Kinetics of Cation and Oxyanion Adsorption and Desorption on Ferrihydrite

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Ferrihydrite is one of the most important mineral adsorbents to control the reactivity and fate of both cation and oxyanion contaminants in soils. Understanding the kinetics of both cation and oxyanion adsorption and desorption on ferrihydrite is crucial for predicting the dynamic behavior of contaminants in soil environments.

In this study, the kinetics of multiple cation and oxyanion adsorption and desorption on ferrihydrite were investigated with a combination of kinetic experiments and mechanistic modeling. The kinetics of As(V), Cr(VI), Cu, Cd, Ni and Pb adsorption and desorption on ferrihydrite under various ion concentrations and reaction pH were systematically studied using a stirred-flow method at a time scale of a few hours. The adsorption equilibrium of those ions on ferrihydrite was studied with a batch method. Based on the experimental results, a unifying kinetics model for both cation and oxyanion adsorption/desorption on ferrihydrite based on the CD-MUSIC model was developed. The key idea of our model is to constrain the adsorption and desorption rate coefficients for each specific binding site and the variations of adsorption or desorption rate coefficients among different binding sites. Thus, the kinetics model had only one fitting parameter related to ferrihydrite sites, and all other parameters were derived based on CD-MUSIC. Overall the model described the kinetic results well for most experimental conditions. We quantitatively demonstrated how the equilibrium binding of cations and oxyanions with various ferrihydrite binding sites affected the adsorption and desorption rates, which varied among cations and oxyanions and depended on the specific reaction conditions. Our results provided a unifying quantitative modeling method for the kinetics of both cation and oxyanion adsorption/desorption on iron minerals.