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PLANT MATERIALS TECHNICAL NOTE

Heavy Metal Analysis of Plants Tested in the Stucky Ridge Comparative Evaluation Planting

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Stucky Ridge Comparative Evaluation Planting (NRCS photo)

ABSTRACT

The Bridger Plant Materials Center and Deer Lodge Valley Conservation District have worked collaboratively since 1995 to restore lands impacted by acid and heavy metal fallout from smelting operations in the Anaconda, Montana area. The work has focused on testing and selecting native plant species tolerant of acid and metal contaminated soils. As part of field testing, and to ensure safe utilization after restoration, plant tissue samples were analyzed for heavy metal content. Tissue samples from all 39 species tested in the Stucky Ridge Comparative Evaluation Planting (CEP) installed in 2003 were collected in 2004, 2005, 2006, and 2007, and 10-gram oven-dry samples of each accession submitted to an analytical laboratory for a determination of heavy-metal concentrations in and/or on the submitted samples. Tissue was analyzed for arsenic, cadmium, copper, lead, and zinc. The frequency of arsenic detected in plant tissue was generally low, and when detected, fell below the Maximum Tolerable Levels for domestic livestock and wildlife, but within the 'Excessive or Toxic' metal level for plants. The frequency of cadmium detected in plant tissue was very low, but when detected, sometimes exceeded the Maximum Tolerable Levels for domestic livestock, but not wildlife. One Indian ricegrass sample measured within the 'Excessive or Toxic' cadmium range for metals in plants. Copper was detected in most sampled tissue, and sometimes exceeded the Maximum Tolerable Levels for domestic livestock and wildlife. Copper levels commonly measured in the 'Excessive or Toxic' range for plants. The frequency of lead detected in plant tissue was very low, and with the exception of only one sample, measuring below the Maximum Tolerable Level for domestic livestock and wildlife, and only once measuring in

the ‘Excessive or Toxic’ range for metal in plants. Zinc was detected in all samples, but measured below the Maximum Tolerable Levels for domestic livestock and wildlife, but sometimes measured within the ‘Excessive or Toxic’ range for metal level for plants. All plant selections released by the Bridger Plant Materials Center and Deer Lodge Valley Conservation District for the Anaconda project, and tested at Stucky Ridge, measured below the Maximum Tolerable Levels for domestic livestock, with the exception of Old Works Germplasm fuzzy tongue penstemon. All plant selections measured below the Maximum Tolerable Levels for wildlife.

INTRODUCTION

To restore lands impacted by the former Anaconda Smelter site it is essential to stabilize the soils to prevent water contamination through runoff, and to prevent contamination of neighboring landscapes by wind-carried dust. The decision to use phytostabilization to reclaim this site was made because it was the most cost effective method of reclamation. The plant species and accessions selected for testing for phytostabilization must tolerate the harsh conditions of the site, as well as metal contaminated soils, and not uptake heavy metals at level deleterious to domestic livestock, wildlife, or humans. Since impacted land in the Butte-Anaconda area is mostly rangeland and likely to be grazed, plant tissue was sampled in order to determine heavy metal levels and identify potential accumulators.

RESULTS

The results of the plant tissue analyses by year are shown in Addendum, Table 1. The “ND” symbol signifies that the concentration of that metal was “not detected” in the sample, whereas a “-“ symbol indicates a plant sample was not available for analysis. The metal concentration entered in the table for each plant species or accession is a combination of metals held on the surface of the sample, as well as metal incorporated into the tissue of the sample. All tissue samples are un-replicated composites of samples from random plants in all four replications of the Stucky Ridge Comparative Evaluation Trial. Metal loads in the sampled tissue were generally below toxic levels for plants (Addendum, Table 2), but exceeded Maximum Tolerable Levels for cadmium, copper, and lead (only 1 accession in one year) in domestic livestock and wildlife (Addendum, Table 3). In the Addendum, Figures 1 through 6 demonstrate the average concentrations of each metal in clipped samples from the Stucky Ridge Comparative Evaluation Planting. Addendum, Table 4 lists the average heavy metal concentrations of each accession averaged across all sampled years.

Arsenic (As)

Arsenic was detected in 19 of the 39 samples tested in 2004, 32 of 40 samples in 2005, 3 of 42 samples in 2006, and in 5 of 38 samples in 2007. Levels ranged from 5 to 35 milligrams per kilogram, which is below the Maximum Tolerable Levels for domestic livestock (50 milligrams per kilogram) and wildlife (50 milligrams per kilogram). All of the detected levels measured within the ‘Excessive or Toxic’ range for metal levels in plants.

Cadmium (Cd)

Cadmium was detected in 1 of 39 samples tested in 2004, and in 5 of 40 samples in 2005 (3 of which were Indian ricegrass). In 2006 and 2007 there was no detection of cadmium in any sample. When detected, cadmium ranged from 1 to 5 milligrams per kilogram, exceeding the Maximum Tolerable Levels for domestic livestock (0.5 milligrams per kilogram), but both below and above the Maximum Tolerable Levels for wildlife (2 milligrams per kilogram). One Indian ricegrass sample measured within the ‘Excessive or Toxic’ range for metal levels in plants.

Copper (Cu)

Copper was detected in all tissue samples tested in 2004, 2005, and 2006, and detected in 29 of 38 samples in 2007. Levels ranged from 5 to 307 milligrams per kilogram. Three of 39 samples tested in 2004, 5 of 40 samples in 2005, and no samples in 2006 and 2007 exceeded the Maximum Tolerable Levels for domestic livestock (100 milligrams per kilogram). The Maximum Tolerable Levels for wildlife (55 milligrams per kilogram) were exceeded in 15 of 39 samples tested in 2004, 19 of 40 samples tested in 2005, and in 1 of 42 samples tested in 2006. None of the 2007 samples exceeded the Maximum Tolerable Levels for wildlife. ‘Excessive or Toxic’ levels of copper in plants were measured in 37 of 39 samples in 2004, 39 of 40 samples in 2005, 10 of 42 samples in 2006, and 2 of 38 samples in 2007.

Lead (Pb)

Lead was not detected in any of the 39 samples tested in 2004. In 2005 lead was detected in 4 of 40 samples, at levels well below the Maximum Tolerable Levels for livestock and wildlife. In 2006 lead was detected in 2 of 42 samples. One of the two samples exceeded the Maximum Tolerable Levels of lead for domestic livestock and wildlife. One sample, 'Trailhead' basin wildrye, measured in the `Excessive or Toxic' range for metal levels in plants.

Zinc (Zn)

Zinc was detected in all plant samples tested, ranging from 8 milligrams per kilogram to 175 milligrams per kilogram, well below the Maximum Tolerable Levels for domestic livestock (500 milligrams per kilogram) and wildlife (300 milligrams per kilogram). 'Excessive or Toxic' levels of zinc in plants was measured in 6 of 39 samples tested in 2004, 4 of 40 tested samples in 2005, 1 of 42 tested samples in 2006, and none of the 38 samples tested in 2007.

Sixty-four percent of the plants in the study had samples measuring greater than the Maximum Tolerable Levels of one or more heavy metals for domestic livestock and wildlife. Addendum, Table 5 identifies plants from the Stucky Ridge study with levels that could be toxic to the domestic livestock or wildlife consuming them. An "X" in the table indicates plant species or accessions that may store toxic levels of a heavy metal in its tissues based on study results. It would not be advisable to plant those species at sites containing significant levels of those heavy metals in the soil, and/or has the potential to be grazed by domestic livestock or wildlife.

Arsenic did not accumulate in plant tissue above the Maximum Tolerable Levels for domestic livestock or livestock in any of the species or accessions tested in the study. Cadmium exceeded the Maximum Tolerable Levels for domestic livestock in 5 species (Addendum, Table 5), and for wildlife in 3 species. Copper exceeded the Maximum Tolerable Levels for domestic livestock in 7 species, and for wildlife in 21 species. Lead exceeded the Maximum Tolerable Levels for domestic livestock and wildlife in only 1 species and accession, 'Trailhead' basin wildrye. Zinc did not accumulate at levels toxic to plants in any of the samples in the study.

Species and/or accessions marked with an "X", (see Addendum, Table 6) uptake or adsorb excessive or toxic levels of heavy metals and may pose a risk to domestic livestock and wildlife, thereby limiting their use as a food source for humans. Caution is advised when considering the use of these species for reclaiming rangeland and pasture because of their potential to remove high levels of these toxic metals from the soil, which domestic livestock (and possibly other domestic animals) and wildlife are likely to graze or utilize as a food source.

CONCLUSION/DISCUSSION

When reclaiming or restoring lands with heavy metal contamination, plant selection should consider the tolerance of the plants for metal contaminated sites, as well as possible metal uptake by grazing domestic livestock and wildlife. Reclaimed areas serving as range or pasture for domestic livestock and wildlife should limit the use of heavy metal tolerant plants to those species that do not absorb or adsorb excessive amounts of heavy metals.

NRCS APPLICATION

Of the species tested at Stucky Ridge, and reported in NRCS Plant Materials Technical Note MT-111, the following selections established well under the harsh conditions at Stucky Ridge, and maintained heavy metal levels below toxic thresholds, and should therefore be safe for consumption by domestic livestock and wildlife: Copperhead Germplasm slender wheatgrass, *Elymus trachycaulus*; 9081621 slender wheatgrass, *Elymus trachycaulus*; Washoe Germplasm basin wildrye, *Leymus cinereus*; Opportunity Germplasm Nevada bluegrass, *Poa secunda*; 'Sherman' big bluegrass, *Poa secunda*; 'Canbar' Sandberg bluegrass, *Poa secunda*; 'Gruening' alpine bluegrass, *Poa alpina*. These selections may be useful in other conservation practices such as critical area practices (#342), and in conservation cover practices (#327).

Addendum, Table 1. Four Year Average Heavy Metal Concentrations of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Planting (2004-2007), Anaconda, MT.

Species	As				Cd				Cu				Pb				Zn			
	mg/kg				mg/kg				mg/kg				mg/kg				mg/kg			
	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007	2004	2005	2006	2007
alpine bluegrass-'Greuning'	ND†	-‡	5	-	ND	-	ND	-	40	-	11	-	ND	-	15	-	36	-	33	-
alpine bluegrass-9016273	7	21	ND*	ND	ND	ND	ND	ND	50	120	18	6	ND	8	ND	ND	45	64	17	24
alpine bluegrass-9082259	8	17	ND	5	ND	ND	ND	ND	78	80	14	6	ND	ND	ND	ND	49	50	15	31
alpine bluegrass-9082266	ND	20	6	7	ND	ND	ND	ND	33	93	8	6	ND	9	ND	ND	62	156	27	41
basin wildrye-'Magnar'	11	8	ND	ND	ND	ND	ND	ND	113	63	16	6	ND	ND	ND	ND	84	69	23	20
basin wildrye-'Trailhead'	ND	8	ND	ND	ND	ND	ND	ND	35	51	25	7	ND	ND	207	ND	85	93	125	27
basin wildrye-9081624	ND	5	ND	ND	ND	ND	ND	ND	62	73	19	6	ND	ND	ND	ND	111	55	26	27
basin wildrye-9081625	6	9	ND	ND	ND	1	ND	ND	72	76	16	7	ND	ND	ND	ND	172	124	30	36
basin wildrye-Washoe	7	ND	ND	ND	ND	ND	ND	ND	47	47	14	10	ND	ND	ND	ND	175	106	28	29
big bluegrass-9081322	ND	9	ND	ND	ND	ND	ND	ND	83	62	32	9	ND	ND	ND	ND	57	64	33	50
bluebunch wheatgrass-'Goldar'	13	12	ND	ND	ND	ND	ND	ND	81	68	9	6	ND	ND	ND	ND	77	58	19	22
bluebunch wheatgrass-9081636	16	20	ND	ND	ND	ND	ND	ND	76	112	21	6	ND	ND	ND	ND	81	84	19	29
Canbar bluegrass-'Canbar'	-	-	ND	7	-	-	ND	ND	-	-	6	12	-	-	ND	ND	-	-	17	53
fuzzytongue penstemon-Old Works	-	14	ND	-	-	ND	ND	-	-	65	15	-	-	ND	ND	-	-	31	10	-
Indian Ricegrass-'Nezpar'	ND	ND	ND	ND	ND	ND	ND	ND	16	21	5	6	ND	ND	ND	ND	51	31	14	17
Indian Ricegrass-'Rimrock'	ND	9	ND	ND	5	1	ND	ND	17	35	9	ND	ND	ND	ND	ND	68	38	10	9
Indian Ricegrass-9081628	6	8	ND	ND	ND	2	ND	ND	39	34	6	ND	ND	ND	ND	ND	123	88	15	11
Indian Ricegrass-9081629	9	8	ND	ND	ND	2	ND	ND	41	35	8	6	ND	ND	ND	ND	111	73	12	18
Nevada bluegrass-Opportunity	9	ND	ND	ND	ND	ND	ND	ND	49	52	19	7	ND	ND	ND	ND	35	44	18	29
red top-'Streaker'	-	35	ND	ND	-	ND	ND	ND	-	243	16	11	-	13	ND	ND	-	78	20	26
red top-9076266	ND	6	ND	ND	ND	ND	ND	ND	74	39	30	21	ND	ND	ND	ND	100	49	23	47
red top-9076276	ND	6	ND	ND	ND	ND	ND	ND	46	62	22	6	ND	ND	ND	ND	54	41	20	31
red top-9081619	ND	ND	ND	ND	ND	ND	ND	ND	100	62	18	8	ND	ND	ND	ND	51	64	17	23
Sandberg bluegrass-9081635	11	14	ND	ND	ND	ND	ND	ND	46	59	24	ND	ND	ND	ND	ND	38	44	17	18
Sherman bluegrass-'Sherman'	9	12	ND	ND	ND	ND	ND	ND	36	52	12	ND	ND	ND	ND	ND	94	106	19	16
silverleaf phacelia-9081632	-	42	-	7	-	ND	-	ND	-	307	-	25	-	15	-	ND	-	91	-	23
slender wheatgrass- 9081621	ND	ND	ND	ND	ND	ND	ND	ND	38	41	17	7	ND	ND	ND	ND	21	22	9	8
slender wheatgrass-'Pryor'	ND	8	ND	ND	ND	ND	ND	ND	25	62	12	ND	ND	ND	ND	ND	37	35	9	12
slender wheatgrass-'Revenue'	ND	7	ND	ND	ND	ND	ND	ND	48	65	15	ND	ND	ND	ND	ND	50	47	11	9
slender wheatgrass-'San Luis'	ND	6	ND	ND	ND	ND	ND	ND	45	27	16	6	ND	ND	ND	ND	40	33	13	15
slender wheatgrass-Copperhead	ND	5	ND	ND	ND	ND	ND	ND	26	47	15	ND	ND	ND	ND	ND	14	16	9	12
Snake River wheatgrass-'Secar'	ND	7	ND	ND	ND	ND	ND	ND	34	59	14	ND	ND	ND	ND	ND	68	65	17	32
tufted hairgrass-'Nortran'	8	-	ND	-	ND	-	ND	-	29	-	11	-	ND	-	ND	-	67	-	18	-
tufted hairgrass-9076290	5	6	7	-	ND	1	ND	-	48	45	80	-	ND	ND	ND	-	63	52	35	-
tufted hairgrass-9082260	8	6	ND	-	ND	ND	ND	-	57	14	19	-	ND	ND	ND	-	87	44	24	-
western wheatgrass-'Rodan'	7	6	ND	ND	ND	ND	ND	ND	52	29	27	ND	ND	ND	ND	ND	56	39	14	20
western wheatgrass-'Rosana'	6	9	ND	5	ND	ND	ND	ND	29	47	26	8	ND	ND	ND	ND	61	52	18	28
western wheatgrass-9081968	6	5	ND	ND	ND	ND	ND	ND	45	41	32	6	ND	ND	ND	ND	86	64	28	25
winterfat-'Open Range'	7.5	ND	ND	ND	ND	ND	ND	ND	108	44	15	12	ND	ND	ND	ND	82	47	14	29

Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07.

† ND – Not Detected.

‡ - No plant biomass available for analyses.

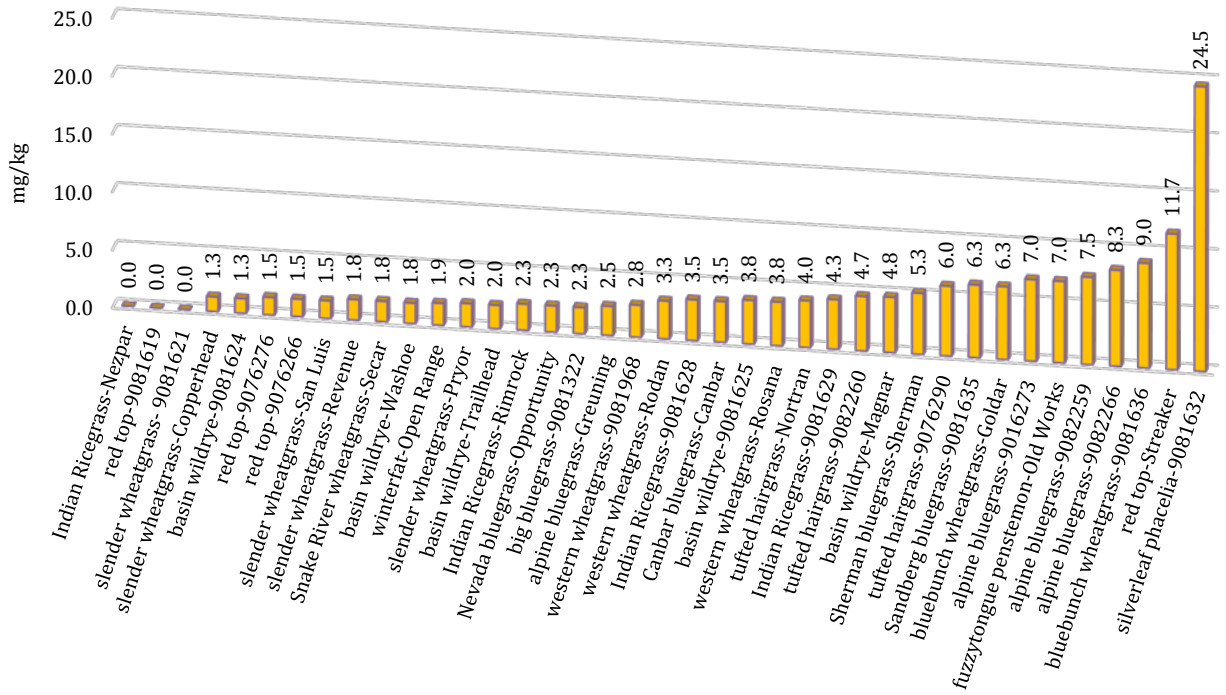
Addendum, Table 2. Metal Levels in Plants.					
Metal levels in Plants [1]	**As**	**Cd**	**Cu**	**Pb**	**Zn**
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Deficient			2 to 5		
Sufficient or Normal	1 to1.7	0.05 to 0.2	5 to 30	5 to 10	27 to 150
Excessive or Toxic	5 to 20	5 to 30	20 to 100	30 to 300	100 to 400
1. Kabata-Pendias and Pendias 1992.					

Addendum. Table 3. Maximum Tolerable Levels of Five Metals for Domestic Livestock, and Wildlife.					
Maximum Tolerable Levels for	**As**	**Cd**	**Cu**	**Pb**	**Zn**
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Domestic livestock [1]	50	0.5	100	30	500
Wildlife [2]	50	2	55	40	300
1. NRC 1980, 2. Ford, 1996.					

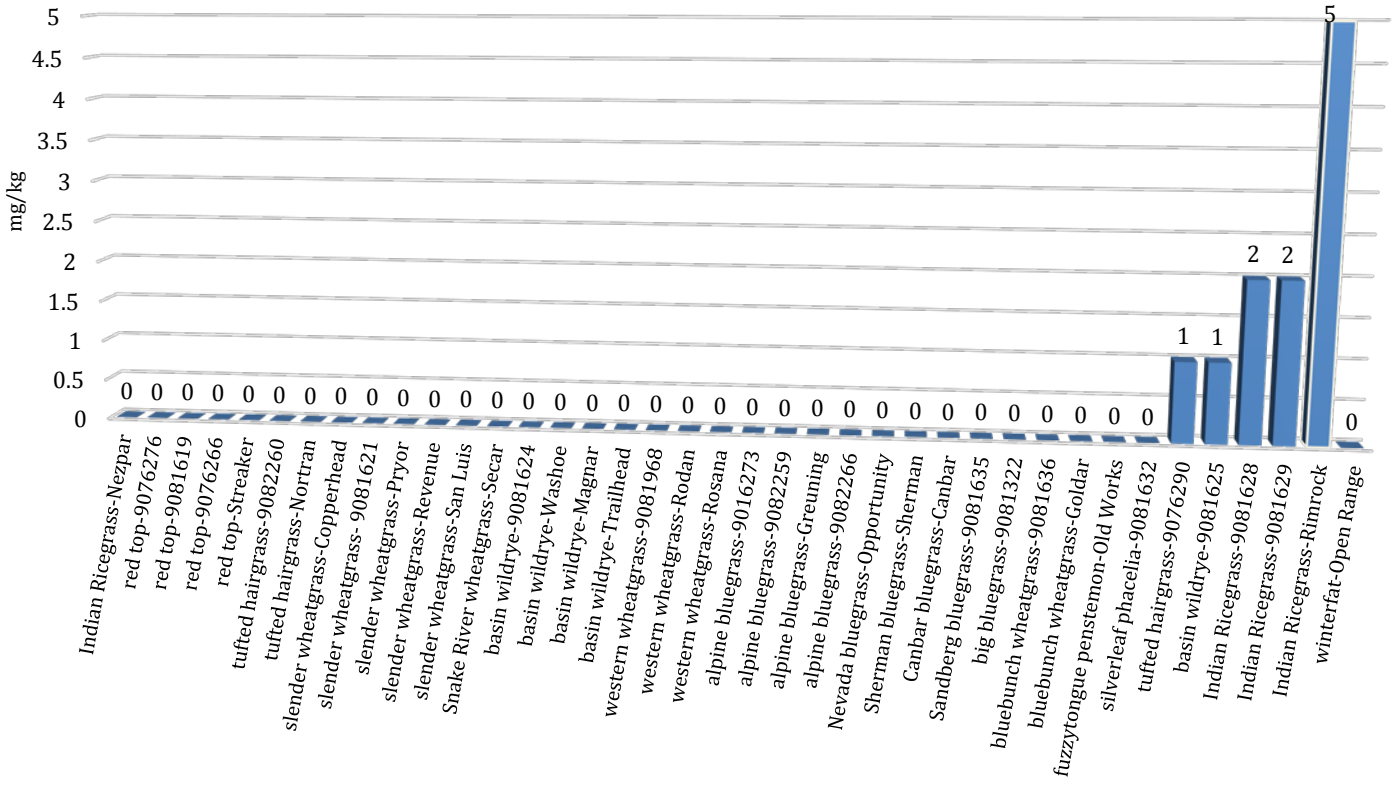
Addendum, Table 4. Average Heavy Metal Concentrations of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center.

	Metal	**As**	**Cd**	**Cu**	**Pb**	**Zn**
Species		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Grasses						
alpine bluegrass	POAL 9016273	7.0	0	48.5	2.0	37.5
alpine bluegrass	POAL 9082259	7.5	0	44.5	0.0	36.3
alpine bluegrass	POAL 'Greuning'	2.5	0	25.5	7.5	34.5
alpine bluegrass	POAL 9082266	8.3	0	35.0	2.3	71.5
basin wildrye	LECI 9081624	1.3	0	40.0	0.0	54.8
basin wildrye	LECI 9081625	3.8	0.25	42.8	0.0	90.5
basin wildrye	LECI Washoe	1.8	0	29.5	0.0	84.5
basin wildrye	LECI 'Magnar'	4.8	0	49.5	0.0	49.0
basin wildrye	LECI 'Trailhead'	2.0	0	29.5	51.8	82.5
big bluegrass	POSE 9081322	2.3	0	46.5	0.0	51.0
bluebunch wheatgrass	PSSP 9081636	9.0	0	53.8	0.0	53.3
bluebunch wheatgrass	PSSP 'Goldar'	6.3	0	41.0	0.0	44.0
Canbar bluegrass	POSE 'Canbar'	3.5	0	9.0	0.0	35.0
Indian Ricegrass	ACHY 9081628	3.5	0.5	19.8	0.0	59.3
Indian Ricegrass	ACHY 9081629	4.3	0.5	22.5	0.0	53.5
Indian Ricegrass	ACHY 'Rimrock'	2.3	1.5	15.3	0.0	31.3
Indian Ricegrass	ACHY 'Nezpar'	0.0	0	12.0	0.0	28.3
Nevada bluegrass	POSE Opportunity	2.3	0	31.8	0.0	31.5
red top	AGGI 9076276	1.5	0	34.0	0.0	36.5
red top	AGGI 9081619	0.0	0	47.0	0.0	38.8
red top	AGGI 9076266	1.5	0	41.0	0.0	54.8
red top	AGGI 'Streaker'	11.7	0	90.0	4.3	41.3
Sandberg bluegrass	POSE 9081635	6.3	0	32.3	0.0	29.3
Sherman bluegrass	POSE 'Sherman'	5.3	0	25.0	0.0	58.8
slender wheatgrass	ELTR Copperhead	1.3	0	22.0	0.0	12.8
slender wheatgrass	ELTR 9081621	0.0	0	25.8	0.0	15.0
slender wheatgrass	ELTR 'Pryor'	2.0	0	24.8	0.0	23.3
slender wheatgrass	ELTR 'Revenue'	1.8	0	32.0	0.0	29.3
slender wheatgrass	ELTR 'San Luis'	1.5	0	23.5	0.0	25.3
Snake River wheatgrass	ELWA 'Secar'	1.8	0	26.8	0.0	45.5
tufted hairgrass	DECE 9076290	6.0	0.33	57.7	0.0	50.0
tufted hairgrass	DECE 9082260	4.7	0	30.0	0.0	51.7
tufted hairgrass	DECE 'Nortran'	4.0	0	20.0	0.0	42.5
western wheatgrass	PASM 9081968	2.8	0	31.0	0.0	50.8
western wheatgrass	PASM 'Rodan'	3.3	0	27.0	0.0	32.3
western wheatgrass	PASM 'Rosana'	3.8	0	27.5	0.0	39.8
Forbs						
fuzzytongue penstemon	PEER Old Works	7.0	0	40.0	0.0	20.5
silverleaf phacelia	PHHA 9081632	24.5	0	166.0	7.5	57.0
Subshrub						
winterfat	KRLA 'Open Range'	1.9	0	44.8	0.0	43.0

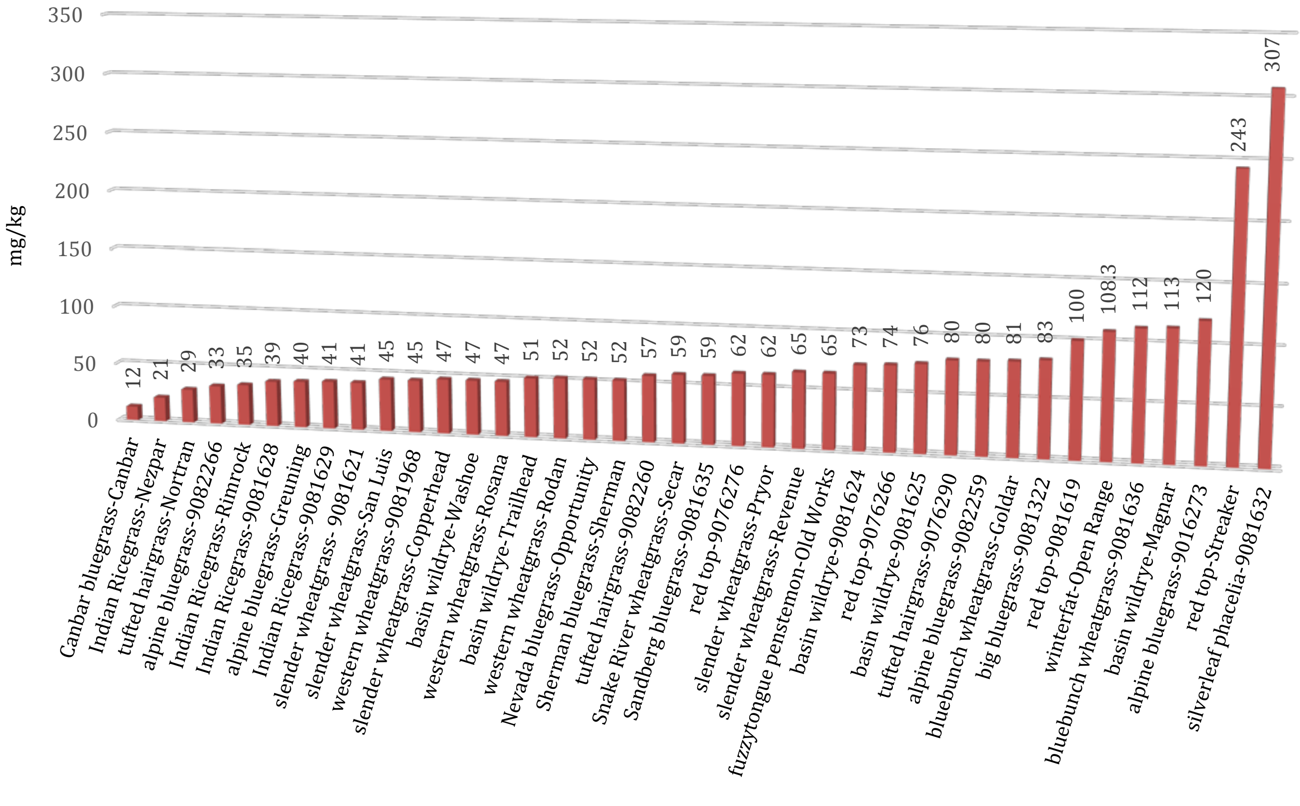
Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07.



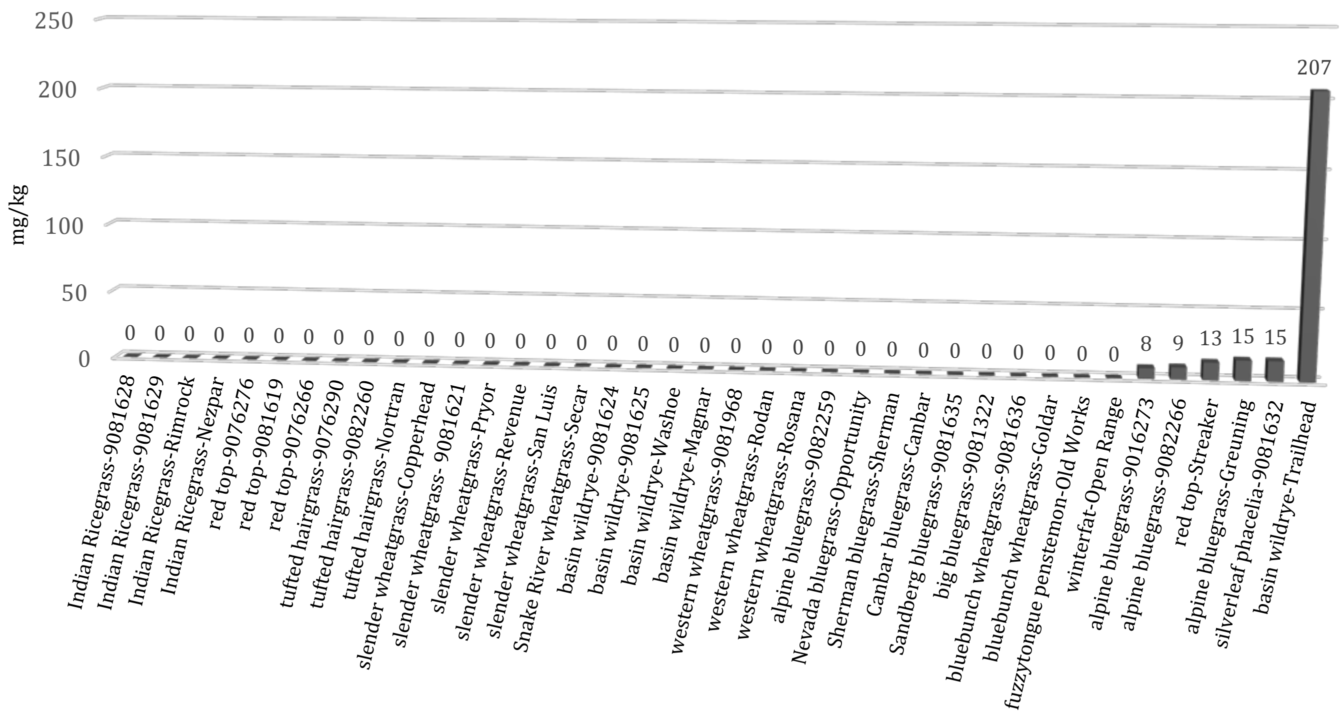
Addendum, Figure 1. Average Arsenic Concentration of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07. Maximum Tolerable Level: domestic livestock and wildlife – 50 mg/kg.



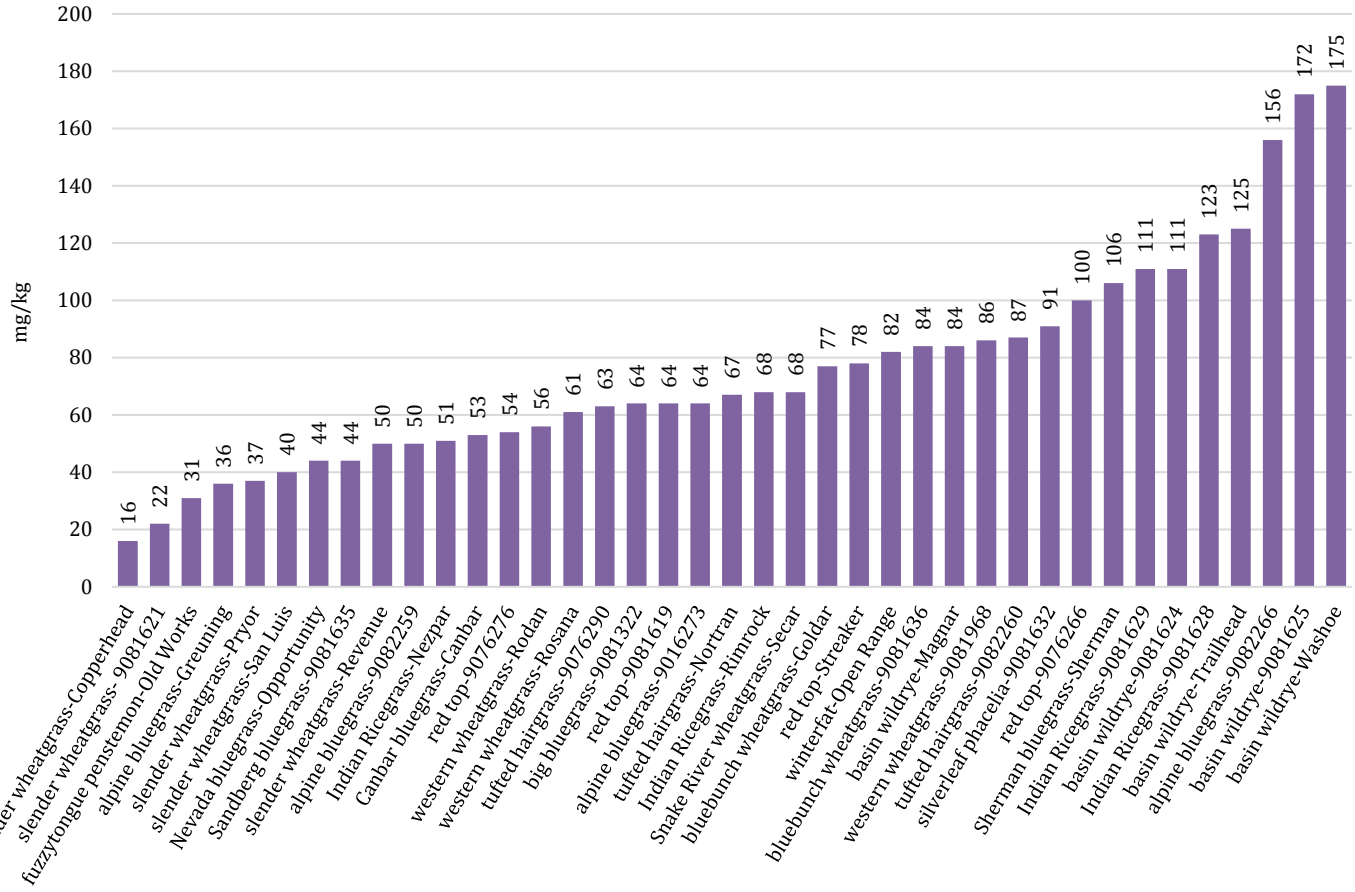
Addendum, Figure 2. Average Cadmium Concentration of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07. Maximum Tolerable Level: domestic livestock – 0.5 mg/kg, wildlife – 2.0 mg/kg.



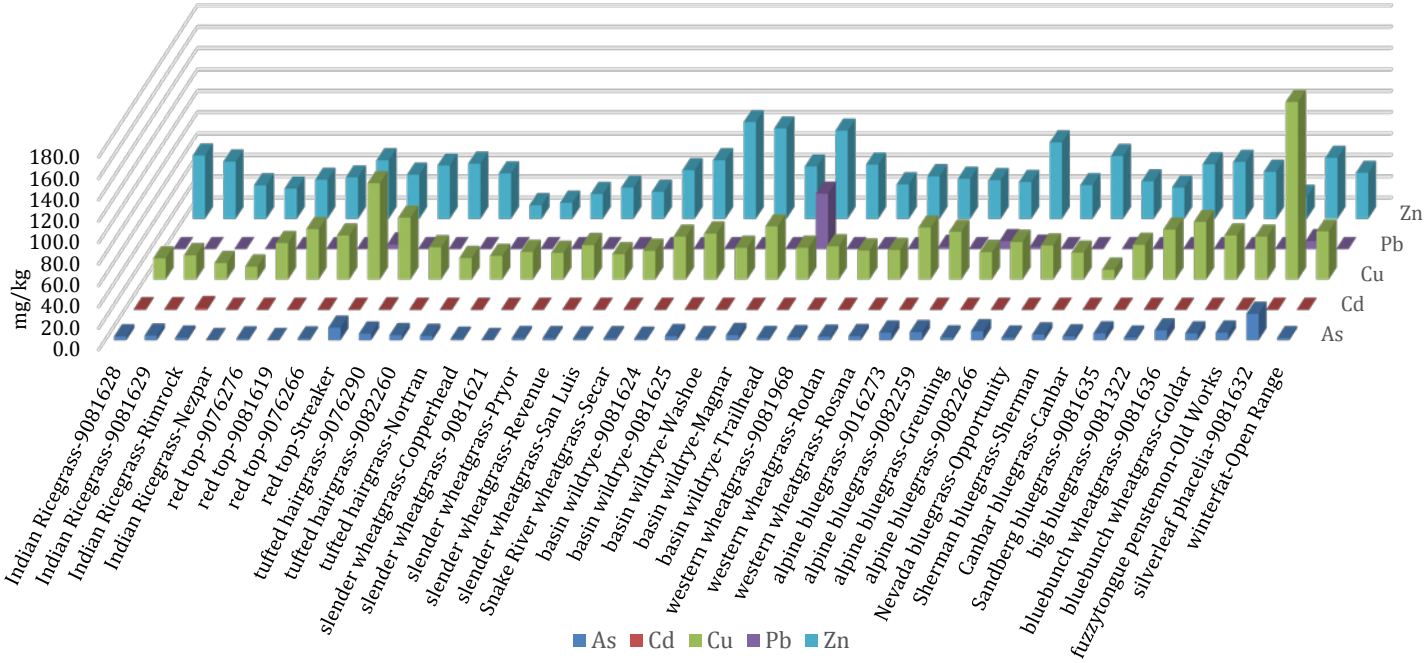
Addendum, Figure 3. Average Copper Concentration of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07. Maximum Tolerable Level: domestic livestock – 100 mg/kg, wildlife – 55 mg/kg.



Addendum, Figure 4. Average Lead Concentration of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07. Maximum Tolerable Level: domestic livestock – 30 mg/kg, wildlife – 40 mg/kg.



Addendum, Figure 5. Average Zinc Concentration of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07. Maximum Tolerable Level: domestic livestock – 500 mg/kg, wildlife – 300 mg/kg.



Addendum, Figure 6. Average Metal Concentrations of Clipped Biomass Samples from the Stucky Ridge Comparative Evaluation Trials near Anaconda, MT. USDA-NRCS Bridger Plant Materials Center. Sampled 9/22/04, 8/29/05, 8/28/06, 8/21/07.

Addendum, Table 5. Plants exceeding the Maximum Tolerable Levels of heavy metals for domestic livestock (DL) and wildlife (W).															
Element	**As**			**Cd**			**Cu**			**Pb**			**Zn**	
Domestic Livestock / Wildlife	DL	W		DL	W		DL	W		DL	W		DL	W
Maximum Tolerable Levels (mg/kg)	50	50		0.5	2		100	55		30	40		500	300
Grasses														
Indian Ricegrass-9081628				**X**	**X**									
Indian Ricegrass-9081629				**X**	**X**									
Indian Ricegrass-'Rimrock'				**X**	**X**									
Indian Ricegrass-'Nezpar'														
red top-9076276								**X**						
red top-9081619							**X**	**X**						
red top-9076266								**X**						
red top-'Streaker'							**X**	**X**						
tufted hairgrass-9076290				**X**				**X**						
tufted hairgrass-9082260								**X**						
tufted hairgrass-'Nortran'														
slender wheatgrass-Copperhead Germplasm														
slender wheatgrass-9081621														
slender wheatgrass-'Pryor'								**X**						
slender wheatgrass-'Revenue'								**X**						
slender wheatgrass-'San Luis'														
Snake River wheatgrass-'Secar'								**X**						
basin wildrye-9081624								**X**						
basin wildrye-9081625				**X**				**X**						
basin wildrye-Washoe Germplasm														
basin wildrye-'Magnar'							**X**	**X**						
basin wildrye-'Trailhead'										**X**	**X**			
western wheatgrass-9081968														
western wheatgrass-'Rodan'														
western wheatgrass-'Rosana'														
alpine bluegrass-9016273							**X**	**X**						
alpine bluegrass-9082259								**X**						
alpine bluegrass-'Greuning'														
alpine bluegrass-9082266														
Nevada bluegrass-Opportunity Germplasm														
Sherman bluegrass-'Sherman'														
Canbar bluegrass-'Canbar'														
Sandberg bluegrass-9081635								**X**						
big bluegrass-9081322								**X**						
bluebunch wheatgrass-9081636							**X**	**X**						
bluebunch wheatgrass-'Goldar'								**X**						
Forbs														
fuzzytongue penstemon-Old Works								**X**						
silverleaf phacelia-9081632							**X**	**X**						
Subshrub														
winterfat-'Open Range'							**X**	**X**						

An **X** marks the plant that exceeds the maximum tolerable levels of that metal for domestic cattle, and wildlife.

Addendum. Table 6. Plants that uptake and incorporate Excessive or Toxic levels of the metal into their tissues.					
Element	**As**	**Cd**	**Cu**	**Pb**	**Zn**
Excessive or Toxic Levels (mg/kg)	5 to 20	5 to 30	20 to 100	30 to 300	100 to 400
Grasses					
alpine bluegrass-9016273	**X**		**X**		
alpine bluegrass-9082259	**X**		**X**		
alpine bluegrass-9082266					**X**
alpine bluegrass-Greuning			**X**		
basin wildrye-9081624			**X**		
basin wildrye-9081625			**X**		**X**
basin wildrye-Magnar			**X**		
basin wildrye-Trailhead			**X**	**X**	**X**
basin wildrye-Washoe			**X**		**X**
big bluegrass-9081322			**X**		
bluebunch wheatgrass-9081636	**X**		**X**		
bluebunch wheatgrass-Goldar	**X**		**X**		
Canbar bluegrass-Canbar					
Indian Ricegrass-9081628			**X**		
Indian Ricegrass-9081629			**X**		**X**
Indian Ricegrass-Nezpar			**X**		
Indian Ricegrass-Rimrock		**X**	**X**		
Nevada bluegrass-Opportunity			**X**		
red top-9076266			**X**		**X**
red top-9076276			**X**		
red top-9081619			**X**		
red top-Streaker	**X**		**X**		
Sandberg bluegrass-9081635	**X**		**X**		
Sherman bluegrass-Sherman	**X**		**X**		**X**
slender wheatgrass-9081621			**X**		
slender wheatgrass-Copperhead			**X**		
slender wheatgrass-Pryor			**X**		
slender wheatgrass-Revenue			**X**		
slender wheatgrass-San Luis			**X**		
Snake River wheatgrass-Secar			**X**		
tufted hairgrass-9076290	**X**		**X**		
tufted hairgrass-9082260			**X**		
tufted hairgrass-Nortran			**X**		
western wheatgrass-9081968			**X**		
western wheatgrass-Rodan			**X**		
western wheatgrass-Rosana			**X**		
Forbs					
fuzzytongue penstemon-Old Works	**X**		**X**		
silverleaf phacelia-9081632	**X**		**X**		
Subshrub					
winterfat-Open Range			**X**		

An **X** marks the plant that will incorporate excessive or toxic levels of the metals into their tissues.

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