Electrochemical Processes for In-Situ Treatment of Contaminated Soils

Project ID: 54661

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Research Objective

The electro-osmotic (EO) flow rate is one of the major factors controlling influence the process performance. Many soil and solution parameters can affect the EO water transport. A number of theories about the EO flow in a capillary have been developed. However, there is no simple and acceptable correlation between the EO water transport and fundamental soil-water parameters, such as the soil water content, the soil surface charge density, and the electrolyte concentration. Consequently, we have tried to develop a semi-empirical equation, as a means to estimate the electro-osmotic water transport in the unsaturated soil. It is expected that the equation can provide a better foundation for the development of an in-situ remediation process for application to the vadose zone.

Research Progress and Implications

Electro-osmotic flow experiments were conducted under several conditions, namely, the solution pH, the electric field strength, the soil water content, and the electrolyte concentration. Results indicate that the EO flow is proportional to the extent of surface charge density and the intensity of electric field. This can be attributed to the negative charges on the soil surface. When an electric field is imposed to the soil-water system, the electrostatic force is the only driving force for the electro-osmotic flow. According to the Coulomb's law, the electrostatic force is a linear function of the intensity of electric field and the quantity of electric charges. Therefore, the EO flow is closely related to both the extent of surface charge density and the intensity of electric field.

The electrolyte concentration has no significant effect on the EO flow if the electrolyte ions do not interact with the soil (i.e., indifferent ions). The electrolyte concentration can only influence the zeta potential rather than the surface charge when there is no chemical reaction between the electrolyte and the soil. In other words, the electrolyte concentration effect compresses the thickness of the double layer but not change the surface charge density of the soil. Consequently, the electrolyte concentration effect is independent of the EO flow rate because the water flow is related to the surface charge density rather than the zeta potential.

The parabolic relationship between the EO flow and the water content was observed in this study. We used the infinite plate model to derive the correlation between the flow rate and the moisture of the soil. The basic assumption of the infinite model is that the shear stress at any surface element in the water layer is proportional to the rate of change of velocity across the element (i.e., the Newtonian fluid). The EO flow rate is theoretically proportional to the square of the soil water content.

The following equation was developed: $Q = K\sigma_0(dE/dx)\omega^2$. Where Q, K, σ_0, dE/dx, and ω, are electro-osmotic flow rate, characterized coefficient, surface charge density, potential gradient, and soil water content, respectively. The characterized coefficient, K, is a collection of several physical properties of the soil including the total soil mass (M), the specific surface area (Σ), and the pore size (w) of the soil and fluid viscosity (η), that is $K = kwM^2/\eta\Sigma^2$.