THE EFFECT OF SELENIUM ON SPOIL SUITABILITY AS ROOT ZONE MATERIAL AT NAVAJO MINE, NEW MEXICO[1]

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ABSTRACT The root zone suitability limits for spoil Se at Navajo Mine in northwest New Mexico are currently 0.8 ppm total Se and 0.15 ppm hot-water soluble Se. These criteria were largely developed by the Office of Surface Mining using data from the Northern Great Plains. Applying these values, approximately 23% of the spoil volume and 47% of the spoil area sampled at Navajo Mine from 1985 to December 1993 were determined to be unsuitable as root zone material. Secondary Se accumulator plants (*Atriplex canescens*) growing in both undisturbed and reclaimed areas were randomly sampled for selenium from 1985 to December 1993. In most cases the undisturbed soil and reclaimed spoil at these plant sampling sites were sampled for both total and hot-water soluble Se. Selenium values for *Atriplex canescens* samples collected on the undisturbed sites averaged 0.64 ppm and ranged from 0.20 ppm to 2.5 ppm. Selenium values for the plants growing on spoil ranged from 0.02 ppm to 7.75 ppm and averaged 1.07 ppm. Total and hot-water Se values for spoil averaged 0.66 ppm and 0.06 ppm respectively, and ranged from 0.0 to 14.2 for total Se and 0.0 ppm to 0.72 ppm for hot-water soluble Se. The plant Se values were poorly correlated to both total and hot-water soluble Se values for both soil and spoil. Therefore, predicting suitable guidelines using normal regression techniques was ineffective.

Based on background Se levels in native soils, and levels found on reclaimed areas with *Atriplex canescens*, it is suggested that a total Se level of 2.0 ppm and a hot-water soluble Se level of 0.25 ppm should be used to represent the suitability limits for Se at Navajo Mine. If these Se values are used, it is estimated that less than 1% of the spoil volume would be unsuitable. This volume of spoil seems to be a more accurate estimate of the amount of spoil with unsuitable levels of Se than the estimated 23% using the current guidelines.

Additional Key Words: Soil selenium, plant selenium, suitability guidelines, mine spoil.

Introduction

Selenium is a naturally occurring trace element in soils. It is essential to animals but can also be toxic to them when they ingest plants with high concentrations. Plant concentrations exceeding 5.0 ppm are generally accepted as levels capable of producing negative effects on the health of animals (NRC, 1976). Normal soil levels of total Se are reported to commonly range from 0.1 ppm to 2.0 ppm in native undisturbed soils (Girling 1984, Tisdale, et al. 1985). In contrast, seleniferous soils contain from 30 to 325 ppm (Girling 1984).

The root zone suitability limits for regraded spoil Se at Navajo Mine are currently 0.8 ppm total Se and 0.15 ppm hot-water soluble Se. These criteria were largely developed using data from the Northern Great Plains. In June 1994, the Wyoming Joint Selenium Task Force produced guidelines for materials containing Se for Wyoming surface coal mines. Rooting zone materials with soluble Se levels <0.15 ppm require no monitoring. Levels of 0.15 - 0.45 ppm require monitoring, and levels >0.45 ppm require monitoring, mitigation and possible bonding. The vegetation must meet a 5.0 ppm dietary standard or baseline concentration.

The primary objective of this study was to determine the amount of regraded spoil exceeding the current Se guidelines at Navajo Mine. A second objective was to evaluate Se levels for spoil, native soil and plant samples collected at Navajo Mine and establish the most appropriate Se suitability guidelines.

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Materials and Methods

Selenium data has been collected from a number of areas at Navajo Mine from 1985 to present. Spoil samples have been collected from 1991 through 1993 to facilitate reclamation efforts. These samples were collected from various areas that have been mined over the past twenty years. All spoil samples were collected to a depth of at least four feet. In addition, randomly selected plots were established in 1985 to determine relationships between plant and soil Se values. Samples were collected from plant tissue, topdressing, and regraded spoil.

Summary statistics consisting of the minimum, maximum, mean, and median for total and hot-water soluble Se were determined for all samples. Criteria were then established that generated subsets of the data for total and hot-water soluble selenium values. The first criteria used were OSM root zone suitability limits of 0.8 ppm total and 0.15 ppm hot-water soluble Se. The second criteria used were 2.0 ppm total and 0.25 ppm hot-water soluble Se. The reason for selecting 2.0 ppm total Se is based on the premise that this value represents a normal level of total Se in the soil (Girling 1984, Tisdale, et al. 1985). The value of 0.25 ppm soluble Se was selected on the basis that similar values observed at Navajo Mine support vegetation with less than 5.0 ppm Se in the plant tissue. In addition, the level of 0.25 ppm is near the mid-point of the root-zone material that is monitored in Wyoming. Summary statistics were then calculated for these subsets of data.

Results and Discussion

A total of 1,042 spoil sites were sampled resulting in a total of 4,169 samples that were analyzed for both total and hot-water Se. The mean values for total and hot water soluble Se were 0.66 ppm and 0.06 ppm, respectively, (Table 1). Minimum values for both total and hot-water soluble Se were below detection levels and maximum values were 5.50 ppm and 0.72 ppm, respectively, (Table 1).

Table 1. Summary statistics for total selenium and hot-water soluble selenium of spoil samples, Navajo Mine, New Mexico.

	Sites	Samples	Min.	Max.	Mean	Median
Total Se	1,042	4,169	0.00	5.50	0.66	0.60
Hot-Water Soluble Se	1,042	4,169	0.00	0.72	0.06	0.05

When the data were sorted using the current OSM guidelines (Table 2) 459 of the sites (44%) and 974 of the samples (23%) exceeded the root-zone suitability limits for total Se. Similarly, 99 of the sites (9.5%) and 148 of the samples (3.5%) exceeded the root-zone suitability limits for hot-water soluble Se (Table 2).

Table 2. Summary statistics for values exceeding total selenium > 0.8 ppm and > 2.0 ppm and hot-water soluble selenium >0.15 ppm and > 0.25 ppm of spoil samples, Navajo Mine, New Mexico.

	Site	Sample	Min.	Max.	Mean	Median
Total Se (>0.8)	459	974	0.85	5.50	1.09	0.95
Total Se (>2.0)	20	24	2.05	5.50	3.01	2.83
Hot-water Soluble Se (> 0.15)	99	148	0.16	0.72	0.21	0.18
Hot-water Soluble Se (> 0.25)	20	21	0.26	0.72	0.35	0.30

The data were also sorted using the criteria of total Se > 2.0 ppm and hot-water soluble Se > 0.25 ppm (Table 2). Using these guidelines, 20 sites (2%) and 24 samples (0.6%) exceeded the 2.0 ppm total Se level. Using the same guidelines, 20 sites (2%) and 21 samples (0.5%) exceeded the 0.25 ppm hot-water soluble Se level.

Plant Se was determined for a total of 143 plant samples collected from reclaimed areas and 78 plant samples collected from native undisturbed areas. Mean selenium values were 1.06 ppm and 0.64 ppm, respectively. Maximum values were 7.75 ppm for plant tissues from reclaimed areas and 2.50 ppm for plants from native areas and median values were 0.80 ppm and 0.53 ppm, respectively (Table 3). It was found that plant Se values were poorly correlated to both total and hot-water soluble Se values. This lack of correlation has been observed by others (Larkin, 1972, Olson et al. 1942).

Table 3. Summary statistics of plant selenium collected from reclaimed and native sites, Navajo Mine, New Mexico.

	Samples	Min.	Max.	Mean	Median
Reclaim Plant Se	143	0.02	7.75	1.06	0.80
Native Plant Se	78	0.02	2.50	0.64	0.53

In a separate study, Se was analyzed for 936 soil samples collected to depths of 0 to 60" from native areas at Navajo Mine. Mean values for total and hot-water soluble Se were 0.30 ppm (SD=0.19) and 0.01 ppm (SD=0.04), respectively. In these native soils, the maximum for total and hot-water Se were 1.55 ppm and 0.04 ppm, respectively. These values were within the range suggested as common to native soils (Girling 1984, Tisdale et al. 1985).

The current OSM root-zone suitability limits of 0.8 ppm total and 0.15 ppm hot-water soluble Se appear to be too restrictive for Navajo Mine for the following reasons. The guidelines were largely developed by OSM using data from the Northern Great Plains, which may not apply to conditions at Navajo Mine. Literature suggests that soil selenium values of 2.0 ppm total selenium are normal (Girling 1984, Tisdale et al. 1985). The 0.25 ppm hot-water soluble selenium value is near the mid-point of a range that requires monitoring in Wyoming soils in contrast to mitigation. In addition, plants (*Atriplex canescens*) growing on spoil with these levels of Se are well below the 5.0 ppm level. Therefore, it is suggested that levels of 2.0 ppm total Se and 0.25 ppm hot-water soluble Se are appropriate as suitability limits for the root-zone material at Navajo Mine. Using these Se values, it is estimated that less than 1% of the spoil volume would be unsuitable as root-zone material.

Conclusions

Root-zone suitability limits at Navajo Mine for spoil Se are currently 0.8 ppm total Se and 0.15 ppm hot-water soluble Se. A total of 4,169 spoil samples were collected and analyzed for Se. Plant samples were randomly collected and analyzed for Se from both reclaimed and native areas. Analysis of the data suggest that establishing the limits of root-zone suitability for selenium at 2.0 ppm total Se and 0.25 ppm hot-water soluble Se may be a more appropriate estimate of evaluating spoil for Se at Navajo Mine than using the present guidelines.

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