Phytostabilization with Organic Compost Amendments and Native Plants In the Tri-State Mining District

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CONTENT

Intro to Tri-State Mining District – Jasper

- *Mine/mill waste, geology, soils, metal concentrations*

Regulatory Context: Superfund – NRDAR

Phytoremediation vs phytostabilization

Mechanisms of plant:metal interactions

Soil Chemistry-soil solution- rhizosphere

Soil Chemistry of soil amendments

Miccorhyza and Miriam's research

TSMD Phytotoxicity and FQA studies

Pb/Zn Mine reclamation project

Webb City Project –

- *City regulatory issues – biosolid disposal and NPDES*
- *Poo study –nutrients, metals, PPCPs, PFAS*
- *NRDAR property purchase, wetland treatment, composting,*
- *Pant species selection*
- *Poo application and revegetation*
- *Wilson Lake and Bens Branch – treatment wetland, biochar, or BCR*
- *Long Term Monitoring*

PHYTOREMEDIATION/PHYTOEXTRACTION VS PHYTOSTABILIZATION

- *Hybrid poplars uptake of soluble organics*
- *Plants that hyperaccumulate metals to be harvested*

- *Goal is to stabilize soil such that metals are not taken up by plants or otherwise mobilized by erosion or bioaccumulation*

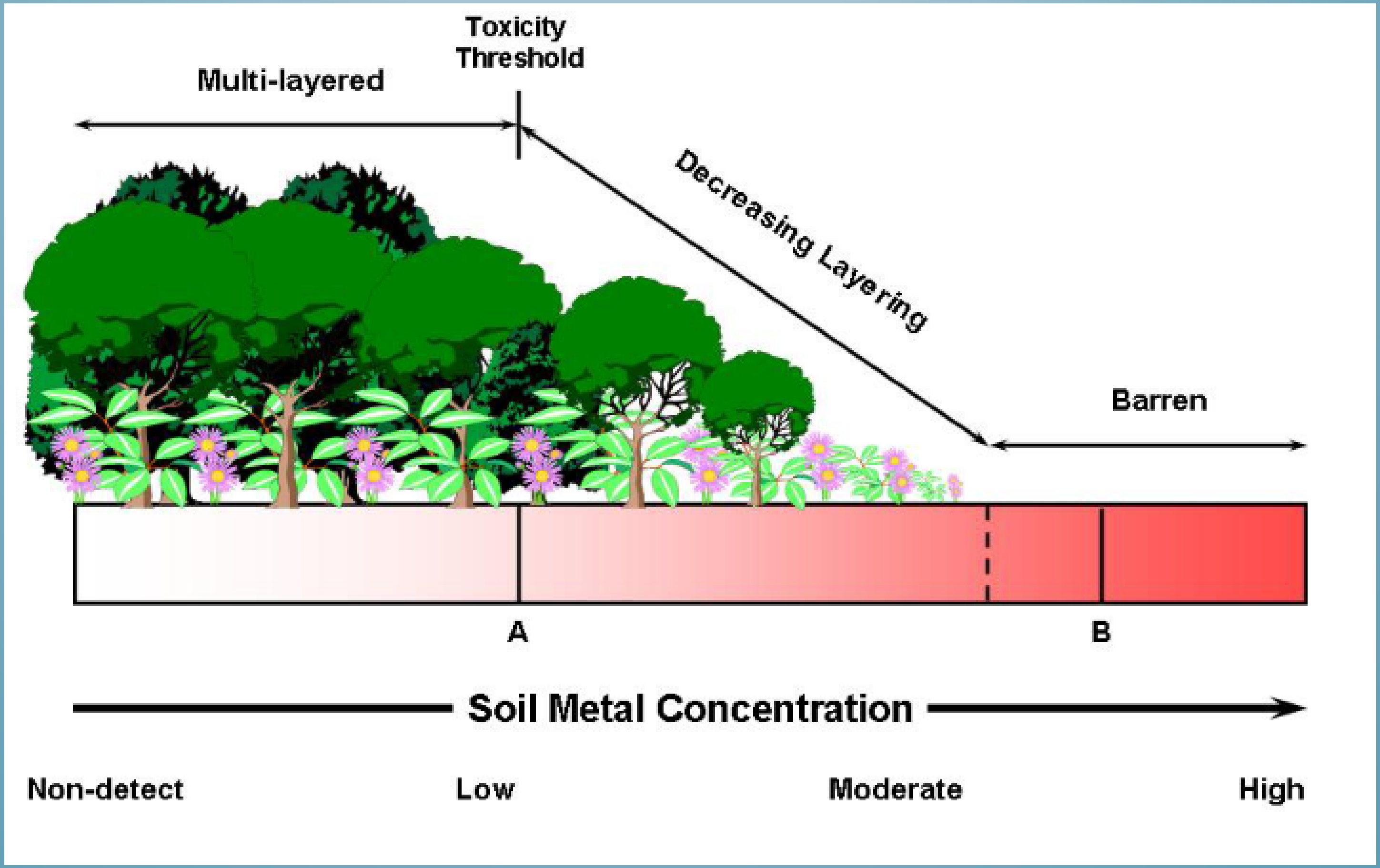
CERCLA RESPONSE AND NATURAL RESOURCE DAMAGE ASSESSMENT AND RESTORATION (NRDAR)

- Determining what resources have been injured by the release of hazardous substances and oil.
- Superfund Sites involve evaluation of residual injury after EPA's remediation.

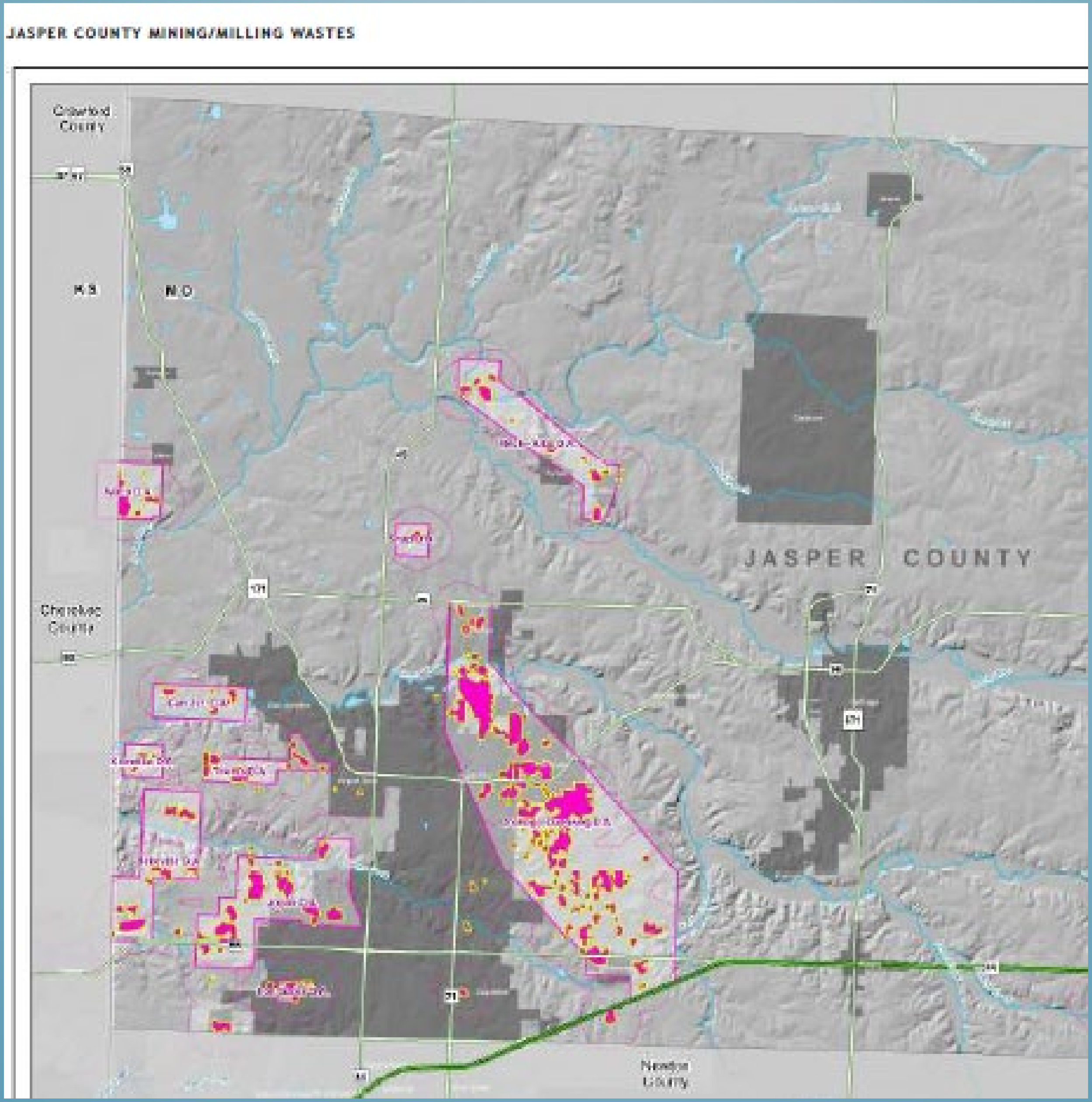
AND

- Compensating the public through environmental restoration for injured natural resources.

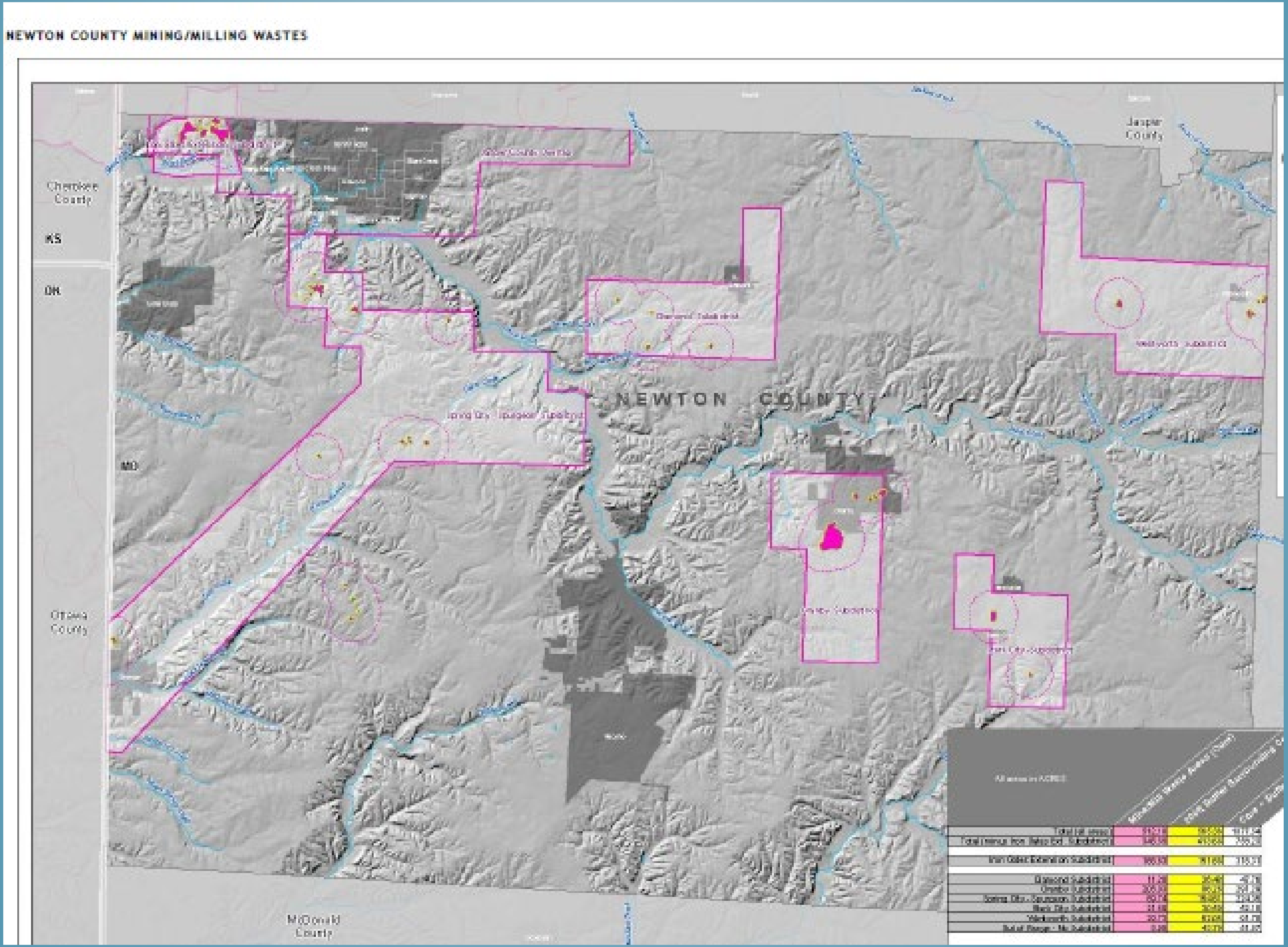
- *NRDAR Trustees investigated phytotoxicity in part due to greater ecosystem implications*



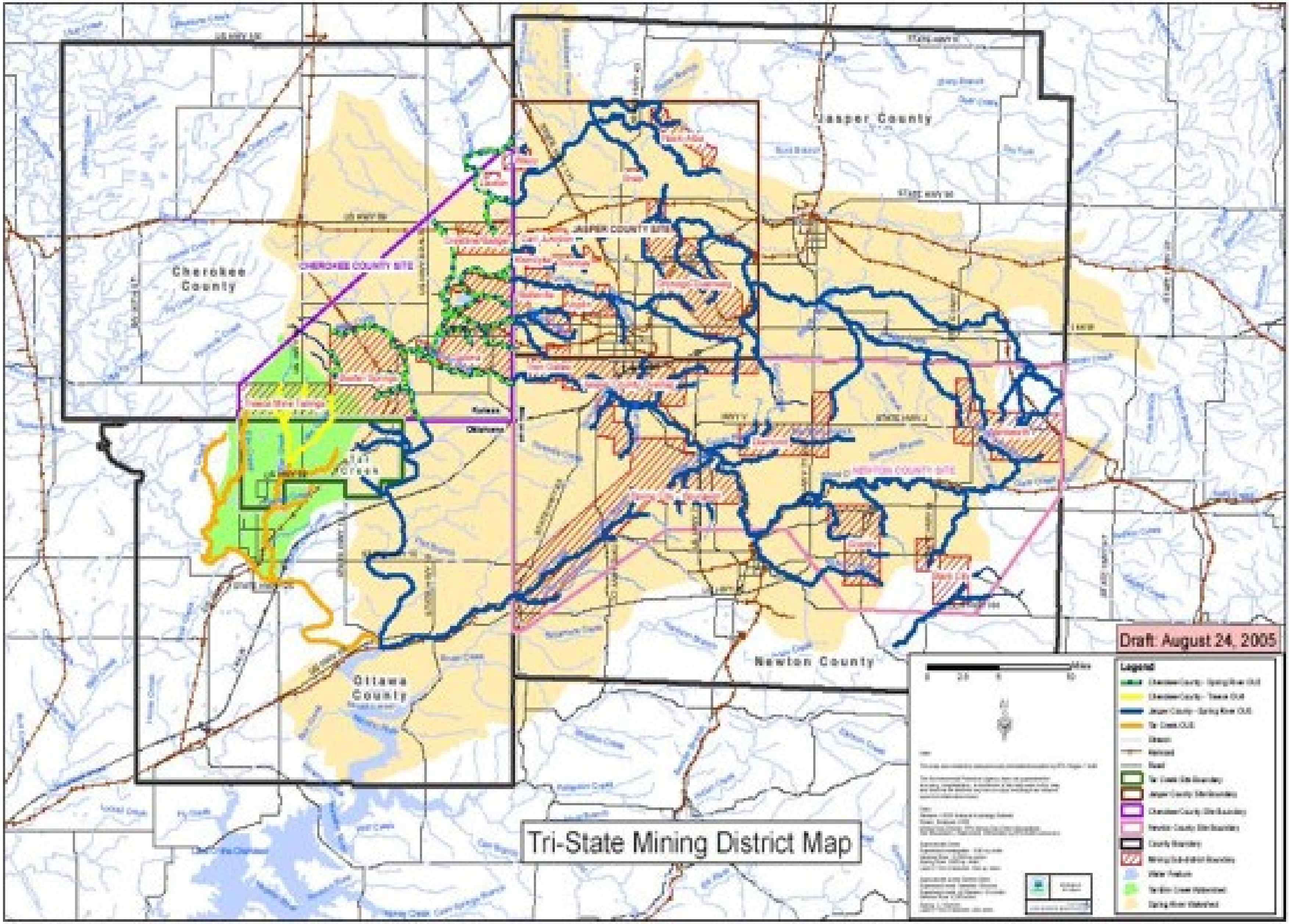
ORONOGO/DUENWEG MINING BELT (JASPER COUNTY) SUPERFUND SITES



NEWTON COUNTY MINING SUPERFUND SITE



Tri-State Mining District



Barren Chat & Mill Foundations


28 5:40PM

Carterville, MO
Chat and Subsidence Pits

NATIVE PRAIRIE
DIAMOND GROVE PRAIRIE CONSERVATION AREA

JASPER COUNTY SITE METAL CONCENTRATIONS

Table 2-2 Chat Data Summary

Designated Area	Total Acres	Volume (cu yds)	Cadmium (mg/kg) Range	Cadmium Avg	Lead (mg/kg) Range	Lead Avg	Zinc (mg/kg) Range	Zinc Avg
Carl Junction	27	79,770	10.2-146	65	48-177	96	14,300-20,800	8,979
Joplin	254	760,970	28.7-124	54	116-1,020	332	5,510-20,800	9,333
Neck/Alba	68	203,158	30.4-92.3	47	22-170	102	7,310-15,400	9,248
Oronogo/Duenweg	1,673	3,595,959	3.7-152	54	72-6,000	943	466-37,200	9,253
Snap	2	8,103	12-24.2	18	152-274	194	3,080-6,650	4,739
Thoms	17	37,441	9.9-64.1	36	61-3,130	1,034	1,000-16,400	5,545
Waco	7	9,247	48.2-107	89	39-260	159	7,480-17,700	12,675
Iron Gates	3	18,600	16-110	67	47-640	307	1,200-38,000	19,757
Belleville	65	444,415	33-140	88	32-550	182	4,800-30,000	18,378
Klondike	78	17,307	5-71	45	54-850	302	960-16,000	8,030
Iron Gates Ext	157	557,220	1.5-80.3	43	43.7-4,130	778	384-34,500	9,105
Totals	2,351	5,732,190	---	55	---	403	---	10,458[1]

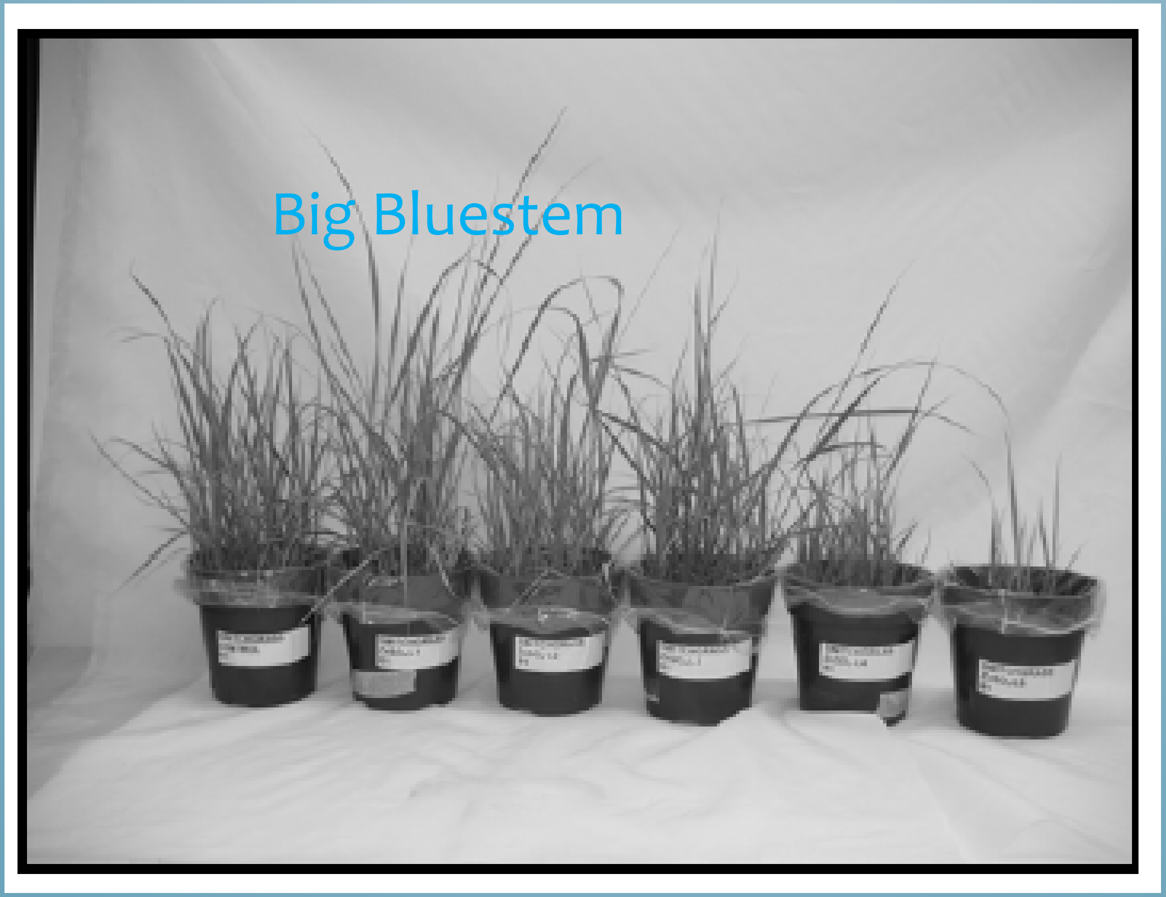
Source: Dames & Moore 1995a; CDM Federal 1995a; and CDM Federal 1995b.
[1] average of DA means.

Table 2-3 Vegetated Chat Data Summary

Designated Area	Total Acres	Volume (cu yds)	Cadmium (mg/kg) Range	Cadmium Avg	Lead (mg/kg) Range	Lead Avg	Zinc (mg/kg) Range	Zinc Avg
Carl Junction	13	28,786	1.4-88.5		27-146	80	261-12,200	3,383
Joplin	215	183,471	3.9-175		47-13,300	1,172	443-28,000	13,232
Neck/Alba	93	85,518	6-190		35-2,500	390	598-25,400	12,268
Oronogo/Duenweg	617	527,371	<2-202		28-7,600	1,217	273-35,800	11,181
Snap	8	6,456	12.9-119		65-1,320	660	2,330-18,300	6,881
Thoms	29	33,539	4-128		46-284	145	444-8,440	3,935
Waco	94	150,408	40.9-148		82-2,600	327	5,580-22,800	12,165
Iron Gates	85	NA	5.9-8		92-210	165	1,600-2,000	1,811
Belleville	214	NA	<1.3-55	14	63-1,200	321	120-4,000	1,562
Klondike	3	NA	12-17	14	93-230	171	1,300-2,500	1,901
Iron Gates Ext	NA	NA	38.9-109	69	76.4-3,360	1,321	9,830-19,300	13,607
Totals	1,371	1,015,549+	---	47	---	543	---	7,307[1]

Source: Dames & Moore 1995a; CDM Federal 1995a; and CDM Federal 1995b
[1] average of DA means.
NA = Volume estimates for vegetated chat not available as the volume estimates are included in the general chat category, Table 2-2.

PIERZYNSKI AND FICK (2005) PHYTOTOXICITY STUDY USING JASPER COUNTY CHAT



Increasing Zn concentration

PHYTOTOXICITY AND FLORISTIC QUALITY

Critical values for 90% of control yield – Switchgrass

	--------------- critical value -------------			
Zn Source	Total Zn	DGT Zn	$Ca(NO_3)_2$	Shoot Zn
	- mg/kg -	-umol/L-	------ mg/kg ------	
Chat	1555a	708a	82a	228a

Sample	n	No. Species	Dominant Species
Chat,>2000	65	3.5a	C. ragweed, moss
Chat,<2000	5	4.8a	S. sumac, G. goldenrod
Soil, >2000	43	4.7a	C. ragweed, moss
Soil, <2000	47	6.3b	B. bluestem, L. bluestem

Floristic Quality Assessment

Metal	FQA measure (y)	Regression equation	p	R^2	Estimated metal concentration (x; milligrams per kilogram) for indicated percent reduction in FQA measure		
					10 percent ($y = 0.9$)	15 percent ($y = 0.85$)	20 percent ($y = 0.8$)
SEMO							
Pb	Mean C	$y = -0.042\ln(x) + 1.179$	<0.001	0.416	713	2318	--
	FQI	$y = -0.043\ln(x) + 1.198$	0.018	0.127	1011	3229	--
Zn	Mean C	$y = -0.053\ln(x) + 1.211$	<0.001	0.452	341	869	--
	FQI	$y = -0.068n(x) + 1.293$	0.001	0.216	326	681	--
TSMD							
Pb	Mean C	$y = -0.100\ln(x) + 1.289$	0.001	0.598	49	80	132
	FQI	$y = -0.124\ln(x) + 1.344$	0.005	0.491	36	54	82
Zn	Mean C	$y = -0.077\ln(x) + 1.299$	<0.001	0.687	175	335	640
	FQI	$y = -0.102\ln(x) + 1.401$	0.001	0.649	134	218	356
Combined (SEMO & TSMD)							
Pb	Generalized Linear Model analyses do not support using combined models for Pb						
Zn	Mean C	$y = -0.072\ln(x) + 1.287$	<0.001	0.679	220	441	884
	FQI	$y = -0.097\ln(x) + 1.412$	<0.001	0.525	193	323	540

Mean C is the arithmetic mean C value of all native species occurring in a site or sampling unit, and is independent of species richness. The Floristic Quality Index (FQI) is the product of Mean C and the square root of the native species richness (FQI= mean C*√n)

EPA PRELIMINARY REMEDIAL GOALS VS PHYTOTOXICITY ASSESSMENTS

- *EPA Cleanup Levels = 400 mg/kg Pb, 40 mg/kg Cd, 6400 mg/kg Zn*
- *Phytotoxicity Levels = 356 to 1555 mg/kg Zn*

- *EPA did not consider phytotoxicity in Jasper County Mine/Mill Waste Cleanup (OU-1)ROD*

- *Trustees must address phytotoxicity to conduct primary (on-site) restoration*

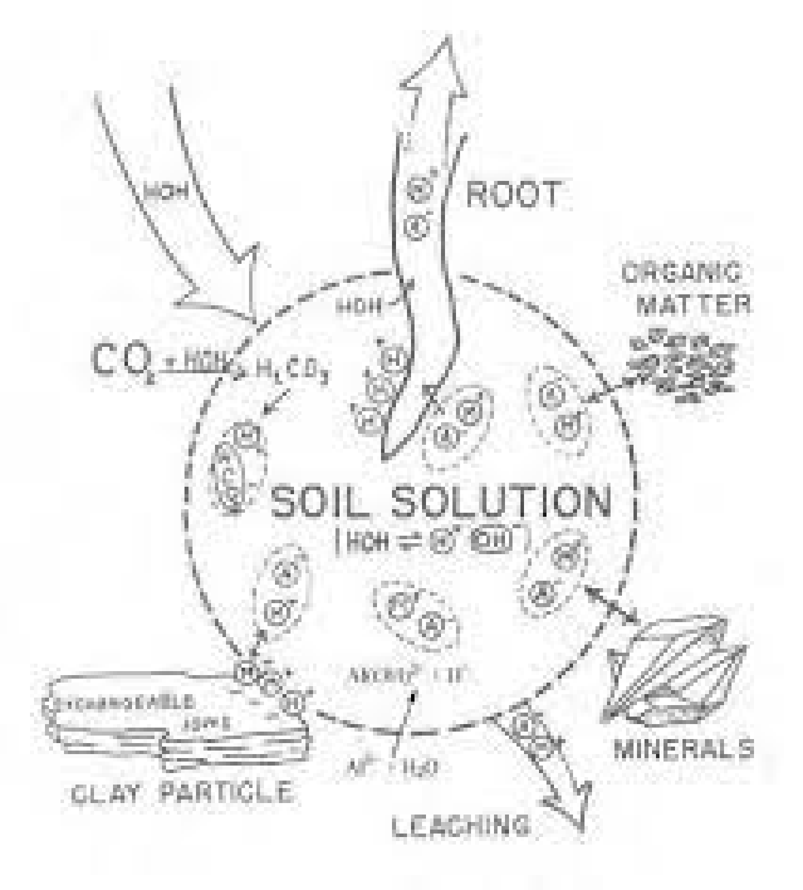
SOIL SOLUTION AND CONTROLLING FACTORS

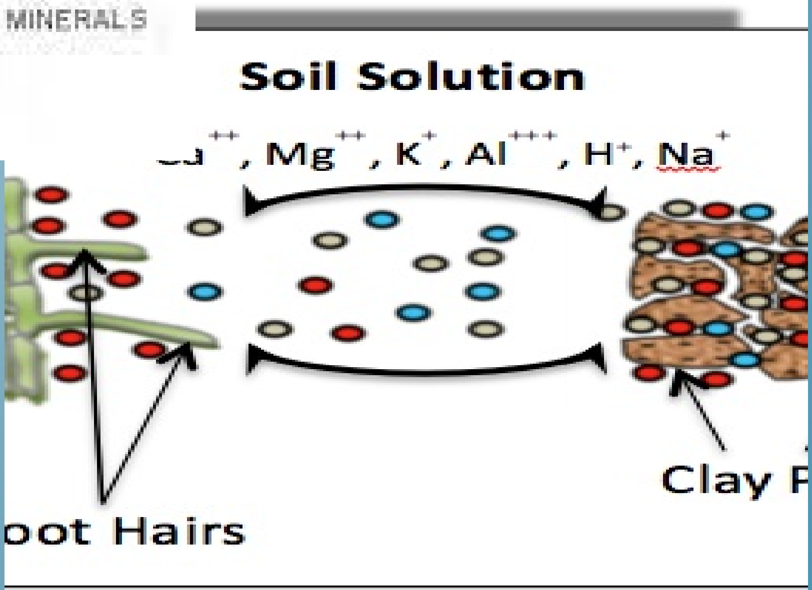
Master variables:

- *pH*
- *OC*
- *CEC*

Metal solubility and phytoavailability:

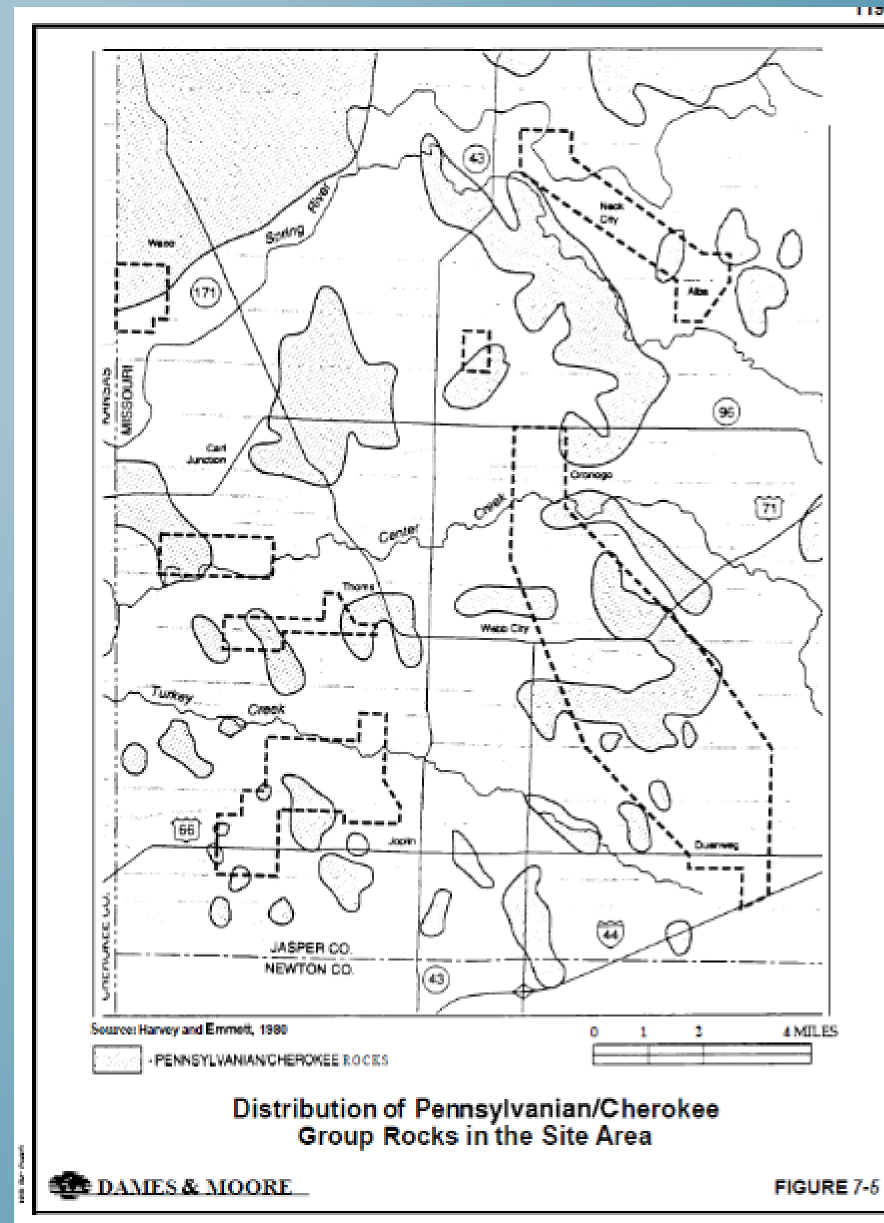
- *Cd>Zn>>Pb*



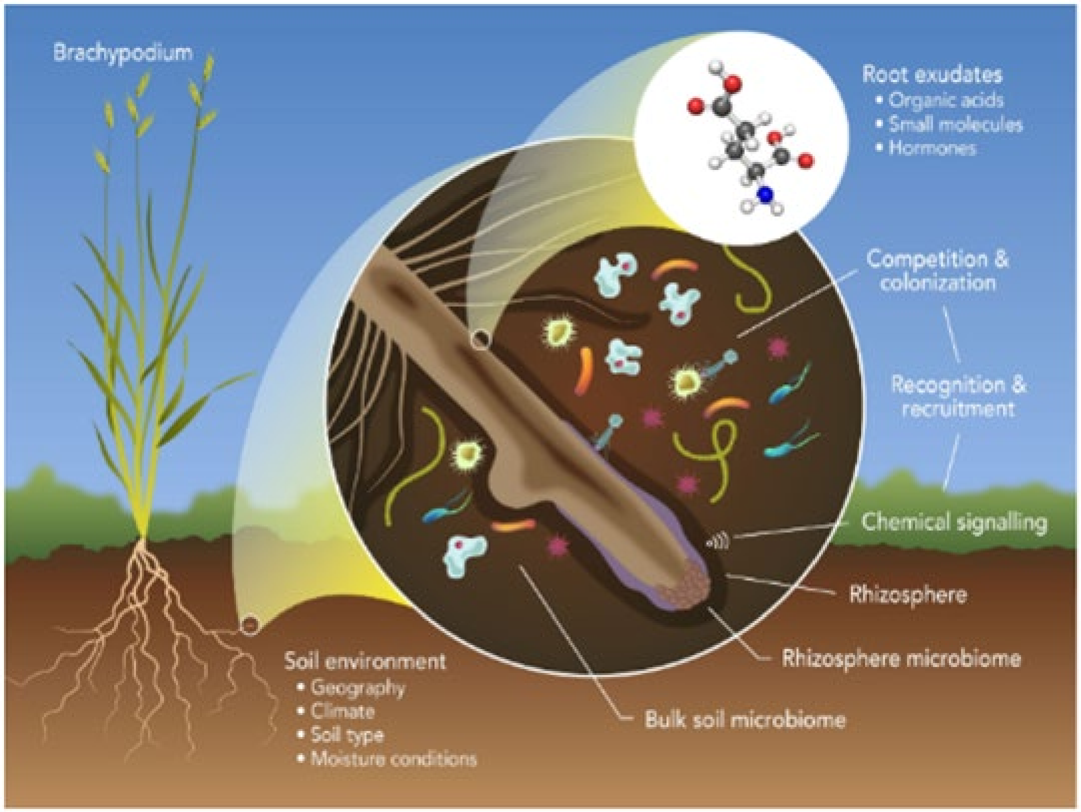


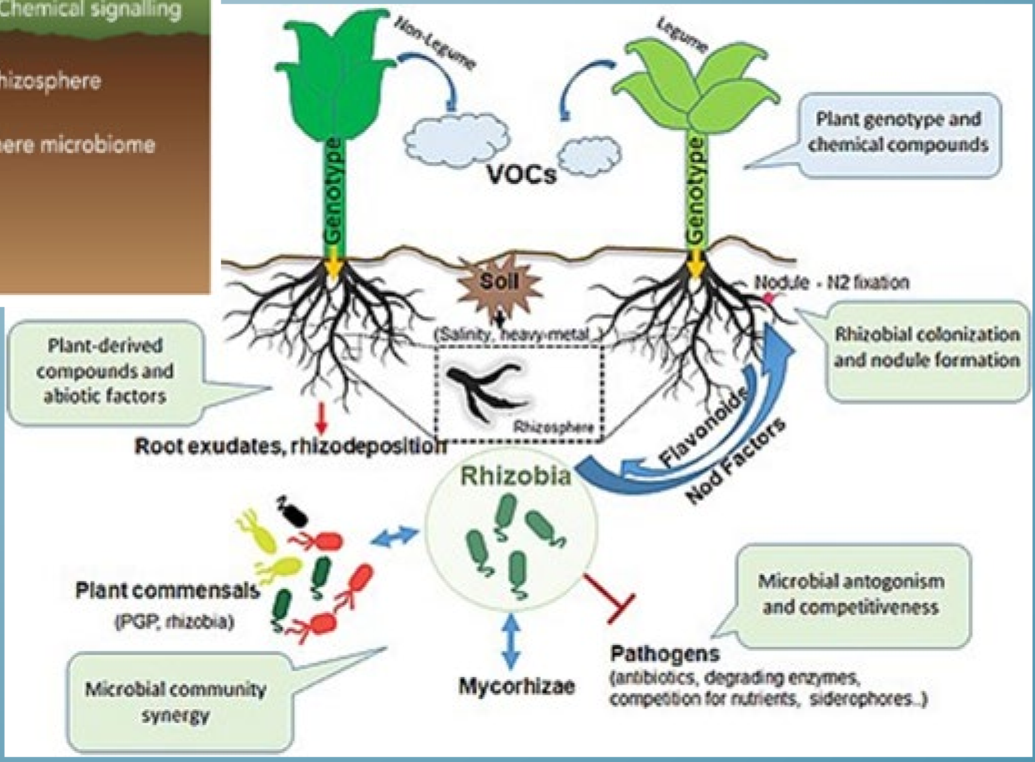
JASPER COUNTY GEOLOGY AND SOILS VARY FROM CALCAREOUS TO SLIGHTLY ACIDIC

- Geology is Pennsylvanian shales to Mississippian limestones and dolomite
- Soils vary from calcareous to slightly acidic
- Alkalinity tends to reduce plant uptake of metals
- Phytotoxicity mechanisms for Zn include competition with Fe and Ca necessary for cell function.



RHIZOSPHERE: WHERE COMPLEX CHEMISTRY AND BIOLOGY HAPPENS THAT CONTROLS NUTRIENT AND POLLUTANT UPTAKE





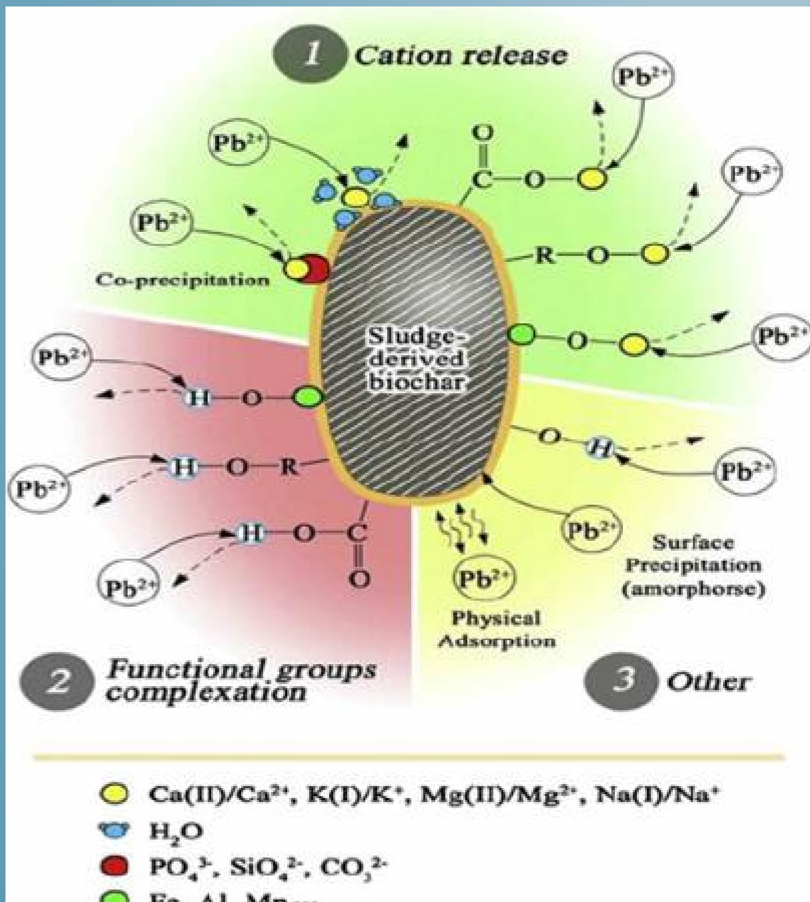
MECHANISMS OF PLANT ACCUMULATION AND RESISTANCE TO METAL TOXICITY

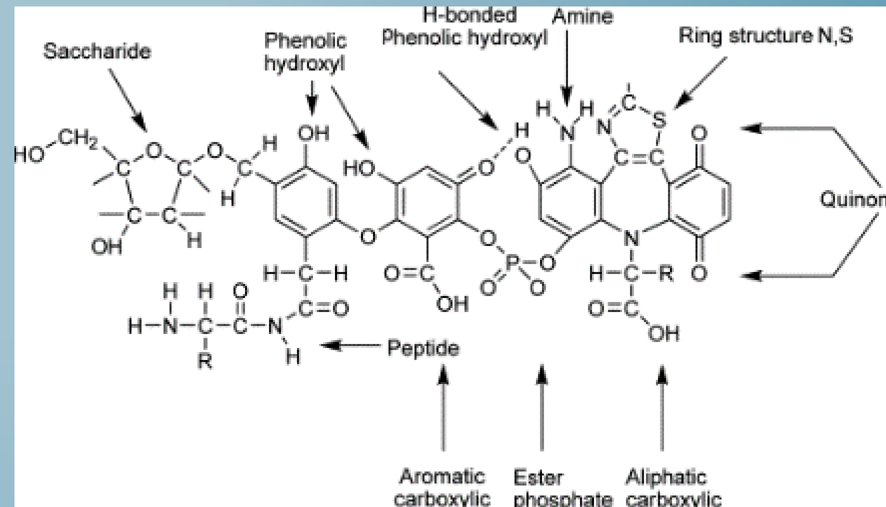
Table 1. Types of plant strategies allowing them to adapt to the presence of heavy metals.

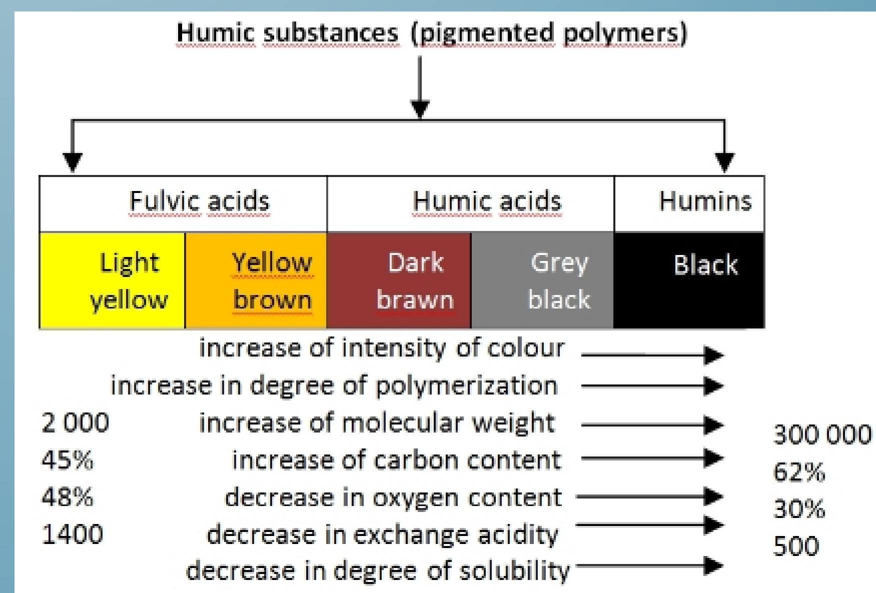
#	Type of Strategy	Description
1	Strategy for avoiding heavy metal uptake	• The formation of symbioses with rhizospheric microorganisms which stimulate plant growth under stress conditions [7]. • Developing mechanisms which prevent heavy metals from entering the root cells by releasing substances into the soil that immobilize metals [8]. • The formation of a rhizosphere oxidation zone which oxidizes metals, thus reducing their solubility and availability [9]. • A rhizospheric pH change, whereby an alkaline environment reduces metal availability [10]. • Reduction in cell wall permeability, which forms a barrier against protoplast metal penetration [11]. • Cell wall modification by creating surface components (callose, lignin, cutin) or by increasing the wall's metal accumulation capacity [12].
2	Strategy of plant tolerance to heavy metals (ion uptake and neutralization)	• Change in expression of genes encoding tonoplast transporters, responsible for metal ion uptake and sequestration, contributes to an activity reduction [13]. • Binding of metal ions (involved in metabolism) by proteins—chaperones and their transport to cellular compartments which use the ions, e.g., incorporating them into enzymatic molecules [14]. • Chelation of heavy metals into the cytosol by metallothionine classes I and II, organic acids, and the amino acids (histidine), glutathione (GSH), phytochelatin (PC), and nicotianamine (NA), followed by transfer of complexes to the vacuole or cell wall [15]. • The production of heat-shock proteins (HSP), with a regenerative function, that efficiently and quickly repair damage [12].

- Skuza L, Szućko-Kociuba I, Filip E, Bożek I. Natural Molecular Mechanisms of Plant Hyperaccumulation and Hypertolerance towards Heavy Metals. Int J Mol Sci. 2022 Aug 19;23(16):9335. doi: 10.3390/ijms23169335. PMID: 36012598; PMCID: PMC9409101.

COMPOST, BIOCHAR, ORGANIC MATTER METAL SEQUESTRATION







RELATED RESEARCH: MARIAM AL-LAMI MS&T ARBUSCULAR MYCORRHIZAE FUNGI (AMF) SYMBIOSIS

Stimulate a Beneficial AMF Symbiosis in Extremely Degraded Tailings

- AMF highly sensitive to **P** which could be the case under **BS** application
- AMF can be sensitive to **metal toxicity**

- **Experimental Design:**
  - Biochar facilitative effects on AMF abundance and functioning

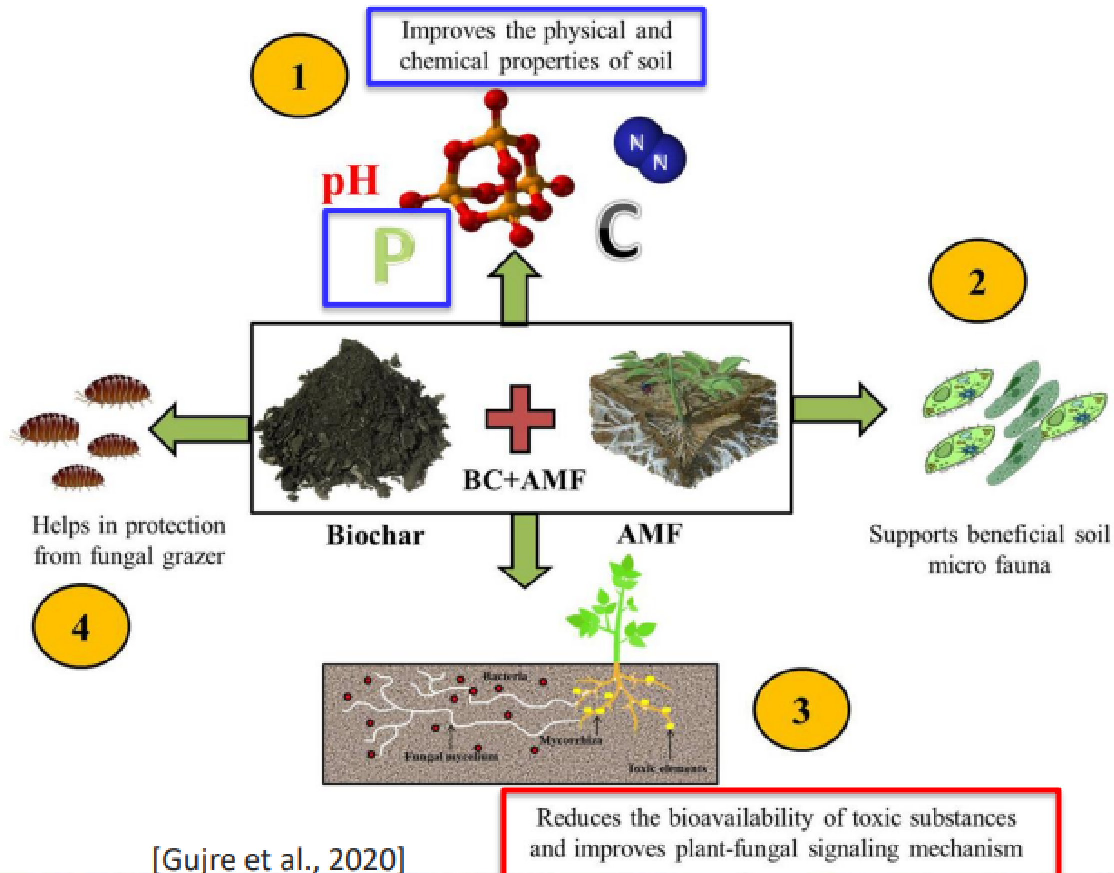
AMF

+

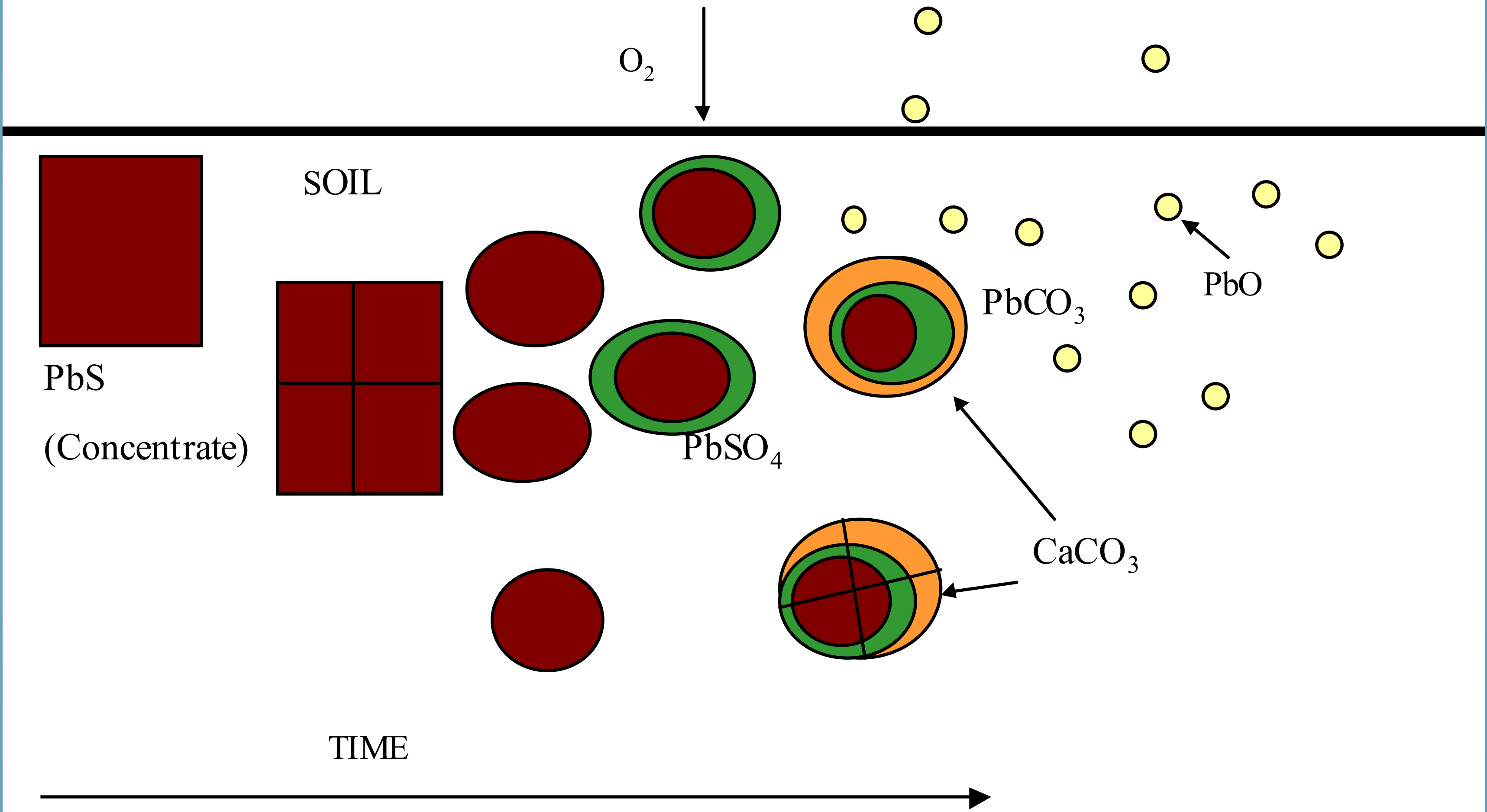
BS + BC

- **The synergistic benefits of this combination never been tested**

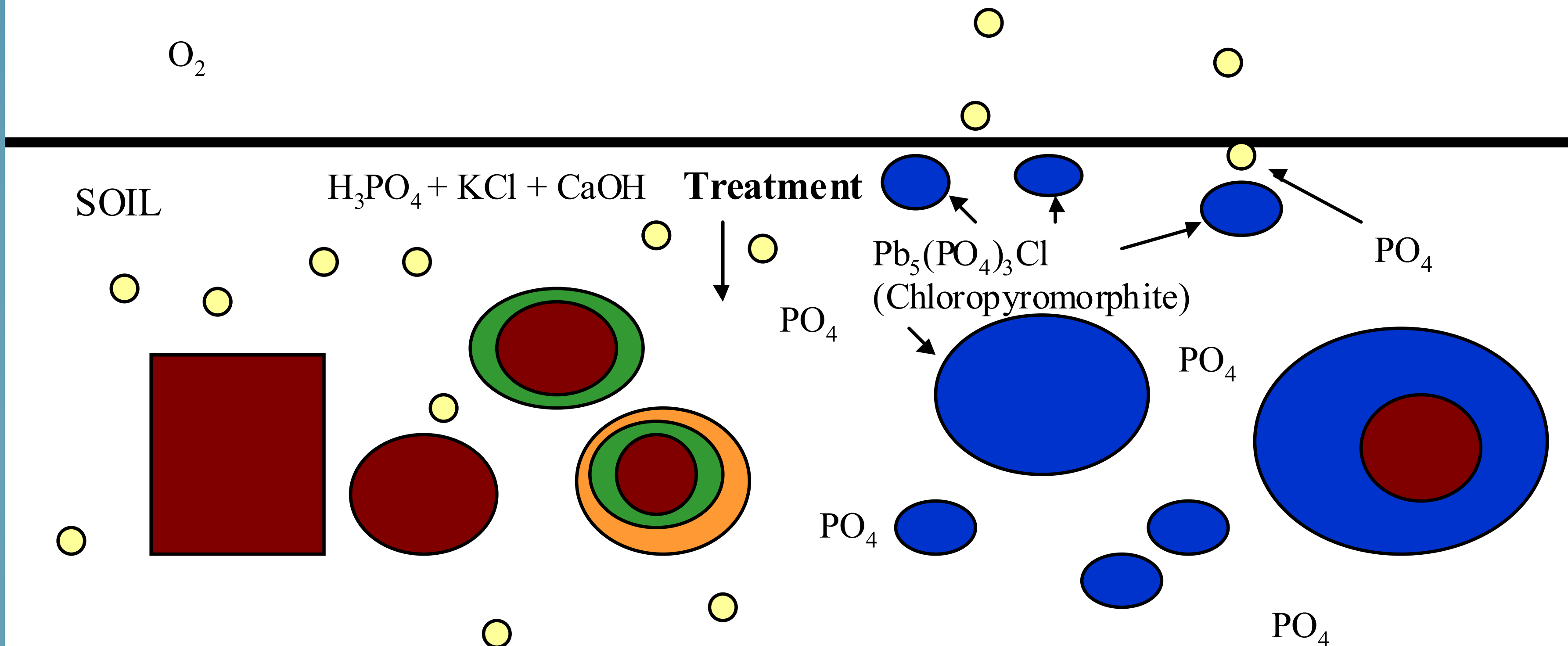
- BC may have multiplicative supporting benefits



[Gujre et al., 2020]



Theoretical Missouri Pb-contaminated Soil Through Time



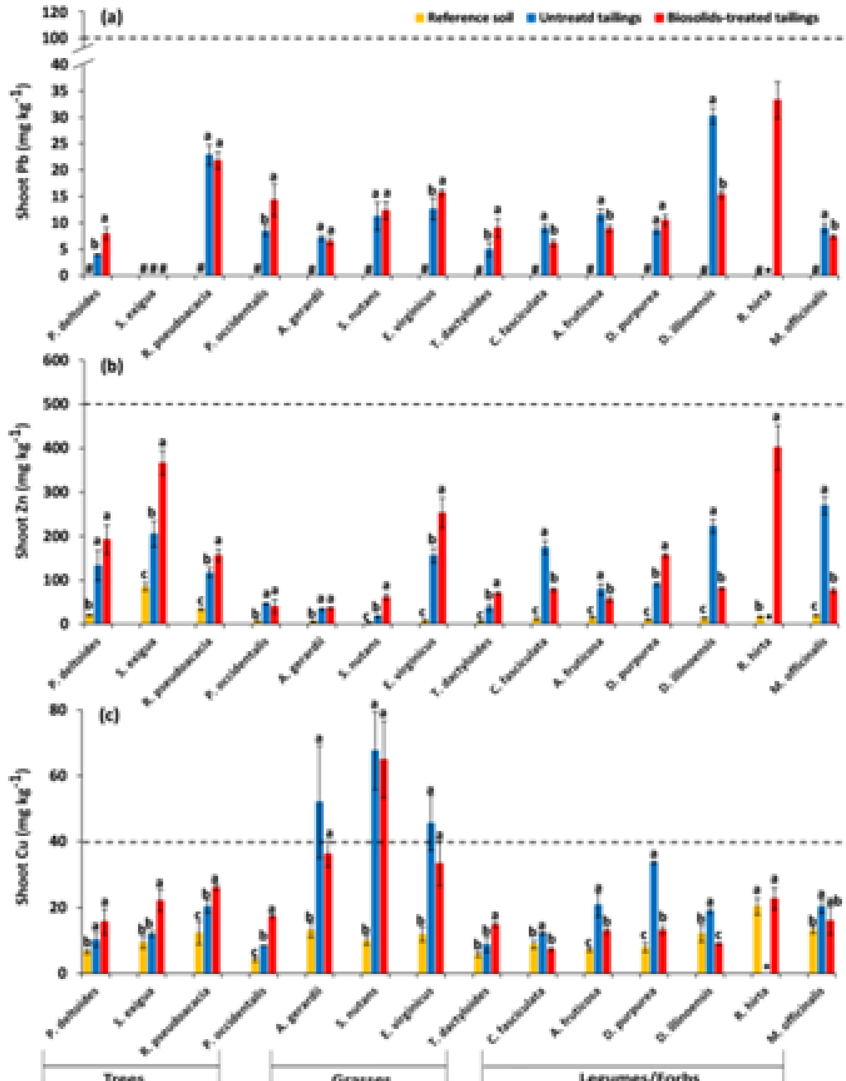
Phosphate Treated Missouri Soil

RELATED RESEARCH: MARIAM AL-LAMI MS&T BIOSOLIDS+BIOCHAR PLANT UPTAKE

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Screening Native/Prairie Plants for Enhanced Revegetation of Mine Tailings & Development of a Non-Destructive Assessment Approach:

- Destructive: metal accumulation



- Dash line represents domestic animal toxicity limit (DATL): maximum tolerable **Pb**, **Zn**, and **Cu** level for cattle (National Research Council, 2005)

Ref: Al-Lami, M. K., Nguyen, D., Oustriere, N., & Burken, J. G. *Science of The Total Environment*, *780*, 146490.

RELATED RESEARCH: MARIAM AL-LAMI MS&T

Missouri University of Science and Technology

Phase 2 (Extended): Role of Co-application of Rich Carbon Residues with BS

Plant response: 4th growing season (A. fruticose prairie legume)

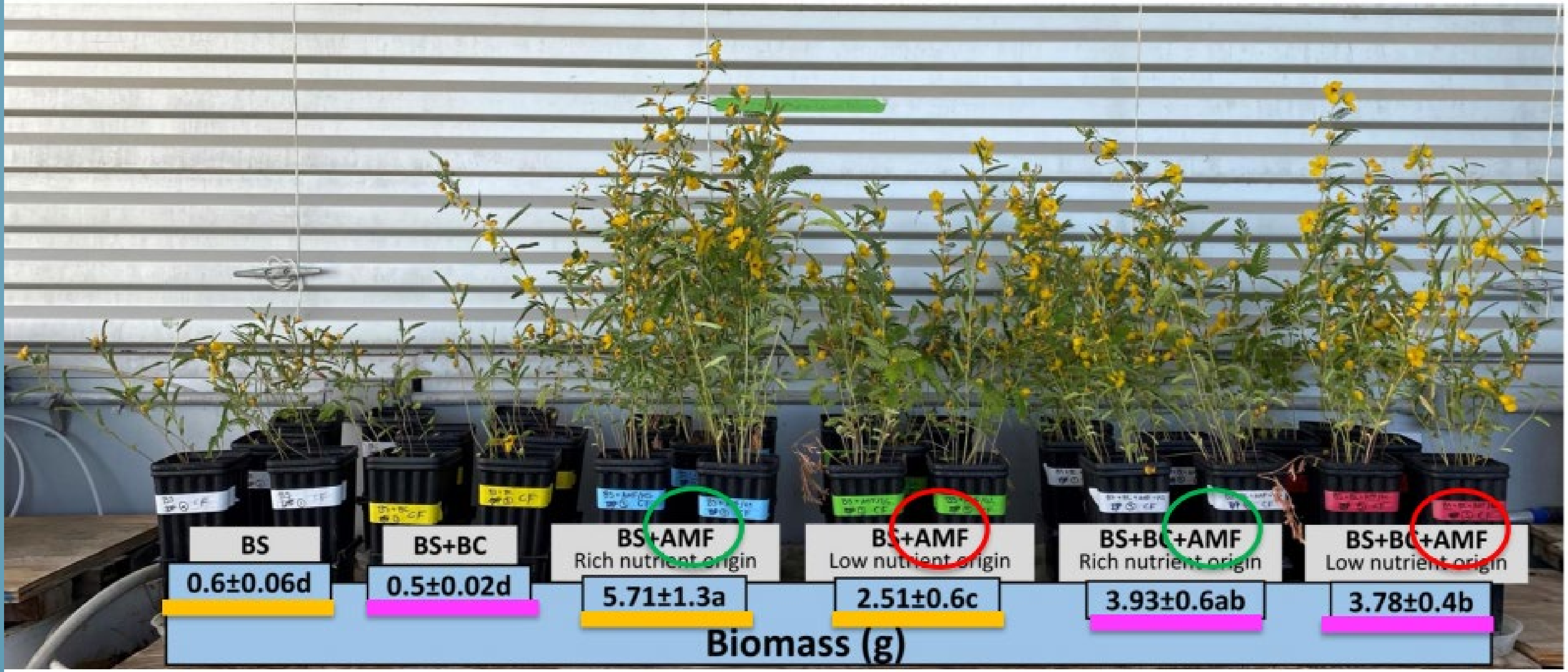
- **Plant response following different behavior compared to 1st season:**

BS+SD, BS+BC, BS+COM supporting more prolonged growth compared to BS alone: indicating more benefits of humified and charred biomass compared to fresh biomass, and also the role of high surface area

RELATED RESEARCH: MARIAM AL-LAMI MS&T

Role of AMF

➢ **Preliminary findings:** Prairie legume *C. fasciculata* grown in Pb/Zn tailings



➢ AMF isolated from two contrasting prairie soils:

- Rich nutrient soil in Kansas City
- Poor nutrient sandy soil in Great Lakes

Former and Abandoned Pb/Zn Mine Demonstration Project

BARREN CHAT & TAILINGS FILLING CREEK CHANNEL - WEBB CITY, MO

1 YEAR POST RECLAMATION
60 TONS BIOSOLIDS/ACRE
WEBB CITY, MO

WEBB CITY PARTNERSHIP

ORGANIC SOIL AMENDMENTS FOR USE IN PRAIRIE RESTORATION ON REMEDIATED LANDS: PILOT STUDY PRELIMINARY RESULTS

- ***Post-Remediation soils are highly degraded and have residual contamination.***

- ***If left alone, these areas do not support adequate vegetation or provide habitat.***

OBJECTIVES OF STUDY

1. *Assess potential risks from runoff constituents*

   - Nutrients, Metals, PPCPs

2. *Evaluate uptake and bioavailability of lead*

3. *Evaluate success of native prairie and wetland plant species*

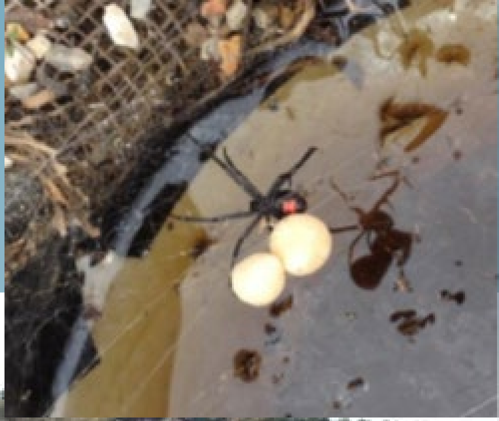
TWO TERRESTRIAL SCENARIOS

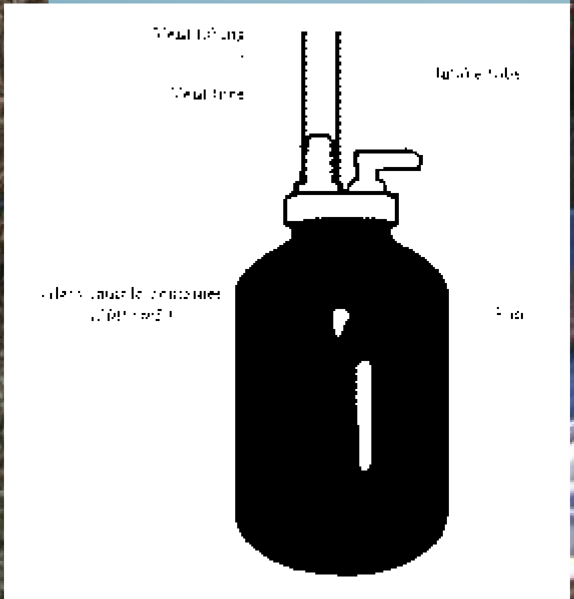
- *Unremediated Chat/Fill*
  - *Biosolids*
  - *Cattle Manure*
  - *High-P Ag Fertilizer*
- *All materials composted with woodchips*
- *No lime added (naturally high soil pH)*

- *Remediated Upland Soil*
  - *Biosolids*
  - *Cattle Manure*
  - *Poultry Litter*
  - *Mulch + Fertilizer*
- *All materials composted with woodchips and 10% biosolids*
- *Soil Limed following amendments*
- *Sod Buffer Strip below plots*

SAMPLE COLLECTION & ANALYSIS

- *Passive runoff sampling techniques*
  - *Total and Dissolved metals*
  - *Nitrogen and Phosphorus*
  - *PPCPs and Toxicity (WET Tests)*
- *Species Composition and Biomass – 20 X 20cm quads*





PHASE 1: VEGETATED CHAT/FILL

- *Zn ~8000, Pb ~1000 ppm*
- *21 Plots - May 2014*
- *3 mixtures of Organics*
  - *Biosolids + Mulch*
  - *Cattle Manure + Mulch*
  - *Composted Mulch with High-P fertilizer*
- *2 application rates*
  - *40 & 80 tons/acre organics*
  - *12 & 23 tons/acre fertilizer*

Plant (Zn) Tolerance

25000+ zn natives	
Scientific Name	Common Name
Agalinis heterophylla	prairie false foxglove
Amaranthus tuberculatus	tall water-hemp
Ambrosia artemisiifolia	common ragweed
Ampelopsis cordata	heart-leaf raccoon-grape
Andropogon virginicus	broom-sedge bluestem
Croton monanthogynus	one-seed croton
Eupatorium serotinum	fall joe-pye-weed
Panicum virgatum	switch grass
Parthenocissus quinquefolia	Virginia creeper
Paspalum laeve	field paspalum
Penstemon digitalis	smooth beardtongue
Persicaria punctata	dotted smartweed
Setaria parviflora	bristlegrass
Solidago canadensis	Canadian goldenrod
Symphyotrichum patens	sky-drop aster

10,000+ zn natives	
Scientific Name	Common Name
Agalinis heterophylla	prairie false foxglove
Amaranthus tuberculatus	tall water-hemp
Ambrosia artemisiifolia	common ragweed
Ambrosia trifida	giant ragweed
Ampelopsis cordata	heart-leaf raccoon-grape
Andropogon gerardii	big bluestem
Andropogon virginicus	broom-sedge bluestem
Apocynum cannabinum	hemp dogbane
Bidens polylepis	coreopsis beggar-ticks
Carex blanda	woodland sedge
Cerastium brachypodum	mouse's-ear-chickweed
Chasmanthium latifolium	broad-leaf wood-oat
Cirsium altissimum	tall thistle
Croton monanthogynus	one-seed croton
Desmodium illinoense	Illinois tickclover
Dichanthelium acuminatum	pointed dichanthelium
Eleocharis sp.	spike-rush
Erigeron strigosus	daisy fleabane
Eupatorium serotinum	fall joe-pye-weed
Juncus interior	inland rush
Leptochloa fusca	bearded sprangletop
Panicum anceps	beaked panicgrass
Panicum virgatum	switch grass
Parthenocissus quinquefolia	Virginia creeper
Paspalum laeve	field paspalum
Penstemon digitalis	smooth beardtongue
Persicaria punctata	dotted smartweed
Plantago virginica	pale-seed plantain
Rhus copallina	dwarf sumac
Rhus glabra	smooth sumac
Rubus flagellaris	American dewberry
Rudbeckia hirta	black-eyed-Susan
Schizachyrium scoparium	little bluestem
Schoenoplectus pungens	common threesquare
Setaria parviflora	bristlegrass
Solidago canadensis	Canadian goldenrod
Sorghastrum nutans	yellow Indian grass
Symphyotrichum patens	sky-drop aster
Symphyotrichum pilosum	hairy aster
Teucrium canadense	Canada germander
Tridens flavus	purpletop
Triodanis perfoliata	Venus'-looking-glass

PHASE 1 RESULTS

Little bluestem
Yellow Indian grass
Broad-leaf wood-oat
Virginia wildrye
Slick-seed wildbean
Blue verbena
Showy partridge pea
New England aster
Black-eyed-Susan
Purple Prairie Clover
Lanceleaf coreopsis
Foxglove Penstemon
Pale Coneflower
Thick-spike gayfeather

Plant diversity:

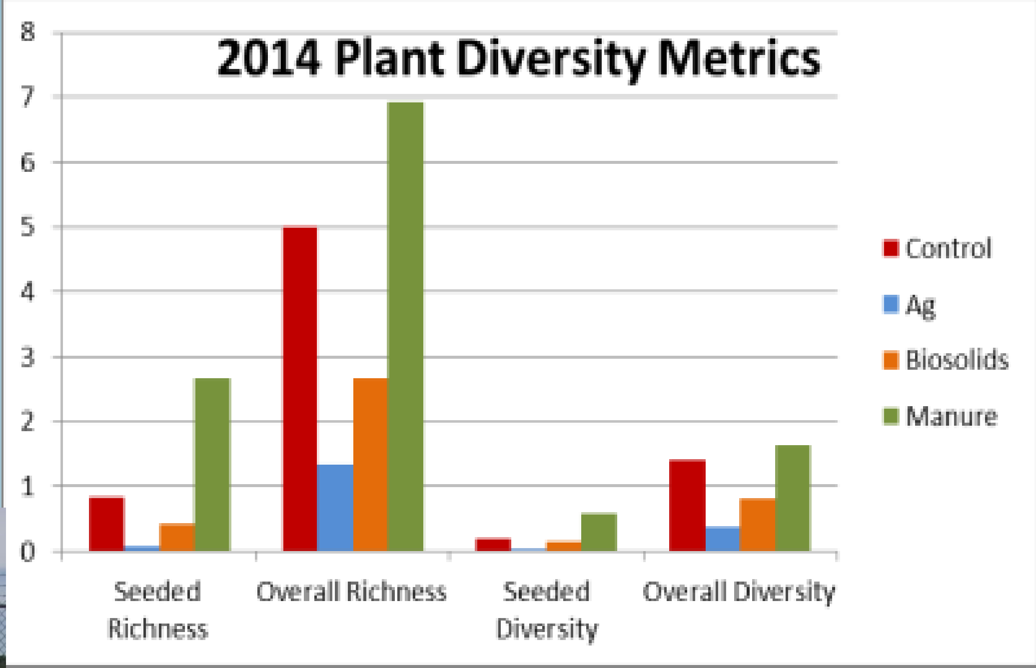
-Late (May) seeding and high soil zinc may affect results.

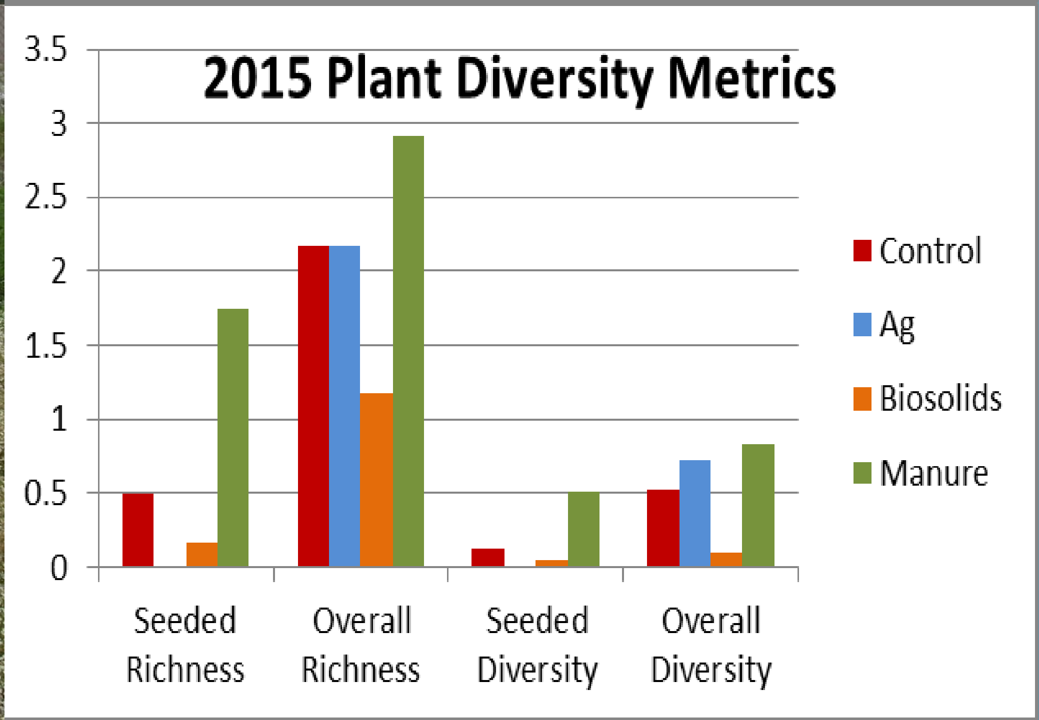
-Manure treatments had 3x the species richness of seeded native plants as control, other treatments' richness were less than control.

-Even though native richness was high in manure plots, they were still dominated by the larger ragweed and pigweed plants.

-Two species, Blue verbena and Partridge pea, completed their lifecycle in the high zinc soils, and won't be seeded in Poo II.

PLANT DIVERSITY RESULTS FROM UNREMEDIATED PLOTS





PHASE 1 RESULTS

Plot 16
Control

Plant biomass:

-The Ag treatment was a biological desert.

-The biosolids treatment grew 5x the biomass as control, but vast majority was ragweed.

Plot 17
Ag High

Plot 18
Biosolids High

Plot 19
Manure High

PHASE 1 RESULTS

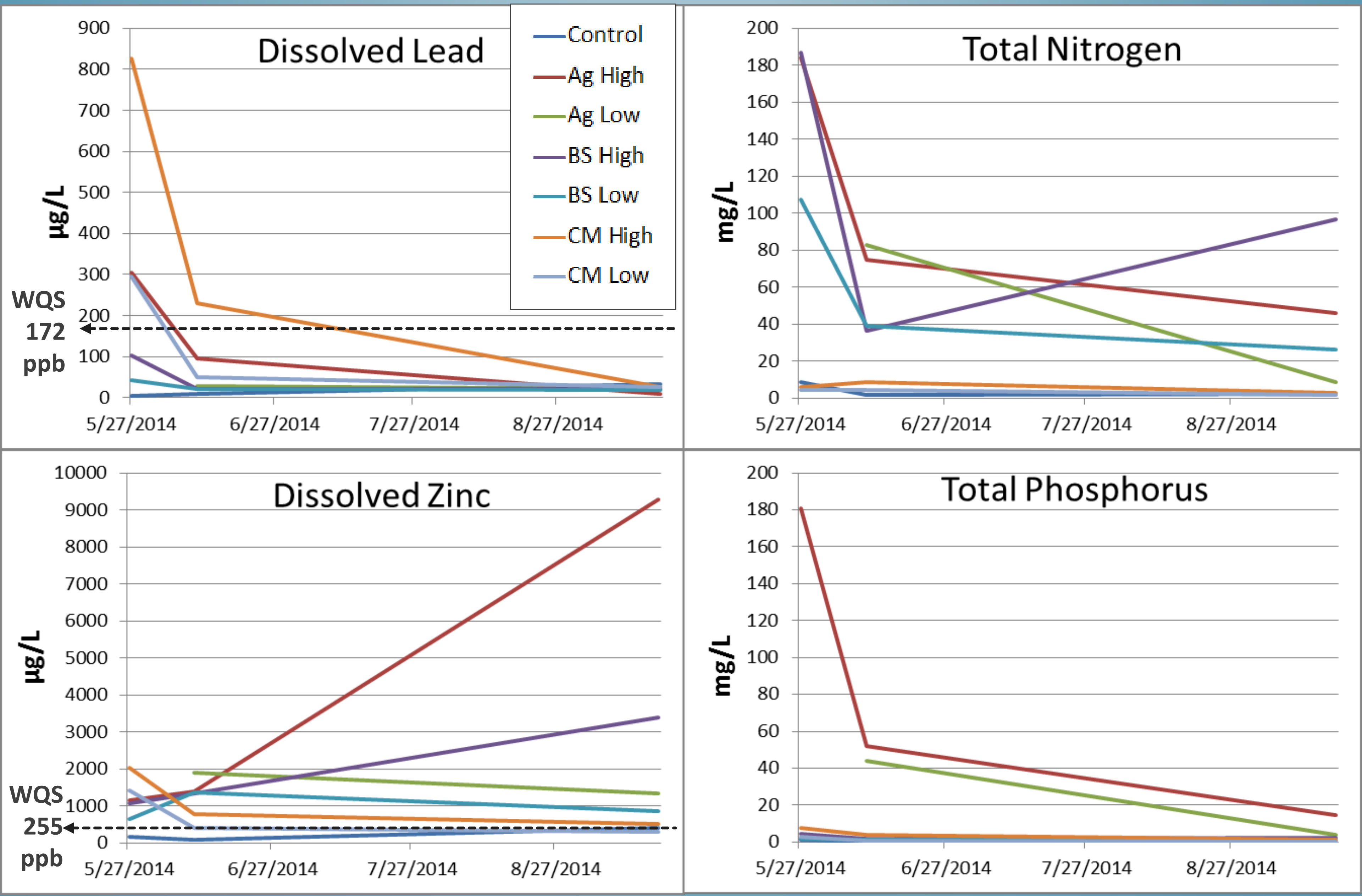
Tissue Uptake of Metals:

Ragweed aboveground tissue collected from every plot, rootzone soil XRF-ed below every ragweed.

-Lead uptake was around 7% of soil lead (~50ppm in tissue), all treatments were significantly lower than control (except Ag)

-Zinc uptake was about 35% of soil (~1100ppm in tissue), only Ag treatment was significant different (higher) from control

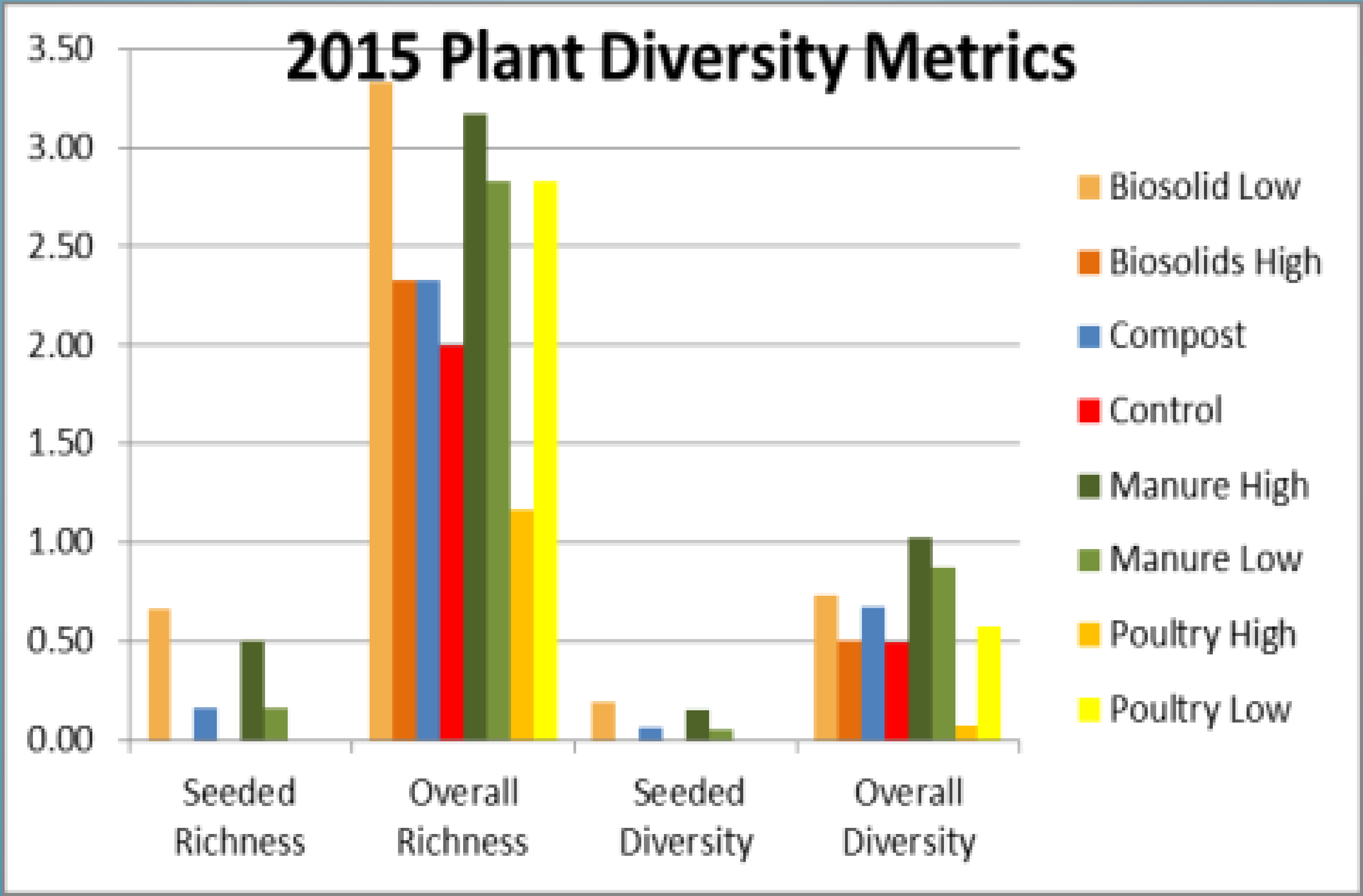
RUNOFF: UNREMEDIATED CHAT/FILL



PHASE 2: POST-REMEDY UPLAND

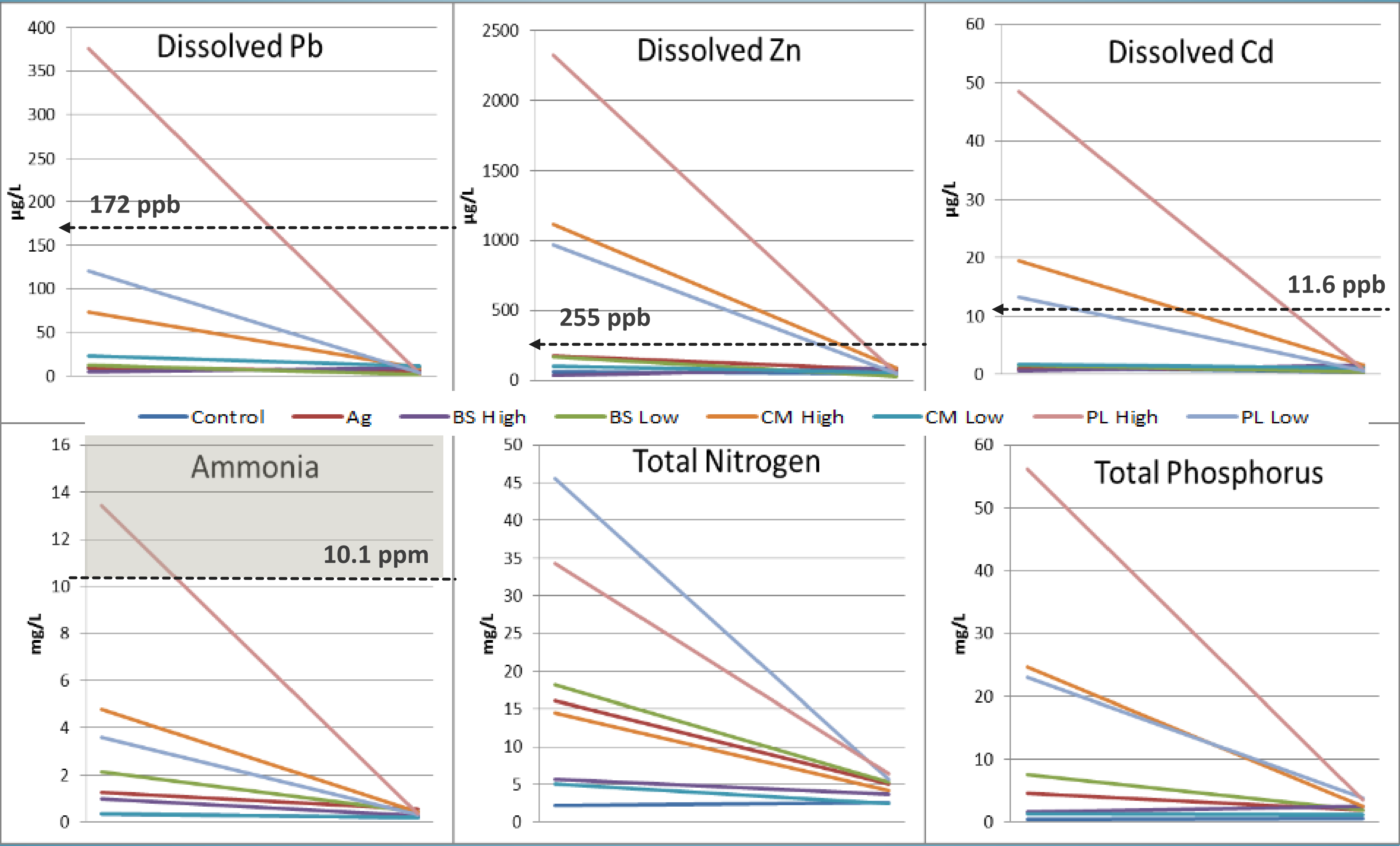
- *Zn: ~4000, Pb ~400 ppm, Degraded subsoil*
- *24 plots - Sept 2014*
- *4 organic mixtures:*
  - *Biosolids*
  - *Cattle manure+biosolids*
  - *Poultry Litter+biosolids*
  - *Mulch composted with fertilizer*
- *40 & 80 tons/acre*
  - *40 ton/acre for mulch/fertilizer*
- *Areas limed*
- *Sod buffer strip below plot*

PLANT DIVERSITY RESULTS FROM REMEDIATED PLOTS



RUNOFF: REMEDIATED UPLAND SOIL

Sampled Nov. 2014 & Sept 2015



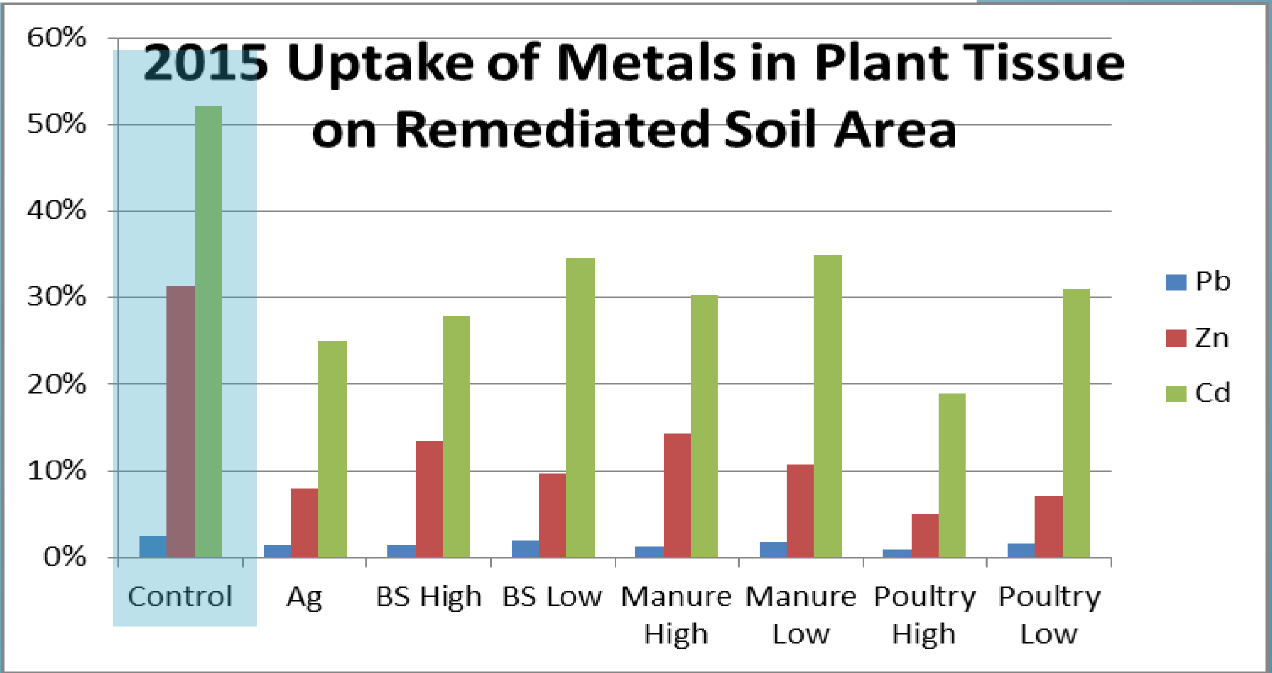
RUNOFF: REMEDIATED UPLAND SOIL WET TEST RESULTS

- *Nov 5, 2014 - 12.5% Dilution:*
  - *No toxic effects of Biosolids, Manure, or Poultry Litter effluent at High application rate*

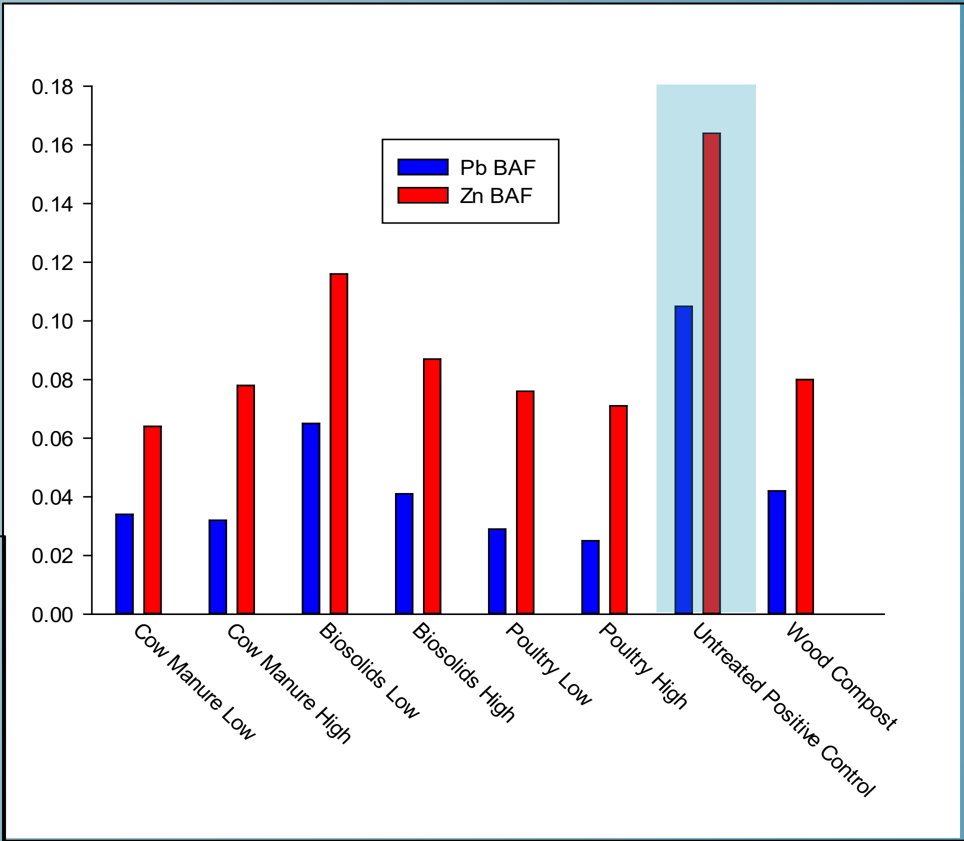
- *Dec 11, 2014 – 50% Dilution:*
  - *Minnow survival 78% in poultry treatment, all others 95-100%*
  - *Minnow growth exceeded bare ground control in all treatments except poultry litter*
  - *Water flea survival 100% in all treatments*
  - *Water flea reproduction equal to internal control except bare ground (control) and poultry litter effluent*

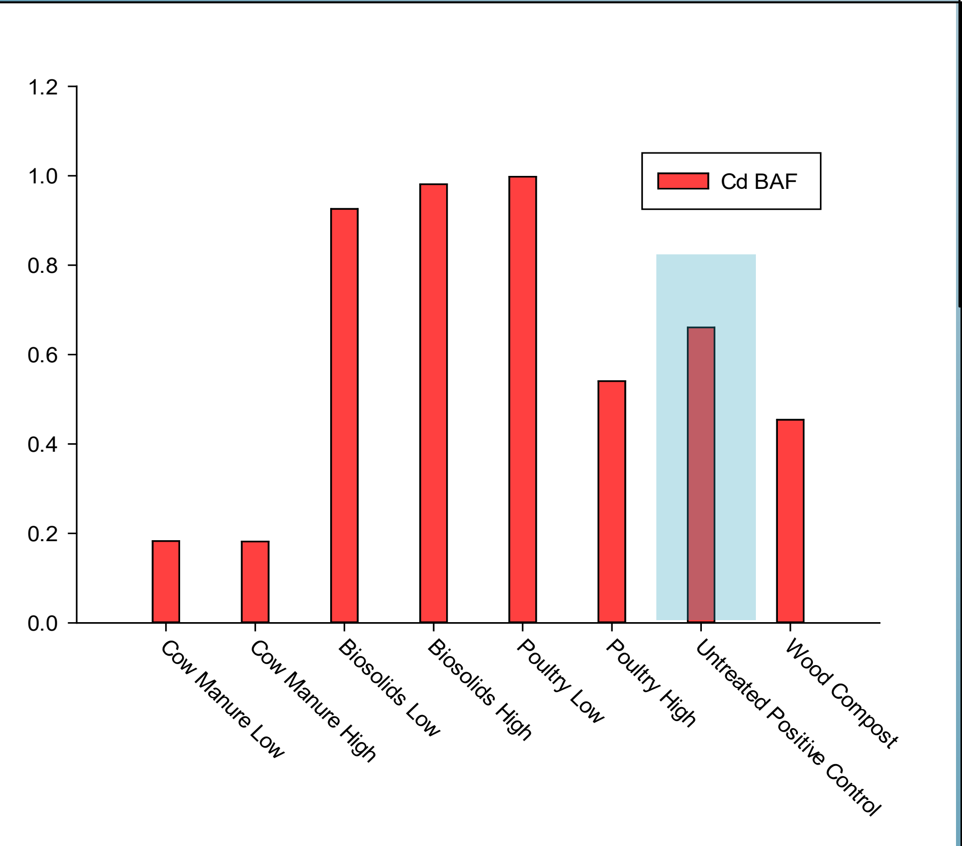
Treatment	Pre-amendment Soil			Post-amendment soil			Plant tissue		
	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn	Cd
Control	491	2578.5	39.5	473.3	2373.5	12.9	10.3	760	13.9
Ag	676	3688.3	56.7	314.1	1977.3	10.7	8.1	256	12.2
BS High	792	2919	54.7	120.6	837.8	5.0	9.4	422	12.3
BS Low	496.7	2626	39.3	77.1	580.5	4.7	7.1	212	11.8
Manure Hig	759	4046.3	58.7	159.7	893.0	6.5	8.5	477	14.2
Manure Lov	504.7	2567.7	46.0	98.7	722.5	6.0	6.1	218	12.4
Poultry Hig	534	3634	68.0	403.4	2705	15.5	11.9	657	13.4
Poultry Low	528.3	2738.3	40.7	144.3	1068.1	10.4	6.5	166	9.8

PLANT METAL UPTAKE



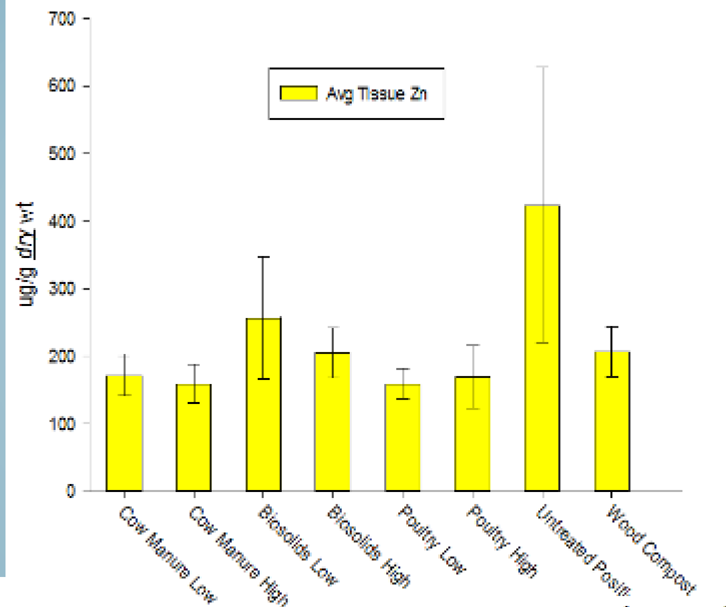
EARTHWORM METAL UPTAKE



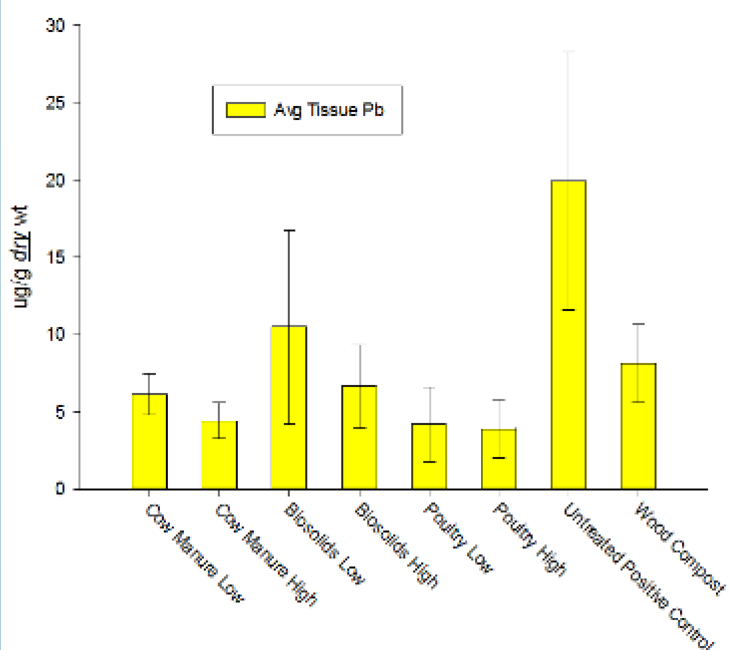


EARTHWORM METAL UPTAKE

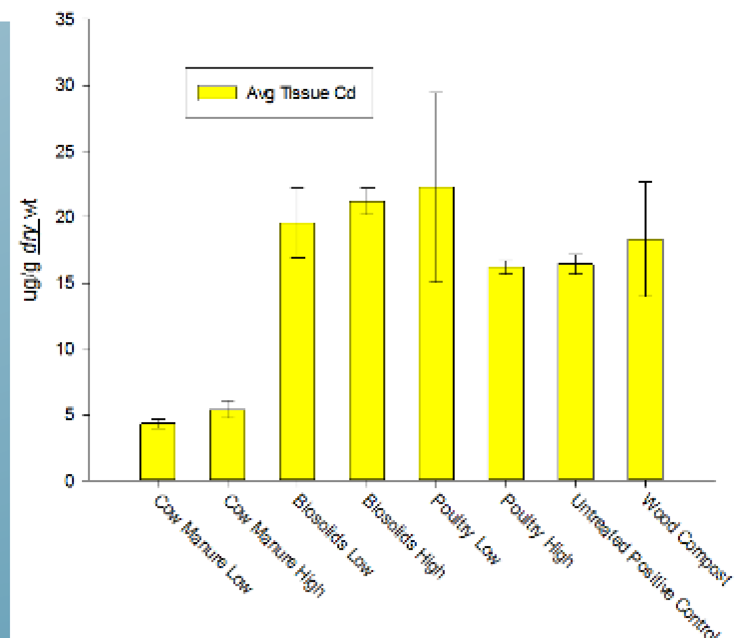
Average Zn Concentration in Worm Tissue

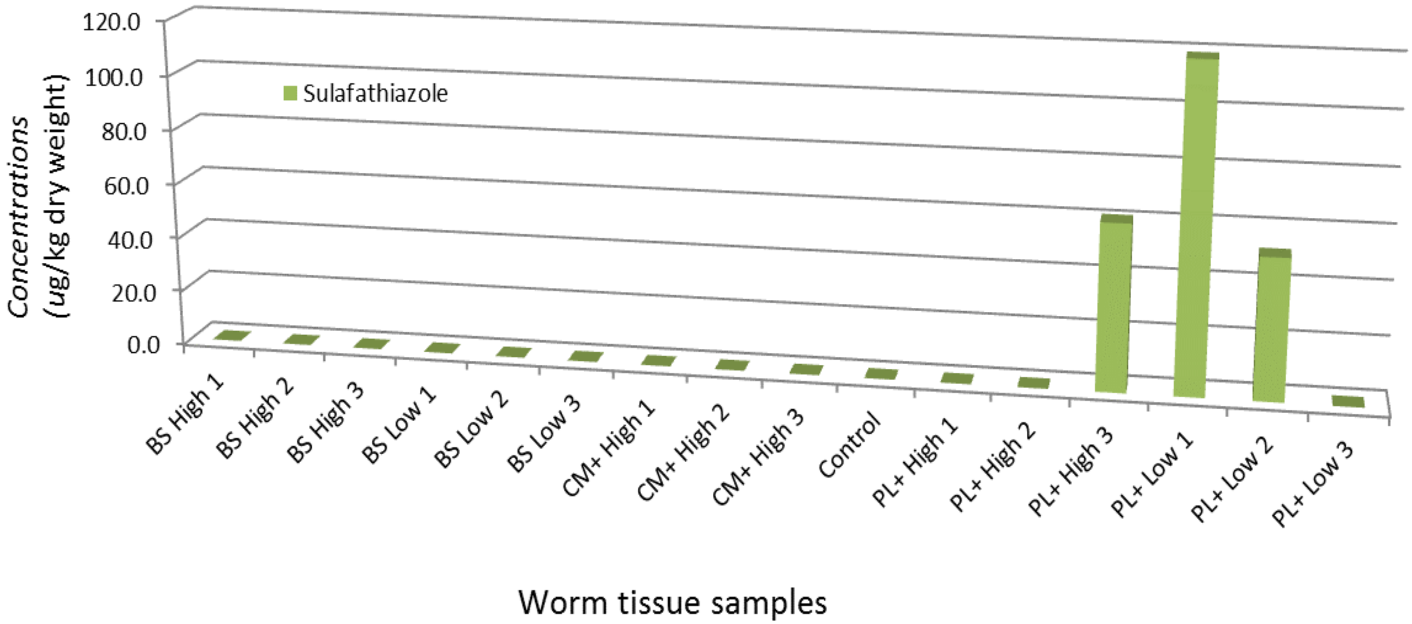


Average Pb Concentration in Worm Tissue

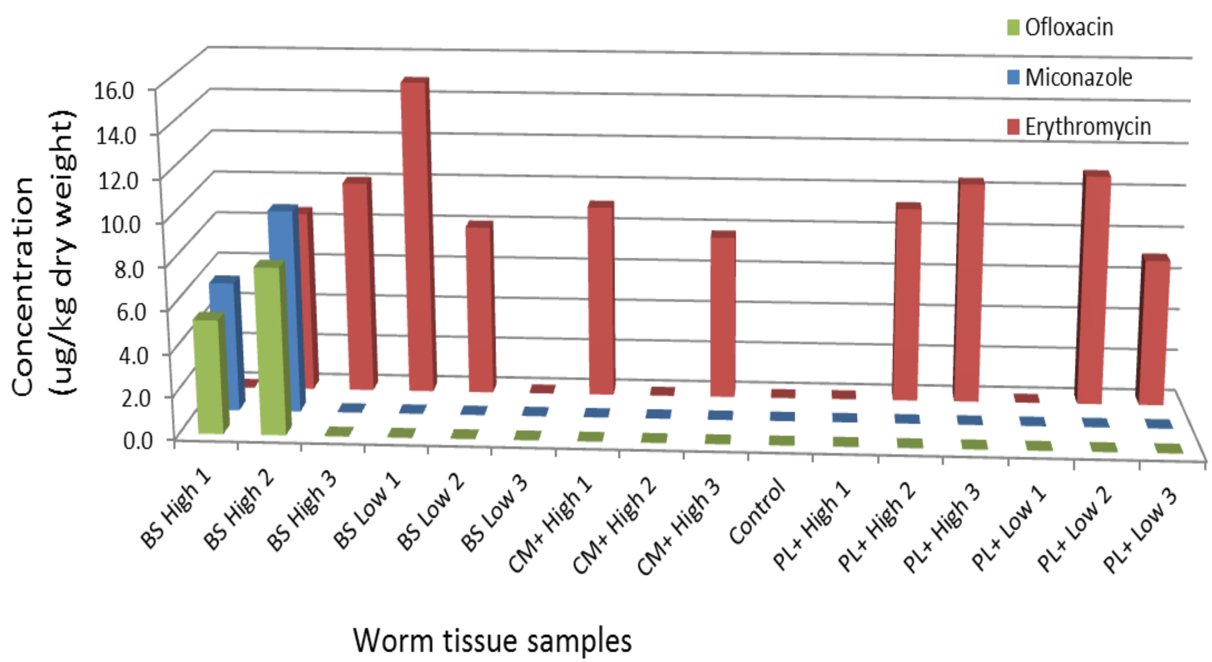


Average Cd Concentrations in Worm Tissue

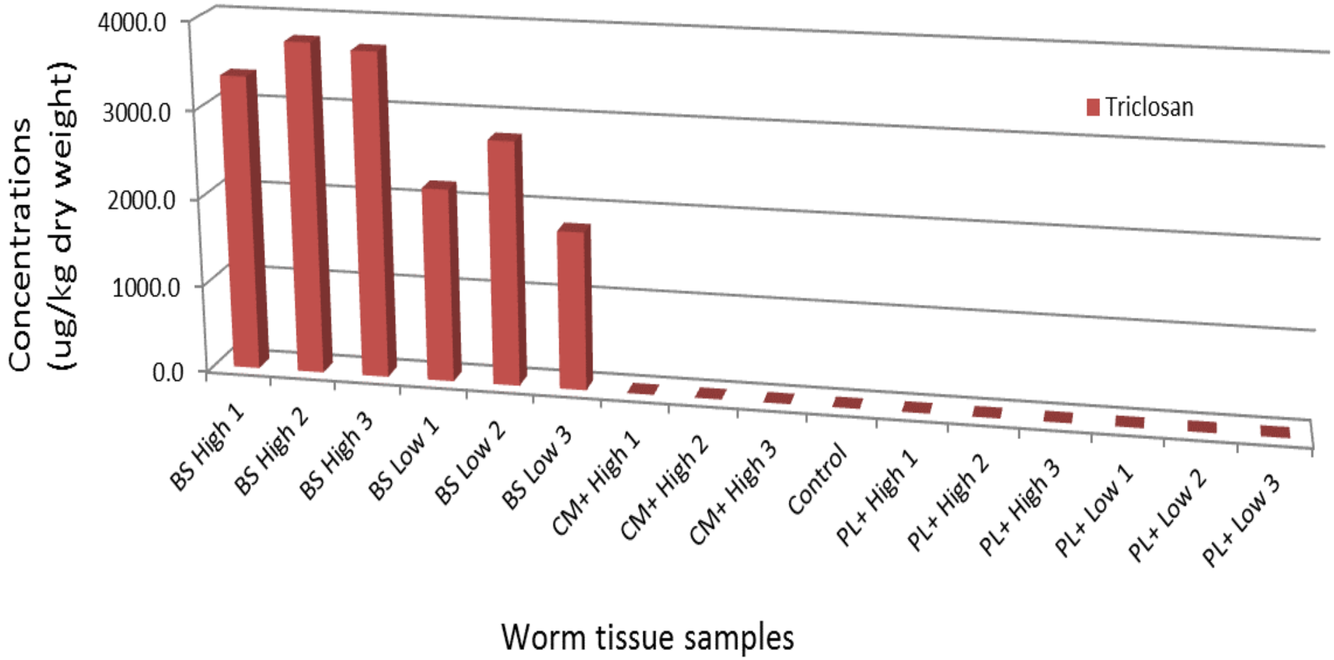


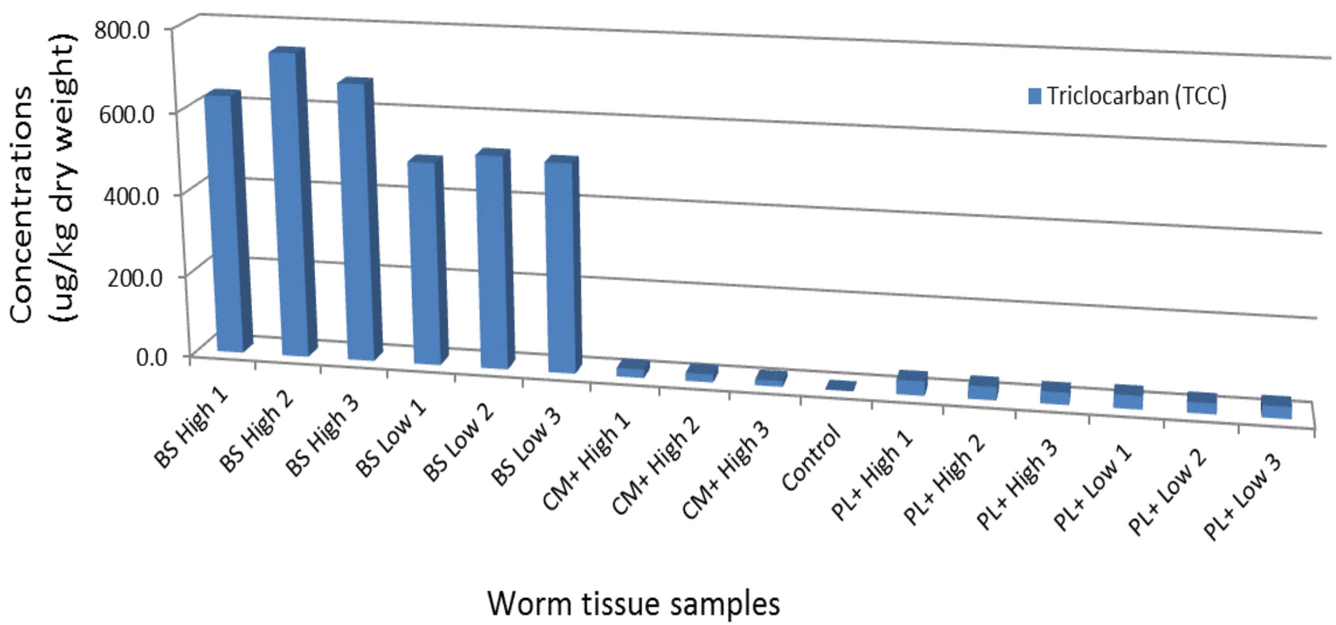


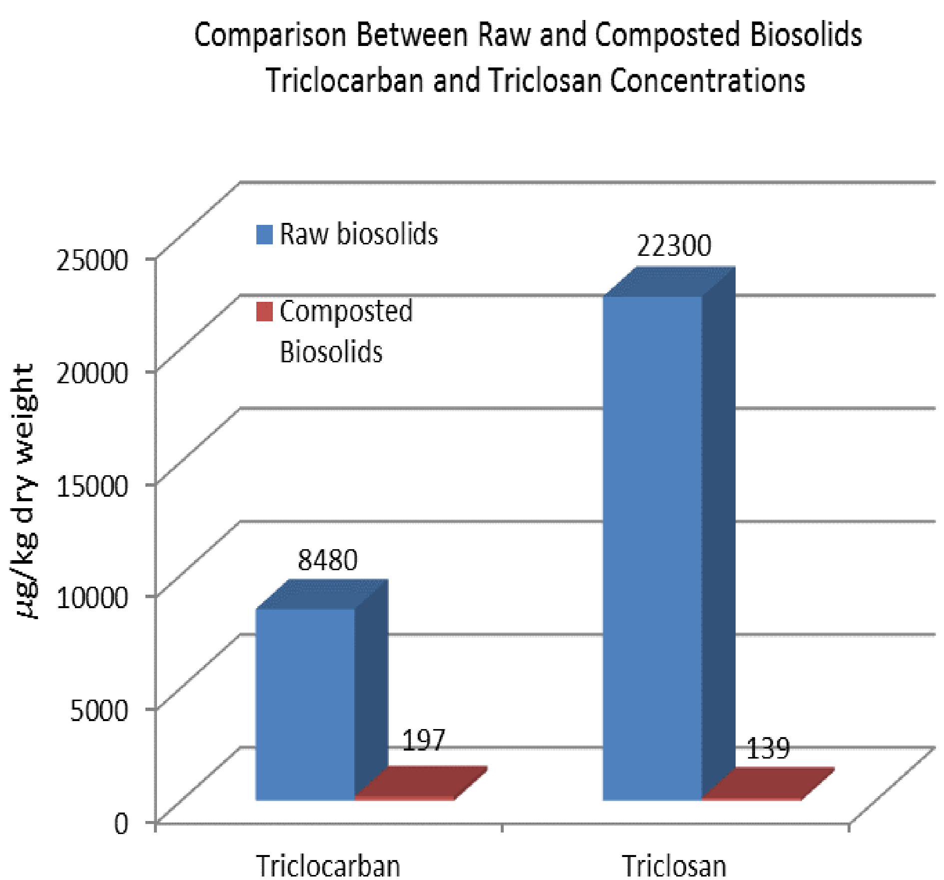
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Concentrations
(ug/kg dry weight)
Sulafathiazole
BS High 1
BS High 2
BS High 3
BS Low 1
BS Low 2
BS Low 3
CM+ High 1
CM+ High 2
CM+ High 3
Control
PL+ High 1
PL+ High 2
PL+ High 3
PL+ Low 1
PL+ Low 2
PL+ Low 3
Worm tissue samples

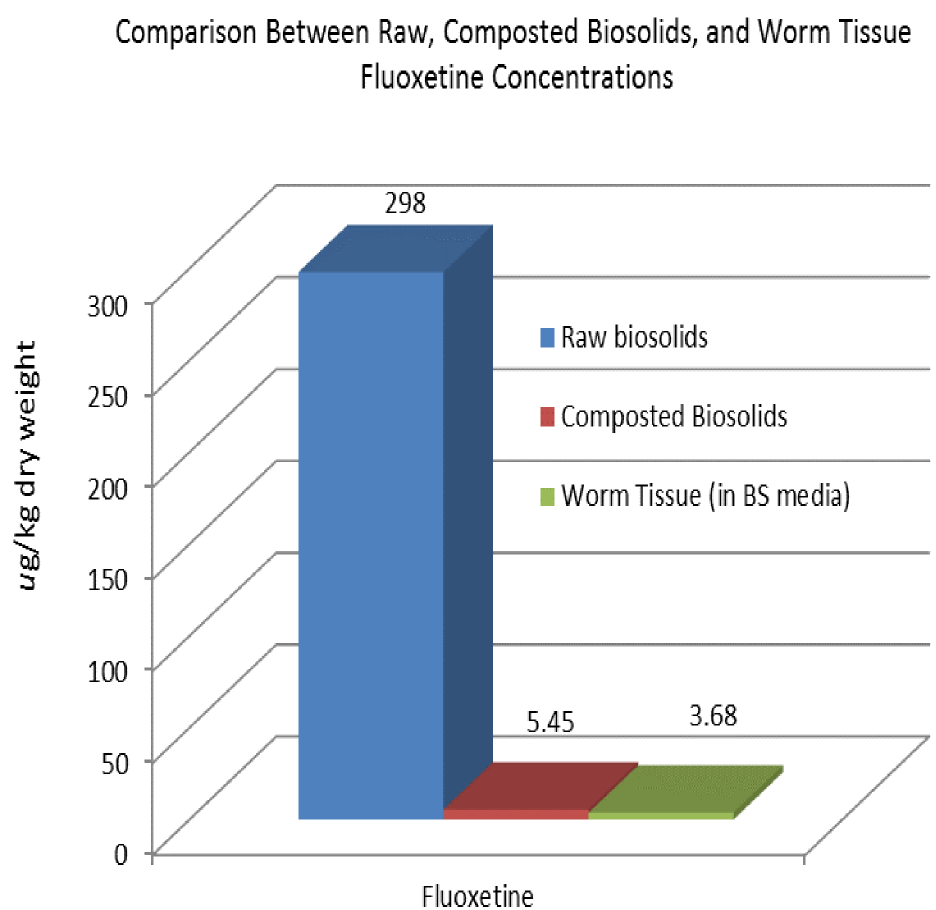


Ofloxacin
Miconazole
Erythromycin
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Concentration
(ug/kg dry weight)
BS High 1
BS High 2
BS High 3
BS Low 1
BS Low 2
BS Low 3
CM+ High 1
CM+ High 2
CM+ High 3
Control
PL+ High 1
PL+ High 2
PL+ High 3
PL+ Low 1
PL+ Low 2
PL+ Low 3
Worm tissue samples


4000.0
3000.0
2000.0
1000.0
0.0
Concentrations (ug/kg dry weight)
Triclosan
BS High 1
BS High 2
BS High 3
BS Low 1
BS Low 2
BS Low 3
CM+ High 1
CM+ High 2
CM+ High 3
Control
PL+ High 1
PL+ High 2
PL+ High 3
PL+ Low 1
PL+ Low 2
PL+ Low 3
Worm tissue samples


800.0
600.0
400.0
200.0
0.0
Concentrations (ug/kg dry weight)
Triclocarban (TCC)
BS High 1
BS High 2
BS High 3
BS Low 1
BS Low 2
BS Low 3
CM+ High 1
CM+ High 2
CM+ High 3
Control
PL+ High 1
PL+ High 2
PL+ High 3
PL+ Low 1
PL+ Low 2
PL+ Low 3
Worm tissue samples


Comparison Between Raw and Composted Biosolids
Triclocarban and Triclosan Concentrations
Raw biosolids
Composted Biosolids
µg/kg dry weight
25000
20000
15000
10000
5000
0
8480
197
22300
139
Triclocarban
Triclosan


Comparison Between Raw, Composted Biosolids, and Worm Tissue
Fluoxetine Concentrations
Raw biosolids
Composted Biosolids
Worm Tissue (in BS media)
ug/kg dry weight
300
250
200
150
100
50
0
298
5.45
3.68
Fluoxetine

WETLAND TUBS

Treatment tubs

Biochemical reactor

Limestone bed

WETLAND TUBS

RESULTS FROM TUBS

Plant success results are dramatic.

The Ag and control pools were nearly barren.

Biosolids had roughly 25% coverage from weedy grasses.

Manure had 80% cover primarily from the planted natives.

Table 16. Metal concentrations and bioaccumulation factors (BAF) of wetland plants grown in contaminated soil treated with organic amendments.

Treatment	Sediment Pb ave (ppm)	error +/-	Sediment Zn ave (ppm)	error +/-	All species plant tissue Pb (ppm)	error +/-	All species plant tissue Zn (ppm)	error +/-	Overall plant uptake Pb (%)	Overall plant uptake Zn (%)
Biosolids 1st gen	211.1	21.3	1590.7	68.9	5.4	0.6	199.0	1.8	3%	13%
Biosolids 2nd gen	128.5	16.0	804.4	46.3	5.0	0.6	100.0	1.3	4%	12%
Manure 1st gen	200.0	20.6	1913.5	74.5	5.0	0.5	110.2	1.4	3%	6%
Manure 2nd gen	68.9	16.5	730.1	55.8	5.5	0.5	54.1	1.0	8%	7%
Control	366.2	26.1	3159.0	91.3	4.8	0.6	216.6	1.7	1%	7%
Poultry	256.3	21.9	1724.5	67.4	4.7	0.6	77.8	1.1	2%	5%
Compost	121.7	15.8	890.1	48.6	5.1	0.6	98.3	1.3	4%	11%

WETLAND TUB RESULTS

Concentrations in micrograms per liter									
PPCP Analyte\ Sampled Media	BS (2nd Mix)	CM+ (composite)	CM+ (duplicate)	Control Rep 1	Control Rep 2	Control Rep 3	PL+ Rep 1	PL+ Rep 2	LOAEC (ug/L) Biological Endpoint
4 Epianhydrochlortetracycline							0.271	0.397	
Acetaminophen	1.52			1.44	1.16	1.34		1.45	
Azitrhomycin	0.0195	0.0106	0.0124	0.0204	0.0205		0.0139	0.0109	
Caffeine	0.105								0.05/amphibian malformation
Carbadox							0.0583	0.0635	
Carbemazepine	0.045			0.0407	0.0272	0.04	0.0427	0.02	100/algal growth
Clarithromycin	0.0116			0.0107		0.0107	0.00635		5/bacterial growth
Diphenhydramine	0.0118						0.00253	0.00388	5.6 / behavioral
Erythromycin H2O	0.0189		0.0226	0.0254		0.0312	0.029	0.0258	22700/shrimp morbidity
Gemfibrozil	0.0405		0.00997	0.0169	0.0134				30400/ crustacean
Licomycin	0.0394								
Miconazole	0.055							0.0573	
Naproxen				0.0853					
Oxolinic Acid	0.0517	0.035	0.073	0.0481	0.0642	0.056	0.0806		
Sulfamethizole					0.0348				
Sulafathiazole	0.0901	0.0161	0.0546	0.0596	0.0426	0.0519	0.0293	0.0594	
Triclocarban	0.535						0.0105	0.103	reproduction (NOAEC)
Triclosan	1.02								0.15/ algal assemblage

Exceeds adverse effects concentration

Concentrations greater (>15%) than highest Control concentration

PFAS… IN TERMS OF MULTIPLES OF BACKGROUND SOIL

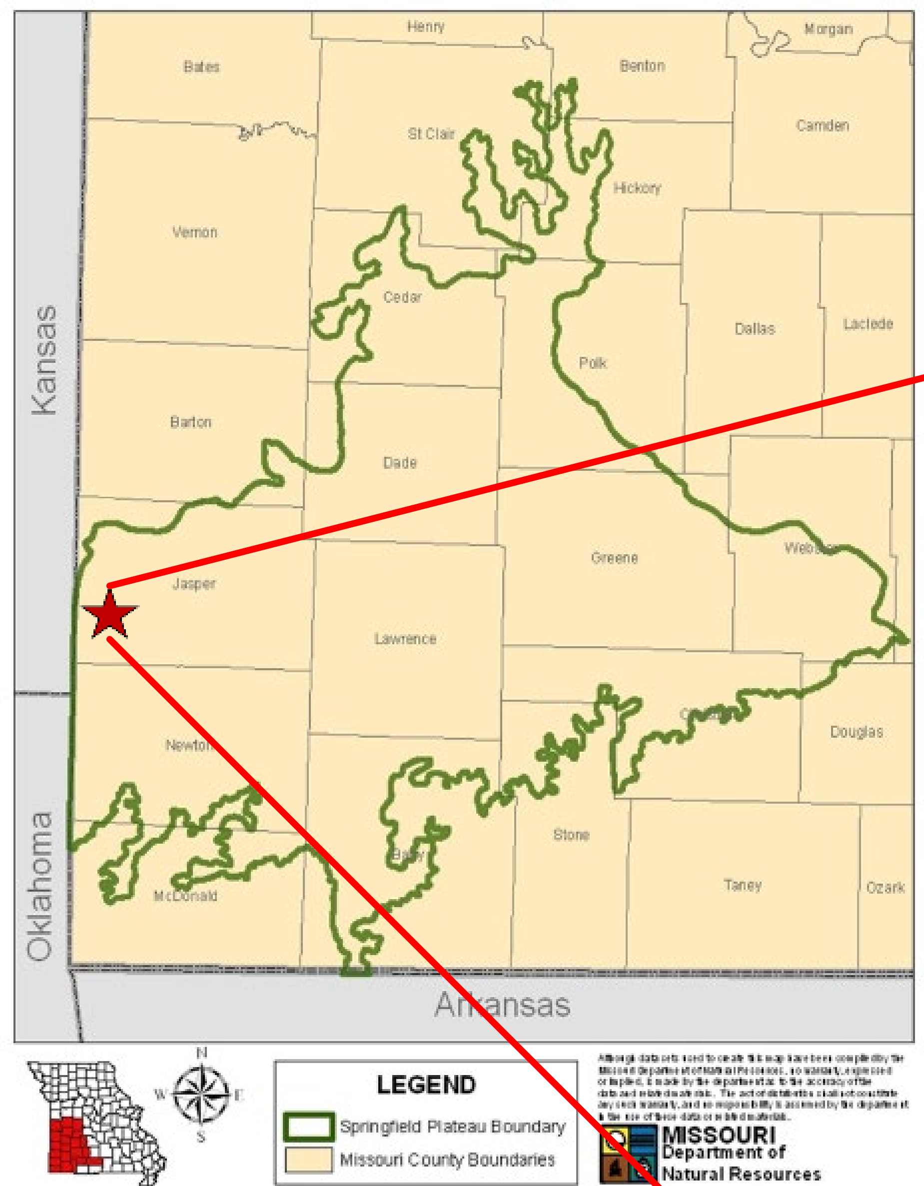
PFAS Concentrations in field collected samples.

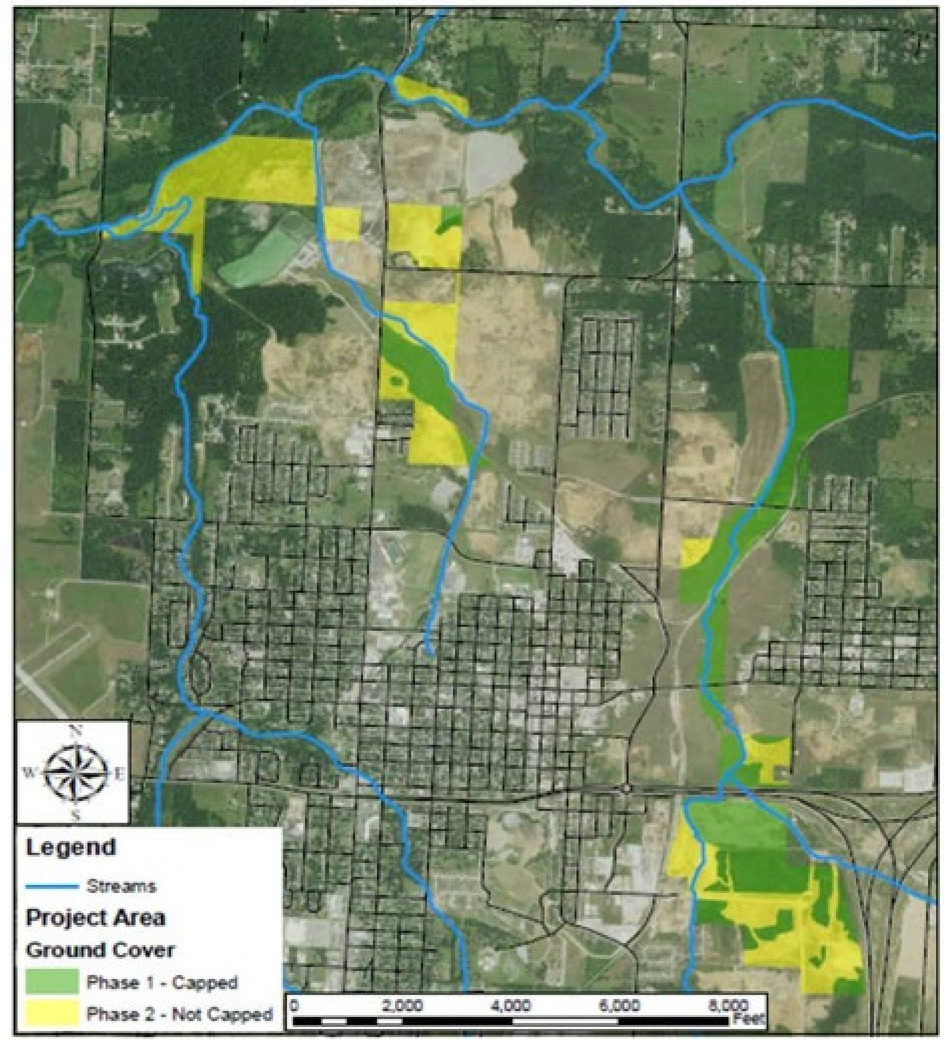
Values Rounded to 3 significant figur Multiples of background soil level

Analyte	Conc	Biosolids1	Biosolids1	Biosolids2	Biosolids3	Manure Pile 1	Manure Pile 2	Manure Mix 1	Manure Mix 2	Wood Chips1	Wood Chips2	Land applied Compost 1	Land applied Compost	Background fill dirt
PFBA	ng/kg	###	16.80	9.69	9.11	0.57	1.15	1.60	1.94	20.29	######	2.63	3.78	1.00
PFPeA	ng/kg	###	6.77	5.47	4.44	####	####	####	####	#####	######	2.10	3.14	1.00
HFPO-DA	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFBSA	ng/kg	###	3.51	2.68	2.17	####	####	####	0.07	#####	######	2.77	3.26	1.00
PFHxA	ng/kg	###	7.30	6.23	5.53	0.19	0.22	0.24	0.28	#####	######	1.55	2.53	1.00
4:2 FTS	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFPeS	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFHpA	ng/kg	###	1.55	1.45	1.27	0.79	0.92	0.77	0.67	0.53	0.53	1.17	1.18	1.00
NaDONA	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFHxSA	ng/kg	###	155.95	60.35	####	3.43	1.04	####	####	#####	######	13.13	14.71	1.00
PFHxS Linear	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	1.00
PFHxS Branched	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	1.00
PFOA	ng/kg	###	6.29	3.71	5.17	0.69	0.80	0.87	0.77	0.95	1.13	2.24	2.48	1.00
6:2 FTS	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFHpS	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	3.04	3.59	1.00
PFNA	ng/kg	###	6.37	4.02	6.18	1.01	1.03	1.01	0.76	#####	######	1.68	1.65	1.00
PFOSA	ng/kg	###	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFOS Linear	ng/kg	###	39.90	15.91	43.18	0.04	0.03	0.05	0.06	0.28	0.24	3.50	3.91	1.00
PFOS Branched	ng/kg	###	12.14	4.74	11.50	0.07	0.04	0.07	0.09	0.26	0.20	2.34	2.61	1.00
PFDA	ng/kg	###	47.39	23.69	49.00	0.07	####	####	0.12	0.22	######	4.46	4.50	1.00
8:2 FTS	ng/kg	###	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
9Cl-PF3ONS	ng/kg	###	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFNS	ng/kg	LOQ	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFUnDA	ng/kg	###	31.64	14.95	31.97	####	####	####	####	#####	######	2.46	2.20	1.00
N-MeFOSAA Linear	ng/kg	###	928.25	445.29	####	####	####	####	####	#####	######	38.70	43.05	1.00
N-MeFOSAA Branched	ng/kg	###	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFDS	ng/kg	###	175.83	59.42	####	####	####	####	####	0.58	0.37	14.58	15.33	1.00
PFDoDA	ng/kg	###	18.54	6.82	15.97	####	####	####	####	0.16	0.11	1.72	1.60	1.00
11Cl-PF3OUdS	ng/kg	LOD	######	######	####	####	####	####	####	#####	######	####	####	#VALUE!
PFTrDA	ng/kg	###	27.40	######	14.77	####	####	####	####	#####	######	####	####	1.00
PFTeDA	ng/kg	###	5.59	1.82	4.02	####	####	####	####	#####	######	0.78	0.65	1.00
SPFAS	ng/kg	###	15.18	6.29	14.88	0.11	0.10	0.12	0.13	0.39	0.22	2.44	2.72	1.00

Conc	Biosolids1	Biosolids2	Biosolids3	Manure Pile 1	Manure Pile 2	Manure Mix 1	Manure Mix 2	Wood Chips1	Wood Chips2	Land applied Compost 1	Land applied Compost 2	Background fill dirt		
ng/kg	1730.00	998.00	938.00	58.30	118.00	165.00	200.00	2090.00	<LOQ	271.00	389.00	103.00		
ng/kg	1510.00	1220.00	991.00	<LOQ	<LOQ	<LOQ	<LOQ	<LOD	<LOD	469.00	701.00	223.00		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	165.00	126.00	102.00	<LOD	<LOD	<LOD	3.21	<LOD	<LOD	130.00	153.00	47.00		
ng/kg	1780.00	1520.00	1350.00	46.00	53.50	57.60	69.00	<LOQ	<LOQ	378.00	617.00	244.00		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	524.00	488.00	428.00	265.00	311.00	258.00	227.00	179.00	179.00	395.00	399.00	337.00		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	35.40	13.70	38.40	0.78	0.24	<LOD	<LOD	<LOD	<LOD	2.98	3.34	0.23		
ng/kg	<LOD	<LOD	<LOD	<LOQ	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOQ	<LOQ	14.50		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	11.90		earthworm LC50
ng/kg	2920.00	1720.00	2400.00	318.00	370.00	402.00	359.00	440.00	525.00	1040.00	1150.00	464.00	ppm	760mg/kg
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOQ	ppb	760000ug/kg
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOQ	<LOQ	<LOQ	17.60	20.80	5.79	ppt	760000000ng/kg
ng/kg	975.00	615.00	945.00	155.00	158.00	155.00	117.00	<LOQ	<LOQ	257.00	253.00	153.00		
ng/kg	2090.00	859.00	2740.00	0.16	0.10	<LOD	<LOD	3.02	2.00	<LOQ	<LOQ	<LOQ		
ng/kg	31600.00	12600.00	34200.00	31.80	25.20	37.10	50.90	222.00	193.00	2770.00	3100.00	792.00		earthworm LC50
ng/kg	170000.00	66300.00	161000.00	1010.00	616.00	983.00	1210.00	3580.00	2800.00	32800.00	36500.00	14000.00	ppm	373mg/kg
ng/kg	11800.00	5900.00	12200.00	17.40	<LOQ	<LOQ	30.50	54.50	<LOQ	1110.00	1120.00	249.00	ppb	373000ug/kg
ng/kg	327.00	200.00	321.00	<LOQ	<LOQ	<LOQ	<LOQ	56.50	15.80	40.70	48.40	<LOD	ppt	373000000ng/kg
ng/kg	7.59	<LOD	7.27	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	<LOQ	<LOQ	<LOQ	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOQ	<LOD		
ng/kg	1930.00	912.00	1950.00	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	150.00	134.00	61.00		
ng/kg	20700.00	9930.00	22400.00	<LOD	<LOD	<LOD	<LOD	<LOQ	<LOD	863.00	960.00	22.30		
ng/kg	4230.00	2010.00	4720.00	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	217.00	235.00	<LOD		
ng/kg	2110.00	713.00	2860.00	<LOQ	<LOD	<LOD	<LOD	6.93	4.43	175.00	184.00	12.00		
ng/kg	2670.00	982.00	2300.00	<LOD	<LOD	<LOD	<LOD	22.80	15.20	247.00	231.00	144.00		
ng/kg	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		
ng/kg	833.00	<LOQ	449.00	<LOD	<LOD	<LOQ	<LOQ	<LOQ	<LOD	<LOQ	<LOQ	30.40		
ng/kg	399.00	130.00	287.00	<LOD	<LOD	<LOQ	<LOQ	<LOQ	<LOQ	55.60	46.30	71.40		
ng/kg	**258000.00**	**107000.00**	**253000.00**	**1910.00**	**1650.00**	**2060.00**	**2260.00**	**6660.00**	**3740.00**	**41400.00**	**46300.00**	**17000.00**		

RESTORATION OF PRAIRIE AND WETLANDS IN THE TSMD PURSUANT TO THE SPRINGFIELD PLATEAU REGIONAL RESTORATION PLAN





Webb City, Jasper County, MO


Doppstadt
DW-3060 K
Bio Power

Field Pilot, seeded May 2016


2 year rootball shows penetration into subsoil, migration of organic matter

After 2 years

WETLAND PLANTING

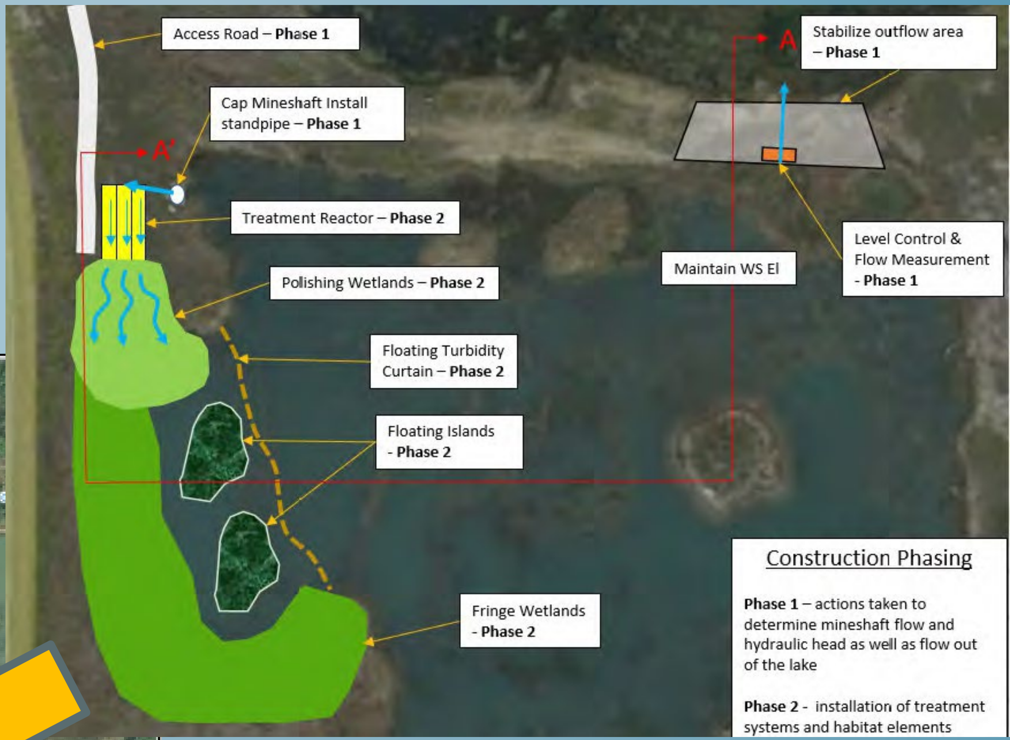
TREATMENT WETLANDS

CONTROL STRUCTURE INSTALLATION

DISCHARGING MINE SHAFTS

HOW TO BEST TREAT CONTAMINATED WATER?

Proposed treatment of Wilson Lake

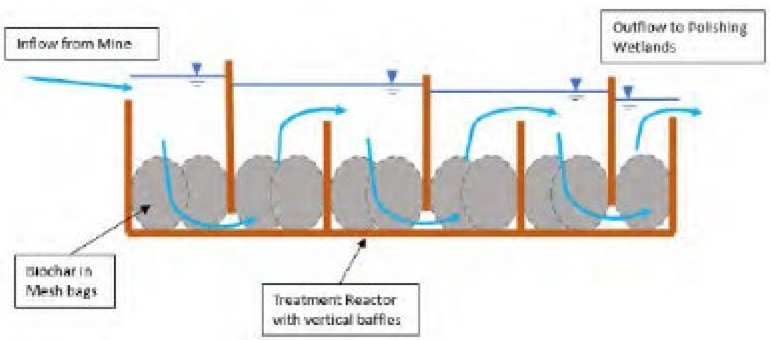


Proposed treatment train for Wilson Lake

Wilson Lake Basis of Design Draft Tech Memo—Jasper County, MO

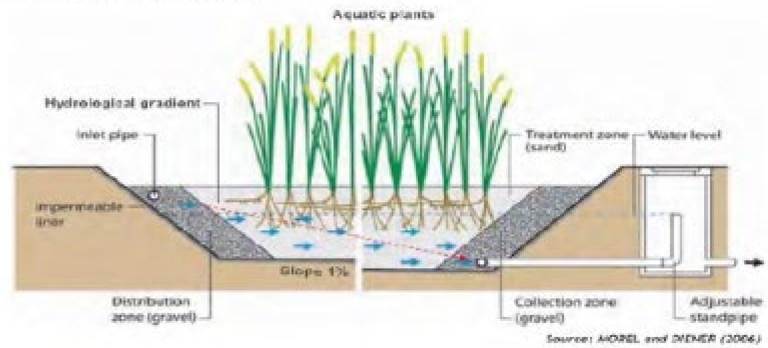
Treatment Reactor

-Provides treatment through adsorption to biochar
-Stainless steel or fiberglass with vertical baffles to ensure flow routing through the biochar with maximum contact time
-Installed with sufficient hydraulic head to drive flow through the biochar
-May need multiple parallel units depending on hydraulic requirements
-Biochar contained in mesh bags for ease of replacement
-Up to 3 parallel treatment reactors may be required
-Requires hydraulic head to push flow through biochar bags



Polishing Wetland

-Horizontal Flow design, large gravel & sand media, planted with aquatic plants
-Anaerobic conditions, proven effective in dissolved metals removal
-Provides final polishing of minewater through adsorption and phytoremediation
-Functions as natural marsh for habitat value (may be fenced to prevent consumption)
-Incorporate biochar in substrate for metals adsorption
-Works with hydraulic head available on site
-Sub-surface flow for year-round function



Flow Measurement

-Contracted Cipoletti thin-plate weir
-Suitable for low-head applications
-Stainless steel
-Incorporate into stop logs to control level
-Confirm mineshaft flowrate to size weir

Legend

Note: Designs not drawn to scale.

Source: HGL, MOREL and DIENER (2006)

HGL

Figure 5
Wilson Lake
Treatment Pilot Project
Design Details
Treatment Reactor and Treatment Wetland

$

$3,071,000 acquisition and real estate services
$740,000 capped restoration
$1,200,000 compost making, application

$950/ac for compost @ 160 dry tons per ac
$950/ac hauling and spreading
$178/ac grading
$283/ac seeding, including cover crop

QUESTIONS?