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Techniques Used in the Reclamation of the Palmerton Zinc Smelter Site

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Introduction

What do you do with a two and one half mile long, 33 million ton heavy metal residue pile that covers 2,000 acres of dead mountain land? This is not a riddle with a simple answer but a real life dilemma that a town, Palmerton, Pennsylvania, faced in the wake of the New Jersey Zinc Company. Many people have actively searched for ways to clean up and reclaim Blue Mountain, located in Palmerton, Pennsylvania. Palmerton hosted the New Jersey Zinc Company that started processing zinc silicate in 1898 and later produced zinc sulfide. The New Jersey Zinc Company actively smelted zinc from 1898 until 1980. Over 2,000 acres of land on Blue Mountain have been contaminated from the emissions of the smelting plant. The emissions from the smelting plant consisted of sulfur dioxide, zinc, lead and cadmium. Before the company started smelting zinc, Blue Mountain was densely forested with mixed oaks (*Quercus* spp.) and chestnut (*Castanea dentata*). The zinc smelter emissions killed all of the trees and vegetation on Blue Mountain. The lack of vegetation allowed the soil to erode down the slope of the mountain into the Lehigh River. The erosion left nothing but bare rock, eroded soil and dead trees. The dead trees were left standing and unable to decompose, because metals such as zinc oxide killed the microbial life in the soil. Nutrient cycling and decomposition of the mountain stopped because of the loss of the microbes.

Two years after the New Jersey Zinc Company quit smelting zinc the U.S. Environmental Protection Agency (EPA) declared the area a Superfund site. The site includes the city of Palmerton and the adjacent mountain land. Blue Mountain, which is adjacent to the city of Palmerton, is the largest Superfund Project undertaken by the EPA. The smelter generated an overwhelming amount of emissions during its existence. Estimates of the total metals emitted over 82 years of active smelting are as follows: cadmium-3,740, or 47 tons/year; lead-7,560 tons, or 95 tons/year; and zinc 286,000 tons, or 3,575 tons/year (Oyler, 1993). Excess cadmium and zinc levels in soil are known to cause human health problems, animal fatalities, and disruption of natural ecosystems (Brown et al., 1994). Cadmium and zinc can leach into the ground water and cause health problems. According to the EPA the New Jersey Zinc Company was named as the Potentially Responsible Party and was therefore responsible for the clean up of the contaminated site (Brown, L., 1996). The New Jersey Zinc Company was ordered to cleanup the site under EPA oversight. There were problems in the negotiation of the cleanup so the EPA initiated the cleanup using money from the federal Superfund (Brown 1996).

Primary Challenges Of The Palmerton Restoration

The main goal of the restoration project was to revegetate Blue Mountain. Restorationists wanted to transform the blackened, rocky eyesore to the lush green mountainside that it was before the zinc smelter emissions took their toll and killed the vegetation. Numerous methods of cleaning up the site were evaluated including removal of the top 30 cm (12 inches) of soil. Since 2,000 acres of topsoil needed to be removed, this alternative was prohibitively expensive.

Consequently, cleanup focused on stabilizing metals on-site through proper pH management and revegetation (Oyler, 1993).

The challenge posed to those involved in the cleanup of the site was to figure out what would work on the steep, rocky slopes of the mountain. Rocky terrain and the fallen tree debris scattered about the mountainside made the site inaccessible to vehicles and created special challenges to the reclamation. In order to start the reclamation project, roads had to be cleared for vehicles to access the site. Rough terrain made soil improvements difficult. The mountainside did not have a soil layer to support the growth of vegetation. Some type of amendment needed to be applied to the mountainside to support growth of vegetation. The task was to find a growing medium that would not wash down the mountain side and into the river once applied, and one that would be economically feasible. Deciding how to apply the amendment was an important challenge that had to be overcome before the restorationists could do a large scale planting. Two amendments that were considered by restorationists were fly ash and municipal sludge.

Fly Ash/Municipal Sludge Amendment

The primary technique that was used to revegetate Blue Mountain was the application of a fly ash and municipal sludge mixture (Sopper, 1988). After experimenting with the fly ash and municipal sludge amendments restorationists decided on a combination of the two. The fly ash used in the restoration of Blue Mountain was a byproduct of a coal-fired electric generating plant near the Palmerton site. The city of Allentown provided restorationists with the sludge at no cost. Allentown found it less expensive to transport the sludge to the contaminated site than to put it in a landfill. Transporting the sludge to Palmerton cost them $25 to $30 a ton and nothing to additional to landfill (Lalo, 1988).

A study was conducted by Sopper (1988) to determine the effectiveness of fly ash and sludge as a growing medium. The fly ash/municipal sludge mixture was proven to be an effective medium when combined with lime and potash. Sludge had previously been used on other reclamation sites alone and then incorporated into the soil. The fly ash/sludge mixture could not be incorporated into the soil at the Palmerton site because of the rocky terrain. If municipal sludge was applied alone it would have dried without incorporation into the soil. The dry medium would not have been conducive to seed germination. The fly ash needed to be mixed with the sludge so that it would not blow away. Restorationists mixed fly ash and sludge to create a gray growth medium (Sopper, 1988). The amendment was blown onto the broken uneven surface with an Estes Aerospreader (Sopper, 1988). The sludge fly ash mixture provided macronutrients, micronutrients and microbial activity for the plants (Oyler, 1993).

The fly ash-sludge mixture was effective at overcoming other soil deficiencies including high temperatures, erosion, and compaction. The light gray color reduced soil temperatures that were often inhibitory to plant growth (Sopper, 1988, Oyler 1993). The sludge fly ash mix remained porous and provided fine materials that had been missing at the site.

Experiments were conducted on revegetation by hydroseeding of five different seed mixtures (Sopper, 1988). The first seed mixture contained Blackwell switchgrass (*Panicum virgatum*). The second mixture contained Niagara big bluestem (*Andropogon gerardi*). The third was

Empire birdsfoot trefoil *(Lotus corniculatus*) and tall fescue (*Festuca arundinacea*). The fourth as Pennfine perrennial ryegrass (*Lolium perenne*) and Lathco flatpea (*Lathyrus sylvestris*). The fifth mixture contained Oahe intermediate wheatgrass (*Agropyron intermedium*). All of the plots were mulched with fiber mulch with the hydroseeder. Ten species of tree seedlings were planted in the plots. The species that were planted were white pine (*Pinus strobus*), Austrian pine (*Pinus nigra*), Virginia pine (*Pinus virginiana*), red pine (*Pinus resinosa*), Japanese larch (*Larix leptolepsis*), black locust (*Robinia pseudoacacia*), Arnot bristly locust (*Robinia fertilis*), European alder (*Alnus glutinosa*), black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), and hybrid poplar (*Populus* spp.). The growth of the different species was evaluated at the end of each growth season in 1986 and 1987. The success was evaluated by visual estimates of the percentage of cover. The highest percentage of vegetation cover was from the mixture of orchardgrass, tall fescue, and crownvetch. In 1986, this seed mixture had an average cover of 90% and ranged from 82 to 95% among the three sludge-flyash amendments. In 1987 the average cover increased to 93%, indicating the mixtures had successfully established. Of the tree species planted, larch had the greatest growth in height of the conifers and black cherry had the greatest of the hardwood species (Sopper, 1988).

Sopper's experiment proved to be very promising, exhibiting that the establishment of vegetative groundcover could be accomplished at the Palmerton site. The vegetation helped stabilize the soil on the slopes to prevent run off and erosion. In 1987 there were two rainstorms that produced large amounts of rain; each event more than six inches. The plots did not show any signs of erosion in the storms. With the success of the revegetation with the fly ash-sludge mixture plans were formulated to apply the amendment to the entire 800 ha of the north slope of the mountain (Sopper, 1988). In May of 1991 the Environmental Protection Agency approved the full-scale project. The revegetation of Blue Mountain was scheduled to be completed in five years. The schedule was as follows: 1991: 100 acres, 1992: 250 acres, 1993: 250 acres, 1994: 250 acres and 1995: 150 acres.

Phytoremediation

Although the fly-ash/ municipal sludge amendment is the technique that has been applied on a large scale to the site, scientists have also researched the possibility of using phytoremediation to clean up the site. Brown et al. (1994) evaluated phytoremediation as a strategy for heavy metal decontamination at Palmerton. The study was conducted off site and was never attempted on the mountainside. The study tested the effectiveness of *Thlaspi caerulescens* and bladder campion (*Silene vulgaris*) in the uptake of zinc and cadmium from the contaminated soils of the Palmerton area. *Thlaspi caerulescens* is a hyperaccumulator plant; *Silene vulgaris* an indicator. Hyperaccumulator plants uptake metals from the soil into their shoot tissue. If successful at accumulating the waste, the plants can be harvested and smelted to recycle the metals. An indicator plant is a species that can tolerate high levels of metals in the soil. Bladder campion is useful for stabilization and recolonization of contaminated sites such as Palmerton. Although bladder campion's main purpose in the study was not as a hyperaccumulator the levels of heavy metals in the shoots were measured. The study tested the effects of soil pH on the ability of *Thlaspi caerulescens* and *Silene vulgaris* to take up zinc and cadmium into their roots and shoots. "If uptake can be increased by lowering soil pH to increase solubility of metals, the number of croppings necessary to remove metals my be decreased (Brown et al 1994)." In the study the tomato (‘Rutgers’) was used as a reference crop because the metal uptake and growth patterns for this species had previously been studied.

The study used zinc-contaminated soil taken from three different sites near the New Jersey Zinc Company smelter. The soil samples were taken from the top 12 cm of the soil profile at each site. The first soil sample was collected from a 5 by 5 meter area from the mountainside that was south of the smelter. The soil from this sample had no plants growing and was classified as made land. Made land is soil that has been stripped, removed or deposited so that original soil profile is no longer determined (Brown, 1994). After the soil samples were collected the soil pH of each was determined. Previous studies have shown a direct relationship between metal adsorption and soil pH. Each soil sample was adjusted to three different pH levels by the addition of elemental S or Ca(OH)2. The pH of the mountainside sample was adjusted to 5.84, 6.67 and 7.04. The pH of the garden soil was adjusted to 5.07, 5.42 and 6.37. The farm soil was adjusted to 5.06, 5.81 and 6.82. The levels of zinc and cadmium varied greatly between the three different soil samples. The mountain soil contained 48,000 mg kg -1 Zn and 1,020 mg kg -1 Cd. The garden soil contained 4,100 mg kg -1 Zn and 37.4 mg kg -1 Cd. The farm contained 2,100 mg kg -1 Zn and 35.2 mg kg -1 Cd. *Thlaspi caerulescens*, bladder campion (*Silene vulgaris*) and the tomato plants were each planted in pots catagorized by soil sample and pH level. After nine days the plants were harvested and dried in an oven. The zinc and cadmium concentrations of each plant were determined by flame atomic absorption. The total Zn and Cd translocated to the shoots was higher in *Thlaspi caerulescens* than *Silene vulgaris* and the tomato plants in all but one treatment. In the farm soil with pH of 5.06 the shoot Zn and Cd was highest in *Silene vulgaris. Thlaspi caerulescens* was proven to be more effective than *Silene vulgaris* for phytoremediation of the contaminated soils of the Palmerton site. Across all pH treatments and all soils *Thlaspi caerulescens* translocated significantly more Zn to shoot biomass on a per-pot basis then either bladder campion or tomato. The Zn to shoot biomass was the greatest in the mountain soil with progressively less in the garden and farm soils, respectively (Brown et al 1994). Although the experiment clearly showed that *Thlaspi caerulescens* does an effective job of translocating Zn and Cd from the soil to the shoots this is not a potentially viable method of remediation for Palmerton. Phytoremediation of Palmerton is not feasible because of the large amount of rough terrain that would have to be planted with small annuals. Not only would it be difficult to plant and harvest the mountainside, but there would be no cover provided for wildlife.

Conclusion

The site of the New Jersey Zinc Company posed a very difficult clean up task. The cost, difficult terrain and feasibility of getting plants to grow all factored into the decision of what technique to use in cleaning up the site. Phytoremediation is a less expensive option than removing soil, but has not been undertaken on a large scale. Phytoremediation was not be a feasible option for remediation of the entire. It would be difficult to cultivate Blue Mountain’s rocky terrain and plant it with small annuals that would need to be harvested and planted yearly. The plants used in the fly-ash municipal sludge technique were a mixture of perennials that could reduce erosion, create cover and habitat for wildlife. The fly ash-municipal sludge amendment is the technique that has been undertaken by the restorationists on a large scale. Economically the fly ash/sludge mixture application was the least expensive way of remediating the site.The amendment of the fly ash-sludge mixture allows vegetation to grow once again on Blue Mountain, but there are still literally tons of zinc, cadmium lead and other metals beneath the vegetation.

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