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Improved Understanding of Hyperaccumulation Yields Commercial Phytoextraction and Phytomining Technologies

Rufus L. Chaney[a,*], J. Scott Angle[b], C. Leigh Broadhurst[a], Carinne A. Peters[c,e], Ryan V. Tappero[d] and Donald L. Sparks[d]

[a] USDA-ARS-Environmental Management and By-Product Utilization Lab., Beltsville, MD 20705
[b] Univ. of Georgia, Athens, GA 30602
[c] Dep. Plant Science and Landscape Architecture, Univ. of Maryland, College Park, MD 20742
[d] Plant and Soil Sciences Dep., Univ. of Delaware, Newark, DE 19717
[e] current address, J.R. Peters, Inc., 6656 Grant Way, Allentown, PA 18106

[*] Corresponding author (Rufus.Chaney@ars.usda.gov).

Received for publication November 28, 2006. This paper reviews progress in phytoextraction of soil elements and illustrates the key role of hyperaccumulator plant species in useful phytoextraction technologies. Much research has focused on elements which are not practically phytoextracted (Pb); on addition of chelating agents which cause unacceptable contaminant leaching and are cost prohibitive; and on plant species which offer no useful phytoextraction capability (e.g., *Brassica juncea* Czern). Nickel phytoextraction by *Alyssum* hyperaccumulator species, which have been developed into a commercial phytomining technology, is discussed in more detail. Nickel is ultimately accumulated in vacuoles of leaf epidermal cells which prevents metal toxicity and provides defense against some insect predators and plant diseases. Constitutive up-regulation of trans-membrane element transporters appears to be the key process that allows these plants to achieve hyperaccumulation. Cadmium phytoextraction is needed

for rice soils contaminated by mine wastes and smelter emissions with 100-fold more soil Zn than Cd. Although many plant species can accumulate high levels of Cd in the absence of Zn, when Cd/Zn > 100, only *Thlaspi caerulescens* from southern France has demonstrated the ability to phytoextract useful amounts of Cd. Production of element-enriched biomass with value as ore or fertilizer or improved food (Se) or feed supplement may offset costs of phytoextraction crop production. Transgenic phytoextraction plants have been achieved for Hg, but not for other elements. Although several researchers have been attempting to clone all genes required for effective hyperaccumulation of several elements, success appears years away; such demonstrations will be needed to prove we have identified all necessary processes in hyperaccumulation.