Quantifying the Bioavailability of Toxic Metals in Soils

Cleanup
CU-1166

Background:

Considerable research and other evaluative efforts have been ongoing in recent years to identify environmentally acceptable endpoints (EAE) in soil, to develop protocols that can be used to determine EAEs, and to make site-specific decisions using EAE data. When applied effectively, these efforts have provided useful descriptions of risk. EAEs for soil most commonly are defined as concentrations of chemicals or other measures of contamination (e.g., biological response or leachability) that are judged acceptable by a regulatory agency or an appropriate entity and are derived either from standard guidelines or following an analysis of site-specific or chemical-specific information and/or testing. There is a need to supplement the current lack of information regarding metals-contaminated soils, which are of particular relevance to the Department of Defense (DoD).

Objective:

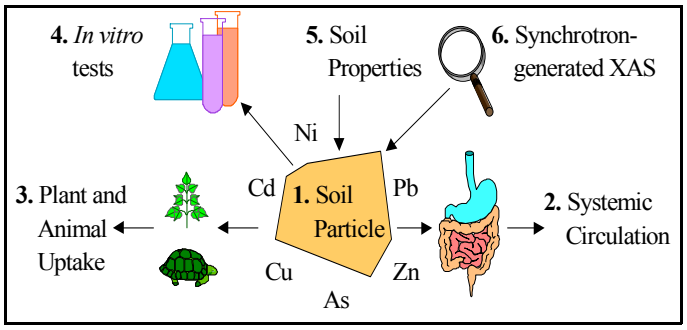
The objective of this project is to investigate the relative bioavailability of toxic metals in soils, primarily in relation to the human health risk posed by soil ingestion, which often controls the degree of cleanup required at metal-contaminated sites. Specific objectives of this investigation are the following: (1) measure changes in relative bioavailability over time in a wide range of soil types that may be encountered at DoD sites within the U.S., (2) develop a predictive capability to quantify toxic metal bioavailability on the basis of soil properties, and (3) investigate the fundamental relationship between molecular-level speciation and bioavailability to enhance the understanding and predictive capability of the fate of toxic metals in soil.

Summary of Process/Technology:

In this research, soil-metal bioavailability will be measured with an in vitro protocol: a physiologically-based extraction test (with an important flow-through modification) to estimate the bioavailability of soil-bound metals in the human gastrointestinal tract. The bioavailability of lead, zinc, copper, cadmium, arsenic, chromium, and nickel will be measured as a function of time in metal-spiked soils with a wide range of soil properties. This research will also feature the use of synchrotron-generated X-ray absorption spectroscopy (XAS), a powerful technique to monitor molecular-level speciation in unaltered soil samples.

Benefit:

Results will provide site managers and risk assessors with tools to make better initial estimates of site risk and EAEs. Although site-specific data will always need to be considered in final cleanup decisions, results from this research can be used to prioritize sites and to justify more definitive site-specific bioavailability studies, such as detailed soil speciation investigations and in vivo studies. These results will contribute to the DoD's goal of mission readiness by avoiding unnecessary diversion of DoD funds for unwarranted site cleanup.



Metals in soils (1) pose a human-health risk via soil ingestion (2) and an ecological risk via plant and animal uptake (3). The goal of this research is to develop a model to predict in vitro-measured (4) bioavailability based on soil properties (5) using XAS (6) to provide a fundamental understanding of the link between molecular-level speciation and bioavailability.

Accomplishments:

Initial results have indicated that the presence of soil reduces the bioavailability of chromium (Cr) and arsenic (As) relative to the Environmental Protection Agency default value of 100%. A multiple regression technique was used to model the observed data and suggested that key soil properties controlled the bioavailability of the toxic metals. The variability in As(II) and As(V) was strongly related to the iron-oxide content, pH, and cation exchange capacity of the soil, whereas the variability in Cr(III) was controlled by the clay content and total organic and inorganic carbon in the soil. XAS confirmed that As was preferentially associated with soil iron-oxides and Cr was precipated on the solid phase as Cr(III) hydroxide, which was consistent with the modeling results.

Contact Information:

Dr. Mark Barnett
Auburn University
208 Harbert Engineering Center
Auburn University, AL 36849
Phone: (334) 844-6291
Fax: (334) 844-6290
E-mail: barnettm@eng.auburn.edu

REVISED 11/16/01