Vetiver Grass Removes Lead From Firing Range Soil*

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Abstract

Vetiver grass (*Vetiveria zizanoides*), along with soil amendments was evaluated for phytoextraction of lead and other metals (zinc, copper, and iron) from the soil of an active firing range at the Savannah River Site, South Carolina. Lead-contaminated soil (300–4,500 ppm/kg) was collected, dried, placed in pots, fertilized, and used as a medium for growing transplanted Vetiver grass plants in a greenhouse. The uptake of metals by the plants was evaluated in response to various fertilization and pre-harvest treatments.

Plants grew better when fertilized with Osmocote fertilizer in comparison to plants fertilized with 10-10-10 (NPK) fertilizer. Application of a chelating agent, EDTA, 1 week before harvest significantly increased the amount of lead that was extracted. Lead concentrations of up to 1,390–1,450 ppm/kg were detected in tissue samples. Maximum lead levels were observed in root tissues. The addition of nonlethal doses of a slow-release herbicide in combination with EDTA did not appear to significantly enhance phytoextraction or the translocation of lead into shoots.

Lead in the Environment

- Lead is a major contaminant in soils, sediments, and water worldwide.
- Lead-contaminated soil is associated with firing ranges at Department of Energy, Department of Defense, national forest, and other facilities throughout the United States.
- Firing range soil is typically contaminated to a depth of 20 cm.

Lead Poisoning

- Lead is most commonly associated with chronic heavy metal poisoning in humans.
- Inorganic sources of lead, such as lead bullets, adversely affect the central and peripheral nervous systems, hematopoietic system, kidney, gastrointestinal tract, liver, myocardium, and reproductive system.

Vetiver grass (Vetiveria zizanoides) is native primarily to Southeast Asia. Originally used for perfume and medicinal purposes, the grass is now mainly used for soil and moisture conservation.

What is Unique About Vetiver Grass?

- Sterile (nonflowering) cultivars are readily available.
- Grows on both acidic (< pH 4) and alkaline soils (pH 11).
- Roots are strong and can grow to depths of 3-4 meters in 1 year.
- Can live for 50 years.
- Resistant to pests and diseases.
- Tolerant of heavy metals and organic pollutants.

***Source:**
Wilde, E. W.; Brigmon, R. L.; Dunn, D. L.; Heitkamp, M. A.; Dagnan, D. C. 2005. Phytoextraction of lead from firing range soil by Vetiver grass. Chemosphere 61(2005): 1451-1457.

Experiment 1 Design

Soils Identification and Collection

- High lead concentrations (>10,000 mg/kg) were identified in soil.
- Surface soil was collected to a depth of approximately 1 m from the face of a section of ''DuPont Berm'' using a backhoe.
- Air-dried and screened samples were distributed into 13.2-liter pots with perforated bottoms (7.5 liters in each of 48 pots).
- Three 50-g aliquots were collected from each pot for subsequent baseline measurements of lead concentration.
- Pots were planted with a sterile strain of Vetiver.
- Commercially available fertilizer was added, 37 ml per pot, at the time of transplanting (Osmocote to half of the plants and 10-10-10 to the other half).
- The plants were then monitored biweekly and were watered with nonchlorinated well water (June 2002 through October 2002).

Pre-harvest Treatments

One week before harvest, each plant received one of three treatments with chelating/uptake agents, to maximize lead uptake and movement within the plants:

1. EDTA (*ethylenediaminetetraacetic acid*) at 5 mmol/kg of soil,
2. a combination of EDTA at 5 mmol/kg soil plus herbicide at 25% of the recommended dosage (Riverdale Foresters along with a surfactant, Cide-Kick11, which combined are chemically equivalent to the slow-release herbicide Roundup), and
3. controls receiving no amendments.

Experiment 2 Design

- The lead levels of the soil collected for Experiment 1 were lower than expected, so a second experiment was conducted on a more limited scale using soil from sites where lead concentrations were known to be highest.
- Soil was collected with a hand auger from a depth of 10-30 cm. These samples had substantially higher lead levels (3,000 ppm range) than the initial collection (300 ppm range).
- Planting, monitoring, and watering protocols were the same as in Experiment 1 except no pre-harvest treatments were applied, and the plants were not measured for length or weight at the conclusion of the experiment (October 2002 through July 2003).

Harvesting Plant Material

- The plants were initially separated from the soil by cutting them at ground level.
- Soil was removed from the roots by drying and shaking loose soil.
- Subsamples of soil, root, and leaf tissues were processed into capsules for metal analysis.

Analysis

Metal Analysis

- Plant tissues and soil samples were analyzed for metal concentrations using a portable, multi-element X-Ray Fluorescence (XRF) instrument.
- The accuracy of the XRF analyses was verified by comparing results from nine randomly selected aliquots with measurements made by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Data Analysis

- Phytoextraction coefficients were calculated by determining the ratio of mg/kg dry weight of metal in the plant to the mg/kg quantity of metal in the dried soil that the plant was grown in.

Results

- Lead measurements from using XRF and ICP-MS differed by less than 10%, demonstrating the efficacy of using the faster and less expensive portable XRF instrument for measuring lead in soil.
- Vetiver plants that received Osmocote fertilizer grew better than plants that received 10-10-10 fertilizer. The addition of EDTA resulted in additional growth over Osmocote alone.
- Pre-harvest treatment with EDTA significantly increased phytoextraction of lead compared with untreated plants. Nonlethal doses of herbicide in addition to EDTA did not significantly enhance phytoextraction or translocation of lead (figure 1).
- Copper and zinc were generally less abundant in the collected soil than in plant roots, and uptake was relatively lower than uptake of lead and iron.
- Phytoextraction in Experiment 2, which used soil with higher concentrations of lead, differed from treated and untreated plants in Experiment 1 in terms of total metal quantities and relative abundance (figures 2 and 3).

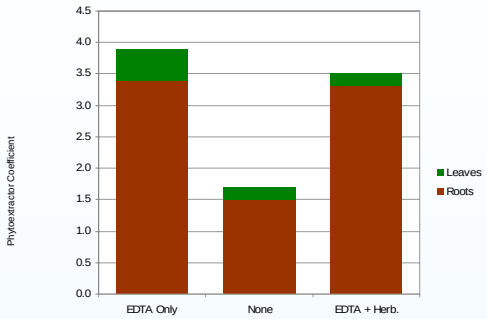

Figure 1—Phytoextraction coefficients for lead were significantly higher in plants treated with EDTA before harvest than in untreated plants.

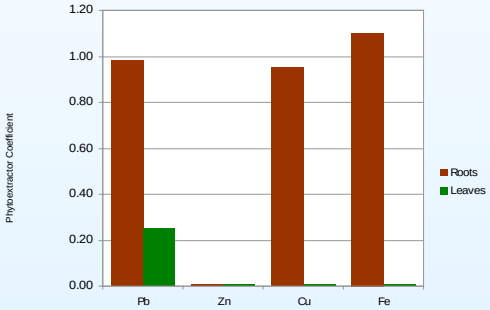

Figure 2—In Experiment 1, which used soil with lower metal levels, phytoextraction coefficients for untreated plants were higher for lead and copper, and lower for zinc and iron than in Experiment 2 (see Figure 3).

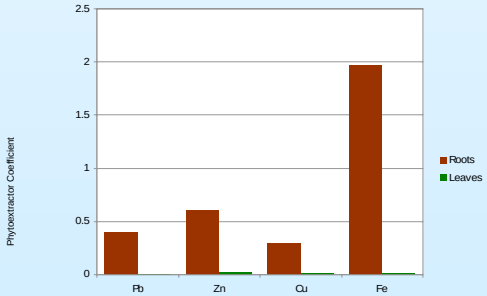

Figure 3—In Experiment 2, which used soil with higher metal levels and untreated plants, lead in roots was higher than in leaves.

Conclusions

- Significant plant accumulation of lead in Vetiver roots with little in leaves shows potential use in phytostabilization of lead contaminants in soil.
- The use of Vetiver grass coupled with amendments has considerable potential for use as a remedial strategy for lead-contaminated soils such as those associated with firing ranges.

The use of trade or firm names is for information only and does not imply endorsement.

This research involved the use of pesticides; however, it does not recommend its use or imply that the use described has been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.