Soil Remediation

***by** Zachary Zeller and Christopher Krieg*

There are many natural processes that operate among soil, rock, and dirt, including erosion and decomposition. However, human activities have escalated some processes beyond what can be naturally observed. For example, industrial activities and improper disposal of agricultural or commercial wastes including chemicals and heavy metals cause toxic contamination of soils. Toxic contamination of soils can be harmful to plants and wildlife, and humans. People and animals living near the polluted site can experience adverse health effects associated with pollutants leaching into water, air, and food. Unfortunately, contamination is widespread throughout the world. In Florida, there are 29 active superfund sites including some in Miami, Ft. Lauderdale, Tampa, and Jacksonville to name a few. A superfund site is a government designation for sites contaminated with hazardous substances and pollutants and can cost hundreds of thousands of dollars to cleanse.

Soil contamination usually renders land unusable and unsafe for humans and animals, thus, there is significant interest in cost-effective strategies to reduce contamination and improve health-outcomes. One such approach is phytoremediation, which is generally defined as the use of plants to restore damaged and polluted ecosystems. Among all extant plants on Earth, many researchers claim to have found an 'unlikely' superhero in pteridophytes, and particularly ferns. Some people hear the word "fern" and think of a mere houseplant growing in their grandma's living room. While these friendly fronds are surely aesthetic additions to one's living space, they are also promising phytoremediationists given their unique physiology, relatively high diversity, and broad ecological niches. The stressful environments that some of these plants have adapted to make them excellent contenders for phytoextraction, phytostabilization, and phytodegradation – all forms of phytoremediation.

One particular way that plants can be used to remove harmful contaminants through phytoremediation is called phytoextraction, i.e. the use of plants to uptake and immobilize contaminants in their tissue. Some plant species act as hyperaccumulators, tolerating high levels of heavy metals and other toxic compounds and concentrating them in their tissue. Hyperaccumulating plants are particularly promising in heavy metal mitigation because they can be harvested and removed from the ecosystem, effectively removing heavy metal particles from the site. One such hyperaccumulator is *Pteridium aquilinum.* Also known as bracken fern, this cosmopolitan species tolerates a wide range of habitats and conditions, including soils with high levels of heavy metals. Researchers in Poland were able to classify *P. aquilinum* as a hyperaccumulator for chromium and nickel, which at high concentrations are toxic to most plants (Kubicka et al. 2015). Even more intriguing was their discovery that the fronds accumulated more of both metals when they were supplied together while the rhizomes accumulate more of each metal when applied separately. Understanding where certain pollutants are stored in the plant is important when creating a plan for extracting the plant material, transporting it, and storing it.

In situations where there is not a sufficient course of action to deal with large amounts of contaminated plant tissue, phytostabilization is a promising solution. This process is similar to phytoextraction; however, the hyperaccumulating plant is not removed from the site. In a phytostabilization treatment, contaminants are immobilized from the soil and water, but not removed completely from the site. These contaminants are stored in roots, shoots, and leaves and are thus prevented from leaching into water or soil. While this method does not remove toxins from the environment, it is generally more cost effective and low maintenance than phytoextraction. The key to phytostabilization is finding species that tolerate elevated levels of pollutants without their growth being impaired. The ecological diversity of ferns make them attractive candidates for phytostabilization across very different habitats. In a study on 10 fern species grown in the presence of heavy metals, researchers at the The University of Sydney found three species that are promising for phytostabilization. In particular, *Nephrolepis cordifolia* and *Hypolepis muelleri* were found to tolerate high levels of copper, lead, zinc and nickel. *Dennstaedtia davallioides* was also found to tolerate heavy metals but only for copper and zinc (Kachenko et al. 2007).

A third technique is phytodegradation, which utilizes plant species that can chemically alter contaminants to make them less toxic, and in some cases, degrade them completely into non-harmful compounds. While more complicated than the aforementioned methods, phytodegradation is especially useful for dangerous and volatile compounds. For example, a team of scientists in the UK developed a transgenic tobacco plant capable of converting TNT, a highly toxic and explosive chemical, into a source of nitrogen (Travis et al. 2007). Imagine the danger involved in transporting large amounts of TNT in your body! A less explosive but equally as important candidate species is *Pteris vittata,* otherwise known as the Chinese brake fern, which has been shown to take up arsenic (Lampis et al. 2015). The phytodegradation component involves the plants symbiosis with local bacteria. One experiment took arsenic resistant soil bacteria from a polluted industrial site in Italy and added them to the growing media of *Pteris vittata.* The researchers demonstrated that some of the bacteria could alter the form of arsenic from arsenate to arsenite, the latter being easier for the plant to take up. Ultimately, the phytoextraction potential increased from 13% to 35% simply through the addition of indigenous microorganisms, some of which altered the chemical composition of the arsenic (Lampis et al. 2015).

The exciting field of phytoremediation is a cost-effective, non-invasive, and aesthetically pleasing treatment for contaminated soil. The specific soil conditions, ecosystem attributes, and targeted pollutant-profile characterize the method of remediation as well as the species used. Still, ferns in particular, are proving to be reliable candidates for phytoextraction, stabilization, and degradation for a wide range of contaminants. From being crucial components of forests to pollution-eating plants, these terrific pteridophytes have come a long way in their 360 million years on Earth.

Fig. 1. Common bracken fern above Blood Geyser, Yellowstone National Park. Photo taken and copyrighted by brewbooks: https://www.flickr.com/photos/brewbooks/27649527464

References

Kachenko Anthony G., Singh Balwant, Bhatia Naveen P. (2007) Heavy metal tolerance in common fern species. *Australian Journal of Botany* **55**, 63-73.

Kubicka, K., Samecka-Cymerman, A., Kolon, K. et al. Environ Sci Pollut Res (2015) 22: 527.

Lampis, S., Santi, C., Ciurli, A., Andreolli, M., & Vallini, G. (2015). Promotion of arsenic phytoextraction efficiency in the fern Pteris vittata by the inoculation of As-resistant bacteria: A soil bioremediation perspective. *Frontiers in Plant Science, 6*.

Travis, E. R., Hannink, N. K., Gast, C. J., Thompson, I. P., Rosser, S. J., & Bruce, N. C. (2007). Impact of Transgenic Tobacco on Trinitrotoluene (TNT) Contaminated Soil Community. *Environmental Science & Technology, 41*(16).

Further Reading

Adesodun, Johnson & O. Atayese, Mutiau & A. Agbaje, T & A. Osadiaye, Bose & F. Mafe, O & Soretire, Adeniyi. (2010). Phytoremediation Potentials of Sunflowers (Tithonia diversifolia and Helianthus annuus) for Metals in Soils Contaminated with Zinc and Lead Nitrates. Water, *Air, and Soil Pollution*. 207: 195-201.

Forum-Using Superplants To Clean Up Our Environment. (n.d.).

Final Report: Phytoremediation and Bioremediation of Land Contaminated By PAHs, PCBs, and TNT. (2003, March 02).

Joonki Yoon, Xinde Cao, Qixing Zhou, Lena Q. Ma, Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site (2006). *Science of The Total Environment*. 368 (2–3).

Mccutcheon, Steven & Schnoor, Jerald. (2004). Phytoremediation Transformation and Control of Contaminants. *Environmental Science and Pollution Research*. 11: 40-40.

Peuke, A. D., & Rennenberg, H. (2005). Phytoremediation. *EMBO Reports*. *6*(6): 497–501.