Transport Properties and Connection to Electrochemistry in Saturated and Partially Saturated Clay-Rich Media

REVIL A

arevil@mines.edu

I developed a model of cross-coupled flow in porous media based on electrokinetic coupling. I start with the local Nernst-Planck and Stokes equations and I use a volume-averaging procedure to obtain the generalized Ohm and Darcy equations with cross-coupling terms at the scale of a representative elementary volume of the porous rock including salt filtration effects. These coupling terms (representing the effects of streaming current and electro-osmotic pore water flow) obey Onsager's reciprocity. Rather than writing the electrokinetic terms in terms of zeta potential (the electrical double layer potential on the slipping plane located in the pore water), I developed our theory in terms of an effective charge density dragged by the flow of the pore water. This effective charge density is found to be strongly controlled by the permeability, both in saturated and unsaturated conditions, and to the saturation itself. I also developed an electrical conductivity equation including the effect of water content on both the bulk and surface conductivities. Finally, the model is compared with various data from the literature including electrical conductivity data, streaming potential coupling coefficient and electroosmotic permeability data at different saturations. I show that we can decompose the material properties (with the exception of electrical conductivity) by taken them as the product of a value at saturation and a relative parameter that depends only on saturation. The excellent agreement between the model predictions and the experimental data indicates the possibility to use this model inside numerical codes to predict various effects of interest to water resources including remotely observing unsaturated flow using a network of non-polarizing electrodes or to use electrical fields or electrical currents to move water or oil in clay-rich formations or to study transport properties for the isolation of nuclear wastes.