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Hydrology and
Earth System
Sciences
Discussions

Interactive comment on "Impact of controlled changes in grain size and pore space characteristics on the hydraulic conductivity and spectral induced polarization response of "proxies" of saturated alluvial sediments" *by* K. Koch et al.

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We found the comments of the referees very insightful, constructive, and useful and hence we shall make a concerted effort to accommodate them in their entirety in the course of the revised version of this manuscript. In the following, we outline in detail our proposed reactions to these reviews.

Replies to comments by Maosong Tong:

1. General comments: The manuscript by Koch et al. shows some results about the influence of the grain size and pore space on the relationship between the SIP response and hydraulic conductivity of the artificial samples. These results are useful for comprehensively understanding of SIP characteristics of the soil. But I thought that this paper needs to be revised.

2. Specific comments: The following comments need to be considered:

(1) In the "Experimental procedure and data analysis" section: (i) The experimental setup needs to be shown. (ii) What kind of impedance spectrometer was used?

To address this point, we propose to add the following new figure (please see new uploaded figure) to the revised manuscript illustrating the experimental setup and impedance spectrometer used in the study. In addition to the text of the corresponding, largely self-contained figure caption, we shall evidently make sure to appropriately accommodate this modification in the body of the text.

"Figure 2 (new): Schematic illustration of the high-sensitivity impedance spectrometer used for the SIP measurements presented in this study. The sample holder corresponds to a plexiglas cylinder with an inner diameter of 6 cm and a length of 30 cm. The current electrodes, C1 and C2, are made of circular porous bronze plates with a diameter of 6 cm and are located at the top and bottom of the sample holder. The potential electrodes P1 and P2 correspond to rings made of silver wire located at a distance of 10 cm from the top and bottom of the measurement cylinder. These silver wires are embedded in grooves to keep them outside the actual sample and the electrical field associated with the current electrodes and thus to minimize electrical polarization effects. Adapted from Zimmerman et al. (2008)."

(iii) The silver wire was used in this paper. It has the electrode polarization, especially at very low frequencies. So the Non-polarizing electrodes need to be used to minimize effects of electrode polarization that can occur at the fluid/electrode interface, other than the used silver wire. (iv) How can the well contacting of the source and measuring electrodes with the samples be achieved?

See caption for newly added figure above. In addition to this, we also propose to make the following changes to the text body of the revised manuscript: Original text: “The potential electrodes are rings of silver wire fixed into grooves at 1/3 and 2/3 of the sample holder’s length thus resulting in a constant, Wenner-type spacing of 10 cm between the individual electrodes.” Modified text: “The potential electrodes correspond to rings made of silver wire placed into grooves along the inner wall of the 30-cm-long measurement cylinder (Figure 2). These groves are located at a distance of 10 cm from either end of cylinder. This results in an equi-distant spacing of 10 cm between individual electrodes and a geometric factor given as k=r2*Pi/l [in the revised manuscript Pi will be written in Greek letters] with r and l denoting the radius of the measurement cylinder and the distance between the potential electrodes, respectively.” We also intend to add the following clarification to the text of the manuscript of the revised manuscript: “Fixing the potential electrodes into grooves aims at avoiding polarization effects by keeping the silver wire outside of the electrical field associated with the current electrodes. The corresponding electrical connection to the electrodes is naturally provided through the conducting pore fluid, which fully saturates the sample filling the cylinder (Zimmermann et al., 2008).”

(v) How was the specific surface area of the samples calculated from the particle size distribution of the used samples? This parameter may be measured by the corresponding equipment.

To address this question, we propose to add the following text to the revised manuscript: “Specific surface measurements based on laser diffraction methods aim at estimating the grain diameters through the assumption of a specific geometrical form factor of the grain, which in our case is spherical. The signal of the diffracted light from a measured grain is thus fitted to that of an equivalent sphere. Hence, specific surface area measurements of this type provide us with the so-called geometric surface area of a grain, which is equal to the surface of the equivalent sphere. The corresponding specific surface area, given by the surface of this equivalent sphere divided by its volume, does therefore neither account for the small-scale grain surface roughness nor to the porosity. For a granulometrically heterogeneous sample, this parameter thus represents a combined measure of sorting and grain size of the overall distribution."

(vi) How was the porosity of the samples measured?

To address this question, propose to add the following text to the revised manuscript: "The porosity (Phi) [again, in the revised manuscript the Greek letter will be used here] was determined by weighting the saturated samples and thus determining its density (Rho) given as [Rho]total=(1-Phi)* [Rho]SiO2 + Phi* [Rho]H2O, where (Rho)total is the inferred density of weighted sample and [Rho]SiO2 and [Rho]H2O are the a priori known densities of quartz and water, respectively.

(2)The author needs to clarify the inversion procedure. For instant, a typical SIP data can be constructed to estimate the Cole-Cole parameters. And the resulted parameters can be compared with the ones used in the SIP data constructing.

To address this question, propose to add the following text to the revised manuscript: "To deal with the strong non-linearity and non-uniqueness of the inverse problem of estimating Cole-Cole model parameters that fit the measured frequency-domain SIP data, we use a Markov chain Monte Carlo (McMC) inversion approach in this study. With standard Monte Carlo parameter estimation methods, random sets of parameter values are generated and then either accepted or rejected based on how well they allow us to fit the measured data. McMC importance sampling intensifies the formerly completely random sampling in more "probable" areas of the model space, which allows for increased efficiency of the procedure. Sets of feasible model parameters are generated with a frequency according to their probability of occurrence. The inversion procedure is based on the work of Mosegaard and Tarantola (1995). For a detailed description of the application to SIP data, and a comparison to a deterministic approach of fitting the Cole-Cole model, please see Chen et al. (2008).”

(3) The relationship between the SIP parameters and the hydraulic conductivity of soil samples has been investigated for many years. Some references about this are needed to be added.

In the “Introduction” (page 6060 line 23 to page 6061 line 8), we try to address this point. We apologize for having missed the paper by Tong et al. (2006) “A time-domain induced-polarization method for estimating permeability in a shaly sand reservoir”, and we propose to add this reference to revised manuscript. We also propose to add the following more detailed discussion of the work by Binley et al. (2005): “In this context, Binley et al. (2005) pointed out that the Cole-Cole model time constant appears to be better correlated with K than with other measures of the interfacial surface, such as, for example, the surface area per unit pore volume. In their work, values of the time constant are compared to median grain size d50 (rˆ2=0.62; as compared to rˆ2=0.64 in our study (graph not shown)), pore throat diameter (rˆ2=0.61), surface area per unit volume (rˆ2=0.75), and hydraulic conductivity (rˆ2=0.78; compared to rˆ2=0.77 for uncompacted samples and rˆ2=0.94 for compacted samples (Fig. 6, 7)). Although these findings are for consolidated sandstone samples, the results agree well with the quality of our findings. However, results shown in Figures 4 and 5 indicate that changes in the sorting have a direct impact on these relationships. This is further indication of the actual complexity of petrophysical parameter relationships and their impact on processes dominating hydraulic conductivity as well as induced polarization measures.”

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 6057, 2010.

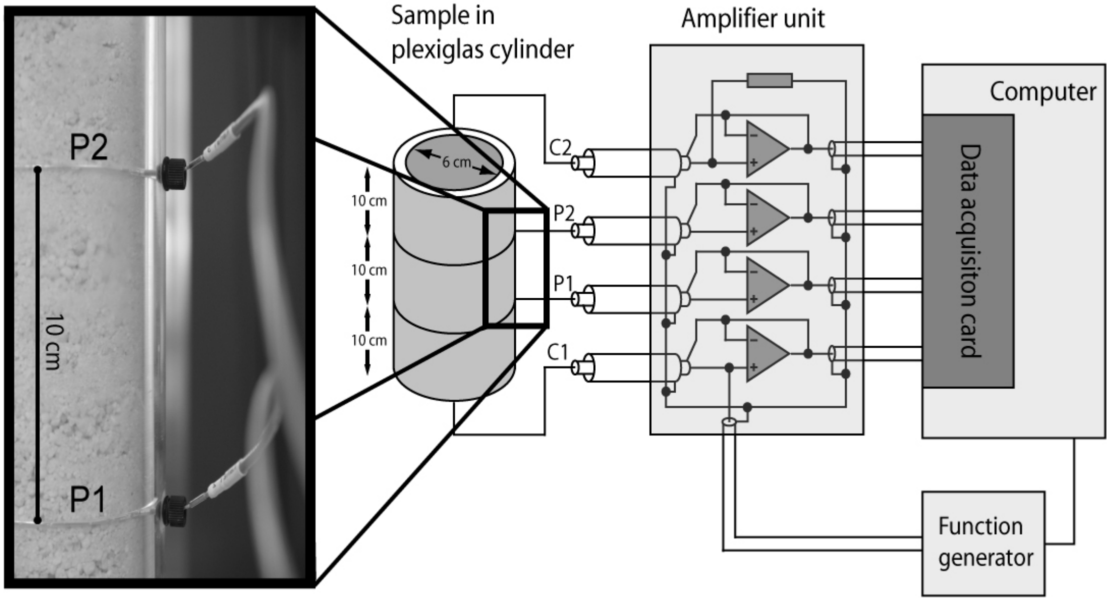

Fig. 1. Experimental setup and schematic illustration of the high-sensitivity impedance spectrometer used for the SIP measurements presented in this study.

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Interactive Discussion

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