Geophysical Research Abstracts
Vol. 21, EGU2019-9812, 2019
EGU General Assembly 2019

Predicting streaming potential under partially saturated conditions, a new analytical model

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Hydrological and environmental studies regarding groundwater flow show an increasing interest in the self-potential (SP) method. This passive geophysical method relies on the measurement of naturally occurring electrical potential differences; one of the contributions to the SP signal is due to an electrokinetic phenomenon directly related to the water flux in porous media. An electrical double layer containing an excess of electrical charges occupies the nearby of the mineral-pore water interface. When the water flows through the pore a fraction of this excess charge, is effectively dragged, generating a streaming current and therefore an electrical field. Recently, a physically-based analytical model was developed to predict the effective excess charge density in saturated porous media. Following this work, we propose an analytical model for partially saturated conditions by upscaling the effective excess charge density dragged in the medium by the water flow. The porous media of the proposed model is represented by a bundle of tortuous capillary tubes following a fractal pore-size distribution law. Under these hypotheses and using a flux averaging approach, the resulting analytical relationship allows the determination of the effective excess charge as a function of the effective water saturation and relative permeability, as well as the ionic concentration and petrophysical properties of the media. The proposed model is consistent with previous models, however, it is much more convenient as it provides a single closed-form expression for the effective excess charge density estimates. The performance of the proposed model has been successfully tested against different sets of laboratory and field data from the literature. We believe that this work constitutes an improvement in the quantification of the streaming potential and a step forward for its use on the vadose zone and reservoir studies.