PHYTOSTABILIZATION OF ACIDIC METALLIFEROUS MINE TAILINGS REDUCES DUST EMISSIONS

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Introduction

Legacy mine tailings disposal sites from either inactive or abandoned hardrock mine sites are prevalent in arid and semiarid regions throughout the world. Such mine tailings are often acidic and have high metal(loid) content. Arid climate conditions impose a number of physicochemical factors, including extreme temperatures especially at the tailings surface, low precipitation, and high winds, that combined with the tailings physico-chemical characteristics inhibit natural plant establishment on the mine tailings (Munshower, 1994). As a result, these tailings represent a highly disturbed matrix that can remain devoid of vegetation for decades.

The absence of vegetative cover leaves tailings susceptible to wind and water erosion. Wind dispersal creates several potential routes of human exposure to contaminants associated with tailings including: inhalation of small particles transported by wind and ingestion due to deposition of dust particles on surfaces, food, and soil (Csavina et al, 2014). A common strategy for reclamation of these sites is to cover or cap the mine waste with an innocuous material, generally waste rock from mining operations, gravel, topsoil from an adjacent site and then seed the cap. Both the cap and the vegetation, once established, act as a barrier to erosion processes. However, it is often difficult and expensive to obtain enough material for a cap and there is no guarantee that the cap material will be effective in supporting long-term plant growth.

An alternative to capping and planting is compost-assisted phytostabilization, wherein compost is introduced into the mine tailings and seeds are directly planted into the tailings (Mendez & Maier, 2008). As plants grow, they act to precipitate metals in situ and act as a barrier to wind and water erosion. Plants which do not accumulate metals into shoot tissues are chosen for use in phytostabilization to prevent metal movement into the food chain.

The objective of this study was to evaluate whether phytostabilization technology could be successfully applied at the Iron King Mine-Humboldt Smelter Superfund Site (IKMHSS). A corollary objective was to evaluate whether phytostabilization would reduce dust transmission in the site. The IKMHSS is an abandoned legacy mine that contains acidic tailings with elevated levels of lead and arsenic (> 3000 mg/kg). The tailings impoundment has a reddish brown color and rises vertically from a hillside with sloped sides and flat top. The top 35 cm of tailings material is characterized by gravelly and silty sands with a loam texture with 34.7% sand, 44.8% silt, and 20.4% clay with a pH ranging from 2.5 to 3.5.

Methodology

IKMHSS Field Trial

An irrigated study area was established on the IKMHSS site in May 2010. Plots were established in the tailings and were either unamended or amended with 20% (w/w) compost (Figure 1). Compost-amended plots were direct seeded with native plants (buffalo grass, Arizona fescue, quailbush, mesquite, and catclaw acacia). Controls included composted unseeded treatments and an uncomposted unseeded treatment. All three treatments (unamended, compost amended, compost amended + seeds) were performed in quadruplicate.

Figure 1. Phytostabilization field trial at the IKMHSS. This photo was taken in October 2013.

Canopy Cover Measurement

Canopy cover and species composition was estimated at 5, 17, 29 and 41 months after seeding using a modified Daubenmire method (Daubenmire, 1959). Only healthy live plants were measured. Observations were made within a 1 m^2 Daubenmire frame place at 3 meter increments along two 15 meter diagonal transects across each plot. Four additional observations were made at random locations within each plot.

Dust Measurement

Horizontal dust flux was measured upwind and downwind of three areas in the study site. The first was a composted and seeded plot, the second an unamended plot, and the third an undisturbed area of tailings that did not receive irrigation. Both the composed and seeded plot and unamended plot were irrigated. A series of modified Wilson & Cooke passive samplers were set up at five heights 6, 18, 25, 30, and 100 cm (Wilson and Cooke, 1980). Flux in and out of each plot was based on wind direction. Passive samplers were collected from the field and taken to the lab to quantify dust deposition by mass. The dust masses for each sampling height were integrated and used to calculate a horizontal net flux.

Results

No plants grew on unamended irrigated tailings plots during this study (Figure 2). In contrast, the compost-amended seeded plots showed germination and growth of plants achieving a canopy cover of nearly 60% after 41 months. The unseeded composted plots had volunteer plants appear, with seeds blown in from the neighboring plots. This treatment achieved a canopy cover of 38% after 41 months. The canopy cover from both the seeded and unseeded composted treatments exceeded or was equivalent to the 30% canopy cover found off-site in an area adjacent to the mine tailings site.

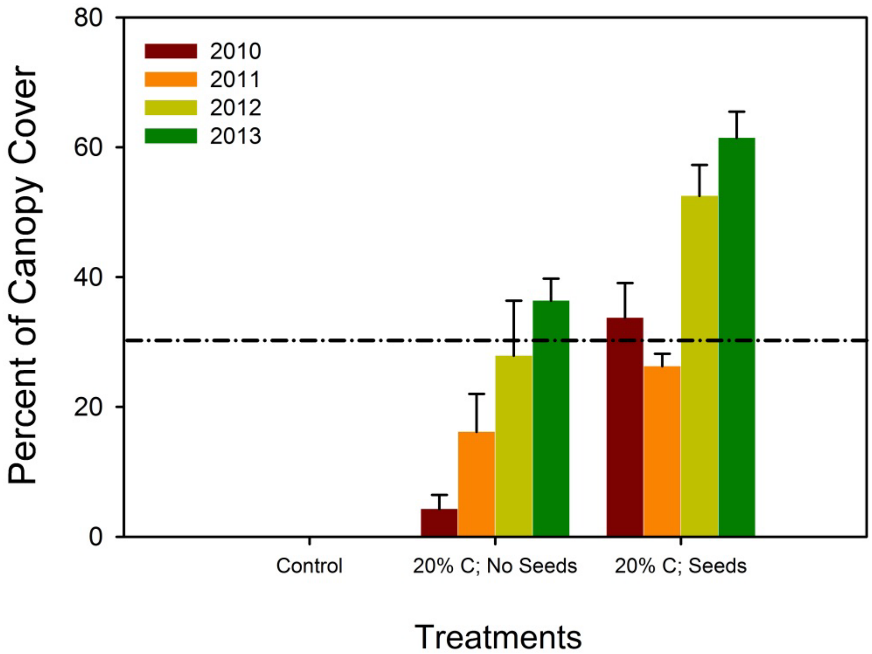

Figure 2. Canopy cover measurement. Canopy cover at 5 (2010), 17 (2011), 29 (2012) and 41 (2013) months. Values are the average and standard deviation for each treatment (n = 4). Three treatments are shown: the control treatment which was unamended but irrigated; the 20% compost amended, unseeded, and irrigated treatment; and the 20% compost amended, seeded, and irrigated treatment. The

dashed line denotes the typical percent canopy cover for locations off-site but adjacent to the IKMHSS (34°29'54.90"N; 112°15'15.18"W).

Dust flux was highest in the area of undisturbed tailings that did not receive irrigation (Figure 3). Irrigation reduced dust flux considerably. In this case the dust flux was equivalent to that observed in disturbed grasslands (overgrazed or impacted by fire). However, for plots with vegetation, it appears that plants were able to adsorb and capture dust moving across the plot, including the fine size particles (data not shown).

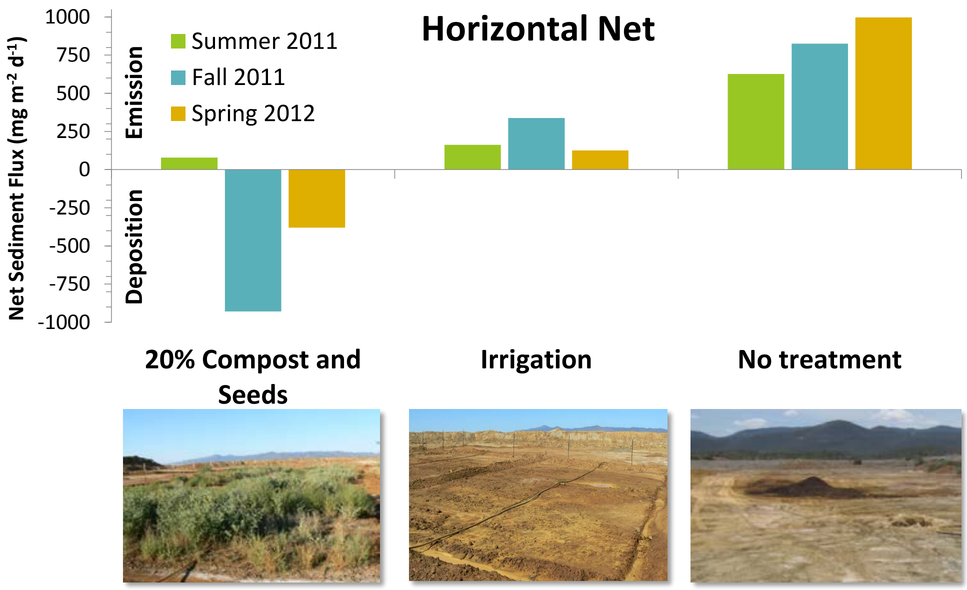

Figure 3. Effect of phytostabilization on dust (sediment) flux. Values represent the net amount of wind-blown dust (dust flux out – dust flux in) across the study area at each measurement time. The Fall 2011 and Spring 2012 measurements in the compost amended seeded treatment show that dust is actually removed by the canopy cover.

Discussion

This study demonstrates that phytostabilization technology can be used to establish plants in a highly acidic metalliferous mine tailings. It is noteworthy that the vegetation cap has survived several heavy rain events as well as snowfall and freezing events during the winter over several seasons. The cap becomes largely dormant during the winter time, but grows back over the summer. The vegetation cover helps prevent both wind and water erosion at the site and results have shown that the vegetation actually traps dust out of the air as it moves over the canopy.

The dust flux measurement performed in this study provided useful measurements. This technique could be used to provide information on the level of disturbance at a mine tailings site and to assess the impact of either phytostabilization or cap and plant strategies on dust suppression.

Conclusions

Direct planting phytostabilization technology at the IKMHSS has resulted in a successful canopy cover. Dust flux measurements show that the established vegetation acts to disrupt dust dispersion pathways which will result in a reduction in human and environmental exposures. This is especially important when toxic metal(loid)s from legacy mining sites might be associated with the dust.

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