THE ADSORPTION, MINERALIZATION AND REDUCTION OF METAL IONS (CADMIUM AND URANIUM) BY MICROORGANISMS IN THE AQUEOUS SYSTEM

Abstract

by

Xue Rui

Toxic heavy metal contamination from human activities has posed a great threat to the ecosystem, and the searching for the remediation strategy has long been a challenge. The fate of heavy metals in subsurface environments is controlled by interrelated adsorption, precipitation, and redox reactions where living bacteria play a critical role. The use of bacteria in the amendment of metal contamination is becoming an important topic in the environmental science research. The work presented in this dissertation utilizes a synchrotron based technique - X-ray absorption fine structure (XAFS) to collect molecular-level information of the interactions between heavy metal ions and microorganisms.

Soluble uranyl ion can form stable mineral with phosphate ligands. Bacteria can affect the extent and the morphology of the resulting precipitate. At first, we identified the nano-particulate mineral on the cell wall of *Bacillus subtilis* in the uranyl-phosphate-bacteria system with the form of HUP ($UO_2HPO_4{\cdot}4H_2O$). Furthermore, we chose three Gram-negative bacteria species: *Anaeromyxobacter dehalogenans* strain K, *Geobacter sulfurreducens*, and *Shewanella putrefaciens* CN32, to reduce U^{VI} in the form of biotically and abiotically formed HUP mineral. The experiments demonstrated that the HUP mineral could be reduced by

the reducing bacteria, and the reducing bacteria only transferred electrons to the aqueous uranium species rather than directly to the mineral surface. The analysis indicated that the mononuclear U^{IV} and ningyoite mineral ($CaU(PO_4)_2 \cdot 2H_2O$) were formed after the reduction.

Extracted from brown algae, alginate is a natural anionic linear copolymer. In order to investigate the binding of metal species by alginate and provide basic knowledge for the study of extracellular polymeric substances (EPS), adsorption and XAFS measurements were performed to the alginate - Cd^{2+} system. The XAFS spectra showed that the major binding sites on alginate involved carboxyl groups. In the following study of Cd adsorption by EPS, *Shewanella oneidensis* and *Pseudomonas putida* were grown to yield biofilms. The XAFS measurements confirmed that the Cd binding environments of the EPS and the bacterial cells were broadly similar. Carboxyl, phosphoryl and sulfhydryl groups were identified as the binding sites in both EPS and cell wall with slightly increasing sulfhydryl site binding in EPS.