

Xanthoparmelia scabrosa is a foliose lichen that grows abundantly on pedestrian and automobile asphalt in New Zealand, which are considered inhospitable habitats for lichens. Samples were collected at eight localities ranging from urban streets to very rural roads and analysed for 28 chemical elements to determine elemental chemistry and to test hypotheses about tolerance mechanisms. Anthropogenic elements (Cu, Pb, and Zn) significantly decreased from urban to rural areas, while nutritional elements (K, P, and S) increased. Samples from urban areas contained 10% calcium. Sulfur increased at both urban and rural sites, possibly due to pollution in the former site and higher levels of sulfur-containing scabrosin esters at the rural sites. The ability of this lichen to accumulate high levels of Cu, Pb and Zn may make it useful as a remediation tool.

Xia, H. and X. a. Cai (2002). Ecological restoration technologies for mined lands: A review. *Yingyong Shengtai Xuebao* 13(11): 1471-1477. Mining activities usually cause catastrophic and extensive environmental changes, and eventually cause major damages to the whole ecosystem. The natural restoration for mine lands and tailings is a very slow process, and even can hardly reach their original states. Therefore, how to develop rapid and efficient approaches to accelerate restoration of mined lands has been highlighted by restorationists and environmental engineers during the past two decades. Almost all studies in this field indicate that the major problems come from soils: such as high metal concentrations, extremely strong acidity resulting from oxidation of pyrite, and poor fertility. Replacement of topsoil is therefore regarded as the most efficient method to alleviate adverse conditions of substrates; if this method is not available, other alternatives with lime, fertilizers, organic manures, garbage, mining wastes, and others will be applicable. In the aspect of using plants, species with strong resistance and rapid growth, like grasses and herbaceous legume, are always the first choice. If utilizing plants for the purpose of phytoremediation, species that are capable of accumulating exceptionally high concentrations of phytotoxic metals and of course, have a huge biomass, are preferably considered. No matter what type of ecosystem a mined land is restored or reclaimed to, an evaluation on whether it is a successful restoration or reclamation should be given. However, more practical, simple, and universal evaluation methods as well as more cost-effective, and operation-easy restoration techniques are still waiting to be developed. A set of artificial restoration methods that can be widely applied was summarized, and a discussion on the advantage and disadvantage of several evaluation systems was conducted in this review.

Xia, H. and X. Ma (2006). Phytoremediation of ethion by water hyacinth (*Echhornia craissipes*) from water. *Bioresource Technology* 97(8): 1050-1054. The potential of water hyacinth (*Echhornia craissipes*) to remove a phosphorus pesticide ethion were investigated. The disappearance rate constants of ethion in culture solutions were 0.01059, 0.00930, 0.00294, and 0.00201 h⁻¹ for the non-sterile planted, sterile planted, non-sterile unplanted, and sterile implanted treatment, respectively, which were significantly different and implied that plant uptake and phyto degradation contributed 69% and that of microbial degradation took up 12% to the removal of the applied ethion. The accumulated ethion in live water hyacinth plant decreased by 55-91% in shoots and 74-81% in roots after the plant growing 1 week in ethion free culture solutions, suggesting that plant uptake and phytodegradation might be the dominant process for ethion removal by the plant. This plant might be utilized as an efficient, economical and ecological alternative to accelerate the removal and degradation of agro-industrial wastewater polluted with ethion. (c) 2005 Elsevier Ltd.

Xia, H. P. (2004). Ecological rehabilitation and phytoremediation with four grasses in oil shale mined land. *Chemosphere* 54(3): 345-353. *Vetiver* grass (*Vetiveria zizanioides*), bahia grass (*Paspalum notatum*), St. Augustine grass (*Stenotaphrum secundatum*), and bana grass (*Pennisetum glaucum* x *P. purpureum*) were selected to rehabilitate the degraded ecosystem of an oil shale mined land of Maoming Petro-Chemical Company located in Southwest of Guangdong Province, China. Among them, *Vetiver* had the highest survival rate, up to 99%, followed by bahia and St. Augustine, 96% and 91%, respectively, whereas bana had the lowest survival rate of 62%. The coverage and biomass of *Vetiver* were also the highest after 6-month planting. Fertilizer application significantly increased biomass and tiller number of the four grasses, of which St. Augustine was promoted most, up to 70% for biomass, while *Vetiver* was promoted least, only 27% for biomass. Two heavy metals, lead (Pb) and cadmium (Cd) tested in this trial had different concentrations in the oil shale residue, and also had different contents and distributions in

the four grass species. Concentrations of Pb and Cd in the four grasses presented a disparity of only 1.6-3.8 times, but their uptake amounts to the two metals were apart up to 27.5-35.5 times, which was chiefly due to the significantly different biomasses among them. Fertilizer application could abate the ability of the four species to accumulate heavy metals, namely concentration of heavy metals in plants decreased as fertilizer was applied. The total amount of metals accumulated by each plant under the condition of fertilization did not decrease due to an increase of biomass. In summary, *Vetiver* may be the best species used for vegetation rehabilitation in oil shale disposal piles. (C) 2003 Elsevier Ltd.

Xia, H., L. Wu, et al. (2003). A review on phytoremediation of organic contaminants. *Yingyong Shengtai Xuebao* 14(3): 457-460. Plants can take up and accumulate most persistent chemicals such as PCBs and PAHs by roots. Some chemicals such as TNT, TCE, and most organic pesticides can be phytodegraded into polar metabolites, or assimilated to CO₂ and water by some plants. On the other hand, more microorganisms in rhizosphere can enhance the degradation rate of organic contaminants in environment. The benefits and some issues on phytoremediation are also discussed.

Xian, Q., H. Chen, et al. (2006). Isolation and identification of anti-algal compounds from the leaves of *Vallisneria spiralis* L. by activity-guided fractionation. *Environmental Science and Pollution Research*. Q. Xian. 13: 233. *Vallisneria spiralis*, a common, submerged macrophyte, is widely available in quiet waters of lakes, ponds, marshes and streams in Southeast Asia. *V. spiralis* plays a significant role not only in decreasing eutrophication of water body for its productivity, but also in inhibiting the growth of blue-green algae. The aim of the paper involves the isolation and identification of allelochemicals from extracts of *V. spiralis* by activity-guided fractionation and column chromatography. Leaves of *V. spiralis* collected from East Taihu Lake in China, were washed free of debris, air-dried and refluxed in 95% EtOH. The extract was isolated using column chromatography and fractionation with anti-algal activity. Potential allelochemicals were analysed by high-resolution gas chromatography-mass spectrometry (HRGC-MS). Two fractions with strong anti-algal activity were isolated using column chromatography and activity-guided fractionation from the extract of *V. spiralis*. 2-ethyl-3-methylmaleimide, dihydroactinidiolide and 4-oxo-beta-ionone were identified in the first fraction, and 3-hydroxy-5,6-epoxy-beta-ionone, loliolide, 6-hydroxy-3-oxo-alpha-ionone and an unknown compound in the second fraction. They had strong inhibitory effects on *Microcystis aeruginosa*. 2-Ethyl-3-methylmaleimide is a byproduct of photooxidation of chlorophyll, and 5 other compounds identified were derivatives of beta-carotene. HRGC-MS and derivatization technology were used to identify and confirm their molecular structures. The formula of the unknown compound was C₁₆H₁₉NO₄. Metabolites of plant pigments had strong inhibitory activities on the growth of algae. Six compounds had been identified in *V. spiralis*, among them, 2-ethyl-3-methylmaleimide was the main allelochemical, and derivatives of ionone were also potential allelochemicals. The results of our research could help us study further mechanisms of inhibitory effect on algae and develop new potential anti-algal substances.

Xiao, K., J. H. Zhang, et al. (2006). Ectopic expression of a phytase gene from *Medicago truncatula* Barrel Medic enhances phosphorus absorption in plants. *Journal of Integrative Plant Biology* 48(1): 35-43. In the present study, the phosphorus-absorption capacity of transgenic *Arabidopsis* plants ectopically expressing a novel phytase gene from *Medicago truncatula* Barrel Medic was evaluated. A full-length cDNA encoding an extracellular form of phytase was isolated from the model legume *M. truncatula*. The phytase gene (MtPHY1) has an open reading frame of 1 632 bp predicted to encode 543 amino acids, including an N-terminal signal peptide of 27 amino acids. The genomic sequence of the MtPHY1 gene is 5 151 bp, containing seven exons interrupted by six introns. Under high-Pi (2 mmol/L) growth conditions, higher levels of MtPHY1 transcripts accumulated in the leaf and stem than in the root. The transcript level was reduced in the stem and increased in the root, with no obvious changes in the hybridization signal detected in the leaf under low-Pi (10 μmol/L) conditions. Chimeric transgenes were constructed by placing MtPHY1 under the control of the constitutive CaMV35S promoter and the root-specific MtPT1 promoter. Phytase activities in root apoplast of transgenic *Arabidopsis* were 12.3- to 16.2-fold of that in control plants. The phytase expressed was secreted into the rhizosphere, as demonstrated by HPLC analysis of phytate degradation by root exudates. Ectopic expression of MtPHY1 in *Arabidopsis*, leading to significant improvement in organic phosphorus absorption and plant growth, indicated that MtPHY1 has great potential for improving plant phosphorus absorption and phytoremediation.

Xiao, K., M. J. Harrison, et al. (2005). Transgenic expression of a novel *M-truncatula* phytase gene results in improved acquisition of organic phosphorus by *Arabidopsis*. *Planta* (Berlin) 222(1): 27-36. A full-length cDNA encoding an extracellular form of phytase was isolated from the model legume *Medicago truncatula*. The phytase cDNA (MtPHY1) has an open reading frame of 1,632 bp predicted to encode 543 amino acids including an N-terminal signal peptide of 27 amino acids. The MtPHY1 gene is 5,151 bp in length, containing 7 exons and 6 introns. MtPHY1 transcripts were detected in leaves and roots and levels elevated in roots during growth in low phosphate conditions. Transgenic *Arabidopsis* lines expressing MtPHY1 under the control of the root-specific MtPT1 promoter or the constitutive CaMV35S promoter were created. Phytase activities in root apoplast of the transgenic *Arabidopsis* were 12.3- to 16.2-fold higher than those of the control plants. The expressed phytase was secreted into the rhizosphere as demonstrated by enzyme activity staining and HPLC analysis of phytate degradation by root exudates. Transgenic expression of the MtPHY1 led to significant improvement in organic phosphorus utilization and plant growth. When phytate was supplied as the sole source of phosphorus, dry weight of the transgenic *Arabidopsis* lines were 3.1- to 4.0-fold higher than the control plants and total phosphorus contents were 4.1- to 5.5-fold higher than the control. Transgenic expression of phytase genes of plant origin has great potential for improving plant phosphorus acquisition and for phytoremediation.

Xiaomei, L., W. Qitang, et al. (2005). Phytoextraction of Zn and Cu from sewage sludge and impact on agronomic characteristics. *Journal of Environmental Science and Health Part A Toxic-Hazardous Substances & Environmental Engineering* 40(4): 823-838. The presence of elevated concentrations of heavy metals limits the usage of sewage sludge as a fertilizer and soil amendment. Experiments were carried out to examine the extent to which seven plant species phytoextracted Zn and Cu from dewatered sludge. The hyperaccumulators *Thlaspi caerulescens* and *Sedum alfredii* showed the greatest removal of Zn, while shoots and tubers of two species of *Alocasia* showed the greatest Cu removal. Cultivation of plants in the sludge resulted in significant decreases in total Zn and changes in the partitioning of Zn between soil pools. However, Cu levels were largely unchanged and remained associated predominantly with the organic matter pool. Agronomic characteristics of the sludge material, such as pH, organic matter content, and nitrogen, phosphorus, and potassium concentrations, did not change significantly during the four-month growth period, indicating that subsequent crops could be sustained by this material. These results suggest that Zn can be phytoextracted from sludge material, provided the rate of metal uptake exceeds the rate of mobilization to the exchangeable fraction. Since there was no appreciable accumulation of Zn and Cu in seeds of *Zea mays* in this study, some tissues from sludge-grown plants could potentially be used as animal fodder.

Xime´nez-Embu´n, P., Y. Madrid-Albarra´n, C. Ca´mara, C. Cuadrado, C. Burbano and M. Mu´zquiz (2002). Evaluation of *LuPinus* Species to Accumulate Heavy Metals from Waste Waters. *International Journal of Phytoremediation* 3(4).

Xiong, Y. H., X. E. Yang, et al. (2004). Characteristics of cadmium uptake and accumulation by two contrasting ecotypes of *Sedum alfredii* Hance. *Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering*. Y. H. Xiong. 39: 2925. The mined ecotype of *Sedum alfredii* has been identified to be a zinc (Zn) hyperaccumulator native to China. In the present study, the characteristics of cadmium (Cd) uptake and accumulation were compared with hydroponic experiments between the mined (ME) and the non-mined ecotypes (NME) of *S. alfredii* in Zhejiang Province. Results indicate that the plants of ME have higher tolerance to Cd than the plants of NME in terms of dry matter yield. The thresholds of external Cd levels for the reduction of plant growth were 100 micromol litre⁻¹ for the NME and 400 micromol litre⁻¹ for the ME, respectively. Kinetic study showed that the rates of Cd influx into roots (IR) and transport to shoots (TR) were higher in the ME than in the NME, with 5-fold higher for the maximum IR and 13-fold higher for the maximum TR in the NME, respectively. Cd concentrations increased with increasing external Cd supply levels. Root Cd concentrations in the NME were higher than that in the ME, with a maximum being 5646 mg kg⁻¹ for the NME and 2889 mg kg⁻¹ for the ME at 1000 micromol Cd litre⁻¹. On the contrary, shoot Cd concentrations of the NME were far lower than that of the ME. Maximum shoot Cd concentrations were 533 mg kg⁻¹ in leaves and 935 mg kg⁻¹ in stems at 1000 micromol Cd litre⁻¹ for NME, whereas, 4933 and 3874 mg kg⁻¹ at 400 micromol Cd litre⁻¹ for the ME, respectively. Meanwhile, Cd concentrations in the shoots of both the NME and ME

increased with advancing Cd treatment time. At 100 micromol Cd litre⁻¹, concentrations of Cd in leaves and stems of the NME sharply increased within initial 8 and 12 days, and those in the ME increased dramatically until the 20th and 16th day, respectively. However, leaf and stem Cd concentrations reached their maximum values on the 4th day for the NME and 8th day for the ME, respectively, when the plants were exposed to 1 micromol Cd litre⁻¹. Cd accumulation by plant shoots was obvious higher in the ME than in the NME at varied Cd supply levels or Cd treatment time. The maximum Cd taken up by the shoots was 1032 microg plant⁻¹ in concentration-dependent uptake, and 1699 microg plant⁻¹ in time-course uptake for the ME, with 15-fold and 18-fold higher than those for the NME, respectively. The shoot:root ratio of Cd ranged from 12 to 39, varying with Cd supply levels, and from 13 to 24 in the varied treatment times for the ME, more than 10 times greater than those for the NME. In addition, Cd distribution in leaves, stems and roots of ME was greatly different from those of NME. The percentage of Cd distribution in shoots was more than 79 at the varied Cd supply levels, or 83 in the varied treatment time for ME, both higher than that for NME. It could be concluded that the ME of *S. alfredii* has a greater ability to tolerate, transport, and accumulate Cd, as compared with the NME.

Xiong, Z. T. (1999). Lead Accumulation and Tolerance in *Brassica Chinensis* L. Grown in Sand and Liquid Culture. *Toxicological & Environmental Chemistry* 69(1): 9-18.

Xiong, Z. T. and P. Lu (2002). Joint enhancement of lead accumulation in *Brassica* plants by EDTA and ammonium sulfate in sand culture. *Journal of Environmental Sciences-China* 14(2): 216-220. When EDTA was added alone in the Pb-contaminated sand, the plant biomass and the total Pb amount in plant decreased in both species, *Brassica*, *pekinensis* and *B. juncea* var. *multiceps*, though the shoot Pb amount increased. In contrast, when (NH₄)₂SO₄ was added alone in the Pb-contaminated sand, little effect was observed on the shoot Pb amount, though the root Pb amount was significantly increased in *B. juncea* var. *multiceps*. When amending EDTA and (NH₄)₂SO₄ in combination, however, the shoot Pb amount in both species substantially increased, being, on an average, 2 times and 9 times higher than that in EDTA alone or (NH₄)₂SO₄ alone amended treatment, respectively. The two amendments showed antagonism for plant growth, but synergism for Pb bioaccumulation. *B. pekinensis* showed its highest level of shoot and total Pb amount in the treatment amended with EDTA and (NH₄)₂SO₄ only a half as much as in the other treatment. It is inferred that the mechanisms responsible for the joint-enhanced Pb accumulation might be concerned with the acidification of the growth medium, cation exchange reaction and relieving EDTA induced toxicity as results by amending ammonium sulfate.

Xiong, Z. T. and T. Feng (2001). Enhanced Accumulation of Lead in *Brassica Pekinensis* by Soil-Applied Chloride Salts. *Bulletin of Environmental Contamination and Toxicology* 67(1): 67-74.

Xiong, Z. (1998). Lead Uptake and Effects on Seed Germination and Plant Growth in a Pb Hyperaccumulator. *Bull. Environ. Contam. Toxicol.* 60(2): 285-291.

Xiong, Z.T. (1997). Bioaccumulation and physiological effects of excess lead in a roadside pioneer species *Sonchus oleraceus*. *Environ. Poll.* 97(3):275.

Xu, H., X. Wang, et al. (2005). Nitrogen and phosphorus removal efficiency of *Deyeuxia angustifolia* wetland ecosystem in Sanjiang Plain. *Rural Eco-Environment*. H. Xu. 21: 38. An area (approximately 1600 m²) of *Deyeuxia angustifolia* wetland in Sanjiang Plain (Heilongjiang, China) was selected to study the function of wetland ecosystems purifying environmental N and P pollutants. Results showed that the N and P removal rates presented a rather steady trend during the vegetation growth and maturation periods, and the average removal rate was 85.62 and 85.94%, respectively. The accumulated concentration of NH₄⁺-N was significantly correlated with TN in the water body of the wetland. Input concentration, mowing and runoff all affected the purification function of the wetland and distribution of N and P. The removal rate decreased with the increase of input concentration and also with mowing. Limited runoff played little role in removing N and P. In a word, the purification efficiency of the *Deyeuxia angustifolia* wetland ecosystem in Sanjiang Plain was remarkable. The total removal rate of N and P reached 97.97 and 99.05%, respectively.

Xu, J.G. and R.L. Johnson (1997). Nitrogen dynamics in soils with different hydrocarbon contents planted to barley and field pea. *Can. J. Soil. Sci.* 77:453-458.

Xu, S. P. and P. R. Jaffe (2006). Effects of plants on the removal of hexavalent chromium in wetland sediments. *Journal of Environmental Quality*. S. P. Xu. 35: 334. The effect of two wetland plants, *Typha latifolia* L. (cattail) and *Phragmites australis* (Cav.) Trin. ex Steud (common reed), on the fate of Cr(VI) in wetland sediments was investigated using greenhouse bench-scale microcosm experiments. The removal of Cr(VI) was monitored based on the vertical profiles of aqueous Cr(VI) in the sediments. The Cr(VI) removal rates were estimated taking into account plant transpiration, which was found to significantly concentrate dissolved species in the sediments. After correcting for evapotranspiration, the actual Cr(VI) removal rates were significantly higher than would be inferred from uncorrected profiles. On average, the Cr(VI) removal rates were 0.005 to 0.017 mg L⁻¹ d⁻¹, 0.0003 to 0.08 mg L⁻¹ d⁻¹, and 0.004 to 0.13 mg L⁻¹ d⁻¹ for the control, *T. latifolia*, and *P. australis* microcosms, respectively. The fate of the removed Cr(VI) was examined by determining the quantity and chemical speciation of the Cr in the sediment and plant materials. Chromium(III) was the dominant form of Cr in both the sediment and plants, and precipitation of Cr(III) in the sediment was the major pathway responsible for the disappearance of aqueous Cr(VI) from the pore water. Incubation results showed that abiotic reduction was the primary mechanism underlying Cr(VI) removal in the microcosm sediments. Organic compounds produced by plants, including root exudates and mineralization products of dead roots, are thought to be the factor that is either directly or indirectly responsible for the gap between Cr(VI) removal efficiencies in the sediments of the vegetated and unvegetated microcosms.

Xu, S. Y., Y. X. Chen, et al. (2005). Uptake and accumulation of phenanthrene and pyrene in spiked soils by Ryegrass (*Lolium perenne* L.). *Journal of Environmental Sciences-China* 17(5): 817-822. Phytoremediation has long been recognized as a cost-effective method for the removal of polycyclic aromatic hydrocarbons (PAHs) from soil. A study was conducted to investigate the uptake and accumulation of PAHs in root and shoot of *Lolium perenne* L. Pot experiments were conducted with series of concentrations of 3.31-378.37 mg/kg for phenanthrene and those of 4.22-365.38 mg/kg for pyrene in a greenhouse. The results showed that both ryegrass roots and shoots did take up PAHs from spiked soils, and generally increased with increasing concentrations of PAH in soil. Bioconcentration factors (BCFs) of phenanthrene by shoots and roots were 0.244-2.5 and 0.17-2.12 for the same treatment. BCFs of pyrene by shoots were 0.20-1.5, except for 4.06 in 4.32 mg/kg treatment, much lower than BCFs of pyrene by roots (0.58-2.28). BCFs of phenanthrene and pyrene tended to decrease with increasing concentrations of phenanthrene and pyrene in soil. Direct uptake and accumulation of these compounds by *Lolium perenne* L. was very low compared with the other loss pathways, which meant that plant-promoted microbial biodegradation might be the main contribution to plant-enhanced removal of phenanthrene and pyrene in soil. However, the presence of *Lolium perenne* L. significantly enhanced the removal of phenanthrene and pyrene in spiked soil. At the end of 60 d experiment, the extractable concentrations of phenanthrene and pyrene were lower in planted soil than in non-planted soil, about 83.24%-91.98% of phenanthrene and 68.53%-84.10% of pyrene were removed from soils, respectively. The results indicated that the removal of PAHs in contaminated soils was a feasible approach by using *Lolium perenne* L.

Xu, S. Y., Y. X. Chen, et al. (2006). Enhanced dissipation of phenanthrene and pyrene in spiked soils by combined plants cultivation. *Science of the Total Environment* 363(1-3): 206-215. Polycyclic aromatic hydrocarbons (PAHs), a class of POPs, are widely distributed in the environment. Phytoremediation has long been recognized as a cost-effective method for removal of PAHs pollutants from soil. This study was conducted to investigate the capability of three plant species separately and their combination to promote the degradation of phenanthrene and pyrene in soil. The performance of three plant species, maize, ryegrass and white clover for phenanthrene and pyrene removal was also compared. The result showed that the presence of vegetation significantly enhances the dissipation of phenanthrene and pyrene in the soil environment. This effect was especially marked with maize. At the end of 60 days treatment, phenanthrene and pyrene concentrations in treated soils declined from an initial 52.52 mg kg⁻¹ and 58.19 mg kg⁻¹ to 4.15 mg kg⁻¹ and 6.77 mg kg⁻¹, respectively, indicating that phenanthrene and pyrene was successfully removed by maize. Around 92.10% of phenanthrene and 88.36% of pyrene were removed from soils planted with maize. Within approximately two months experimental period, the

dissipation extent showed that the 4-ring pyrene was more recalcitrant than 3-ring phenanthrene. Although the extents did not differ significantly among three tested species, the rates of degradation were different. The maize treatment had the highest rate of contaminant removal after two months, followed by white clover and annual ryegrass. As compared to single plant cultivation, combined plants cultivation significantly enhanced the destruction rate and extent of phenanthrene and pyrene in soils. Around 98.22% of phenanthrene and 95.81% of pyrene were removed from soils planted with maize and ryegrass. This research indicates the potential for phenanthrene and pyrene mineralization in combined plants cultivation, which may be especially useful for phytoremediation of soils contaminated with PAHs. (c) 2005 Elsevier B.V.

Xu, S.-y., Y.-x. Chen, et al. (2005). Uptake and accumulation of phenanthrene and pyrene in spiked soils by Ryegrass (*Lolium perenne* L.). *Journal of Environmental Sciences (China)* 17(5): 817-822. Phytoremediation has long been recognized as a cost-effective method for the removal of polycyclic aromatic hydrocarbons (PAHs) from soil. A study was conducted to investigate the uptake and accumulation of PAHs in root and shoot of *Lolium perenne* L. Pot experiments were conducted with series of concentrations of 3.31-378.37 mg/kg for phenanthrene and those of 4.22-365.38 mg/kg for pyrene in a greenhouse. The results showed that both ryegrass roots and shoots did take up PAHs from spiked soils, and generally increased with increasing concentrations of PAH in soil. Bioconcentration factors (BCFs) of phenanthrene by shoots and roots were 0.244.25 and 0.17-2.12 for the same treatment. BCFs of pyrene by shoots were 0.20-1.5, except for 4.06 in 4.32 mg/kg treatment, much lower than BCFs of pyrene by roots (0.58-2.28). BCFs of phenanthrene and pyrene tended to decrease with increasing concentrations of phenanthrene and pyrene in soil. Direct uptake and accumulation of these compounds by *Lolium perenne* L. was very low compared with the other loss pathways, which meant that plant-promoted microbial biodegradation might be the main contribution to plant-enhanced removal of phenanthrene and pyrene in soil. However, the presence of *Lolium perenne* L. significantly enhanced the removal of phenanthrene and pyrene in spiked soil. At the end of 60 d experiment, the extractable concentrations of phenanthrene and pyrene were lower in planted soil than in non-planted soil, about 83.24%-91.98% of phenanthrene and 68.53%-84.10% of pyrene were removed from soils, respectively. The results indicated that the removal of PAHs in contaminated soils was a feasible approach by using *Lolium perenne* L.

Xu, W., Z. Xiong, et al. (2005). Effects of Zn stress on Zn accumulation and anti-oxidant enzymes activity in four varieties of ryegrass. *Wuhan University Journal of Natural Sciences*. W. Xu. 10: 1051. A study was conducted to investigate the possibility of antioxidant enzymes as biomarkers in selecting plants for phytoremediation of slight to moderately heavy metal-contaminated soils. We investigated the influence of different Zn²⁺ treatments (0, 2, 4, 8, 16 mmol kg⁻¹) on plant growth, activities of peroxidase (POD) and superoxide dismutase (SOD), free proline content and Zn accumulation in 4 ryegrass (*Lolium perenne*) varieties (Airuisi, Taide, Yeying and Tuoye) by pot culture experiment. The results showed that plant biomass increased at the ranges of 0-2 (Tuoye), 0-4 (Yeying), 0-8 mmol kg⁻¹ (Airuisi and Taide), and then decreased under excess Zn. The POD and SOD activities, and the proline content in shoots decreased initially, and then increased with increasing Zn content. The plant biomass, and POD and SOD activities in Taide were evidently higher than in the other 3 varieties. Root tolerance index and Zn transport ratio from root to shoot (S/R) in Taide exceeded 1.0. The maximum Zn content was found in the shoots of Taide variety (583.9 mg/kg at 16 mmol kg⁻¹).

Xu, X. H., J. Y. Shi, et al. (2006). An investigation of cellular distribution of manganese in hyperaccumulator plant *Phytolacca acinosa* Roxb. using SRXRF analysis. *Journal of Environmental Sciences-China* 18(4): 746-751. *Phytolacca acinosa* Roxb. (*P. acinosa*) is a recently discovered manganese hyperaccumulator plant from southern China. It is a good candidate for phytoremediation of manganese (Mn) polluted soil for its high biomass and fast growth. Knowledge of the tissue localization and identification of heavy metals can provide essential information on metal toxicity and bioaccumulation mechanisms. Synchrotron radiation X-ray fluorescence spectroscopy (SRXRF) microprobe was used in this study to investigate the cellular distributions of Mn and other elements in root, stem, leaf, petiole and midrib of *P. acinosa*. The highest Mn content was found in the vascular tissues of root, stem, petiole and midrib. Cortex in root played a key role in Mn absorption and Mn was limited in the vascular bundle during the process of transportation in stem. Moreover, Mn content in leaf epidermis was higher than that in mesophyll, which

suggested that the sequestration of Mn in leaf epidermis might be one of the detoxification mechanisms of *P. acinosa*. The significance of other elemental (such as P, S, K, Ca, Fe, Zn and Cu) distribution patterns and the correlation with Mn were also discussed.

Xue, S. G., Y. X. Chen, et al. (2004). Manganese uptake and accumulation by the hyperaccumulator plant *Phytolacca acinosa* Roxb. (Phytolaccaceae). *Environmental Pollution* 131(3): 393-399. The perennial herb *Phytolacca acinosa* Roxb. (Phytolaccaceae), which occurs in Southern China, has been found to be a new manganese hyperaccumulator by means of field surveys on Mn-rich soils and by glasshouse experiments. This species not only has remarkable tolerance to Mn but also has extraordinary uptake and accumulation capacity for this element. The maximum Mn concentration in the leaf dry matter was 19,300 $\mu\text{g/g}$ on Xiangtan Mn tailings wastelands, with a mean of 14,480 $\mu\text{g/g}$. Under nutrient solution culture conditions, *P. acinosa* could grow normally with Mn supplied at a concentration of 8000 $\mu\text{mol/l}$, although with less biomass than in control samples supplied with Mn at 5 $\mu\text{mol/l}$. Manganese concentration in the shoots increased with increasing external Mn levels, but the total mass of Mn accumulated in the shoots first increased and then decreased. At an Mn concentration of 5000 $\mu\text{mol/l}$ in the culture solution, the Mn accumulation in the shoot dry matter was highest (258 mg/plant). However, the Mn concentration in the leaves reached its highest value (36,380 $\mu\text{g/g}$) at an Mn supply level of 12,000 $\mu\text{mol/l}$. These results confirm that *P. acinosa* is an Mn hyperaccumulator which grows rapidly, has substantial biomass, wide distribution and a broad ecological amplitude. This species provides a new plant resource for exploring the mechanism of Mn hyperaccumulation, and has potential for use in the phytoremediation of Mn-contaminated soils. (C) 2004 Elsevier Ltd.

Xue, S. G., Y. X. Chen, et al. (2005). Manganese uptake and accumulation by two populations of *Phytolacca acinosa* Roxb. (Phytolaccaceae). *Water Air and Soil Pollution* 160(1-4): 3-14. *Phytolacca acinosa* (Phytolaccaceae) is a recently discovered manganese hyperaccumulator plant from Southern China. Manganese uptake and accumulation by two contrasting populations of *P. acinosa* were investigated. One population (MP) was from Xiangtan manganese tailings and the other (NMP) was from a *Magnolia grandiflora* plantation with lower Mn status. In addition to these field investigations, seedlings of the two populations were raised under glasshouse conditions to study biomass production and Mn uptake from nutrient solutions supplemented with increasing amounts of Mn (5, 1000, 2000, 5000, and 8000 $\mu\text{mol L}^{-1}$ Mn). Although, concentrations of Mn in the plant tissues (leaves, stems and roots) of *P. acinosa* (MP) and the associated soil from manganese tailings were significantly higher than those of the plant tissues and the soil collected in the clean site, significant differences were not found between the two populations of *P. acinosa* grown in nutrient culture. The two populations of seedlings showed similar growth responses, manganese uptake and accumulation when exposed to the same level of Mn supply for 45 days. All these results suggest that both high tolerance and hyperaccumulating ability of Mn in *P. acinosa* are constitutive properties. Furthermore, the plant grows rapidly, produces substantial biomass, and has broad ecological amplitude. *P. acinosa*, therefore, offers great potential for use in the phytoremediation of Mn-contaminated soils.

Xue, S., Y. Chen, et al. (2004). Manganese tolerance and hyperaccumulation of *Phytolacca acinosa* Roxb. *Acta Pedologica Sinica*. S. Xue. 41: 889. Identification of new hyperaccumulators is of great importance to successful phytoremediation of the environment contaminated with heavy metal. A new manganese (Mn) hyperaccumulator plant, *Phytolacca acinosa*, was found growing in Southern China through field surveys on Mn mine tailings dumps and greenhouse experiments. This species has not only remarkable tolerance to Mn, but also an extraordinary capacity for this element. With the maximum Mn concentration in the leaf reaching 19300 mg kg^{-1} , the plant grew well on Mn tailings dump in Xiangtan, Hunan Province, with Mn concentration being as high as 114000 mg kg^{-1} . Under hydroponic conditions, the Mn concentration in the plant leaves could reach as high as 36380 mg kg^{-1} with the bioaccumulation coefficient of 55 at a Mn supply level of 12 mmol litre^{-1} . *P. acinosa* could grow quite well hydroponically with Mn supplied at a level of 8 mmol litre^{-1} , although its biomass was less than that of the control with Mn supplied at 0.005 mmol litre^{-1} . With the increasing Mn concentration in the media, the Mn concentration in the shoots increased, but the bioaccumulation coefficient gradually decreased. The total Mn accumulated in the aerial parts of the plant rose first and then declined. At the Mn concentration in the solution reached 5 mmol litre^{-1} , the Mn accumulation in the aerial parts of the plant was the highest (258.2 mg plant^{-1}).

Partitioning of Mn between the aerial parts and the roots showed that 87-95% of Mn was transported into the former in all the treatments, demonstrating the great capacity of the plant transporting Mn from the roots to the aerial parts. *P. acinosa* therefore offers great potential for use in phytoremediation of Mn-contaminated soils and waters.