Soil Treatability Study

Energy Technology Engineering Center • U.S. Department of Energy

STIG Meeting
February 12, 2015

Phytoremediation Study

FINAL RESULTS

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CAL POLY

Phytoremediation: Use of plants for remediation of contaminated soil

Objectives:

1. Determine which plant species presently growing in SSFL Area IV soils may contribute to phytoremediation
2. Estimate ability of plants to reduce concentrations of contaminants of interest (COIs) in soils
3. Determine what nutrients/additives can be added to stimulate/increase phytoremediation rates
4. Identify potential phytoremediation mechanisms for contaminant uptake/degradation

Phase 1:
Field Screening

→ Collected plants growing in SSFL soil

- Tested for contaminant uptake
- Selected species for further study

Phase 2:
Greenhouse Microcosms

→ Grew select species in greenhouse

- Measured contaminant uptake
- Estimated soil remediation rates
- Tested effects of additives

Phase 1:
Plant Screening for contaminant uptake

Field Sampling: January and May 2014

Scientific Name	Common Name	Date Sampled
Nassella pulchra	Purple Needlegrass	May 2014
Hirschfeldia incana	Summer Mustard	Jan 2014
Asclepias fascicularis	Narrowleaf Milkweed	Jan 2014
Sambucus nigra	Blue Elderberry	Jan 2014
Malosma (Rhus) laurnia	Laurel Sumac	Jan 2014
Baccharis salicifolia	Mule-Fat	Jan 2014
Ericameria palmeri	Palmer Goldenbush	Jan 2014
Baccharis pilularis	Coyote Brush	Jan 2014
Eriodictyon crassifolium	Thickleaf Yerba Santa	Jan 2014

Field Sampling Method

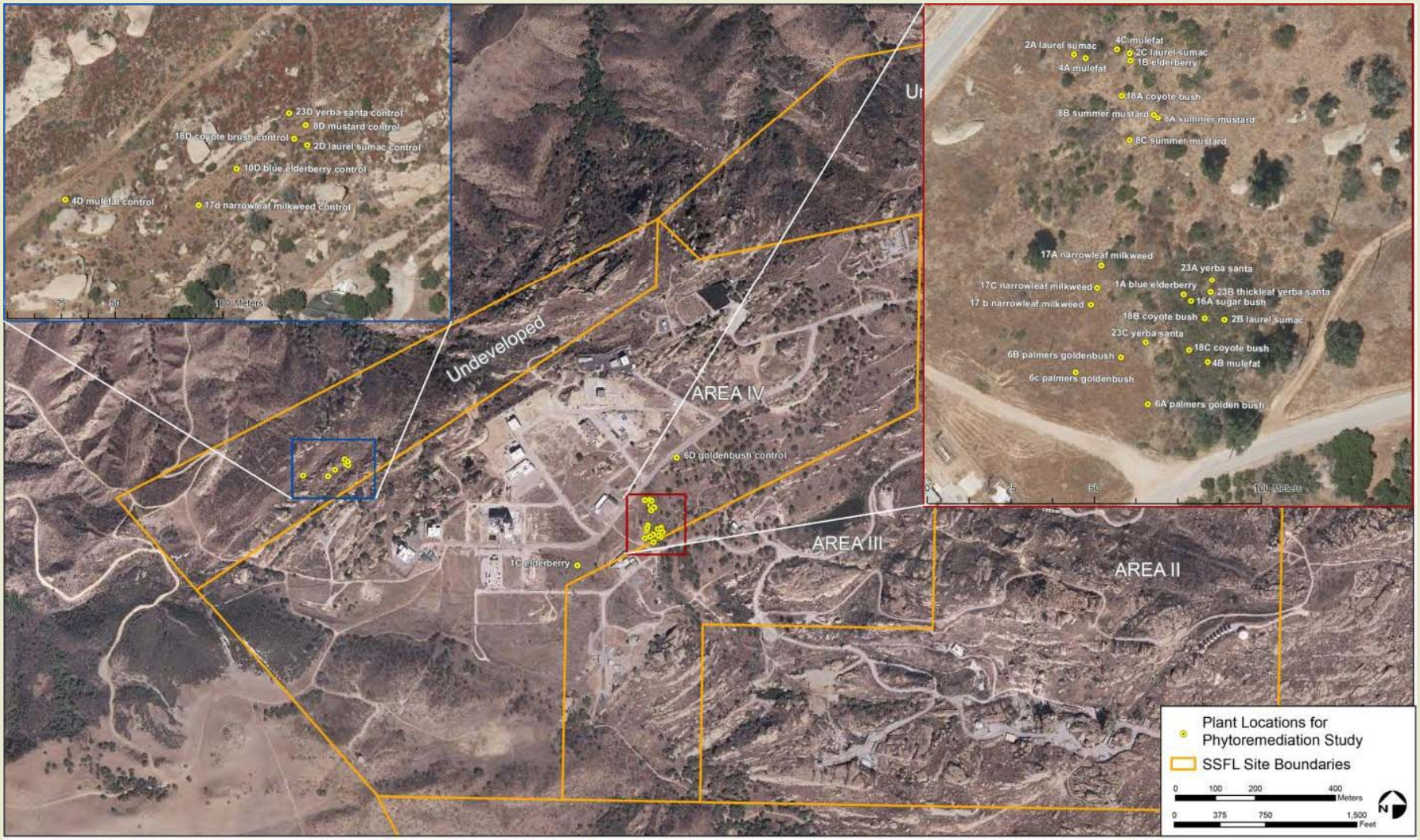
- 3 specimens of each species growing in contaminated soil
- 1 specimen of each species growing in clean soil (control)

Foliage

Roots

Root Zone Soil

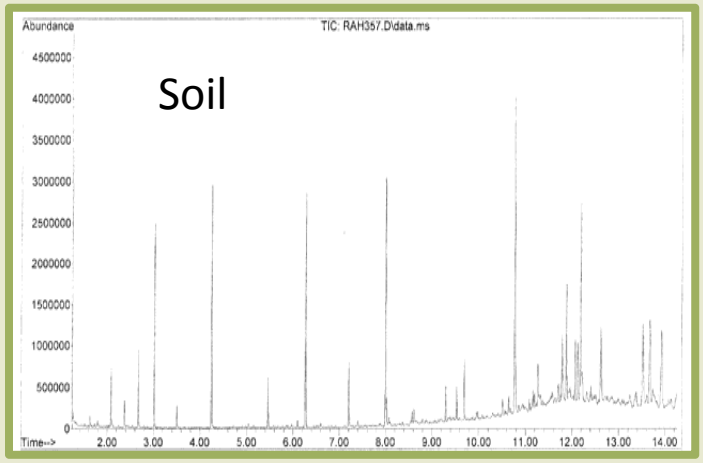
Phase 1: Plant sampling locations

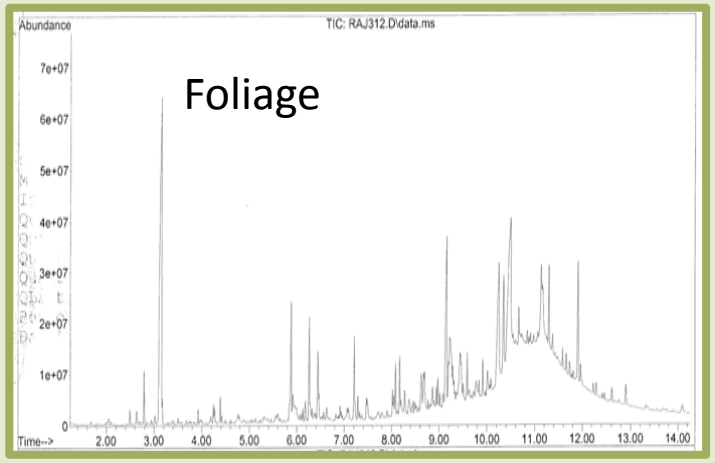


Vegetation Monitoring Sites for Cal Poly

Field Results: **Petroleum Hydrocarbons**

- Extractable Fuel Hydrocarbons (EFH) were observed in the roots and foliage of all species
  - Soil EFH concentrations 200 mg/kg
  - Foliage EFH concentrations 1,000 – 12,000 mg/kg
  - Hydrocarbons observed in plant tissue appear to be phytogenic (produced by plants)

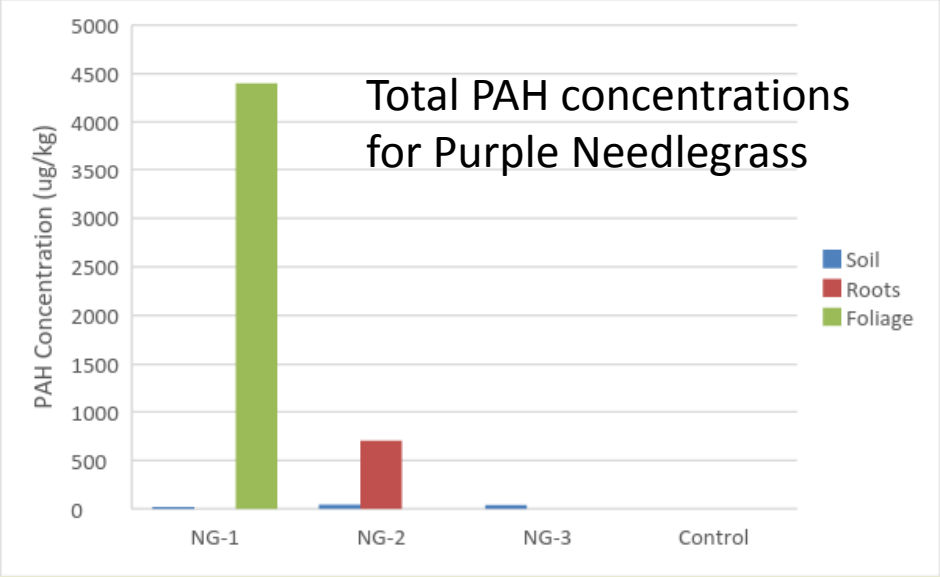




Chromatograms of Palmer's Goldenbush semi-volatile compounds

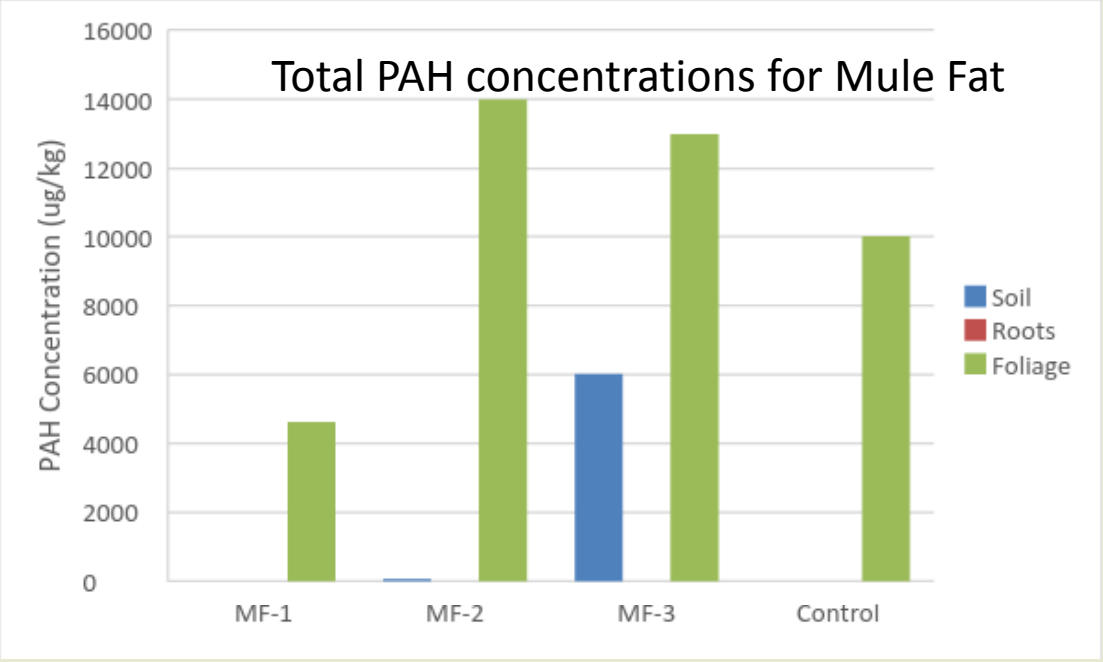
Field Results: **Polyaromatic Hydrocarbons**

- PAHs were detected in the roots of most species at low levels
- Blue Elderberry, Yerba Santa, and Purple Needlegrass showed the most PAH uptake – but only for some specimens



Field Results: **Polyaromatic Hydrocarbons Cont'd**

- PAHs detected in some species appear to be phytogenic
- Mule Fat: High PAH concentrations in foliage, even for control growing in clean soil

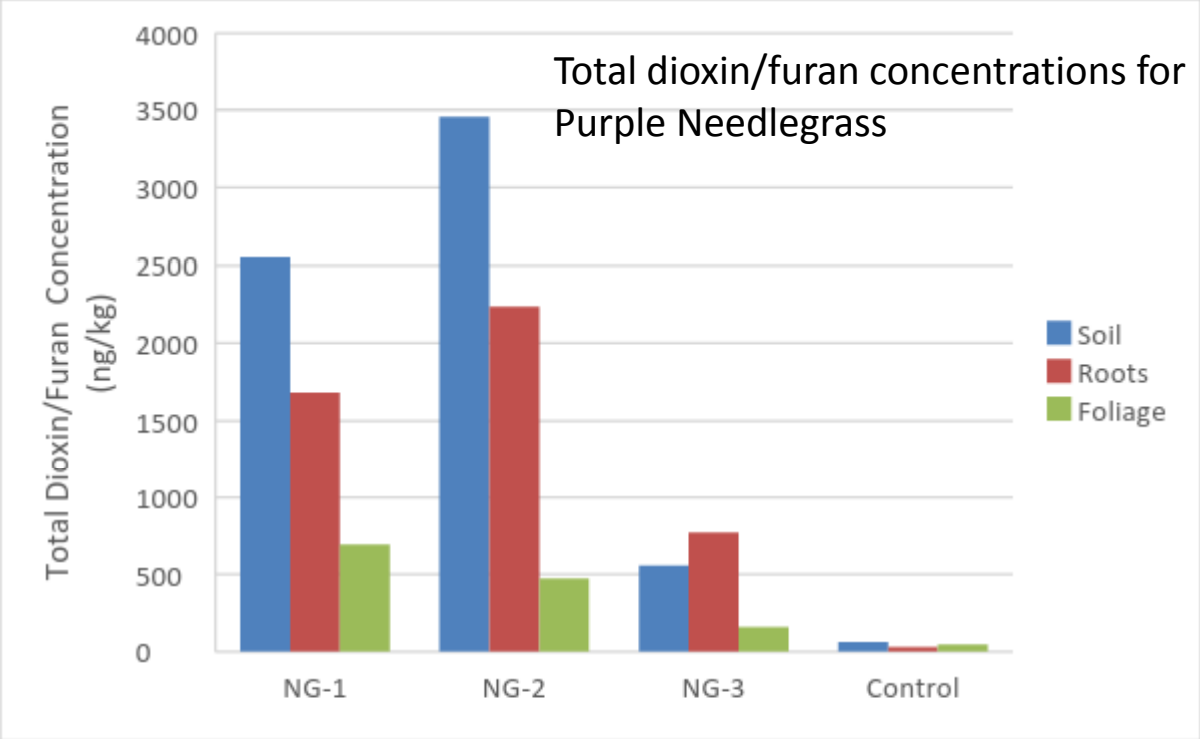


Field Results: **Polychlorinated Biphenyls (PCBs)**

- No PCB uptake was observed for any plant species
- All root and foliage PCB concentrations were below the detection limit of 50-200 ug/kg
- PCBs were not detected in the soils associated with Palmer's Goldenbush or Purple Needlegrass specimens (so no PCB uptake was possible)

Field Results: **Chlorinated Dioxins/Furans**

- Chlorinated dioxins found in Blue Elderberry, Palmer's Goldenbush, Yerba Santa, and Purple Needlegrass
- Other species showed possible uptake into roots

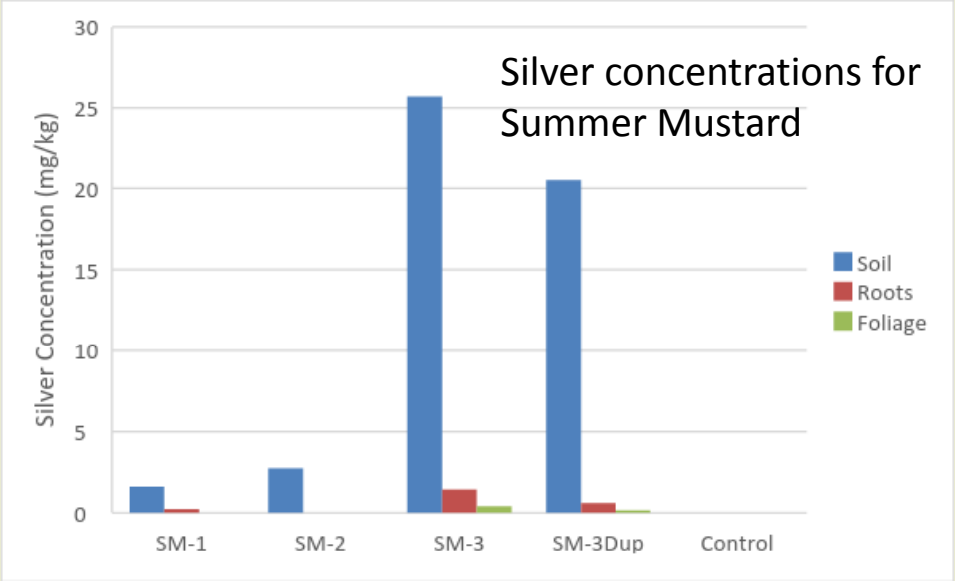


Field Results: **Mercury**

- No mercury uptake observed by any species
- All root and foliage mercury concentrations were below the detection limit of 0.1 mg/kg
- Mercury was below the detection limits in soil associated with Palmer's Goldenbush, Narrowleaf Milkweed, and Purple Needlegrass (so no Hg uptake was possible)

Field Results: **Silver**

- Silver was observed in the roots of all plant species except for Palmer's Goldenbrush and Purple Needlegrass
- Summer Mustard was the only species that showed uptake of silver into the foliage – but at much lower concentrations than the soil



Field Screening Summary

Contaminant	Plant Species	Root Conc.	Foliage Conc.
PAHs	Blue Elderberry	1740 ug/kg	-
	Yerba Santa	200 ug/kg	-
	Purple Needlegrass	703 ug/kg	-
Chlorinated Dioxins/Furans	Blue Elderberry	1026 ng/kg	-
	Yerba Santa	421 ng/kg	901 ng/kg
	Purple Needlegrass	2237 ng/kg	694 ng/kg
	Palmer's Goldenbush	432 ng/kg	757 ng/kg
Silver	Laurel Sumac	7.34 mg/kg	-
	Summer Mustard	1.43 mg/kg	0.405 mg/kg
PCBs	No Uptake	-	-
Mercury	No Uptake	-	-

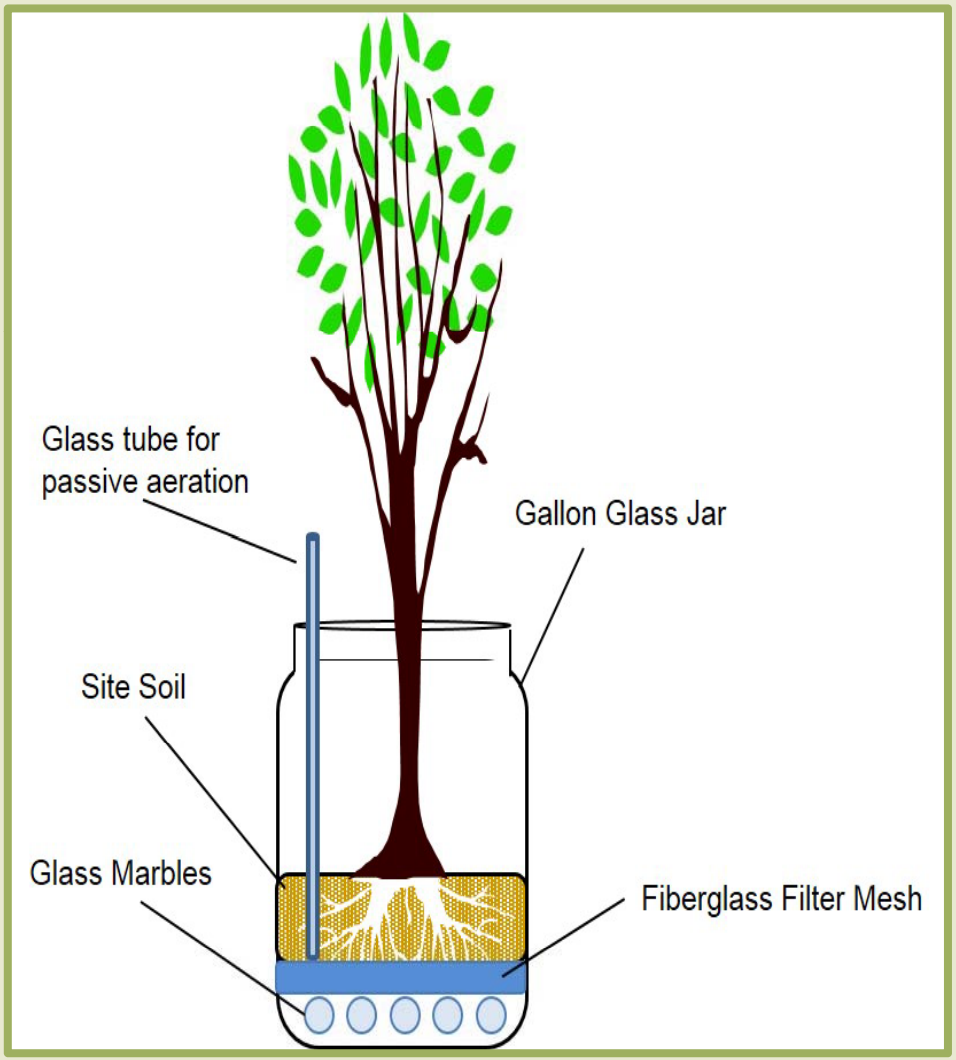
Phase II Greenhouse Microcosms

- Soil collected from SSFL Area IV
- Planted with three species
- 7-month growth
- Measured soil and plant tissue for all COIs

Soil Collection for Greenhouse Experiments

- Bulk soil collected
  - Collected from the pond area where the plants were sampled
  - Soil sieved (#4 sieve -4.75mm)
  - Homogenized

Microcosm Construction



Unplanted Microcosm

Selection of Species for Phase II (Greenhouse Experiments)

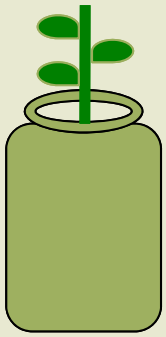
- Coyote Brush (*Baccharis pilularis*) and Mule Fat (*Baccharis salicifolia*) both showed uptake of most contaminants
- A grass species had to be selected without field screening due to growing-season constraints
  - Purple needlegrass (*Nassella pulchra*) was chosen because it is native to the site and known for its resilience

Coyote Brush

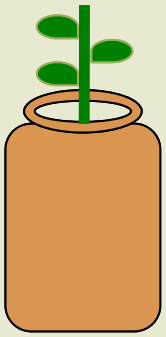
Mule-Fat

Purple Needlegrass

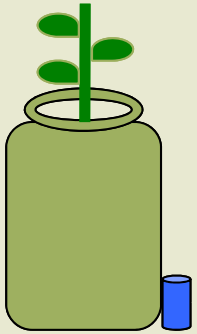
Greenhouse Microcosms



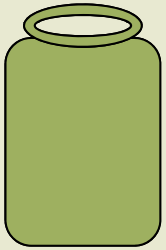
Un-amended Microcosms
Three species



Sterilized Microcosms
Only one species

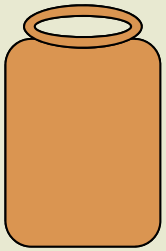


Fertilized Microcosms
Only one species



Unplanted Microcosms

Chelated Microcosms
Only one species



Sterilized (gamma)
Unplanted Microcosms

5 replicates for each treatment

7-month greenhouse study – soil analyzed at 0, 3 and 7 months

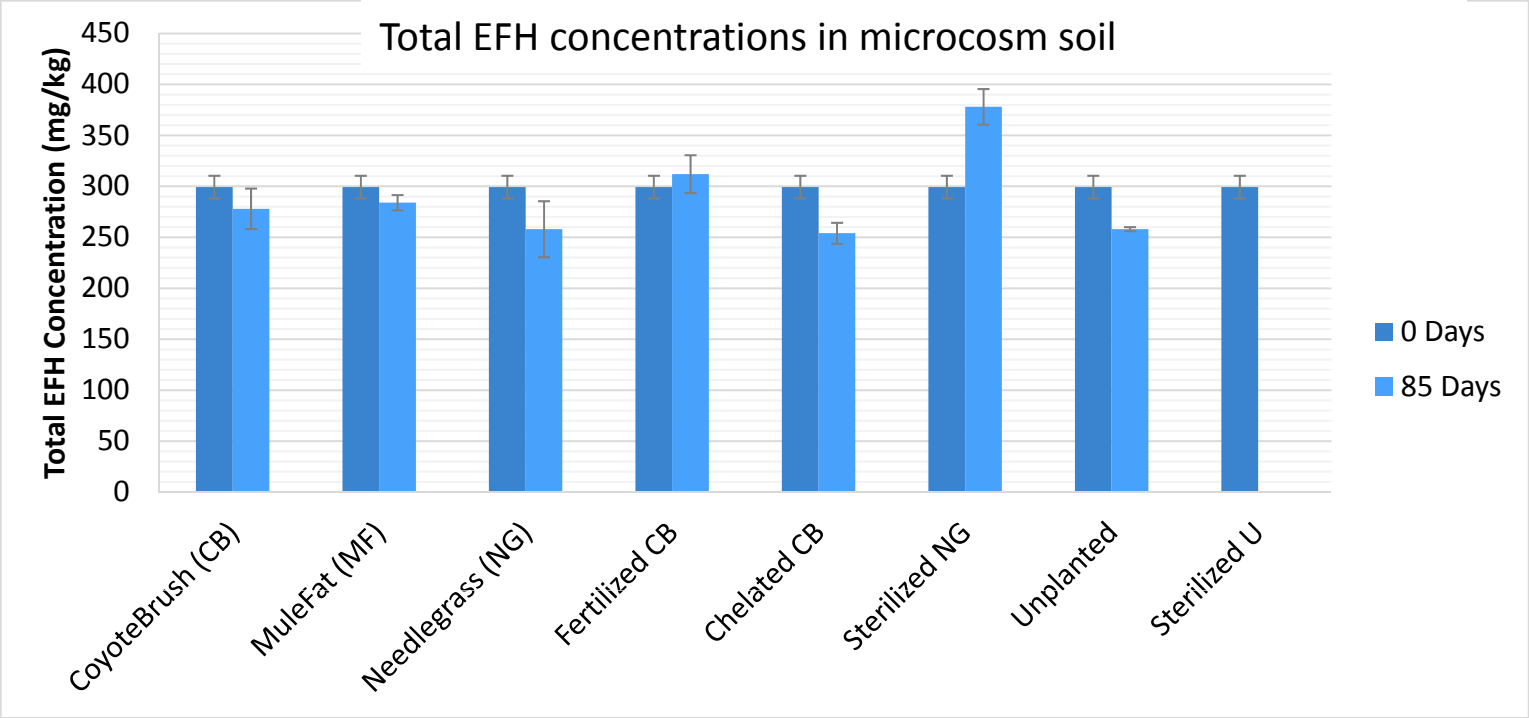
Final Sampling

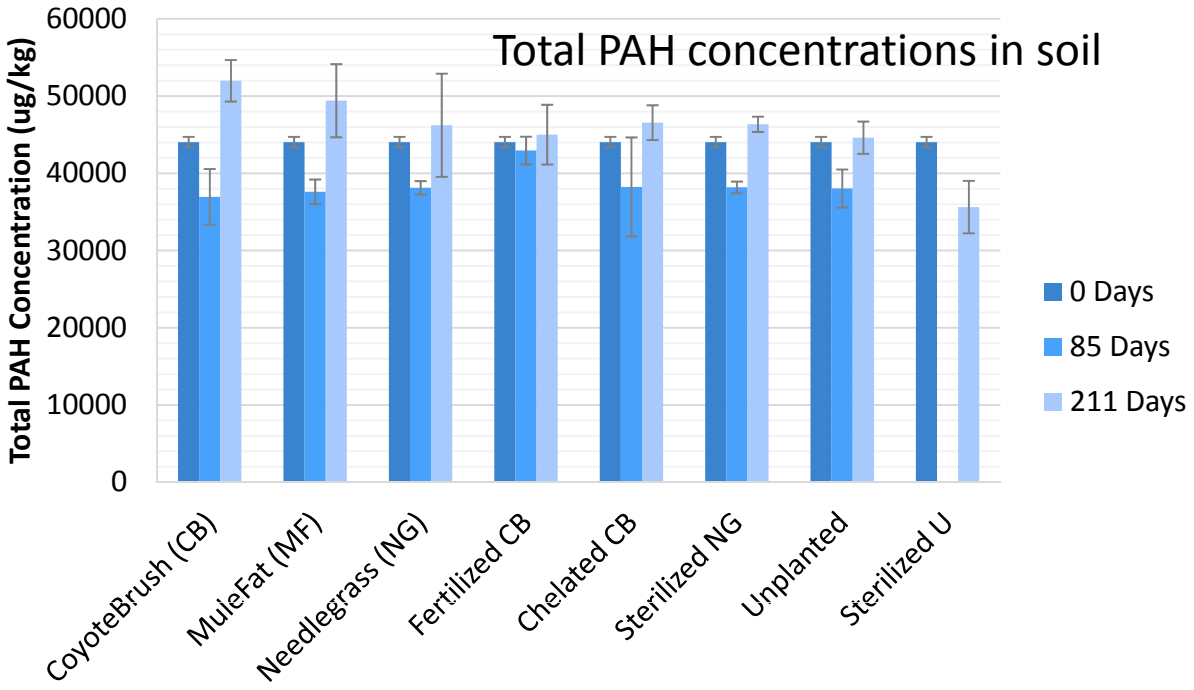
Plants at Day 211

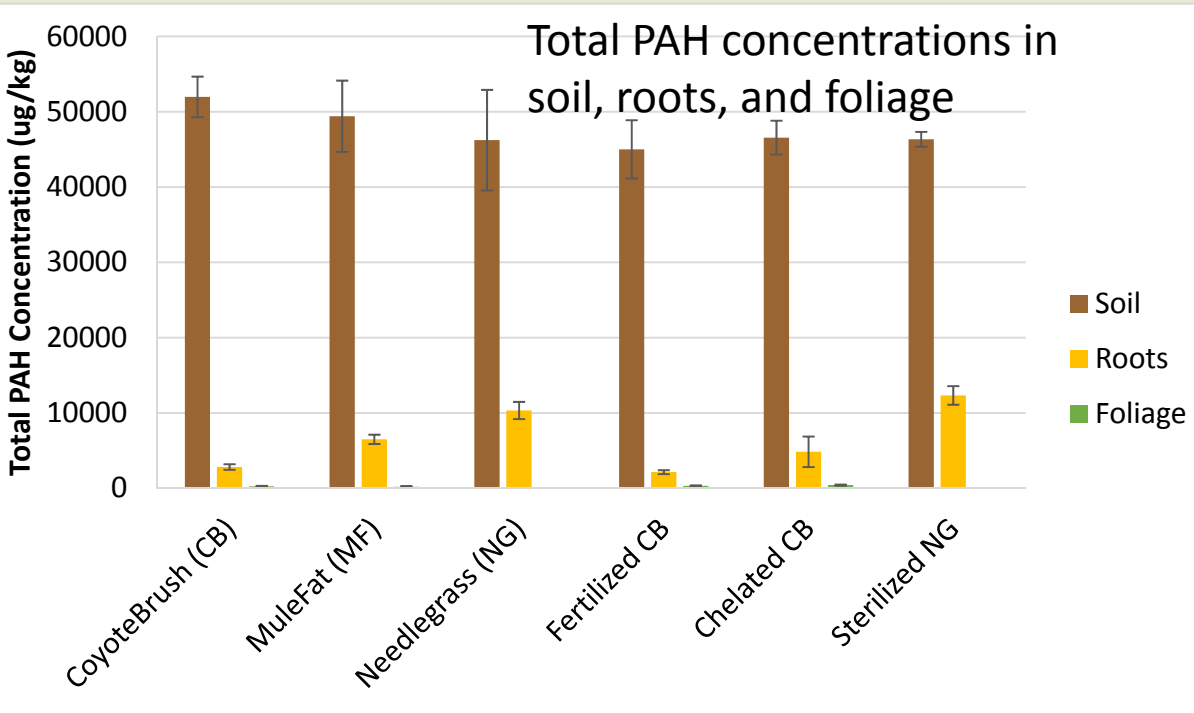
Roots and Foliage Drying

Microcosm Results: **Petroleum Hydrocarbons**

- Slight decreases in EFH soil concentration observed after 85 days incubation for all microcosms except the sterilized control and the fertilized microcosms
- EFH concentrations at Day 211 under investigation
- Plant tissue was not analyzed for EFH because compounds produced by the plants interfered with the EFH analysis





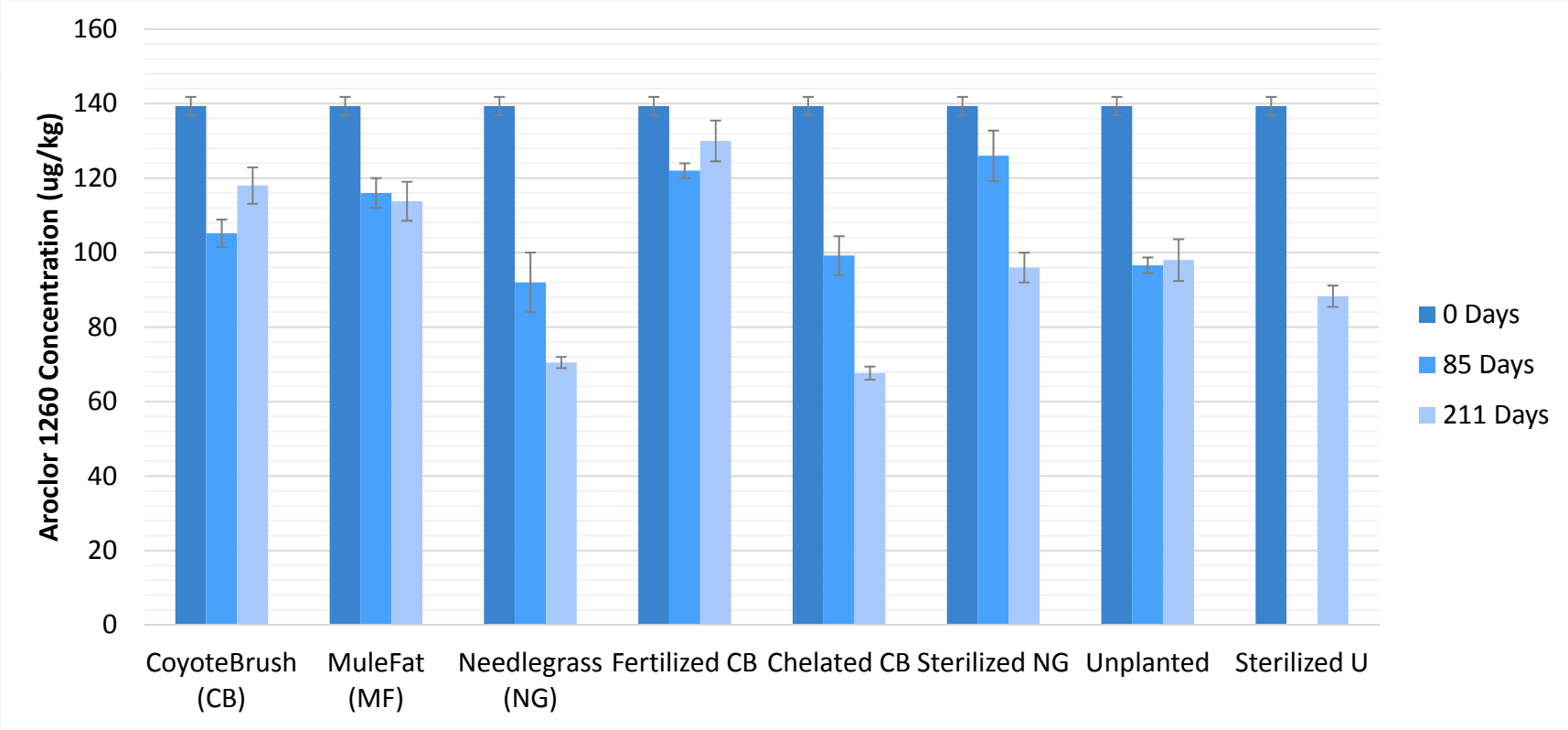


Microcosm Results: **Polyaromatic Hydrocarbons (PAHs)**

- **No statistically significant change in soil PAH concentrations observed after 211 days.**
- **PAHs observed in the root tissue of all plants.**

Microcosm Results:
Polychlorinated Biphenyls (PCBs)

- PCB (Aroclor 1260) concentrations appeared to decrease in all soils for all microcosm treatments

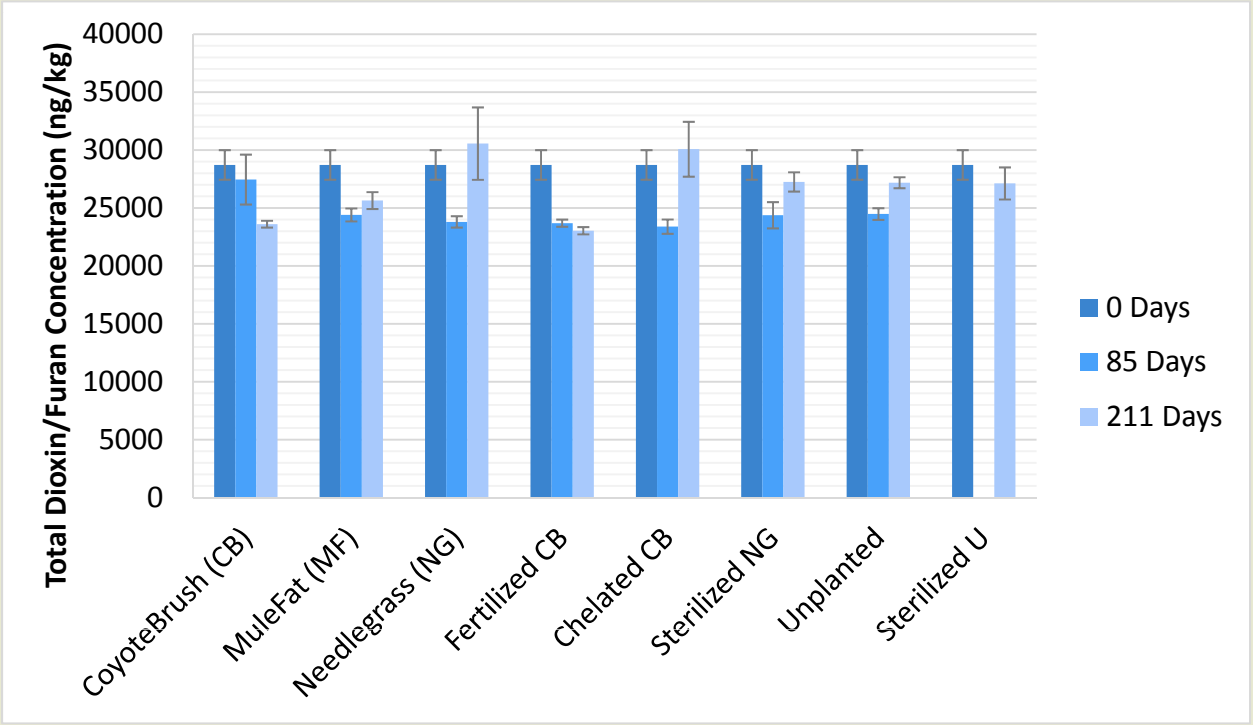


Microcosm Results:
Polychlorinated Biphenyls (PCBs) cont'd.

- Decreases in Aroclor 1260 soil concentrations were:
  - Unplanted control: 29.7%
  - Sterilized Purple Needlegrass: 31.1%
  - Sterilized unplanted: 36.6%
  - Purple Needlegrass: 49.4%
  - Chelated Coyote Brush: 51.4%
- Only Purple Needlegrass plant tissue was analyzed for PCBs and it was not detected

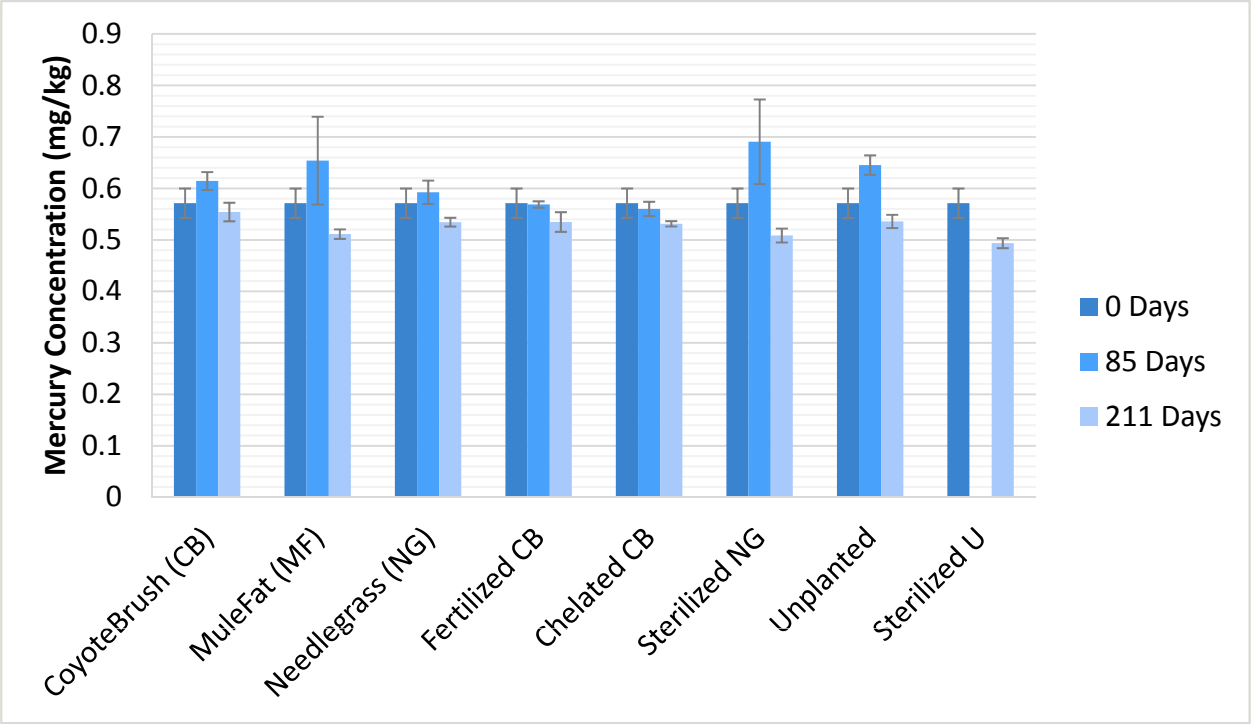
Microcosm Results:
Chlorinated Dioxins/Furans

- Coyote Brush (fertilized and unfertilized) showed significantly lower dioxin/furan soil concentrations than the unplanted control
- Some dioxin uptake observed in roots of Coyote Brush



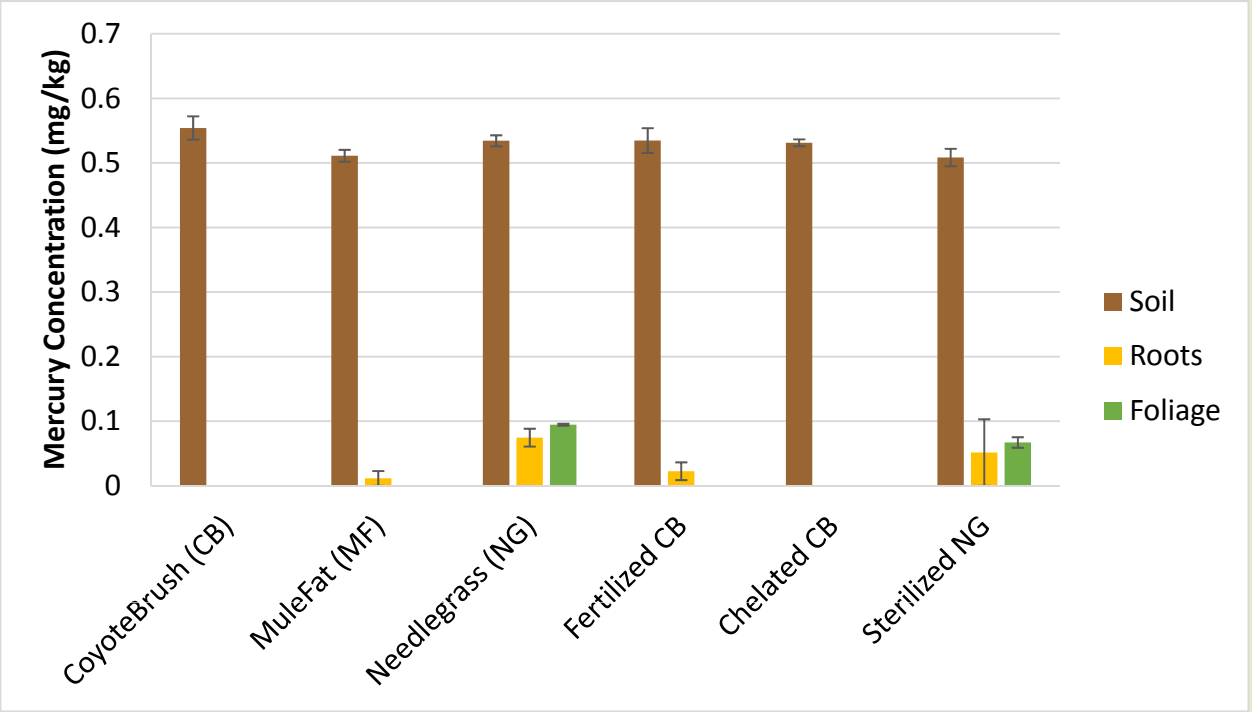
Microcosm Results: **Mercury**

- Mercury concentrations in the soil of all microcosms decreased slightly (but not statistically significant)
- Chelation with EDTA did not enhance uptake of mercury



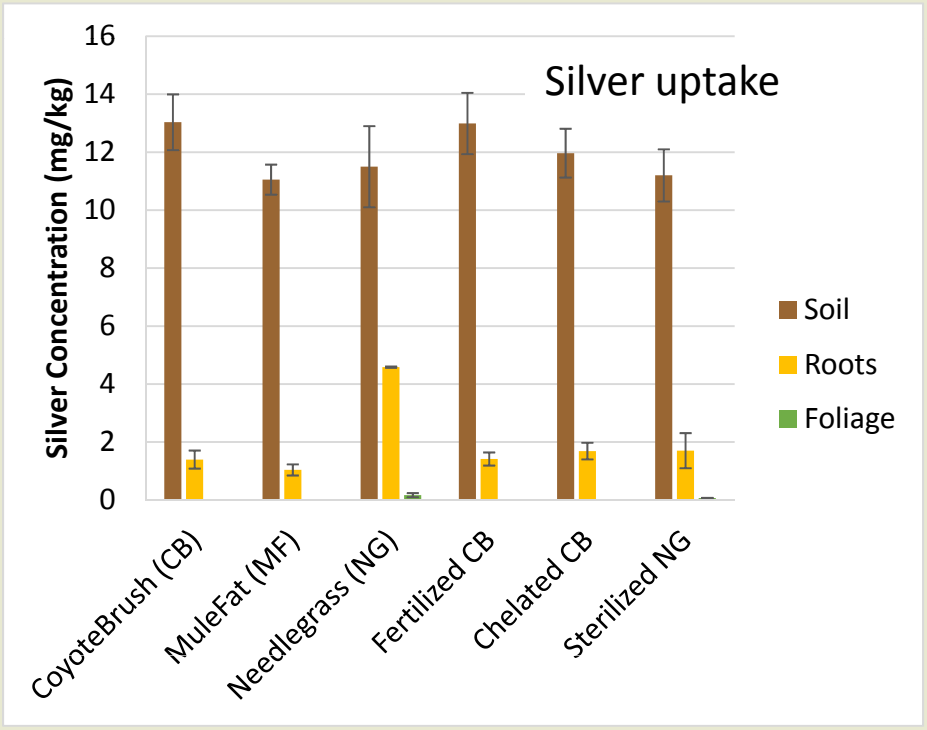
Microcosm Results: **Mercury cont'd.**

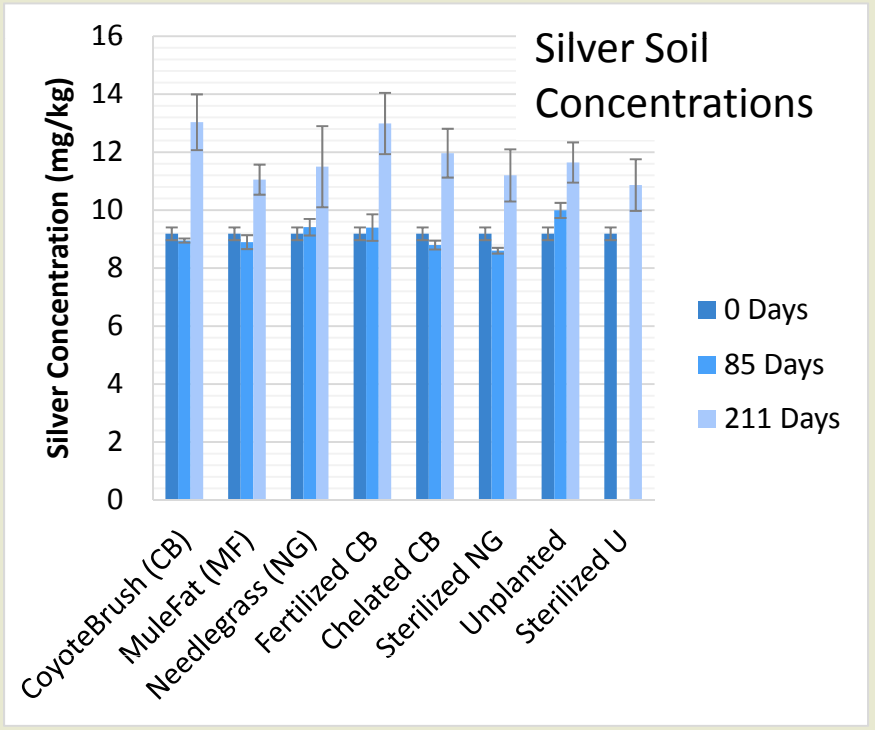
- Mercury uptake into roots and foliage only observed for Purple Needlegrass
- Chelation with EDTA did not enhance uptake of mercury



Microcosm Results: **Silver**

- Silver was observed in the root tissue of all plant species tested, but no decreases in silver concentration were observed in soil.
- Silver concentrations in the soil appeared to increase at Day 211, but this is likely an analytical anomaly since all silver concentrations increased.





Volatilization from Plants

- Preliminary tests were done to test for volatilization of COIs from the plants
- No COIs were detected
- Chemicals that were detected in off gas from plants growing in contaminated soil included: D-limonene, stearic and oleic acids, and stigmastan-3, 5-diene
  - Stearic and oleic acids are produced by plants of the *Baccharis* genus and also found on human skin
  - Stigmastan-3, 5-diene is an antimicrobial compound emitted from avocado roots and appears to be produced by the greenhouse plants

Conclusions

- Petroleum hydrocarbons:
  - Petroleum hydrocarbon degradation rates appeared to be slow over the first 85 days – with or without plantings.
  - Final EFH concentrations at 211 days are inconclusive because of an apparent anomaly in EFH measurement by two different labs - we are currently looking into this.
- Polyaromatic hydrocarbons (PAHs):
  - No significant reductions of soil concentrations of PAHs were observed for any of the microcosms.
- Mercury:
  - No reductions of soil concentrations of mercury were observed.
  - Chelation with EDTA did not improve mercury uptake
- Silver:
  - No reductions of soil concentrations of silver were observed.

Conclusions cont'd.

- Polychlorinated biphenyls (PCBs)
  - Soil PCB concentrations decreased by 13-15% over 7 months for soil microcosms planted with purple needlegrass and coyote brush, relative to sterile controls
  - Since no PCBs were observed in the plant tissue, the mechanism for this reduction appears to be stimulation of soil bacteria.
  - Significant variability of PCB concentrations was observed.
- Chlorinated dioxins/furans:
  - Soil dioxin concentrations decreased by 18-20% over 7 months for soil microcosms planted with coyote brush.
  - Rhizostimulation again appears to be the operative mechanism.
- Overall:
  - Phytoremediation of the residual COIs may be slow and more aggressive forms of remediation may be required to reduce the concentrations of COIs quickly.
  - Phytoremediation could be useful in conjunction with site restoration in areas with low COI concentrations