Research Brief 163: The Role of Soil Bacteria in Phytostabilization of Mine Tailings

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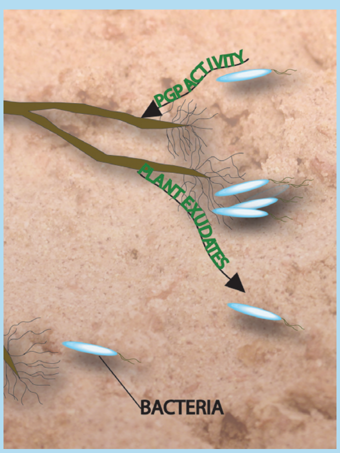
Background:

Tailings piles at abandoned mines contain toxic levels of metals, contain no organic matter, are low in nutrients, and are often quite acidic; as a result, the piles generally have minimal vegetation or are completely barren, making them vulnerable to wind and water erosion. The dispersion of tailings spreads particles across large geographic areas, contaminating ground and surface water, and exposing humans and animals to significant levels of fine particulate matter (PM2.5).

In the United States there are ~550,000 abandoned mine sites, which have generated 45 billion tons of mine waste.

Removal and in situ treatment are not economically feasible at most mining sites. Chemical and physical stabilization technologies have been used, but are expensive and may not be permanent solutions. Phytostabilization, establishing a vegetative cap for the long-term stabilization and containment of tailings, is a promising remediation strategy that could reduce remediation costs as well as re-establish healthy, stable ecosystems. Dr. Raina Maier at the University of Arizona SBRP leads a team of researchers working to optimize phytostabilization strategies for mine tailings sites in semiarid locations. Her group conducts extensive greenhouse and field studies and has identified nine native plants suitable for phytostabilization projects. They are working to minimize the amounts of organic matter (compost) and water needed to establish and maintain the vegetation.

Advances:



Buchloe dactyloides (buffalo grass) in non-composted Klondyke tailings demonstrating enhanced growth when inoculated with isolated PGPB's.

Dr. Maier's group works on-site and with samples collected from the Klondyke mill site in Aravaipa Valley, Arizona. This state Superfund site contains ~70,000m3 of acidic tailings with elevated levels of arsenic, cadmium, lead, and zinc. The researchers' current work focuses on the role of soil bacteria in establishing healthy plant communities. Diverse heterotrophic microbial communities can support plant growth via a variety of mechanisms, including suppressing plant pathogens; producing growth hormones; and increasing availability and uptake of nutrients.

One strategy being explored to enhance revegetation is inoculation of seeds with plant growth-promoting bacteria (PGPB). To identify bacteria with potential of plant growth-promoting (PGP) activity, the researchers began with 131 bacterial isolates and identified 20 that are metal tolerant and able to grow in acidic conditions. The researchers then evaluated the 20 isolates for the ability to enhance the growth of two native plants (quailbush and buffalo grass), while reducing the amount of compost necessary to establish the plants. Previous work by Dr. Maier's group demonstrated that 15% (W/W) compost addition restored growth to levels comparable to that observed in an off-site soil control, however, treatments of 0% and 10% did not.

The researchers evaluated bacterial isolates for the ability to enhance plant growth at the 0% and 10% suboptimal compost treatment levels by measuring plant survival and plant biomass. They found that:

- In 0% amended treatments, some of the isolates increased plant survival, but did not enhance plant biomass. The researchers believe these isolates be used as part of a PGPB mixture to enhance overall survival and growth.
- Some of the isolates that yielded the greatest plant biomass increase in the 10% compost treatment were not effective in the 0% compost treatment.
- The impact of PGPB was plant specific: buffalo grass responded more strongly to the PGPB at the 0% compost treatment, whereas quailbush responded more strongly in the 10% compost treatment.
- PGP activity of some isolates changed over time, suggesting that environmental factors (e.g., pH, metal toxicity) may impact long term survival of bacteria in the zone surrounding the roots of plants (rhizosphere).

In a separate study, Dr. Maier's group used phylogenetic analysis to compare microbial communities from moderately acidic and extremely acidic areas of the Klondyke site to an off-site control area. The microbial communities in the control area samples were significantly more diverse than those from the mine site, and contained more types of heterotrophic bacteria. The samples from the moderately and extremely acidic areas were not only less diverse, but contained iron- and sulfur-oxidizing bacteria not found in the control sample. Dr. Maier believes that the presence or absence of heterotrophic bacteria could serve as a bioindicator of the degree of site disturbance. Such a profile could be usedto assess the potential for plant establishment at a site.

Significance:

Dr. Maier's research demonstrates the important role of bacteria in the phytostabilization of mine tailings. Specific populations of endemic bacteria in tailings should be assessed and, perhaps, monitored. Introduced populations of bacteria that serve as PGPB can successfully enhance the growth of native plants in mine tailings from arid environments and partiallyreplace the requirement for compost amendment. This work highlights the importance of identifying PGPB that not only provide plants with key PGP mechanisms, but that can persist in the tailings rhizosphere.

Klondyke State Superfund Site (adjacent to the Aravaipa Creek near Klondyke, Arizona) has remained unvegetated for over 50 years. Mine tailings are composed of fine to coarse sand sized particles with the consistency of flour.

Dr. Maier emphasizes the need for monitoring the long-term success of phytostabilization projects. Plants must not only survive and grow, but must self-propagate to colonize the area with no additional inputs. In addition, it will be critical to monitor changes in the rhizosphere as evolving microbial communities and weathering and decomposition of organic materials may result in conditions that alter the speciation, bioavailability, and phase distribution of metal contaminants.

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To learn more about this research, please refer to the following sources:

Mendez, Monica O. and Raina M. Maier. 2008. Phytostabilization of mine tailings in arid and semiarid environments--an emerging remediation technology. Environmental Health Perspectives. 116(3):278-83.

Mendez, Monica O., Raina M. Maier, Jon Chorover, B. Machado, and C.J. Grandlic. 2008. Plant growth-promoting bacteria for phytostabilization of mine tailings. Environmental Science and Technology. 42(6):2079-2084.

Mendez, Monica O., Julia W. Neilson, and Raina M. Maier. 2008. Characterization of a bacterial community in an abandoned semiarid lead-zinc mine tailing site. Applied and Environmental Microbiology. 74(12):3899-3907.