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MOLYCORP, INC.
Questa Division

RRR198

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This is the early 90's / late 80's SCS uptake study - Report was never issued as a final -

The name (because I am sure you can't read the cover sheet) is: Plant Uptake by 10 Heavy Metals by Species Planted on Reclaimed Molybdenum Tailings. Interim Report. by USDA - Soil Conserv. Service Plant Materials Center Los Lunas, NM

PLANT UPTAKE OF 10 HEAVY METALS BY SPECIES PLANTED ON RECLAIMED MOLYBDENUM TAILINGS

INTERIM REPORT

PREPARED FOR:

Unocal 76 Molycorp Mine
Questa Division
Questa, New Mexico

DRAFT

USDA Soil Conservation Service
Plant Materials Center

DRAFT

EXECUTIVE SUMMARY

In response to a request by Molycorp related to the permiting of a new tailings pond during 1989 the above-ground vegetation concentrations of 10 heavy metals aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), zinc (Zn) were determined in 14 plant species. The purpose was to determine if the above-ground heavy metal concentrations in these species differ between Molybdenum-mine tailings depository sites and no-tailings background sites. Therefore plant samples for heavy metal concentrations were taken from both tailings depository and no-tailings sites including the proposed new site.

The 14 species average concentrations of Al, As, Cd, Pb, Ni, Se and Zn do not appear to differ between the tailings depository and background sites (Figure 1). The 14 species average concentration

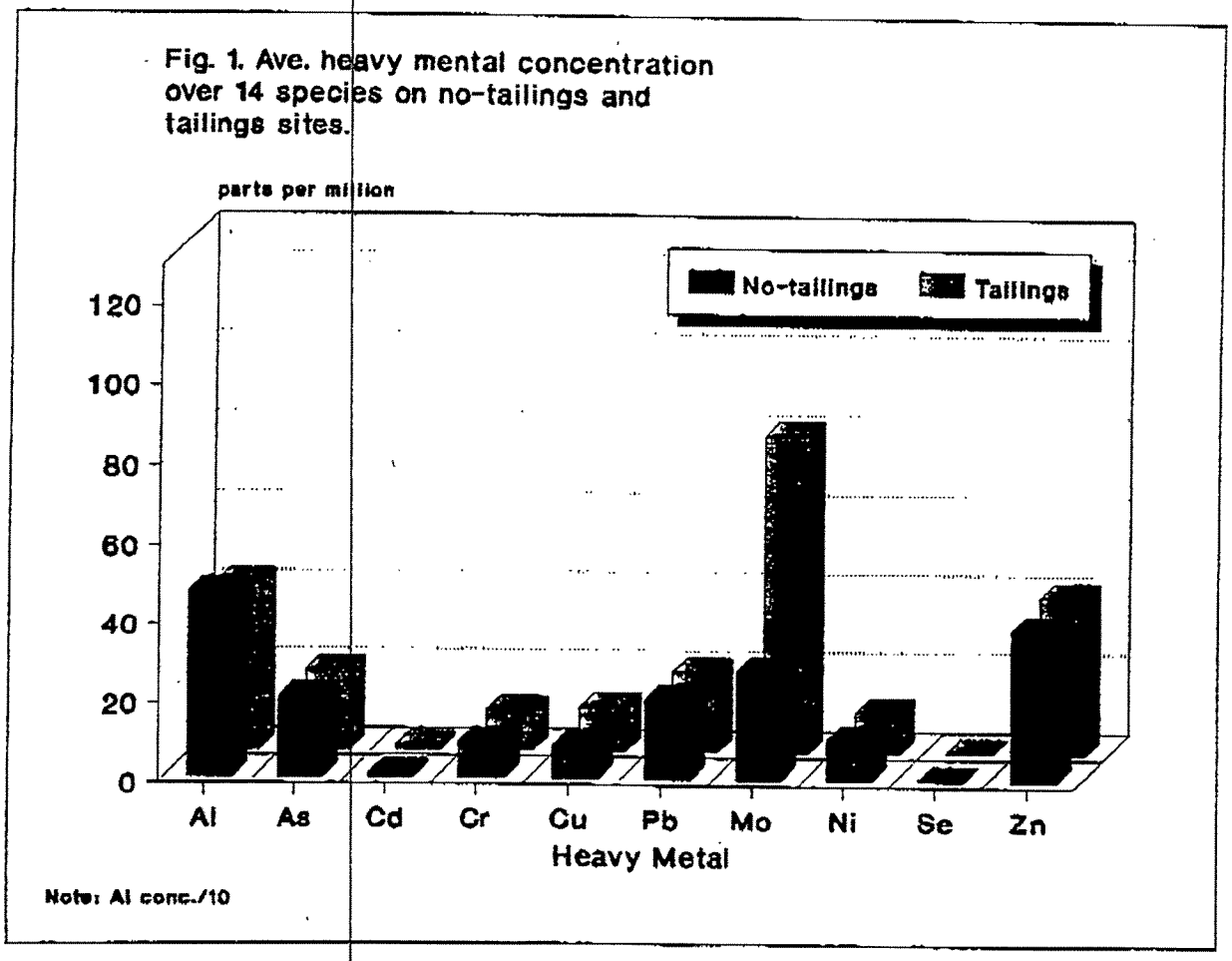
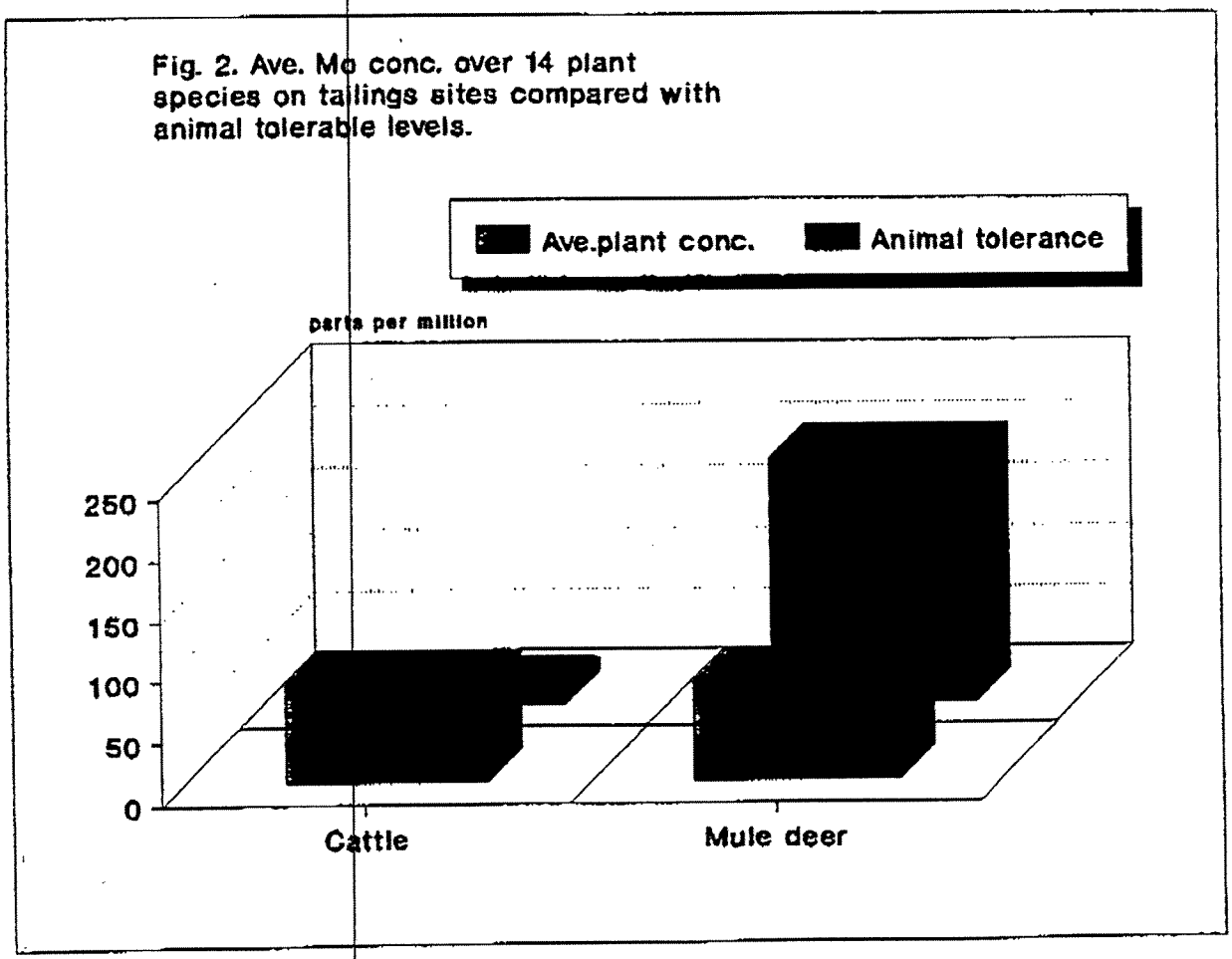


Fig. 1. Ave. heavy mental concentration over 14 species on no-tailings and tailings sites.

for both Cr and Cu increased slightly (10-25%) for plants growing on tailings depository sites. The 14 species average concentration for Mo increased substantially (196%) for plants growing on tailings depository sites although this varied considerably by species with some species showing no increase.

The scientific literature indicates that heavy metal intake by wildlife, via plant comsumption, is influenced by several complex factors. The concentration of heavy metals in plant tissue varies with season and plant phenological age. Plant species differ in their tissue concentration of heavy metals, and each animal species consumes a different mixture of plant species. Animal species differ in the size of their foraging area; this is important if high heavy metal concentrations are localized. The scientific literature also indicates that maximum tolerable dietary levels for heavy metals are influenced by several complex factors. Animal species differ considerably in their sensitivity to dietary levels of each heavy metal. The maximum tolerable dietary level of a particular metal can vary by a factor of ten depending

Fig. 2. Ave. Mo conc. over 14 plant species on tailings sites compared with animal tolerable levels.

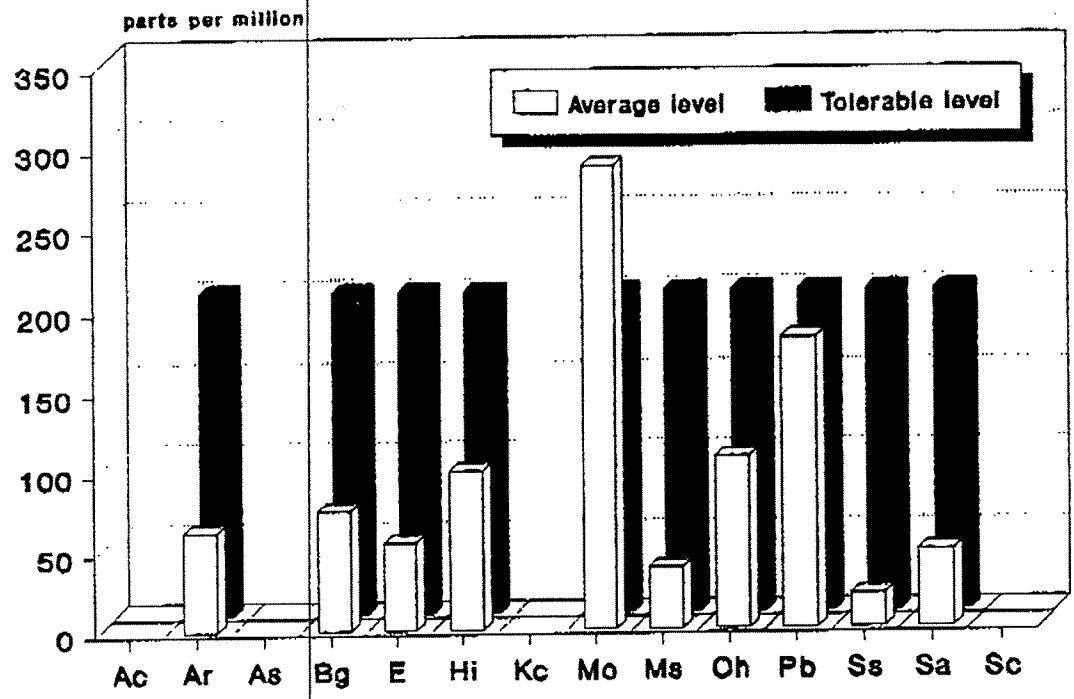


on the dietary intake of other elements. For example, the maximum tolerable dietary of Mo increases as the dietary Cu:Mo ratio increases.

All heavy metal concentrations, except Mo, of plants on the tailings sites were always less than the maximum tolerable dietary level for domestic cattle. The 14 species average concentration of Mo on the tailings sites was greater than the dietary maximum tolerable level for cattle but less than the maximum tolerable level for wildlife species such as mule deer (Figure 2). This may or may not be a problem depending on Mo maximum tolerable dietary levels. Mule deer were studied at locations near Colorado mining areas. Despite increased levels of Mo, deer tissue showed no significant elevation of Mo above control areas (Kienholz, 1977).

Mammalian wildlife in general is much more resistant to high dietary Mo levels than domestic ungulates (U.S. Fish and Wildlife Service, 1988). The primary determinate of susceptibility to Mo poisoning is not the absolute level of dietary Mo but the Cu:Mo ratio (U.S. Fish and Wildlife Service, 1988). Dietary Cu supplementation protected cattle from dietary Mo concentrations up to 150 parts per million (ppm) (U.S. Fish and Wildlife Service, 1988). Most of the plant species evaluated in this study exhibited Mo concentrations of less than 150 ppm when growing on tailings sites (Figure 3). Only one plant species sweet clover *(Melilotus officinalis)* exhibited a Mo concentration greater than the maximum tolerable dietary level for mule deer. Species of the *Melilotus* genus are known Mo accumulators. The SCS-Plant Materials Center recommended seed mix for planting on Mo tailings depository sites does not contain *Melilotus* species. The species *Menodora scabra, Schizachyrium scoparium,* and *Sporobolus airoides* exhibited low Mo concentrations on the tailings sites compared to the other species evaluated.

Fig. 3. Comparison of average Mo conc. over the tailings sites with the maximum tolerable level for mule deer.



Ac Agropyron cristatum
Ar Agropyron riparium
As Agropyron smithii
Bg Bouteloua gracilis
E Elymus species
Hj Hilaria jamesii
Kc Koeleria cristata
Mo Melilotus officinalis
Ms Menodora scabra
Oh Oryzopsis hymenoides
Pb Penstemon barbatus
Ss Schizachyrium scoparium
Sa Sporobolus airoides
Sc Sporobolus cryptandrus

Suggestions for Additional Research

1) Of the 14 species sampled in 1989, seven were present on tailings sites but not on background sites. We should find plants of these species if they occur naturally, on or near the Questa area. We should note the soil types of the sites. We should sample these newly found plants.

To increase the reliability of our information, we should resample all plants on the new site, tailings (topsoil) 1, and tailings (topsoil) 2 sites during September, 1990.

2) During 1989, we sampled 4 of the 12 species in the recommended seed mix for planting on mine tailings sites. During spring 1991, we should plant seed from the recommended seeding mix, with the goal of at least 20 plants of each species on both tailings and no-tailings sites. We should plant in short rows with three replications per site. The plants established on the new site location will provide baseline values for comparison with plants after tailings deposition. We could establish these plants using transplants or seed.

3) We should take soil samples (at least three locations per site) for the elements measured in plant tissue.

4) Based on the 1989 work we can feel safe in only measuring concentrations of the following elements:

- Mo - Because of the possibility of concentrations greater than the maximum tolerable levels for domestic livestock.
- Cu - Because of the importance of the Cu:Mo ratio in Mo toxicity.
- S - Because of the importance of the Cu:Mo:S ratio in Mo toxicity.
- Cd - Because Cd concentrations should be measured to the precision of 0.50 ppm because that is the safe level based on human food residue considerations.
- Al - Some vegetative concentrations of Al from both tailings and no-tailings sites were greater than the maximum tolerable dietary level for horses. Therefore, we should ascertain with a high degree of probability the effect of tailings on Al concentrations.

5) We should sample at least 20 plants per site to account for genetic variability within the species. We probably do not need 20 analysis per site depending on the repeatability of analysis.

6) We should review the scientific literature to determine if the Mo concentration varies with plant phenological age and if above-ground plant parts differ for Mo concentration. Greenhouse studies could be initiated to evaluate these items.

INTRODUCTION

In the summer of 1989, the Los Lunas Plant Materials Center (PMC) was contacted concerning plant uptake of heavy metals by species being evaluated at Molycorp's Questa tailing. The interest related to Molycorp's request for establishment of a new tailings pond area. The PMC has been evaluating various ecotypes and species at the Questa site since 1979. This provided a logical site to determine if species used in reclamation mixes were concentrating heavy metals.

In order to better understand the role of heavy metal elements in the environment as they relate to plant and animal physiology, in both natural and elevated levels of occurrence, a review was undertaken of citations in the scientific literature pertinent to the southern Rocky Mountains.

Several basic concepts are evident. Elements of heavy metals occur naturally in soils (Table 1) and when they occur at low levels, play an essential role in the nutrition and regulation of body functions of those animals which feed upon plants containing these elements. However, plants with high levels of heavy metal elements cause chronic or toxic reactions in animals utilizing plant tissue. It is also documented that certain species of plants are capable of accumulating or concentrating various elements in tissues at ratios exceeding the background concentration in the soil (Table 2).

Table 1. Total Endogenous Soil Concentrations of Selected Elements
(U.S. Fish and Wildlife Service/OBS, 1978)

Element	Range (ppm)	Average Concentration (ppm)
Arsenic	0.10 - 40.00	6.00
Barium	100.00 - 3000.00	500.00
Beryllium	1.00 - 40.00	6.00
Boron	2.00 - 100.00	10.00
Cadmium	0.01 - 7.00	0.06
Chromium	5.00 - 3000.00	100.00
Cobalt	1.00 - 40.00	8.00
Copper	2.00 - 100.00	20.00
Fluorine	30.00 - 300.00	200.00
Lead	2.00 - 100.00	10.00
Manganese	100.00 - 4000.00	850.00
Mercury	0.01 - 4(?)	-
Molybdenum	0.20 - 5.00	2.00
Nickel	10.00 - 1000.00	40.00
Selenium	0.01 - 80.00	0.50
Vanadium	20.00 - 500.00	100.00
Zinc	10.00 - 300.00	50.00

The availability of these elements in the soil to uptaking vegetation is a function of the solubility of the element, the cation exchange of the soil, reaction with organic matter, soil moisture, activity of microorganisms and the location of plant feeder roots (U.S. Fish and Wildlife Service/OBS, 1978).

While the literature provides a large amount of quite exact information on tolerances of domestic animals (Table 3) to heavy metals in their diets, there is much less information known about tolerances of wild animals, such as elk, mule deer, wild turkey or rabbits.

However, there are known similarities in free choice diets of range livestock and wild ungulates. A study (Hansen and Clark, 1977) found that the diets of elk, horses and cattle were similar, while mule deer utilized large amounts of browse from shrubs and trees. Another study (Hansen, Clark and Lawhorn, 1977) indicated that wild horses and cattle utilized primarily grasses while mule deer ate shrubs such as sagebrush and mountain mahogany. Dietary overlap of horses and deer was only 1%; cattle and deer was only 4%; while horses and cattle was 77%. These similarities and discrepancies between known diets of domestic livestock and wildlife is useful in predicting possible tolerances of wildlife to heavy metals in plant tissue. (See Appendix I).

Table 2. Plant: Soil Concentration Ratios
(U.S. Fish and Wildlife Service/OBS, 1978)

Element	Concentration Ratio [a]
Arsenic	0.14
Barium	0.03
Beryllium	0.02
Boron	5.30
Cadmium	10.70
Chromium	0.02
Cobalt	0.11
Copper	0.47
Fluorine	0.03
Lead	0.45
Manganese	0.066
Mercury	0.02-0.50
Molybdenum	0.57
Nickel	0.045
Selenium	1.00
Vanadium	0.01
Zinc	0.64

[a]This is a generalized approximation of the ability of plants to accummulate trace elements. The concentration ratio is the ratio of the average concentration of each trace element in plants to the average concentration of each trace element in soils.

The U. S. Fish and Wildlife Service has published a series of reports which describe the known relationships between heavy metals and wildlife toxicity (U.S. Fish and Wildlife Service, 1988). Some pertinent excerpts provide a broad overview:

Arsenic is essential for the growth and development of plants and animals. Arsenic is bioconcentrated by organisms; but is not biomagnified in the food chain.

Cadmium is not biologically essential to plants or animals. Mammals and birds are comparatively resistant to the biocidal properties of cadmium.

Chromium is adverse to wildlife in the 5.1 to 10.0 ppm ranges. biomagnification has not been reported.

Mercury is both bioconcentrated and biomagnified through food chains.

Selenium effects, such as metabolism and degradation, are significantly modified by interactions with various heavy metals. Livestock and terrestrial wild mammals are tolerant.

Table 3. General Summary of Trace Element Concentrations Known to be Toxic to Animals
(U.S. Fish and Wildlife Service/OBS, 1978)

Trace Element	Concentration
Fluorine	100-300 ppm in diet
Mercury	20-50 mg/kg body weight
Manganese	500-5000 ppm in diet
Selenium	5-30 ppm in diet
Arsenic toxic to sheep	3 ppm in plants
Vanadium	10-500 ppm in diet
Beryllium	Very toxic*
Copper	20-30 ppm in diet
Nickel	1000 ppm in diet
Zinc	500-1000 ppm in diet
Lead	80-150 ppm in diet
Chromium	500 ppm in water
Boron	1-5 g/kg body weight
Cobalt	1-3 ppm in diet
Cadmium	15 ppm in diet

*Major hazard to humans, and presumably to animals, is through inhalation. Average short-term (24-hour) or monthly concentrations of beryllium must not exceed 0.01 g/m^3 in ambient air. Toxicity data on the ingestion hazard are meager.

A study of heavy metal concentrations in white-tailed deer utilizing uranium mining areas in Texas (King, Leleux and Mulhern, 1984) indicated the variations which can occur. Elemental copper was low in background soils and plants, not meeting the dietary needs of the deer. Despite active mining, deer tissue was low in copper and had no detectable molybdenum.

Mule deer were studied at locations near Colorado mining areas. Despite increased levels of molybdenum, deer tissue showed no significant elevation of molybdenum above control areas (Kienholz, 1977).

A literature review of heavy metals and wildlife effects was prepared for the ore-shale areas of Colorado (Nagy, 1978). Arsenic concentrations in plant materials normally are in the range 0.1 to 1.0 ppms; but surface contamination (i.e. mining) may raise plant concentration to well above 0.5 ppm.

Arsenic has an antagonistic effect on selenium toxicity; thereby reducing the hazard. They reported no specific effects to wildlife via feeding on plants. Uptake of molybdenum by plants is increased with higher levels of soil moisture. Concentrations in plants may increase tenfold over levels in the soil. Toxicity symptoms occur in animals when plant tissue levels exceed 200 to 300 ppm. Mule deer are reported to show more tolerance to molybdenum toxicity than sheep or cattle. Molybdenum uptake is high in clovers.

Concentration of selenium is found in the growing portion of plants, and varies widely during the progression through the seasons.

A great deal of information is available on the toxicity of mercury to domestic livestock. An excellent reference is available to summarize what is known about mercury effects in wild animals; mostly aquatic forms (Wren, 1984). It is known that mercury is biomagnified within terrestrial food chains. Concentrations are typically low in herbivorous animals, but higher in carnivores. Elevated mercury levels have been reported in terrestrial animals living near point sources of mercury contamination in the environment. Proximity to high levels of mercury is the most significant abiotic factor influencing metal uptake in mammals.

MATERIALS AND METHODS

The bove ground portion of 14 plant species were sampled over five sites at the Molycorp Mine during the week of on July 3, 1989 (Table 4). Species selection was based on species availability and presence at multiple sites. None of the species were present at all sites. Five samples of each species present were collected at the Questa north, tailings (topsoil) 1 and 2, and tailings only sites, except that only three samples of *Penstemon barbatus* were collected at the tailings only site. Each sample from the Questa north, tailings (topsoil) 1 and 2, and tailings only sites consisted of the above-ground portion of one plant. At the new site only one sample of each species present was collected. Each sample from the new site consisted of the above-ground portion of a composite of several plants.

Table 4. Plant species sampled for element concentrations at each of five sites.

	Site#				
Species	**New Site**	**Questa North**	**Tailings (topsoil)1**	**Tailings (topsoil)2**	**Tailings Only**
Agropyron cristatum	-	*	-	-	-
Agropyron riparium	-	-	*	*	*
Agropyron smithii	*	*	-	-	-
Bouteloua gracilis	*	-	*	*	-
Elymus sp.	-	-	*	*	-
Hilaria jamesii	-	-	*	*	-
Koeleria cristata	*	-	-	-	-
Melilotus officinalis	-	-	-	-	*
Menodora scabra	-	-	*	*	-
Oryzopsis hymenoides	*	-	-	-	*
Penstemon barbatus	-	-	-	-	*
Schizachyrium scoparium	*	-	*	*	-
Sporobolus airoides	-	-	*	*	-
Sporobolus cryptandrus	-	*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.
*Indicates species sampled

Element concentrations were determined by the Agronomy and Horticulture Department, New Mexico State University. All samples were dried at 65°C and ground on a Wiley mill. Samples were digested with perchloric acid, and the concentration of ten elements was determined with a plasma spectrometer. The ten element concentrations measured were aluminum (Al), arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn).

RESULTS AND DISCUSSION

The element concentrations of the 14 plant species are presented in Tables 5-14 and in Appendix II (Figures 4-18). Within species comparisons for plant heavy metal concentrations between no-tailings and tailings sites can be made only for *Bouteloua gracilis*, *Oryzopsis hymenoides*, and *Schizachyrium scoparium*. Both within and between species comparisons suggest that the plant concentrations of Al, Ar, Cd, Pb, Ni, Se and Zn are not effected by the presence of tailings. Both within and between comparisons suggest that the presence of tailings increases the plant concentrations of Cr, Cu and Mo.

A comparison of plant heavy metal concentrations averaged over the three tailings sites with maximum tolerable dietary levels is presented in Figure 4 and Table 15. All plant heavy metal concentrations, except the Mo concentration of *Melilotus officinalis*, are less than the maximum tolerable levels. Legumes particularly *Melilotus* and *Lotus* species are known Mo accumulators (U.S. Fish and Wildlife Service, 1988).

The maximum tolerable dietary Mo level utilized in Figure 4 and Table 15 is that for mule deer (200 ppm). Domestic cattle and sheep are more sensitive to Mo than non-ruminants and wildlife (U.S. Fish and Wildlife Service, 1988). Cattle grazing pastures containing more than 10 ppm Mo may develop molydbenosis also called teart disease (U.S. Fish and Wildlife Service, 1988). Molydbenosis is a Cu defficiency disease caused by the depressing effect of Mo on the physiological availabilty of Cu. A low Cu:Mo ratio (<2) rather than the absolute dietary concentration of Mo is the primary determinant of molydbenosis susceptibility (U.S. Fish and Wildlife Service, 1988). Increasing the dietary Cu to 13 to 16 ppm protected cattle against Mo concentrations in the diet up to 150 ppm (U.S. Fish and Wildlife Service, 1988). The Cu:Mo ratios of plants sampled at Molycorp, from both no-tailings and tailings containing sites, are less than 2 (Table 15). This suggests that the diets of cattle and sheep grazing these areas should be supplemented with Cu.

The Mo concentration of *Schizachyrium scoparium* on the tailings sites was lowest of the species sampled (Table 11). The Cu:Mo ratio of *Schizachyrium scoparium*, *Oryzopsis hymenoides*, and

Menodora scabra appear high compared to the other species sampled, and the Cu:Mo ratio of *Melilotus officinalis* and *Hilaria jamesii* appear low.

Suggestions for Additional Research

1) Of the 14 species sampled in 1989, seven were present on tailings sites but not on background sites. We should find plants of these species if they occur naturally, on or near the Questa area. We should note the soil types of the sites. We should sample these newly found plants.

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4) Based on the 1989 work we can feel safe in only measuring concentrations of the following elements:

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Cd - Because Cd concentrations should be measured to the precision of 0.50 ppm because that is the safe level based on human food residue considerations.

Al - Some vegetative concentrations of Al from both tailings and no-tailings sites were greater than the maximum tolerable dietary level for horses. Therefore, we should ascertain with a high degree of probability the effect of tailings on Al concentrations.

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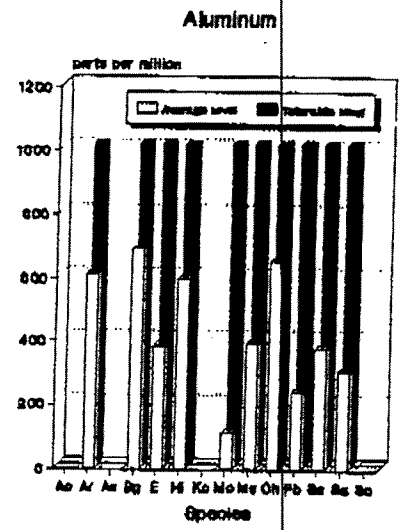
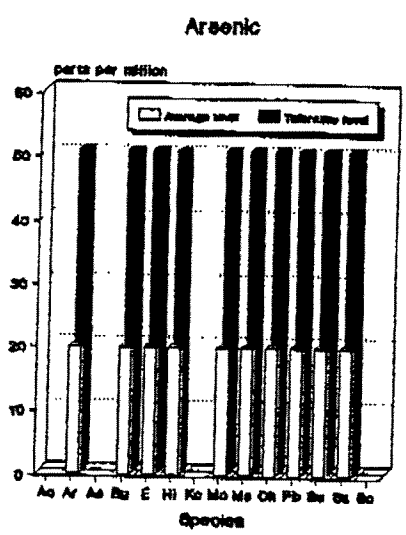
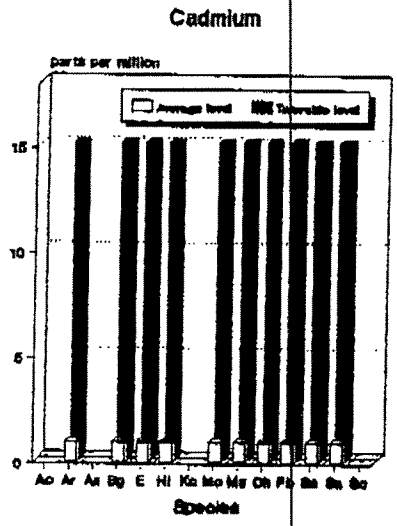
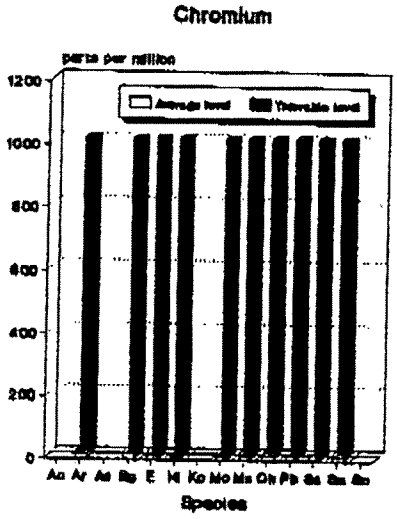








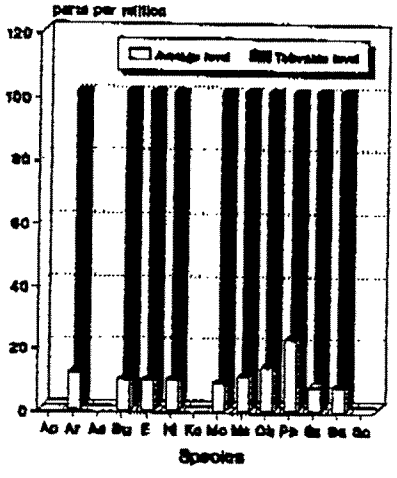
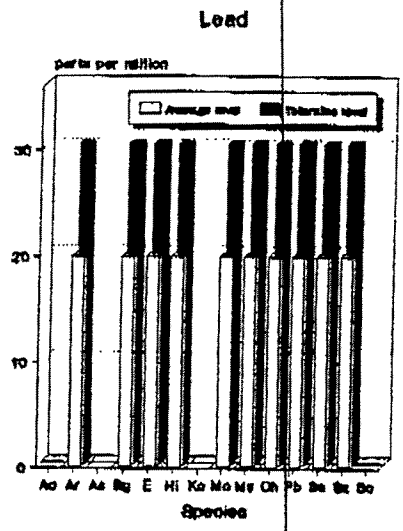
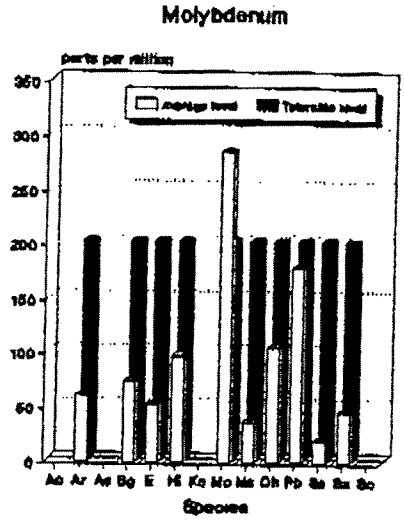
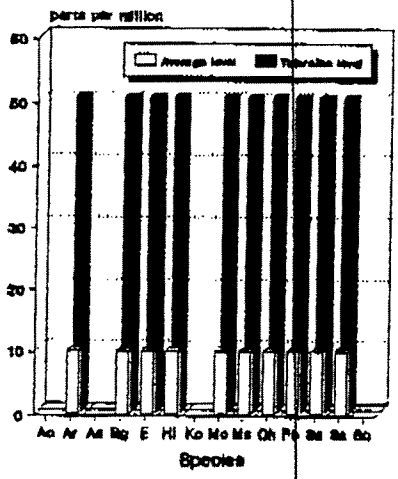
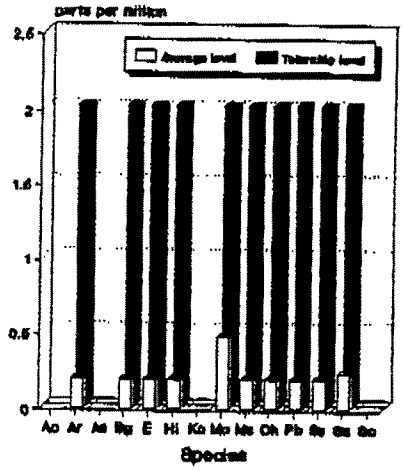


Fig. 4. Comparison of average plant heavy metal concentration over the three tailings containing sites with each metal's maximum tolerable level. Maximum tolerable levels are those in Appendix I for cattle, except for Cd which is the level toxic to animals in Table 3, and for Mo which is the level tolerable for mule deer (200 ppm) as discussed on page









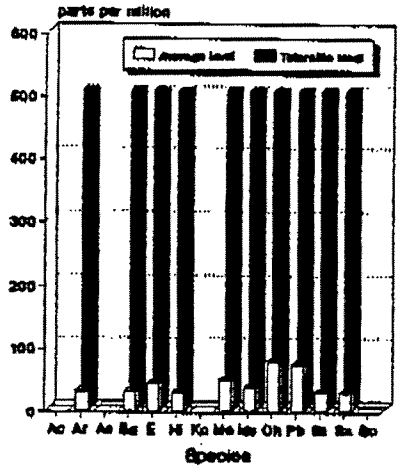


Fig. 4 (cont'd)

Ac - Agropyron cristatum
Ar - Agropyron riparium
AS - Agropyron smithii
Bg - Bouteloua gracilis
E - Elymus species
Hj - Hilaria jamesii
Kc - Koeleria cristata
Mo - Melilotus officinalis
Ms - Menodora scabra
Oh - Oryzopsis hymenoides
Pb - Pensternon barbatus
Ss - Schizachyrium scoparium
Sa - Sporobolus airoides
SC - Sporobolus cryptandrus

Table 5. Aluminum concentrations of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	*95*	-	-	-
Agropyron riparium	-	-	*774*	*686*	*372*
Agropyron smithii	*984*	*154*	-	-	-
Bouteloua gracilis	*1252*	-	*680*	*702*	-
Elymus sp.	-	-	*530*	*238*	-
Hilaria jamesii	-	-	*364*	*831*	-
Koeleria cristata	*50*	-	-	-	-
Melilotus officinalis	-	-	-	-	*111*
Menodora scabra	-	-	*460*	*327*	-
Oryzopsis hymenoides	*622*	-	-	-	*654*
Penstemon barbatus	-	-	-	-	*241*
Schizachyrium scoparium	*354*	-	*358*	*395*	-
Sporobolus airoides	-	-	*274*	*335*	-
Sporobolus cryptandrus	-	*254*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 6. Arsenic concentration of 14 plant species over five sites.

Species	Site[1]				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	*<20*	-	-	-
Agropyron riparium	-	-	*<20*	*<20*	*<20*
Agropyron smithii	*<20*	*<20*	-	-	-
Bouteloua gracilis	*<20*	-	*<20*	*<20*	-
Elymus sp.	-	-	*<20*	*<20*	-
Hilaria jamesii	-	-	*<20*	*<20*	-
Koeleria cristata	*<20*	-	-	-	-
Melilotus officinalis	-	-	-	-	*<20*
Menodora scabra	-	-	*<20*	*<20*	-
Oryzopsis hymenoides	*<20*	-	-	-	*<20*
Penstemon barbatus	-	-	-	-	-
Schizachyrium scoparium	*<20*	-	*<20*	*<20*	-
Sporobolus airoides	-	-	*<20*	*<20*	-
Sporobolus cryptandrus	-	-	-	-	-

[1]New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 7. Cadmium concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	<1	-	-	
Agropyron riparium	-	-	<1	<1	<1
Agropyron smithii	<1	<1	-	-	-
Bouteloua gracilis	<1	-	<1	<1	-
Elymus sp.	-	-	<1	<1	-
Hilaria jamesii	-	-	<1	<1	-
Koeleria cristata	<1	-	-	-	-
Melilotus officinalis	-	-	-	-	<1
Menodora scabra	-	-	<1	<1	-
Oryzopsis hymenoides	<1	-	-	-	<1
Penstemon barbatus	-	-	-	-	<1
Schizachyrium scoparium	<1	-	<1	<1	-
Sporobolus airoides	-	-	<1	<1	-
Sporobolus cryptandrus	-	<1	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 8. Chromium concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	*9*	-	-	
Agropyron riparium .	-	-	*12*	*12*	*15*
Agropyron smithii	*8*	*11*	-	-	-
Bouteloua gracilis	*8*	-	*11*	*10*	-
Elymus sp.	-	-	*9*	*10*	-
Hilaria jamesii	-	-	*9*	*10*	-
Koeleria cristata	*8*	-	-	-	-
Melilotus officinalis	-	-	-	-	*9*
Menodora scabra	-	-	*9*	*11*	-
Oryzopsis hymenoides	*8*	-	-	-	*13*
Penstemon barbatus	-	-	-	-	*7*
Schizachyrium scoparium	*8*	-	*10*	*10*	-
Sporobolus airoides	-	-	*8*	*12*	-
Sporobolus cryptandrus	-	*10*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 9. Copper concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	4	-	-	
Agropyron riparium	-	-	7	15	13
Agropyron smithii	4	11	-	-	-
Bouteloua gracilis	8	-	9	10	-
Elymus sp.	-	-	10	10	-
Hilaria jamesii	-	-	4	15	-
Koeleria cristata	8	-	-	-	-
Melilotus officinalis	-	-	-	-	9
Menodora scabra	-	-	10	11	-
Oryzopsis hymenoides	6	-	-	-	14
Penstemon barbatus	-	-	-	-	23
Schizachyrium scoparium	12	-	7	8	-
Sporobolus airoides	-	-	5	11	-
Sporobolus cryptandrus	-	9	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 10. Lead concentrations sampled for element concentrations at each of five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	<20	-	-	-
Agropyron riparium	-	-	<20	<20	<20
Agropyron smithii	<20	<20	-	-	-
Bouteloua gracilis	<20	-	<20	<20	-
Elymus sp.	-	-	<20	<20	-
Hilaria jamesii	-	-	<20	<20	-
Koeleria cristata	<20	-	-	-	-
Melilotus officinalis	-	-	-	-	<20
Menodora scabra	-	-	<20	<20	-
Oryzopsis hymenoides	<20	-	-	-	<20
Penstemon barbatus	-	-	-	-	<20
Schizachyrium scoparium	<20	-	<20	<20	-
Sporobolus airoides	-	-	<20	<20	-
Sporobolus cryptandrus	-	<20	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 11. Molybdenum concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	*10*	-	-	
Agropyron riparium	-	-	*52*	*67*	*68*
Agropyron smithii	*10*	*10*	-	-	-
Bouteloua gracilis	*10*	-	*78*	*72*	-
Elymus sp.	-	-	*33*	*77*	-
Hilaria jamesii	-	-	*54*	*144*	-
Koeleria cristata	*10*	-	-	-	-
Melilotus officinalis	-	-	-	-	*287*
Menodora scabra	-	-	*38*	*38*	-
Oryzopsis hymenoides	*10*	-	-	-	*107*
Penstemon barbatus	-	-	-	-	*181*
Schizachyrium scoparium	*144*	-	*17*	*24*	-
Sporobolus airoides	-	-	*10*	*85*	-
Sporobolus cryptandrus	-	*12*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 12. Nickel concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	*<10*	-	-	-
Agropyron riparium	-	-	*<10*	*<10*	*<10*
Agropyron smithii	*<10*	*<10*	-	-	-
Bouteloua gracilis	*<10*	-	*<10*	*<10*	-
Elymus sp.	-	-	*<10*	*<10*	-
Hilaria jamesii	-	-	*<10*	*<10*	-
Koeleria cristata	*<10*	-	-	-	-
Melilotus officinalis	-	-	-	-	*<10*
Menodora scabra	-	-	*<10*	*<10*	-
Oryzopsis hymenoides	*<10*	-	-	-	*<10*
Penstemon barbatus	-	-	-	-	*<10*
Schizachyrium scoparium	*<10*	-	*<10*	*<10*	-
Sporobolus airoides	-	-	*<10*	*<10*	-
Sporobolus cryptandrus	-	*<10*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 13. Selenium concentrations sampled for element concentrations at each of five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	<0.2	-	-	-
Agropyron riparium	-	-	<0.2	<0.2	<0.2
Agropyron smithii	<0.2	<0.2	-	-	-
Bouteloua gracilis	<0.2	-	<0.2	<0.2	-
Elymus sp.	-	-	<0.2	<0.2	-
Hilaria jamesii	-	-	<0.2	<0.2	-
Koeleria cristata	<0.2	-	-	-	-
Melilotus officinalis	-	-	-	-	<0.5
Menodora scabra	-	-	<0.2	<0.2	-
Oryzopsis hymenoides	<0.2	-	-	-	<0.2
Penstemon barbatus	-	-	-	-	<0.2
Schizachyrium scoparium	<0.2	-	<0.2	<0.2	-
Sporobolus airoides	-	-	<0.3	<0.2	-
Sporobolus cryptandrus	-	<0.2	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 14. Zinc concentration of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	parts per million				
Agropyron cristatum	-	17	-	-	-
Agropyron riparium	-	-	16	37	43
Agropyron smithii	20	21	-	-	-
Bouteloua gracilis	26	-	23	49	-
Elymus sp.	-	-	24	66	-
Hilaria jamesii	-	-	16	42	-
Koeleria cristata	92	-	-	-	-
Melilotus officinalis	-	-	-	-	52
Menodora scabra	-	-	51	24	-
Oryzopsis hymenoides	14	-	-	-	80
Penstemon barbatus	-	-	-	-	75
Schizachyrium scoparium	100	-	20	42	-
Sporobolus airoides	-	-	24	34	-
Sporobolus cryptandrus	-	16	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

Table 15. Averages of 10 elements over three tailings containing sites expressed as a percentage of the element's maximum tolerable level. Values are averages over the tailings (topsoil)1, tailings (topsoil)2, and tailings only sites.#

	Element*									
Species	Al	As	Cd	Cr	Cu	Pb	Mo	Ni	Se	Zr
	%									
Agropyron cristatum	-	-	-	-	-	-	-	-	-	-
Agropyron riparium	61	40	7	1	12	67	31	20	10	6
Agropyron smithii	-	-	-	-	-	-	-	-	-	-
Bouteloua gracilis	69	40	7	1	10	67	38	20	10	6
Elymus sp.	38	40	7	1	10	67	28	20	10	9
Hilaria jamesii	60	40	7	1	10	67	50	20	10	6
Koeleria cristata	-	-	-	-	-	-	-	-	-	-
Melilotus officinalis	11	40	7	1	9	67	144	20	24	10
Menodora scabra	39	40	7	1	11	67	19	20	10	8
Oryzopsis hymenoides	65	40	7	1	14	67	54	20	10	16
Penstemon barbatus	24	40	7	1	23	67	91	20	10	15
Schizachyrium scoparium	37	40	7	1	8	67	11	20	10	62
Sporobolus airoides	31	40	7	1	8	67	24	20	12	6
Sporobolus cryptandrus	-	-	-	-	-	-	-	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.

*Maximum tolerable levels are those in Appendix I for cattle, except for Cd which is the level toxic to animals in Table 3 and for Mo which is the tolerable level for mule deer as discussed on page 4.

Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.

Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.

Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.

Tailings only - South end of Section 35 tailings done in test plot area.

Table 16. Copper to molybdenum ratios of 14 plant species over five sites.

Species	Site#				
	New Site	Questa North	Tailings (topsoil)1	Tailings (topsoil)2	Tailings Only
	ratio				
Agropyron cristatum	-	*0.4*	-	-	
Agropyron riparium	-	-	*0.2*	*0.2*	*0.4*
Agropyron smithii	*0.4*	*1.1*	-	-	-
Bouteloua gracilis	*0.8*	-	*0.1*	*0.2*	-
Elymus sp.	-	-	*0.3*	*0.3*	-
Hilaria jamesii	-	-	*0.1*	*0.1*	-
Koeleria cristata	*0.8*	-	-	-	-
Melilotus officinalis	-	-	-	-	*0.1*
Menodora scabra	-	-	*0.6*	*0.3*	-
Oryzopsis hymenoides	*0.6*	-	-	-	*0.5*
Penstemon barbatus	-	-	-	-	*0.2*
Schizachyrium scoparium	*0.1*	-	*0.5*	*0.4*	-
Sporobolus airoides	-	-	*0.5*	*0.1*	-
Sporobolus cryptandrus	-	*0.8*	-	-	-

#New site - Native vegetation site above and west of proposed tailings dam.
Questa North - Native area adjacent to highway 522 (west side), six miles north of Questa traffic light.
Tailings (topsoil)1 - South end of Section 35 tailing done in reclaimed test plots area.
Tailings (topsoil)2 - North end of Section 35 tailing dam in reclaimed test plot area.
Tailings only - South end of Section 35 tailings done in test plot area.

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