τ_1 (s)	0.369	0.212	0.193	0.1923	0.046

←

Table 1: relaxation time constants of the different treated soils.

This work emphasises the practical potential of SIP to identify dominant species, with environmental and agricultural importance, in the vadose zone.

Reference

Chen, J., Kemna, A. and Hubbard, S., 2008. A comparison between Gauss-Newton and Markov-chain Monte Carlo–based methods for inverting spectral induced-polarization data for Cole-Cole parameters. *Geophysics*, 73, F247-F259.