Sorption of Heavy Metals and Radionuclides on Mineral Surfaces in the Presence of Organic Co-Contaminants

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Executive Summary

A review of the known inventory of chemical wastes at DOE facilities reveals that a large fraction of the waste is present as complex mixtures containing radionuclides, heavy metals, fuels, oils, organic solvents, and a variety of organic metal complexing agents (Riley and Zachara 1992). This situation is a result of a history of co-disposing wastes associated with chemical processing, metal surface cleaning, decontamination, and fabrication procedures used in the production of nuclear fuels and weapon components. Similar conditions also exist in industry where mixed wastes with heavy metals and chelating agents have been produced. The large inventory of complex and potentially unstable wastes must be stored until suitable treatment, confinement or disposal technologies have been developed. Unfortunately, in many cases the waste materials have been either discharged directly into open pits, or have since escaped from temporary containment facilities and now contaminate surrounding soils and groundwater.

The chemical complexity of these wastes present particularly challenging problems with respect to predicting subsurface migration of the radionuclides and heavy metals, and developing suitable remediation strategies. Among the organic compounds at DOE sites are a number of organic chelating agents that can form stable solution complexes with metals, radionuclides, and their oxy-ions. Examples include ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acid (NTA), and citric acid. It would be reasonable to predict that the formation of metal-organic complexes, especially those with stable multi-dentate structures, will influence the mobility of the metals and radionuclides in soils and groundwater. A general prediction that is consistent with the few available field studies would be that metal complexing organic ligands should increase metal mobility. This has already been demonstrated in a number of studies (e.g., Means et al., 1978; Girvin et al., 1993; Zachara et al., 1995). However, recent work with uranium and citric acid (Redden et al., 1996) and cadmium and citric acid (Boily and Fein, 1996) on metal oxides has shown that, under particular chemical conditions, complexing agents can actually enhance metal adsorption. Mobility of ionic solutes in groundwater is a function of the extent of partitioning between the mobile (water) and immobile (soil, mineral) phases. Organic ligands compete with reactive surface binding sites for metal solutes, or bind directly to surfaces thereby altering the type and availability of binding sites. In most field applications, increased mobility of soil and groundwater contaminants is not desirable since retrieval of the contaminants or isolating the public from hazardous conditions becomes more difficult as zones of contamination expand. However, in some cases, where remediation involves contaminant recovery, maximum mobility can be a distinct advantage.

At present, with the available experimental database, broad generalizations concerning the effect of organic ligand and chelating agents on metal or radionuclide mobility cannot be made. The quantitative predictions of partitioning that are necessary to estimate contaminant transport are not yet possible, and specific details of the chemical mechanisms are still hypothetical. In order to make reasonable transport predictions, an expanded database is needed for a range of priority heavy metal contaminants, common ligands, and representative mineral surfaces. Elucidating the mechanisms by which organic ligands affect metal partitioning at surfaces will provide information necessary for the design of effective treatment strategies.