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Salt diffusion in charged porous media

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Some porous media such as clay have charged surfaces. The presence of these charged surfaces results in a complex system where water flow, salt transport, and the electric field are coupled. This system is important in many fields, such as geotechnical engineering, storage of radioactive waste in clay barriers, enhanced oil recovery, and irrigation with marginal water. The charged surfaces alter the transport properties of ions. For example, clay minerals are often negatively charged due to isomorphous substitution. Cations are therefore attracted to the mineral surface, while anions are repelled, creating a diffuse double layer around the clay particle. Cations are therefore transported preferably over anions through such charged pores. To conserve electroneutrality, a streaming potential develops to counteract diffusion by electromigration. This results in smaller effective diffusion coefficients compared to uncharged porous media. We developed a pore-network model to quantify the effect of the double layer processes on the effective diffusion coefficient. Pore-network models are a suitable tool to include the heterogeneity of pore sizes and surface charge densities seen in nature. In pore-network modeling, the geometry of the pore space is simplified, but the network properties are based on realistic statistics such as pore size distribution and connectivity. The larger scale behavior can be identified by averaging over a large number of pores. The results were strongly dependent on the salinity, as this controls the thickness of the double layers. At high salt concentrations, the diffuse double layer is thin and the differences between charged and uncharged porous media are negligible. However, at low salinity, the double layers are thick and the effective diffusion coefficient of salt was reduced by 25% in charged porous media compared to uncharged porous media, due to salt transport being slowed down to conserve electroneutrality. Hence, the presence of charged mineral surfaces can significantly alter transport rates under low salinity conditions.