

# Vegetation Impacts of Inorganics in an Ash-Impacted Cattail Marsh

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## ABSTRACT

An active coal-fired electric generating station operates adjacent to a cattail marsh that receives shallow groundwater discharge from an area that contains coal combustion residuals (CCR). Federal land managers are actively treating portions of the wetland with an herbicide to eliminate cattails to allow for restoration with native plant species. Land managers raised the concern that the uptake of inorganic contaminants by cattail rhizomes and the subsequent release through decay of rhizomes from dead cattails may cause stress to restored plant communities. The study reported here was undertaken specifically to determine if rhizomes are accumulating inorganic elements at concentrations above surrounding soil. Co-located soil and rhizome samples were collected from eight locations near the generating station and three reference area locations, and analyzed for 14 elements. Of particular concern near the area containing CCR are arsenic, boron, molybdenum, and selenium. Variations in vegetation plant uptake factors (VUFs) by area and station could not be explained by soil binding properties such as total organic carbon (TOC) and cation exchange capacity (CEC). VUFs, however, exhibited decreases with increasing soil levels, indicating that higher soil concentrations do not produce proportionately higher plant tissue concentrations. In addition, concentrations of CCR-related inorganics were generally lower in rhizome plant tissue than in surrounding soils. Overall, the results do not indicate that rhizome bioaccumulation and subsequent release through decay will increase inorganic loading to the marsh system over time. Biocycling related to cattail eradication is not expected to result in stress to desirable marsh plantings.

## INTRODUCTION

A coal-fired electric generating facility in operation since 1962 occupies an approximately 350-acre parcel of property in an industrial area in the Midwestern United States. The Facility is bordered by a National Lakeshore managed by the National Park Service (NPS). The conceptual site model that describes the means by which plants within the National Lakeshore may be exposed to site constituents includes:

- Historic releases from settling ponds and ash fill areas released coal combustion residuals to groundwater, which discharged to shallow soils and surface water within the National Lakeshore;

- Measurements of soil, sediment, surface water, groundwater and plant tissues show plumes of Site-related constituents in groundwater have previously and currently migrate from the facility to the National Lakeshore;
- Shallow plumes of site-related constituents of concern in groundwater extend from the Facility through shallow wetland sediments and discharge to surface water within National Lakeshore wetlands;

As a result, plants within the National Lakeshore wetlands are exposed to site constituents in soil, sediments, surface water and shallow groundwater. NPS theorized that metals may bioconcentrate in cattail rhizomes and be subsequently released during the decay of plant matter following application of herbicides to eradicate the cattails, and that the release of metals in soils is a potential cause of plant stress observed in the plant restoration areas.

This study addresses these concerns as well as possible uncertainties surrounding the conservative linear models that are typically used to estimate concentrations in plants. The simplest linear model that is often used to estimate concentrations in plants from soil is the vegetation uptake factor (VUF), the ratio of the concentration of a chemical in a plant to that in the soil. Published VUFs can be used to estimate the concentration of a particular contaminant in a plant by multiplying the VUF by the concentration of that contaminant in the soil. Through this linear model, chemical concentrations in plants and soil are assumed to be at equilibrium; and higher concentrations in soil yield proportionately higher concentrations in plant tissue<sup>1</sup>. The linear vegetation uptake model does not take into account the fact that uptake factors may, in fact, vary with soil concentration.

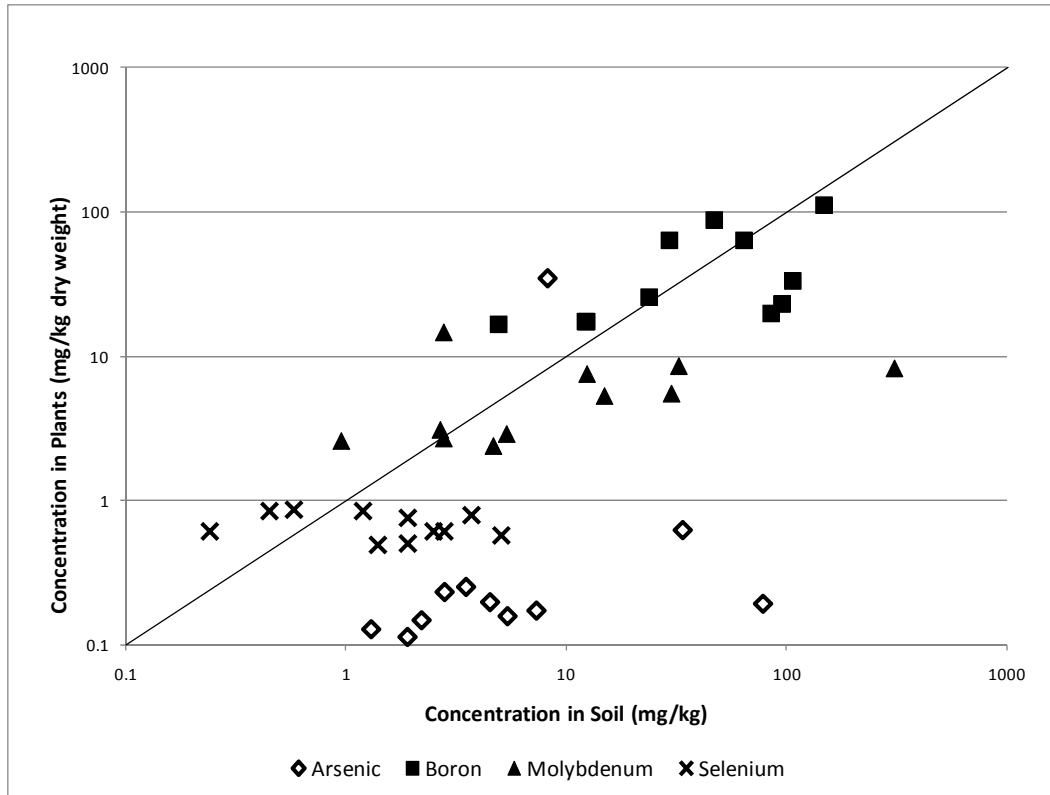
## **METHODS**

In June of 2010, co-located soil and cattail rhizome tissue samples were collected down gradient of the coal-fired electric generating facility and in a reference area for chemical analysis of site-related metals. A total of eight samples were collected within or downgradient of the facility property, while three others were collected in reference locations approximately five miles east of the site.

Soil was removed from the rhizome samples first using a soft-bristled brush, and then by rinsing the rhizomes under running tap water followed by a deionized water rinse. The soil samples were collected from within and immediately below the rhizome mat, to ensure that the soil and rhizome samples were co-located. Plant tissue samples were analyzed for metals, nitrogen, phosphorus and percent moisture. Soil samples were analyzed for metals, nitrogen, phosphorus, organic carbon content, pH, sulfate, cation exchange capacity (CEC) and percent moisture. Soil and plant results are expressed on a dry weight basis.

## RESULTS AND DISCUSSION

This study focuses on the concern over plant bioconcentration of metals and subsequent release back to soils. Therefore, plant bioconcentration is a concern only if the vegetation uptake factor (VUF, expressed as the ratio of plant to soil concentration from collocated samples) is greater than 1.0. **Figure 1** presents a scatterplot comparing concentrations in plants with concentrations in soil for the constituents of concern at this site. The line extending from the origin with a slope of 1 corresponds to a VUF of 1.



**Figure 1: Scatter plot of chemical concentrations in vegetation versus plants.**

In order to determine if plant and soil concentrations are, in fact, in equilibrium, VUFs were calculated for all samples located within the Study Area, as well as those located in reference areas. **Table 1** presents VUFs for all analyzed metals.

Chemical	Study Area VUFs								Reference Area Sample VUFs		
	VS01	VS02	VS03	VS04	VS05	VS06	VS07	VS08	REF01	REF02A	REF03
ALUMINUM	0.1	0.01	0.02	0.02	0.005	0.01	0.01	0.01	0.01	0.01	0.005
ARSENIC	<b>4.2</b>	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
BARIUM	<b>1.2</b>	0.3	0.8	0.9	0.1	0.2	0.3	0.2	0.2	0.6	0.2
BORON	<b>1.1</b>	1.0	<b>2.2</b>	<b>1.9</b>	0.8	0.2	0.2	0.3	<b>1.4</b>	<b>3.4</b>	<b>1.4</b>
CADMIUM	0.3	0.1	0.6	0.4	0.0	0.1	0.1	0.04	0.1	0.2	0.1
CHROMIUM	0.3	0.1	0.5	0.4	0.1	0.05	0.1	0.1	0.2	0.3	0.2
COPPER	0.6	0.2	0.7	0.7	0.1	0.1	0.1	0.2	0.1	0.2	0.2
IRON	<b>2.0</b>	0.1	0.5	0.4	0.03	0.2	0.1	0.4	0.02	0.02	0.01
LEAD	0.2	0.01	0.05	0.02	0.01	0.01	0.01	0.01	0.002	0.01	0.00
MANGANESE	<b>2.3</b>	0.7	<b>2.7</b>	<b>3.2</b>	0.8	0.4	0.7	0.6	<b>1.2</b>	<b>1.3</b>	<b>1.0</b>
MOLYBDENUM	<b>5.2</b>	0.4	0.6	0.3	0.03	0.5	0.5	0.2	1.0	<b>2.7</b>	<b>1.1</b>
SELENIUM	0.7	0.2	<b>1.9</b>	<b>1.5</b>	0.1	0.2	0.4	0.2	0.4	<b>2.5</b>	0.3

**Table 1: Calculated VUFs for Study Area and Reference Area samples**

Results showed constituents with VUFs above one for arsenic barium, boron, iron, manganese, molybdenum and selenium. The constituents of concern for this site are arsenic, boron, molybdenum, and selenium, and are discussed below.

Arsenic VUFs ranged from <0.02 to 4.2. At one location (VS01), the arsenic VUF was greater than one. However, the VUFs calculated for the seven other Study Area locations, all of which are located within 335 meters (1100 feet) of VS01, were below one. This result indicates that arsenic is generally not bioaccumulating in Study Area rhizomes.

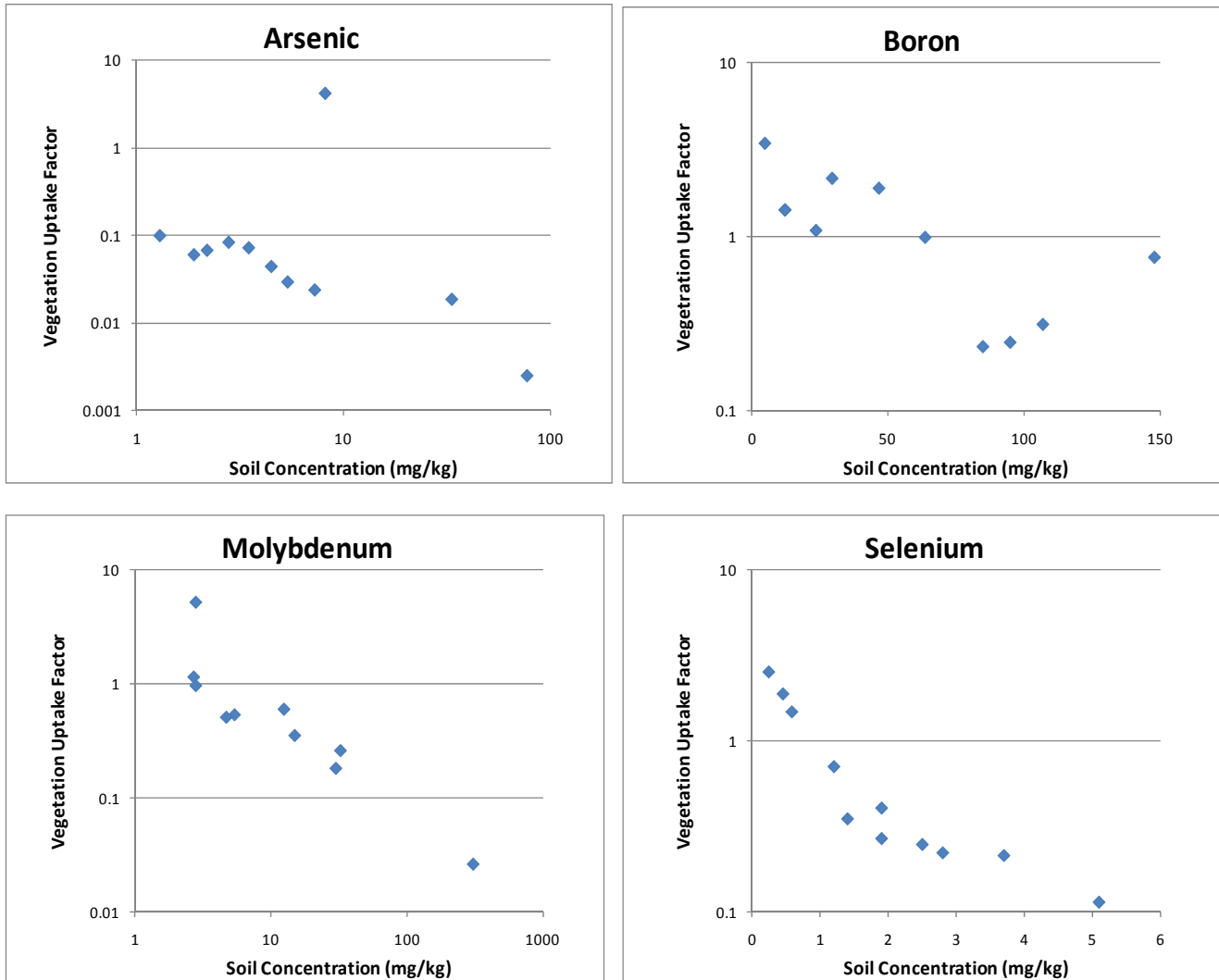
Boron VUFs ranged from 0.2 to 3.4 with VUFs greater than 1.0 at three sampling locations; VS01, VS03 and VS04. All of the Study Area boron VUFs were below Reference Area VUFs, which indicates there is no enhanced boron bioconcentration in wetland rhizomes for Study Area samples with higher concentrations of boron in soil.

Molybdenum VUFs ranged from 0.03 to 5.2 and one Study Area sampling location (VS01) exceeded a VUF of 1. However, the concentration of molybdenum in soil at locations VS02, VS04 and VS05, all located within 76 meters (250 feet) of Location VS01, were greater than in the Location VS01 rhizome. This result indicates there is no significant molybdenum bioconcentration in Study Area rhizomes.

Selenium VUFs ranged from 0.1 to 2.5 with two Study Area VUF greater than 1.0. Nonetheless, all of the VUFs on-site were below the VUF observed in Reference Area Location VS02.

Overall, these VUFs show that concentrations were generally higher in surrounding soils than in rhizomes. As shown in Figure 2, which depicts the relationship between VUFs and soil concentrations, VUFs decreased with increasing soil concentrations for arsenic, boron, molybdenum and selenium. These results indicate that higher soil concentrations do not produce proportionately higher plant tissue concentrations, and

thus the use of linear uptake model would not be appropriate at this site. The relationship between concentrations in soil and VUFs appears to be logarithmic.



**Figure 2: Calculated vegetation uptake factors versus concentrations in soil. Vegetation uptake factors represent the ratio of chemical concentration in plants to concentration in soil. When a compound was not detected in either media,  $\frac{1}{2}$  the reporting limit was used to calculate the respective VUF.**

## CONCLUSIONS

The results of this study indicate that there is no significant bioconcentration of metals in rhizomes at the site. While some metals were slightly higher in rhizomes when compared to collocated soil samples, when the comparison is applied across the entire Study Area and background locations, concentrations were generally higher in soil than rhizomes. Other metals did not exhibit bioconcentration in plant tissue, or had lower

bioconcentration than Reference Areas. Overall, it does not appear as if bioconcentration and then subsequent release of metals back to soils is a concern.

The results of this study also indicate that the use of a VUF linear model does not adequately predict plant uptake. Regardless of total concentration or availability of metals in soil, the plant species studied appear to have a finite capacity to uptake specific metals over time.

Overall, the results do not indicate that rhizome bioaccumulation and subsequent release through decay will increase inorganic loading to the marsh system over time. Biocycling related to cattail eradication is not expected to result in stress to desirable marsh plantings.

## **REFERENCES**

[1] US Department of Energy, Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants. September 1998.