Optimizing arsenic phytoextraction from pyrite cinders using a hyperaccumulating fern

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Millions of tons of soil are contaminated with industrial byproducts like pyrite cinders, characterized by high concentrations of arsenic (As), lead (Pb), copper (Cu), and zinc (Zn) coupled with low pH, which leads to risks of leaching and groundwater contamination. Sustainable soil remediation options including plant-based technologies offer an alternative to conventional excavation, which only relocates contamination elsewhere. Arsenic phytoextraction using the hyperaccumulating fern *Pteris vittata* is an emerging technology to remediate soils with shallow As contamination with minimal site disturbance. While *P. vittata* tolerates As through hyperaccumulation, it is not well understood whether and how the fern tolerates elevated metals, especially at low pH, and how well *P. vittata* can remove As from high Fe soils where As availability is low. Remediation rates, which remain slow with *P. vittata* generally, could be further reduced in the presence of metals.

The objective of this study is to determine the effects of soil fertilization on As extraction by *P. vittata* under field conditions in the presence of As and metals, to optimize remediation efficiency and decrease remediation time. The field site is adjacent to a former sulfuric acid plant and is contaminated with pyrite cinders (As 80-100 mg/kg, Pb ~100 mg/kg, Cu 520 mg/kg, Zn 120 mg/kg, Fe up to 50,000 mg/kg) The soil was tilled, homogenized and limed before 1 of 5 treatments was mixed into individual plots, with 6 replicate plots per treatment. Treatments included compost (15% by volume), inorganic N (50 kg N ha^{-1}), low and high application rates of inorganic P (85 kg P ha^{-1} and 624 kg P ha^{-1}), or inoculation with mycorrhizal fungi (*Funneliformis mosseae*), with no-treatment controls established for comparison. Soil was sampled before ferns were planted at a 30 cm spacing. Here, we present results of As, Pb, Cu, and Zn uptake in fern roots and fronds after 8 months of growth, coupled with porewater and surface soil As, Pb, Cu, and Zn concentrations, to estimate remediation rates and determine if treatments could accelerate remedition. Additionally, we characterize the chemical form of As and Fe in the unremediated soil to offer insights into As phytoavailability.