Effects of phosphate rock on long-term arsenic removal by *Pteris vittata*

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Phytoremediation using *Pteris vittata* offers a simple, non-invasive, and cost-effective method to remediate As-contaminated soil. A disadvantage of phytoremediation is the lengthy remediation period (years – decades). The capacity of *P. vittata* in remediation are based on experiments conducted with short growing periods (~12 weeks) under conditions not representative of a soil environment (i.e., greenhouse; <1.5 kg soil; small pots). This study aims to simulate natural soil conditions to gauge the potential of *P. vittata* to remediate As-contaminated soils over several growing seasons. In addition, we evaluated the effect of phosphate rock (PR) on As uptake and growth of *P. vittata* because it provides a long-term supply of sparingly-soluble P. Since P and As compete for uptake by *P. vittata* roots, we hypothesized that the physiological and biochemical responses of plant roots in a P-limiting environment will increase As solubility and uptake by *P. vittata*. Three soils (CCA, DVA, and DVB) were collected from Alachua County Florida, containing 22 - 129 mg As kg^{-1} and mixed with 15 g^{-1} kg^{-1} PR and placed into raised beds (1.44 m^2) containing four quadrants (0.36 m^2) to a 30 cm depth. Plants were spaced 15 cm apart in Dec 2009 (9 per quadrant; 36 per bed). Control ferns were grown with no PR and 10:4:10 fertilizer. Soil cores were taken at time of planting and at each harvest (June 2010, Jan 2011, and July 2011). Fronds were collected by clipping the stems ~15 cm from the base, leaving fiddleheads. Over 3 harvests, fronds (dry weight) from PR soils averaged 30.4, 24.5, and 23.4 g $plant^{-1}$ while control harvest averaged 17.7, 16.2, and 11.4 g for CCA, DVA, and DVB soils respectively. Average frond As concentrations were 3103, 1070, and 1137 mg^{-1} kg^{-1} compared to the controls 1795, 601, and 409 for CCA, DVA, and DVB soils, respectively. Likely due to limited P availability, root biomass was observed to be 55% greater in plants grown with PR and fronds averaged 32.3% less total P. The greater root mass and reduced P availability created conditions for optimizing rates of biological accumulation (frond:soil As ratio). Rates for PR vs. control were 26 vs. 15 for CCA, 40 vs. 34 for DVA, and 57 vs. 22 for DVB. Using PR amendments along with improved harvesting practices, our results show *P. vittata* remediates, on average, ~5 times faster than previously published studies, which shows that *P. vittata* has greater capacity to remediate As-contaminated soils than previously recognized.

Abbreviations: Copper chromated arsenic (CCA), Dipping vat (DVA/B), Phosphate Rock (PR)