Quantification of Arsenic Bioavailability in Spatially Varying Geologic Environments at the Watershed Scale using Chelating Resins

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Abstract

Elevated levels of arsenic and other uranium-associated elements have been observed in surface and ground waters of the Nueces and San Antonio River watersheds, Texas. These watersheds drain the Catahoula formation that includes the Gulf Coast U Province that is enriched in trace elements, including As, V, and U. These elements have been released from the U province through natural geochemical weathering over geologic time scales and intensive U mining from the 1960's to the 1980's. Mining activities have potentially impacted groundwater quality through infiltration and lateral migration of mineral-rich plumes generated by rainfall infiltration and leaching of ore bodies and spoil piles, recharge from contaminated rivers and streams, and infiltration from mine pits. Potential toxicity of arsenic in different geologic environments is dependent on the total concentration and bioavailability of arsenic. It is important to identify those geologic environments that sequester contaminants because these systems retard contaminant transport through the watershed, limit toxicity, and act as long-term sources for the contaminant.

The objective of this project is to quantify the bioavailability of arsenic in different geologic environments at the watershed scale using chelating resins as infinite sinks. Inductively Coupled Plasma Mass Spectrometry and Atomic Adsorption will be used to quantify total arsenic and vanadium sorbed by the pre-treated chelating resins. Loaded resins will be placed in field sampling devices and exposed to individual soil and sediment layers. The laboratory technique will be applied to the resins exposed to field environments to quantify the bioavailability of total arsenic, arsenic(III), and arsenic(V) over time. Such information has been identified as a critical need for protecting the agricultural and aquacultural resources, and the ecological quality of the Nueces Estuary system, a designated Estuary of National Significance by the U.S. Congress via the Water Quality Act in 1987.

Cows resting on the banks of Lyssy Pond, a stock tank for these cattle. This area is a remediaded open pit uranium mine.The cows drink this water and eat the vegetation around it.

Sulfur Creek, North. Dr. Bruce Herbert points out animal tracks near the standing water in Sulfur Creek. This is an indication animals are using the water. If the water is contaminated, the animals may be ingesting bioavailable metals.

Graciela Lake observes the standing water under a bridge at Scared Dog Creek. The metal concentrations in such low levels of surface water can be extremely high. Standing water is easily accessible to grazing animals. *(photo by V. Moore)*

Geology and Geochemistry

- introduction of metals to a system via weathering and/or erosion

- contaminant bioavailability is a function of the geology and geochemistry of the environment (Heiny and Tate, 1997) [e.g. if phosphorous is limited in an aerated environment and arsenic is available, the chance for uptake of arsenic by organisms increases because of similar geochemical properties of phosphorous and arsenic (Reynolds et al., 1999; Campbell, 1995)]

- contaminates can accumulate in certain geologic environments where they are sequestered and their bioavailability is reduced

Bioavailable Metals

- metals associated with mobile collodial particles

- free aqueous species

Uptake of Metals

- metal uptake by plants and microorganisms

- intake of metals by animals (i.e. drinking contaminated water)

- particle ingestion

Toxicity

- metals sorbing to cell walls and membranes

- amount (activity), chemical speciation, and initial heath of the organism are all functions of toxicity

- uptake of metals by plants and ingestion of metals by animals interferes with natural functions at the cellular level; may lead to malnourishment or death

Bioavailability, Uptake, andToxicity

Bioavailability - defined by the free-ion activity model, is the potential for a contaminant to bind with a cell (Morel, 1983)

Uptake - the process of a cell accepting a bioavailable metal (Campbell, 1995); can also be thought of like sorption to sediment

Toxicity - the activity of a substance that is harmful to an organism and inhibits them from functioning in a normal matter (Speir et al., 1999)

Project Objectives

The objective of this project is to use chelating resins as chemical assays to estimate bioavailability of arsenic in different geologic environments at the watershed scale. This will be accomplished by:

(1) Designing a laboratory technique to determine the total amount and speciation of arsenic (III and V) sorbed by chelating resins in solution and soil samples.

(2) Quantifying arsenic extracted from a pre-treated chelating resin exposed to various geologic environments over different intervals of time in an area once exposed to uranium mine drainage.

Implications

- Bioavailablity of arsenic and associated metals (i.e. U, V, Mo, Se) affects human health through drinking water, dust, or food
- Arsenic is a known carcinogen; reported cases in Bangladesh, Taiwan, and Western United States (Smedley and Kinniburg, 2001)
- Better understanding of arsenic bioavailability at the field scale will aid in the future federal regulation of arsenic in drinking water

A.

B.

A. Javalina in South Texas. The wildlife population in South Texas can be adversly affected by bioavailable arsenic.

B. Lake Corpus Christi, Texas. This body of water is a drinking water source for the city of Corpus Christi, Texas and a potential sink for mobilized arsenic species. *(photo by Ronald L. Parker)*