Tacoma Smelter Plume
Chinese Brake Fern Phytoremediation Study
December 2005 Study Update

NOTE: This information is from a 2005 website and may be out of date. Study details and data tables start on page 6.

With the harvest of the fern fronds in October, the first year's study of the Chinese Brake ferns and their ability to remove arsenic from the soil is now complete on Vashon-Maury Island, and at Point Defiance Park. This is an interim update sharing what we have learned at this point in time.

Introduction

In spring 2005, Ecology, with the assistance of Public Health-Seattle & King County and the Tacoma-Pierce County Health Department, planted approximately 100 fern plants in each of seven test plots. Five test plots are on Vashon-Maury Island, and two are at Point Defiance Park.

During the planting, we collected soil and frond samples to determine the baseline levels of arsenic, lead, and cadmium.

In October, we harvested the fronds before they wilted and fell to the ground potentially releasing the arsenic they had removed back to the soil. We sampled the soil and fronds for arsenic, lead, and cadmium. Here's what we have learned...

Summary of Results

- Chinese Brake Ferns (Pteris vittata) grown in arsenic-containing soil in western Washington do take a lot of arsenic into their fronds (hyper-accumulate or bio-concentrate arsenic).
- Brake ferns do not seem to take up lead and cadmium.
- Brake ferns seem to absorb large amounts of arsenic whether the soil contains 30 or 160 parts per million (ppm) arsenic.
- Fronds from brake ferns grown in arsenic containing soil are a dangerous waste at the end of the growing season.
- Brake ferns seem to do best with one-half to two-thirds of a day of full sun, and moderately heavy watering during the growing season.

- Brake ferns do not grow vigorously in shady or cool areas, or when soils become dry.
- We can not yet determine, based on soil sample results, how much arsenic the ferns have removed from the soil. This is probably because of soil contaminant variability.
- Brake ferns developed mature spores in one plot of the seven plots planted. We do not know if these spores can develop into new plants in this climate.
- We do not know if the brake ferns will survive the winter.

Frequently Asked Questions

1. Phyto-WHAT???? What is "Phytoremediation"?

Phytoremediation (phyto= plant, remediation = contamination "remedy" or cleanup) is the use of plants to remove contaminants from the environment. In this case, using Chinese Brake Ferns to remove arsenic contamination from soil.

2. Are Chinese Brake Ferns invasive?

Ecology has consulted with the Washington Department of Agriculture and the California Noxious Weeds Commission. Experts in both agencies believe the ferns are not likely to be invasive in western Washington. We are, nonetheless, watching careful to see if there are any indications the plants will reproduce and spread.

Careful plant counts are made in each plot. To date, 2-8 plants have died in each plot, indicating something around 5% mortality in the plots this year. In one plot, ferns were observed with mature spore bodies under the frond leaflets. Mature spores did not form on plants in any other plot this year. We will continue to monitor for signs of possible invasiveness for the duration of the study.

3. What is "hyper-accumulation"?

Literally translating to extra-accumulating, an organism that concentrates anything from the environment, and maintains a higher concentration in it's body than in the surrounding environment or food it eats. So you and I are also hyperaccumulaters, at least of calcium (bones), phosphorous (muscle), and other "normal" nutrients.

Most plants more complex than algae also hyper-accumulate phosphorous, nitrogen and other essential nutrients. Arsenic, however, isn't a nutrient that's needed in large quantities, so the brake fern's hyper-accumulation, or extreme gathering of arsenic is unusual. This characteristic may be helpful for environmental cleanups, however. We do not know why brake ferns hyper-accumulate arsenic.

4. Did you clean up any of the test plots you grew the ferns in?

Soil sampling results show that none of the plots we grew ferns in this year had the arsenic reduced below the cleanup standard of 20 ppm.

What's Next?

After harvesting the fronds, we covered the ground with a mulch layer to protect the root balls from frost.

Late winter we will check to see if the plants are putting out new fronds. If the plants survived the winter, we will continue care for the plants (watering and weeding), and sample the soil, and fronds every again next year.

If you are interested in helping tend the plots, please contact Norm Peck at (509) 454-7837 or email Norm.Peck@ecy.wa.gov.

Further Details and Data Tables

Spring 2005, Ecology planted One hundred Chinese Brake Ferns (*Pteris vittata*) in each test plot in April and May (Vashon-Maury Island plots) and June (Point Defiance plots) in fenced, covered enclosures with warning signs. The following is further detail of the first year's results.

Arsenic uptake by the Chinese Brake Fern

The young ferns planted in April through June this year contained less than 1 part per million (ppm) arsenic in their fronds at the time of planting. At season's end, the arsenic concentration in the fronds ranged from 828 to 16,000 ppm (dry weight). Arsenic concentrations in the fronds for each plot are shown in the pale green column in the summary table on page 5.

Some factors affecting the rate of arsenic uptake are understood; certainly others are not. For example, we do not know why the fronds at the Point Defiance maintenance facility plot (PD 1) had almost ten times as much arsenic as any other plot (even though the plot was planted in June). We do know that the ferns are taking up arsenic from the soil.

Arsenic reduction in the soil

Soil samples were collected prior to planting the ferns to determine baseline concentrations for arsenic, lead, and cadmium. Soil samples were collected again in October during frond harvest. The soil concentrations are displayed in the tan columns in the summary table.

In some plots, arsenic concentrations appear to have increased. However, this is likely due to the high variability of arsenic in soil as shown in our past Tacoma Smelter Plume studies. This variability makes determining soil removal rates difficult, especially over only one year and two sample sets (baseline and harvest in 2005). Mass balance calculations indicate a slight reduction, though less than predicted. We cannot point to a definable reduction in soil arsenic concentration in the test plots this year.

Waste disposal of harvested ferns

When the arsenic-containing fronds are harvested, they must be disposed of properly to avoid simply moving the contamination to another place where they could expose people, animals, or other plants to harmful levels of arsenic.

Ecology tested the harvested fronds using a laboratory protocol called the Toxicity Characteristic Leaching Procedure (TCLP). This test method is required under the state's Dangerous Waste rules to determine if a waste is dangerous. Dangerous waste must be disposed of in special landfills for dangerous waste, rather than solid waste landfills that take our household garbage.

The results for all fronds tested show that they are dangerous waste. A waste is a dangerous waste if TCLP arsenic results are more than 5 mg/l (milligrams per liter) in the leachate. The TCLP results ranged from 5.5 to 132 mg/L, and are shown in the summary table on page 6.

The harvested fronds from this year's pilot test were shipped to a hazardous waste landfill. Because of the arsenic content, it's very important that the fronds not be composted (contaminating a much larger volume of compost that will end up on someone's yard) or burned (putting extremely poisonous arsine gas into the air).

Growing conditions

Dockton Park 2 (VIDP2) received the least water of any plot, because water had to be hauled to it. The fronds in this plot showed a significantly lower arsenic concentration than other plots (828 mg/kg), and the lowest frond growth (1.2 lb or 0.544 kg). This plot was also well shaded. The other forested plots (Dockton Park 1 and Vashon Island School District 3) showed similar low plant mass.

In contrast, the plot near Chautauqua Elementary School (Kindergarten Play Area, VISD1) produced 18.6 lbs (8.44 kg) of fronds that had an average arsenic concentration of 1732 mg/kg, or more than twice the concentration of Dockton Park 2. This plot received 2/3 of a day of full sun, was watered moderately heavily twice per week, and was initially planted with more mature plants.

These observations suggest that in the western Washington climate, significant supplemental watering, in combination with ½ to 2/3 day of full sun, provide optimal growing conditions for the ferns.

What's next?

Survival: The next critical part of the study is to see if the ferns will survive the winter here. Chinese Brake Ferns are reportedly not able to survive soil temperatures below 20 degrees Fahrenheit. All plots were straw-mulched to a depth of about four inches to provide some additional frost protection.

Invasiveness: Only ferns in VISD1 formed mature spores. Two fronds with mature spores were left standing in the plot, and we will look very carefully to see if any young fern plants form in that plot or nearby.

This next year we will see how well the ferns do when started from established rhizomes compared to new plants. We will determine how many survive the winter. If the plants survived the winter, we will continue care for the plants (watering and weeding), and sample the soil every 6 months, and sample the fronds every 3 months.

Phytoremediation Pilot Study Summary Data Table

	Tissue			Soil				
		Total Conc.	TCLP Conc.	Metal	Baseline		October 2005	
Plot	Metal				Conc. S	Conc. D	Conc. S	Conc. D
VISD 1	**As**	**1732.5**	13.15	**As**	25.2	**N/A**	36	31.3
	Cd	0.34	0.001	Cd	NS	NS	0.4	0.6
	Pb	2.15	0.001	Pb	NS	NS	89.3	72.8
VISD 2	**As**	**983.2**	8.44	**As**	37.3	31	40.3	27.4
	Cd	0.34	0.001	Cd	1.235	0.874	0.2	0.2
	Pb	2.63	0.004	Pb	129.3	81.3	104.5	72.2
VISD 3	**As**	**1846.5**	12.5	**As**	40.5	**9.6**	37.9	**10.9**
	Cd	0.4	0.001	Cd	0.38	0.1	0.3	0.3
	Pb	8.02	0.001	Pb	57.5	12.5	61.4	16.5
VIDP 1	**As**	**1710**	12.3	**As**	46.5	29.5	113.4	91.4
	Cd	0.339	0.001	Cd	NS	NS	2.4	1.2
	Pb	10.05	0.013	Pb	109.2	67.9	**281.5**	146
VIDP 2	**As**	**828.5**	5.5	**As**	80.1	38	80.1	38
	Cd	0.142	0.0001	Cd	NS	NS	0.3	ND
	Pb	9.17	0.004	Pb	173.3	74.3	117.6	53.9
PD 1	**As**	**16000**	132.5	**As**	158.25	153.25	147.5	117.5
	Cd	.03ND	.003ND	Cd	3.13	2.78	1.78	1.48
	Pb	.2ND	0.02ND	Pb	213	196	182.5	162.5
PD 2	**As**	**6975**	43.8	**As**	80.13	38.03	89	20.3
	Cd	.01ND	.001ND	Cd	2.15	0.4	1.24	0.49
	Pb	.2ND	0.02ND	Pb	151.6	34	135	21.8

All concentrations are in parts per million (ppm). Numbers in red indicate values above regulatory cleanup or waste designation values.

Metals: As = arsenic Cd = cadmium Pb = lead

S = shallow soil sample (0-6") D = deep soil sample (6-12")

NS = not sampled ND = not detected N/A = not applicable

Test Plots

VISD1: Vashon Island School District 1, located just north of the Kindergarten Play Area adjacent to Chautauqua Elementary School.

VISD2: Vashon Island School District 2, located in the southeast corner of the School District/ High School Horticultural Garden, near the old district administration building.

VISD3: Vashon Island School District 3, located about 300 yards east of the Chautauqua Elementary School building near the walking path in the woods.

VIDP1: Vashon Island Dockton Park 1, located about 75 yards east and slightly north of the shower/restroom building at Dockton Park, Maury Island, this plot is visible from the path up the hill from the picnic area just before reaching Dockton Road.

VIDP2: Vashon Island Dockton Park 2, located just off the horse/walking trail about 75 yards south of the parking area south of Dockton Road, and visible from the path.

PD 1: Point Defiance 1, located near the north edge of the Metro Parks maintenance facilities on the east side of Point Defiance Park, also just east of the go-cart track.

PD 2: Point Defiance 2 is located near the west end of Never Never Land, just off the east edge of the parking lot.