Morphology of Lead(II) and Chromium(III) Reaction Products on Phyllosilicate Surfaces as Determined by Atomic Force Microscopy

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Abstract: Redox and acid-base reactions play important roles in the fate of metal contaminants in soils and sediments. The presence of significant amounts of Cr, Pb and other toxic heavy metals in contaminated soils and sediments is of great environmental concern. Oxidation states and dissolution characteristics of the heavy metals can exert negative effects on the natural environment. Atomic force microscopy (AFM) was used to follow the changes in morphology and structure of reaction products of Cr and Pb formed on mineral surfaces. Nitrate salts of Cr(III) and Pb(II) were used to replace the native exchangeable cations on muscovite and smectite surfaces and the metal-mineral systems were then reacted at different pH's and redox conditions.

For Pb, aggregate morphological forms were found at pH 6.1 and 12.4. At pH 6.1, the mean roughness value was 0.70 nm, and at pH 12.4 it was 5.30 nm. The fractal dimensions were 2.03 at pH 6.1 and 2.05 at pH 12.4. For Cr(III), both layered and aggregate morphological forms were found at pH 6.8 and 10.8. The mean roughness values were 0.90 nm at pH 6.8 and 4.3 nm at pH 10.8. Fractal dimensions for both were 2.00. The effect of redox conditions on morphological characteristics was studied on a smectite substrate. The reduced clays were more compacted than oxidized ones and the reduced clay could reduce Cr(VI) to Cr(III), forming new minerals on the surfaces.

A geochemical equilibrium model, MINTEQA2, was used to simulate the experimental conditions and predict possible reaction products. Simulation results agreed well with data from experiments, providing evidence that modeling can provide a useful “reality check” for such studies. Together, MINTEQA2 and AFM can provide important information for evaluating the morphologies and chemical reactivities of metal reaction products formed on phyllosilicate surfaces under varying environmental conditions.

Key Words: Atomic Force Microscopy • Clay • FTIR • Geochemical Equilibrium Model • Mica • Remediation • Smectite • X-ray

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