

# PHYTOTOXIC CONSTRAINTS ON VEGETATION ESTABLISHMENT AT THE ANACONDA SMELTER SUPERFUND SITE<sup>1</sup>

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**Extended Abstract.** Soil chemistry imparts a strong influence on vegetation development observed at disturbed sites. Thousands of acres of land near Anaconda, MT have been degraded by uncontrolled releases of metals and arsenic. The associated risk to human health and the environment led to listing of the Anaconda Smelter Site as a Superfund site. Soil treatment and revegetation are required to remediate the phytotoxic conditions observed, and to mitigate ecological risk caused by residual soil contamination. Since many acres of barren and sparsely vegetated land will be revegetated by in-place treatment without removal of contaminants an understanding of the residual phytotoxic effect following treatment is required.

Phytotoxic conditions are common across several thousand acres of land near the former smelter site. Phytotoxicity, however, is species dependent and mitigated by availability of rootzone water, organic matter and localized edaphic conditions. The resulting mosaic of vegetation is a patchwork of unique plant communities, bare ground and noxious weeds. Contaminant avoidance is a common plant growth strategy employed by plants that can reproduce by asexual reproduction. Quaking aspen (*Populus tremuloides*), Woods' rose (*Rosa woodsii*), and Western wheatgrass (*Pascopyrum smithii*) are all present by virtue of plant colonization by roots spreading underneath surficial contamination. Soil contamination is often restricted to the upper 5-15 cm. Contaminant tolerance is demonstrated by introduced species such as redtop (*Agrostis alba* and *A. stolonifera*) as well as noxious weeds (*Centaurea stoebe*, *Cirsium arvense*, *Euphorbia esula* and *Cardaria draba*). Of greater interest to reclamation activities required by the CERCLA statute is the metal tolerance of native species used during remediation and restoration. Many of the native species commonly available have demonstrated sensitivity to soil contamination. Basin wildrye (*Leymus cinereus*) is an exception. Basin wildrye is widely found growing in highly contaminated soil on Smelter Hill in areas of deep soil and especially where accentuated rootzone water is available. Many of the other native species have not performed well in soils with elevated metals. Lime is often added to low pH, metal enriched soil during remediation to achieve neutral soil pH. Under this remedial prescription, soil metals are less available in the soil solution, therein improving the probability of vegetation success. However, residual levels of soil metals have been observed either restricting or precluding establishment of seeded native species.

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Diagnostic monitoring was performed at the Anaconda Smelter Superfund site in areas previously reclaimed and reseeded with native grasses. Co-located soil chemistry and vegetation condition measurement allow for modeling of expected phytotoxicity responses prior to and following treatment. Soil and vegetation samples were collected both from areas of good and poor vegetation to characterize the soil conditions required for vegetation establishment and persistence as well as soil conditions lethal to seeded species.

Available data strongly suggest that even at neutral soil pH phytotoxic conditions will exist when metal levels remain elevated following remediation. Species specific variation to elevated metals has been observed. Yet, the overall general trend of decreasing performance of native perennial grass species with increasing soil total metal levels appears to hold true without regard for metal tolerance imparted by individual species. The predictive phytotoxic model, as published by EPA in the site ecological risk assessment, in which the sum to total  $\text{As} + \text{Cd} + \text{Cu} + \text{Pb} + \text{Zn}$  ( $\text{mg/kg}$ ) =  $520 * \text{pH} - 2300$ , appears to be valid in establishing a ceiling concentration above which vegetation problems are anticipated. For example, at neutral soil pH (7.0) when the sum of total  $\text{As} + \text{Cd} + \text{Cu} + \text{Pb} + \text{Zn}$  is greater than 1340  $\text{mg/kg}$ , phytotoxic conditions are expected with increasing severity as the sum of total metals increases above the threshold. At acidic pH conditions the effect of metal contamination is progressively stronger.

Remediation planning at the Anaconda Smelter Site has emphasized in-place treatment of contaminated soil. However, when strongly elevated soil metals are present, removal of contaminants and replacement with imported coversoil is preferred for reestablishment of native grasses.