Jackson, D.B., and D.J. Dollhopf. (1994). Abstract: Revegetation of contaminated streamside mine wastes. p. 124. In L.E. Erickson, D.L. Tillison, S.C. Grant, and J.P. McDonald (eds.), Proceedings of the 9th Annual Conference on Hazardous Waste Remediation, June 8-10, 1994, Bozeman, MT.

Jackson, L. (1997). Why choose phytoremediation - Looking through the eyes of the customer. IBC's Second Annual Conference on Phytoremediation, June 18 - 19, 1997, Seattle, WA. International Business Communications, Southborough, MA.

Jackson, M.B. and P.A. Attwood. (1996). Root of willow (*Salix viminalis* L.) show marked tolerance to oxygen shortage in flooded soils and in solution culture. Plant and Soils 187: 37-45 .

Jackson, P.J. (1996). Luminescence studies of radionuclide and heavy metal binding to plant cells. International Phytoremediation Conference, May 8-10, 1996, Arlington, VA. International Business Communications, Southborough, MA.

Jackson, W. A., K. Tan, et al. (2004). Distribution, degradation, and uptake of perchlorate (PC) in contaminated stream sediments. In situ and on-site bioremediation -- 2003. Proceedings of the Seventh International In Situ and On-Site Bioremediation Symposium, Orlando, Florida, USA, 2-5 June, 2003. Colombus, Battelle Press: 10. The goal of this study was to determine the fate of perchlorate (PC) in streams and near surface sediments at the Naval Weapons Industrial Reserve Plant (NWIRP) near McGregor, TX, including distribution, plant uptake, and biological transformation potential. Results indicated that perchlorate penetration and persistence was seasonally dependent. Perchlorate distribution closely mirrors nitrate distribution in sediments when nitrate concentration was below 10 mg/l and perchlorate penetration into bed sediments ranged from 0-20 cm with greatest penetration in non-summer months. Biodegradation of perchlorate can occur over a depth of only a 1-5 cm although this active depth changes seasonally. Plant uptake of perchlorate from streams was substantial with dry leaf concentrations up-to 2 orders of magnitude greater than bulk water concentrations. Microcosm studies indicated that perchlorate degradation was variable with both the biodegradation rate and lag time dependent on such factors as pre-exposure, concentration of nitrate in the sediments, and organic substrate availability.

Jackson, W. A., L. Martino, et al. (2005). Application of a dialysis sampler to monitor phytoremediation processes. Environmental Monitoring and Assessment. 107: 155. A cylindrical dialysis sampler (1.2 m in length; 5 cm in diameter) was designed and constructed to sample small-scale phytoremediation processes in the root zone of poplar trees. The study site was a 183-tree plantation of hybrid poplars located at Aberdeen Proving Ground, Maryland, at the J-Field Area of Concern. The grove was planted in 1996 to intercept a chlorinated solvent plume containing 1,1,2,2-tetrachloroethane (1,1,2,2-TeCA, trichloroethene (TCE) and daughter products). Two dialysis samplers were installed: one directly in the poplar grove (approximately 0.3 m from the trunk of a mature tree) and the other outside of the grove but in the plume. Data collected included concentrations of chlorinated VOCs, organic acids, chloroacetic acids, Cl-, and dissolved gases (ethane, ethene, CH4, CO2). At the control location, the VOC profile was dominated by cis- 1,2-dichloroethene (cis-1,2-DCE) and trans-1,2-dichloroethene (trans-1,2-DCE) with concentrations ranging from 0.88-4.5 to 4.4-17.6 mg/L, respectively. Concentrations of VOCs were similar across the vertical profile. At the tree location, 1,1,2,2-TeCA and TCE were the dominant VOCs detected but as opposed to the control location were highly variable within the root zone, with the greatest variability associated with locations in the sampler where roots were observed. This highly variable profile at the tree location is indicative of VOC rhizosphere biodegradation and uptake near the active roots. This variability appears to be on the centimeter scale, emphasizing the importance of these high-resolution samplers for the study of rhizosphere influences.

Jacob, D. L. and M. L. Otte (2004). Influence of *Typha latidolia* and fertilization on metal mobility in two different Pb-Zn mine tailings types. Science of the Total Environment 333(1-3): 9-24. Storing metal-rich mine waste (tailings) under submerged and reduced conditions can prevent the release of metals to the water column, but introduction of wetland plants on these sediments may alter the reducing environment through root oxygen diffusion or organic matter accumulation. Fertilization of these wetlands can enhance plant growth, but also may either strengthen reducing conditions via microbial stimulation, or increase the

redox potential (Eh) through increased root radial oxygen loss. This long-term study (2.25 years) investigated the porewater As, Fe, and Zn concentrations of waterlogged Pb-Zn tailings from two Irish mines, Silvermines and Tara mines, with addition of *Typha latidolia*, fertilizer, or both treatments combined. In both tailings types, the fertilized plants showed significantly increased total biomass production, but the plants grew greater biomass in Tara tailings relative to Silvermines tailings even without fertilization. In Tara mines tailings, the addition of plants increased Eh and mobilized Zn; the addition of fertilizer enhanced reducing conditions and increased porewater concentrations of As and soluble sulfides; and the combination of treatments on these tailings resulted in complex interactions. In Silvermines tailings, there were negligible effects of the treatments. For effective sequestration of metals in these tailings, Silvermines would require only water cover, but Tara mines tailings would require either both treatments or neither because each treatment individually would increase solubility of As or Zn. These results show also the necessity of evaluating treatment effects specific to individual tailings, that long-term studies (years) are crucial for tailings equilibration and valid experimental conclusions, and that passive accumulation of organic matter may take decades. (C) 2004 Elsevier B.V.

Jacobs, L.W., G.A. O'Connor, M.R. Overcash, M.J. Zabek, and P. Rygwiecz. (1987). Effect of trace organics in sewage sludges on soil plant systems and assessing their risk to humans. pp. 101-143. In A.L. Page et al. (eds.), Land application of sludge. Lewis Publ., Chelsea, MI.

Jacobsen, C.S. (1997). Plant protection and rhizosphere colonization of barley by seed inoculated herbicide degrading Burkholderia (*Pseudomonus*) cepacia DBO1 (pRO101) in 2,4-D contaminated soil. Plant Soil. 189(1):139-144.

Jacquet, T. (2005). Phtorestoration first for France. World Water and Environmental Engineering. T. Jacquet. 28: 21. The waste water treatment plant at Honfleur is the first in France to treat waste water botanically (phytorestoration). This system treats waste sustainably, enhances the environment and is cutting pollution to the Seine estuary. A series of planted environments such as reed-filters, macrophyte pools and humid forest use the capabilities of plants, microorganisms, promoters and substrates, to extract of naturally fix a variety of pollutants. The advantages of phytorestoration over traditional waste water treatment are briefly discussed.

Jaffre', T., R.R. Brooks, and J.M. Trow. (1979). Hyperaccumulation of nickel by *Geissois* species from New Caledonia, indicator plants. Plant Soil. 51(1):157-162.

Jaffre', T., R.R. Brooks, J. Lee, and R.D. Reeves. (1976). *Sebertia acuminata*: A hyperaccumulator of nickel from New Caledonia. Science. 193:579-580.

Jagetiya, B. L. and P. Purohit (2006). Effects of various concentrations of uranium tailings on certain growth and biochemical parameters in sunflower. Biologia 61(1): 103-107. Effects of different concentrations (25, 50, 75 and 100%) of uranium tailings conditioned with garden soil on growth and biochemical parameters in sunflower were studied. The shoot and root length, fresh and dry mass as well as leaf area and chlorophyll contents showed significant negative correlation with the applied uranium tailing concentrations. The influence on plant growth was also measured in terms of Tolerance Index (TI) and Grade of Growth Inhibition (GGI). Yellowing of leaves was recorded in all the tailing concentrations. Soluble proteins (leaf) showed significant enhancement as the concentration of uranium tailing increased indicating a breakdown of structural insoluble proteins. Survival of sunflower plants over 100 days on higher tailing concentrations (up to 75%) showed that sunflower may be helpful in revitalization of uranium mining waste.

Jala, S. and D. Goyal (2006). Fly ash as a soil ameliorant for improving crop production - a review. Bioresource Technology 97(9): 1136-1147. Fly ash, a. resultant of combustion of coal at high temperature, has been regarded as a problematic solid waste all over the world. Many possible beneficial applications of fly ash are being evaluated to minimize waste, decrease cost of disposal and provide value-added products. The conventional disposal methods for fly ash lead to degradation of arable land and

contamination of the ground water. However fly ash is a useful ameliorant that may improve the physical, chemical and biological properties of problem soils and is a source of readily available plant macro and micronutrients. In conjunction with organic manure and microbial inoculants, fly ash can enhance plant biomass production from degraded soils. Detailed studies oil the nature and composition of fly ash, conducted during the latter half of the 20th century have helped in repeatedly confirming the various useful applications of this hitherto neglected industrial waste. The purpose of this paper is to review the available information oil various attributes of fly ash and explore the possibility of exploiting them for agronomic advantage. (c) 2004 Elsevier Ltd.

Jalajas, E.W.P. First phytoremediation project in New Hampshire. (1998), 14th Annual Conference on Contaminated Soils. October. University of Massachusetts at Amherst, Amherst, MA.

Jamal, A., N. Aub, M. Usman and A. Khan. (2002). Arbuscular Mycorrhizal Fungi Enhance Zinc and Nickel Uptake from Contaminated Soil by Soybean and Lentil. International Journal of Phytoremediation 4(3).

Jamal, A., N. Ayub, et al. (2002). Arbuscular mycorrhizal fungi enhance zinc and nickel uptake from contaminated soil by soybean and lentil. International Journal of Phytoremediation 4(3): 205-221. Generally, soils in Pakistan are deficient in P and N. Due to intensive cropping and irrigation, Pakistani soils have also become deficient in micronutrients such as Zn, Fe, Cu, and Mn. Arbuscular mycorrhizal fungi, which form symbiotic associations with roots of most land plants, are known to enhance uptake of P and trace elements such as Cu, Ni, Pb, and Zn. The present study was conducted to investigate the role of arbuscular mycorrhizae (AM) in uptake of nickel (Ni) and zinc (Zn) by crops viz. soybean (Glycine max (L.) Merrill) and lentil (Lens culinaris Medic). Zn and Ni were applied as ZnSO(4)7H(2)O and NiCl2 respectively, in four concentrations (0.0, 1.0, 3.0, and 5.0 g kg(-1) soil). AM inoculum. consisted of sand containing sporocarps, spores, and AMF infected root pieces from a pot culture of *Glomus* mosseae. Control plants received pot culture filtrate containing soil microflora minus AM fungal propagules. A significant difference ($p < 0.05$) was observed in the dry weights of roots and shoots of the mycorrhizal (M) and nonmycorrhizal (NM) cereal plants. The sievate-amended treatments did not stimulate plant growth to the same extent as the AM fungal amended treatments. Trace metals inhibited the extent of mycorrhizal colonization of the cereal roots. The concentrations of the trace metals in the plant tissues of 12-week old cereal plants were found significantly ($p < 0.05$) higher in M than NM plants. These results indicate that mycorrhize can be used as effective tools to supply sufficient Zn in generally Zn-deficient Pakistani soils and to ameliorate the toxicity of trace metals in polluted soils. The contents of Ni in mycorrhizal soybean plant tissues were higher than those in the mycorrhizal lentil plant tissues. The implications of these results in mycorrhizo remediation of agricultural soils are discussed.

James, L.F., K.E. Panter, H.F. Mayland, M.R. Miller, and D.C. Baker. (1989). Selenium poisoning in livestock: A review and progress. p. 123-131. In L. Jacobs (ed.), Selenium in agriculture and the environment. SSSA Spec. Publ. 23. ASA and SSSA, Madison, WI.

Janouskova, M., D. Pavlikova, et al. (2005). Arbuscular mycorrhiza decreases cadmium phytoextraction by transgenic tobacco with inserted metallothionein. Plant and Soil. 272: 29. The effect of arbuscular mycorrhiza (AM) on the phytoextraction efficiency of transgenic tobacco with increased ability to tolerate and accumulate cadmium (Cd) was tested in a pot experiment. The tobacco plants bearing the yeast metallothionein CUP1 combined with a polyhistidine cluster were compared to non-transgenic tobacco of the same variety at four Cd concentrations in soil, non-inoculated or inoculated with two isolates of the AM fungus *Glomus intraradices*. Mycorrhizal inoculation improved the growth of both the transgenic and non-transgenic tobacco and decreased Cd concentrations in shoots and root to shoot translocation. Differences were found between the two AM fungal isolates: one isolate supported more efficient phosphorus uptake and plant growth in the soil without Cd addition, while the other isolate alleviated the inhibitory effect of cadmium on plant growth. The resulting effect of inoculation on Cd accumulation was dependent on Cd level in soil and differed between the more Cd tolerant transgenic plants and the less tolerant non-transgenic plants. Mycorrhiza mostly decreased the phytoextraction efficiency of transgenic plants while increased that of non-transgenic plants at Cd levels in soil inhibitory to tobacco growth. Mechanisms of the observed effects of inoculation on growth and Cd uptake are discussed as well as the

possible implications of the results for the exploitation of AM in phytoextraction of heavy metals from contaminated soils.

Janouskova, M., D. Pavlikova, et al. (2005). Influence of arbuscular mycorrhiza on the growth and cadmium uptake of tobacco with inserted metallothionein gene. Applied Soil Ecology. 29: 209. The effect of arbuscular mycorrhiza (AM) on the growth and cadmium (Cd) uptake of transgenic tobacco with increased ability to accumulate Cd was assessed. The transgenic tobacco bearing yeast metallothionein gene combined with a polyhistidine cluster was compared to non-transgenic tobacco in two pot experiments with different substrates -- soil and river sand -- amended or unamended with Cd. The development of AM did not differ between the transgenic and non-transgenic plants in either experiment. AM improved the phosphorus nutrition of the tobacco plants in both experiments, their biomass production, however, was increased only in sand, while in soil, it was lower or remained unchanged compared to non-mycorrhizal plants. AM decreased the Cd uptake of the tobacco plants per unit of shoot biomass in both experiments and decreased the Cd accumulation in the shoots of the transgenic tobacco relatively to the non-transgenic tobacco. It is concluded that AM symbiosis is likely to influence the heavy metal (HM) accumulation ability of plants targeted by transgenosis. Thus, AM must be considered in testing the transgenic plants as it can change the relative performance of the transgenic plants compared to the non-transgenic plants.

Jansen, M. A. K., L. M. Hill, et al. (2004). A novel stress-acclimation response in *Spirodela punctata* (*Lemnaceae*): 2,4,6-trichlorophenol triggers an increase in the level of an extracellular peroxidase, capable of the oxidative dechlorination of this xenobiotic pollutant. Plant Cell and Environment 27(5): 603-613. Peroxidases are haem-containing enzymes capable of oxidizing a wide range of substrates. This article describes the presence of peroxidase activity in the growth medium of axenic Spirodela punctata (*Lemna*ceae) cultures. It was found that the release of extracellular peroxidase activity is specifically enhanced by phytotoxic, halogenated phenols but not by other abiotic stress-factors, elicitors or plant metabolites. Based on the concentration dependence of 2,4,6-trichlorophenol (TCP)-enhanced peroxidase release, it is concluded that release is not simply a consequence of physiological damage, but rather requires metabolically healthy fronds. In vitro studies (UV/VIS spectroscopy and liquid chromatography/mass spectrometry) show that the extracellular duckweed peroxidase (SpEx), which was partially purified from Spirodela growth medium, is capable of catalysing the oxidative dechlorination of TCP with hydrogen peroxide as the electron acceptor. It is proposed that the ability of S. punctata to specifically sense environmentally persistent phytotoxic chlorophenols, and to respond by increasing extracellular levels of a peroxidase capable of catalysing their oxidative dechlorination, is part of the protection strategy of this aquatic plant against xenobiotic stress.

Jarvis, M. D. and D. Leung. (2002). Chelated Lead Transport in *Pinus Radiata*: An Ultrastructural Study. Environ. & Experimental Bot. 48(1): 21-32.

Jauert, P., T. E. Schumacher, A. Boe and R. N. Reese. (2002). Rhizosphere Acidification and Cadmium Uptake by Strawberry Clover. J. Environ. Qual. 31(2): 627-633.

Jayaweera, M. W. and J. C. Kasturiarachchi (2004). Removal of nitrogen and phosphorus from industrial wastewaters by phytoremediation using water hyacinth (*Echhornia craissipes* (Mart.) Solms). Water Science and Technology. 50: 217. This paper elucidates the phytoremediation potential of water hyacinth (*Echhornia craissipes* [Mart.] Solms) for TN and TP rich industrial wastewaters determined for 15 weeks under different set-ups of 2-fold (56 TN mg/l and 15.4 TP mg/l), 1-fold, 1/2-fold, 1/4-fold and 1/8-fold and a control with no nutrients in duplicate. A mass balance was conducted to evaluate the phytoremediation efficiencies and to identify the key mechanisms of nutrient removal from the wastewaters. Our results manifested that water hyacinth is a promising candidate for a batch removal of TN and TP from wastewaters. 100% removal of both TN and TP was observed at the end of the 9th week in all the set-ups mainly due to assimilation and the period between 6-9 weeks became the optimum period after which complete harvesting is recommended. Plants having an age of 6 weeks are ideal to commence the free-floating wetland and 21 days hydraulic retention time (HRT) is recommended for optimum removal of TN

and TP. Assimilation and denitrification were the key mechanisms of TN removal while assimilation and sorption became the prominent mechanisms in the removal of TP from wastewaters.

Jemison, J.M., Jr., and R.H. Fox. (1991). Corn uptake of bromide under greenhouse and field conditions. Commun. Soil Sci. Plant Anal. 23:283-297.

Jennings, E.M., K. Duncan, E. Levetin, P. Buck, K. Sublette, K. Lawlor, and J.B. Fisher. (1997). Toxicity and botanical effects on crude oil contamination: Three years post-bioremediation. 4th International Petroleum Environmental Conference; Environmental Issues and Solutions in Exploration, Production, and Refining, September 9-12, 1997, San Antonio, TX.

Jensen, IV, I.J., and H.R. Haise. (1963). Estimating evapotranspiration from solar radiation. J. Irrig. Drain Div. Am. Soc. Civ. Eng. 1:5-41.

Jia, L. and L. An (2004). Studies of desalting ability and desalting structure in *Karelinia caspica*. Acta Botanica Boreali-Occidentalia Sinica. L. Jia. 24: 510. The desalting ability and structures of Karelinia caspica were studied by electron microscopy and experimentation. *Karelinia caspica* can reduce soil salt content by 52-56% in the first year after planting and by about 80% after two years. In the surface layer of soil (0-40 cm), the soil salt content can be reduced under 1% and the soil made agriculturally viable. In the anatomic structure of *Karelinia caspica*, there are many salt glands, salt accumulating cells in the epidermis, and the ability for active ion transport across membranes. It is concluded that Karelinia caspica is an outstanding plant to improve the inland saline environment.

Jian, S., Z. Yang, et al. (2003). The effects of nutrition polybag on the growth, N-fixation and heavy metal accumulation of *Sesbania rostrata* grown on Pb/Zn tailings. Journal of Tropical and Subtropical Botany. S. Jian. 11: 34. This study investigated the growth, nitrogen fixation and heavy metal accumulation of *Sesbania rostrata* transplanted on acidified Pb/Zn tailings in Lechang, Guangdong Province, China. Experiments were carried out by transplanting seedlings prepared with nutrition polybags of 9.5 cm in diameter and 10 cm height containing 1 kg soil (A), of 7.5 cm in diameter and 8 cm height containing 0.5 kg soil (B) and without polybag (C). The results showed that *S. rostrata* succeeded to establish, grow and fix N on the tailings of pH 5-7, but failed to grow at pH < 3. After transplanting on tailings for 84 days, the plant height (140-144 cm), basal diameter of stem (1.59-1.68 cm), individual biomass (36.6-38.8 g DW), dry matter production (5124-5432 kg hm-2) and nitrogen accumulation (77-107 kg hm-2) in treatments A and B were significantly higher than those in treatment C which were 117 cm, 1.35 cm, 20.2 g, 2828 kg hm-2, and 40 kg hm-2, respectively. The contents of Pb, Zn, Cu and Cd were highest in the roots followed by stems and leaves, and the amounts of these four heavy metals in whole plant were in the order Zn (186-221 mg kg-1) > Pb (96-145 mg kg-1) > Cu (17-30 mg kg-1) > Cd (3-4 mg kg-1). Transplanted seedlings with nutrition polybag could improve the growth and nitrogen fixation, and significantly decreased heavy metals accumulation in *S. rostrata*. It is suggested that *S. rostrata* is a good pioneer species for bioremediation of the tailings.

Jian, S., Z. Yang, et al. (2004). Establishment and growth of *Lolium multiflorum* for phyto-remediation of Pb/Zn tailings. Yingyong Shengtai Xuebao 15(2): 255-260. Following the cropping of *Sesbania rostrata*, *Lolium multiflorum* was cropped as the subsequent species on an acidified Pb/Zn tailings site. As the experimental treatments, S. *rostrata* issues harvested on the site were removed from the site or buried into the tailings as the green manure. Changes of tailings chemical and physical properties, germination, growth and heavy metal accumulation of *Lolium multiflorum* were investigated. The results showed that cropping of *S. rostrata* improved the chemical and physical properties of the tailings, especially for the contents of organic matter, total nitrogen, available phosphorus and available potassium. The strong acidity (pH3) in the Pb/Zn tailings was the main factor that limited the establishment of *L. multiflorum*. The tailings acidity was decreased temporarily by lime application and it seemed to be helpful only for the germination because the strong acidity was restituted in the end of the experiment. In the most cases, L. *multiflorum* succeeded to germinate, grow and establish on the Pb/Zn tailings, and yielded relatively great biomass (DM 1.4 apprx 3.2 tcntdot km-2). Compared to CK (without *S. rostrata* cropping), cropping *S. rostrata* increased the biomass of subsequent L. *multiflorum* by 4.8 % apprx 39.5 % in case without *S.*

rostrata green manure using and by 7.7 % apprx 139.5 % in case with the green manure using, and the green manure application resulted in 2.7 % apprx 75.8 % increment of *L. multiflorum* biomass. The results proved that the artificial vegetation process using S. *rostrata* and subsequent *L*. *multiflorum* would be a successful pioneer stage for restoration of the Pb/Zn tailings.

Jiang, L. and E. Yang Xiao (2004). Chelators effect on soil Cu extractability and uptake by *Elsholtzia spledens*. Journal of Zhejiang University (Science) 5: 450. Phytoremediation is emerging as a potential cost-effective solution for remediation of contaminated soils, and bioavailability of metal in the soil for plant uptake is an important factor for successful phytoremediation. This study aimed at investigating the ability of EDTA and citric acid for enhancing soil bioavailability of Cu and phytoremediation by *Elsholtzia spledens* in 2 types of soils contaminated with heavy metals (i.e. mined soil from copper mining area (MS), and paddy soil (PS) polluted by copper refining). Results showed that addition of 2.5 mmol/kg EDTA significantly increased the H2O extractable Cu concentration from 1.20 to 15.78 mg/kg in MS and from 0.26 to 15.72 mg/kg in PS, and that shoot Cu concentration increased 4-fold and 8-fold as compared to the control. There was no significant difference between the treatment with 5.0 mmol/kg EDTA and that with 2.5 mmol/kg EDTA, probably because that 2.5 mmol/kg EDTA was enough for elevating Cu bioavailability to the maximum level. As compared with the control, citric acid had no marked effect on both soil extractable Cu and shoot Cu concentration or accumulation. The results indicated that EDTA addition can increase the potential and efficiency of Cu phytoextraction by *E. spledens* in polluted soils.

Jiang, L. Y., X. E. Yang, et al. (2003). Uptake, distribution and accumulation of copper in two ecotypes of *Elsholtzia*. Pedosphere 13(4): 359-366. Two ecotypes of *Elsholtzia, Elsholtzia spledens* and *E*. *argyi*, are dominant plants growing on Cu and Pb-Zn smelters, respectively. Samples of the two ecotypes and the corresponding soils from fields of a copper mining area and a Pb-Zn mining area of Zhejiang Province, China, were analyzed to investigate Cu or Zn tolerance of these two ecotypes. Effects of nine Cu levels (0, 5, 10, 20, 40, 80, 160, 240 and 320 mg Cu L-1 as CuSO4.5H(2)O) on: growth and uptake, translocation and accumulation of Cu in these two ecotypes were examined in a solution culture experiment. The experimental results showed that dry weights (DW) of shoots and roots were depressed, and growth of *E*. *spledens* was less depressed than that of *E*. *argyi* when treated with greater than or equal to 5 mg Cu L-1. Concentrations of Cu in shoots of *E*. *spledens* and *E*. *argyi* exceeded 1000 mg kg(-1) DW at greater than or equal to 40 mg Cu L-1. The maximum Cu accumulated in the shoots of Cu-treated *E*. *spledens* and *E*. *argyi* reached 101 and 142 mug plant(-1). Furthermore, analysis of plant samples from the fields showed that these two ecotypes can tolerant excess heavy metals and produced high dry matter, and *E*. *spledens* can accumulate 11.7 mg Cu plant(-1) grown on the Cu smelter. Therefore, *E*. *spledens* and *E*. *argyi* could be good plants for phytoremediation.

Jiang, L. Y., X. E. Yang, et al. (2004). Copper uptake and tolerance in two contrasting ecotypes of *Elsholtzia argyi*. Journal of Plant Nutrition 27(12): 2067-2083. Information is desired on plant species that have a great potential in phytoremediation of copper (Cu) contaminated soils. Two contrasting ecotypes of *Elsholtzia argyi* were comparatively studied using nutrient solution culture for their growth response and uptake, distribution, and translocation of Cu. The results show that the ecotype from an old mined area (Sanmen-ecotype) had greater tolerance to Cu than that from the nonmined area (Jiuxi-ecotype) based on dry matter yield at different Cu supply levels. Inhibited root and leaf growth was noted at the external Cu levels > 50 mumol L-1 for the Sanmen-ecotype, and at the Cu supply levels > 5 mumol L-1 for the Jiuxi-ecotype. Stem growth was most sensitive to Cu toxicity in *E*. *argyi*, and was inhibited at the Cu levels greater than or equal to 2.5 mumol L-1 for Jiuxi-ecotype and greater than or equal to 25 mumol L-1 for Sanmen-ecotype. Root Cu concentrations were higher in Sanmen-ecotype than in Jiuxi-ecotype, but leaf, especially stem Cu concentrations were much lower in the former than in the latter. Furthermore, Jiuxi-ecotype was much more efficient than Sanmen-ecotype in the translocation of Cu from root to the shoot, and it had higher ratios of stem/root and leaf/root Cu concentration. At the Cu supply levels higher than 10 mumol L-1, root concentrations of potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), and zinc (Zn) considerably decreased in Jiuxi-ecotype, but were not affected or even increased in Sanmen-ecotype. Zinc concentrations in the stems, particularly in the leaves of Sanmen-ecotype increased by 3 folds, but were hardly changed in Juixi-ecotype when grown at the Cu levels higher than 10 mumol L-1. These results indicate that the Sanmen-ecotype of *E*. *argyi* is a Cu-tolerant ecotype, and its tolerance to

high Cu levels was mainly related to its extraordinary capability to restrict Cu uptake, especially Cu translocation from root to the shoot, probably by competitive uptake and translocation of Zn.

Jiang, L. Y., X. E. Yang, et al. (2004). Growth response and phytoextraction of copper at different levels in soils by *Elsholtzia spledens*. Chemosphere 55(9): 1179-1187. Phytoremediation is a promising approach for cleaning up soils contaminated with heavy metals. Information is needed to understand growth response and uptake mechanisms of heavy metals by some plant species with exceptional capability in absorbing and superaccumulating metals from soils. Greenhouse study, field trial, and old mined area survey were conducted to evaluate growth response and Cu phytoextraction of *Elsholtzia spledens* in contaminated soils, which has been recently identified to be tolerant to high Cu concentration and have great potential in remediating contaminated soils. The results from this study indicate that the plant exhibited high tolerance to Cu toxicity in the soils, and normal growth was attained up to 80 mg kg(-1) available soil Cu (the NH4OAc extractable Cu) or 1000 mg kg(-1) total Cu. Under the field conditions, a biomass yield of 9 ton ha(-1) was recorded at the soil available Cu level of 77 mg kg(-1), as estimated by the NH4OAc extraction method. Concentration-dependent uptake of Cu by the plant occurred mainly at the early growth stage, and at the late stage, there is no difference in shoot Cu concentrations grown at different extractable soil Cu levels. The extractability of Cu from the highly polluted soil is much greater by the roots than that by the shoots. The NH4OAc extractable Cu level in the polluted soil was reduced from 78 to 55 mg kg(-1) in the soil after phytoextraction and removal of Cu by the plant species for one growth season. The depletion of extractable Cu level in the rhizosphere was noted grown in the mined area, even at high Cu levels, the NH4OAc extractable Cu in the rhizosphere was 30% lower than that in the bulk soil. These results indicate that phytoextraction of E *spledens* can effectively reduce the plant-available Cu level in the polluted soils. (C) 2004

Jiang, X. J., Y. M. Luo, et al. (2004). Effects of cadmium on nutrient uptake and translocation by Indian Mustard. Environmental Geochemistry and Health 26(2): 319-324. Plants that hyperaccumulate metals are ideal subjects for studying the mechanisms of metal and mineral nutrient uptake in the plant kingdom. Indian Mustard (*Brassica juncea*) has been shown to accumulate moderate levels of Cd, Pb, Cr, Ni, Zn, and Cu. In this experiment, 10 levels of Cd concentration treatments were imposed by adding 10 - 190 mg Cd kg(-1) to the soils as cadmium nitrate [Cd(NO3)(2)]. The effect of Cd on phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and the micronutrients iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) in *B. juncea* was studied. Plant growth was affected negatively by Cd, root biomass decreased significantly at 170 mg Cd kg(-1) dry weight soils treatment. Cadmium accumulation both in shoots and roots increased with increasing soil Cd treatments. The highest concentration of Cd was up to 300 mg kg(-1) d. w. in the roots and 160 mg kg(-1) d. w. in the shoots. The nutrients mainly affected by Cd were P, K, Ca, Fe, and Zn in the roots, and P, K, Ca, and Cu in the shoots. K and P concentrations in roots increased significantly when Cd was added at 170 mg kg(-1), and this was almost the same level at which root growth was inhibited. Zn concentrations in roots decreased significantly when added Cd concentration was increased from 50 to 110 mg kg(-1), then remained constant with Cd treatments from 110 to 190 mg kg(-1). However, Zn concentrations in the shoots seemed less affected by Cd. It is possible that Zn uptake was affected by the Cd but not the translocation of Zn within the plant. Ca and Mg accumulation in roots and shoots showed similar trends. This result indicates that Ca and Mg uptake is a non-specific process.

Jiang, X., Y. Luo, et al. (2003). The role of EDTA in Cd absorption and translocation by Indian Mustard. Acta Pedologica Sinica. 40: 205. There are two theories for cation-EDTA uptake: (i) metal-EDTA complex formed in the soil could increase metal solubility, and promote diffusion, and, hence, elevate potential uptake; and (ii) complexation of metals with EDTA reduced the activities of free ions in the soil solution, and, therefore, decreased uptake. Pot experiment was conducted to study the role of EDTA in cadmium absorption by Indian mustard (*Brassica juncea*). H2O and NH4NO3 extractable Cd significantly increased in soils receiving EDTA treatment. Cadmium accumulation in the roots of *B. juncea* significantly decreased after EDTA application. However, Cd in shoots significantly increased when Cd added was more than 130 mg kg-1 in soils, and Cd toxicity was observed. The results suggested that Cd concentration increased in soil solution after addition of EDTA, which resulted in increasing absorption and translocation when plant was affected with toxicity.

Jiang, Y., B. Feng, et al. (2005). Improving heavy metal tolerance of yeast by transferring a phytochelatin synthase gene from garlic. Acta Phytoecologica Sinica. Y. Jiang. 29: 659. Remediation of soils contaminated by heavy metals is one of the most pressing environmental problems facing the biosphere. Phytoremediation is a new biotechnique to clean environmental pollutants by plants, including heavy metals. In the long term, major improvements in phytoremediation will rely on the isolation and application of the genes from various plant, bacteria, and animal sources that can enhance metal accumulation. Phytochelatin is a type of polypeptide that combines heavy metals in plants, and its synthesis is regulated by phytochelatin synthesase (PC synthase). In this study, we determined that the roots of garlic (*Allium sativum*) can accumulate up to 3 000 mg.kg-1 cadmium. A yeast-expressed plasmid with PC synthesase from garlic (AsPCS) was constructed and transferred into heavy metal sensitive yeast mutant cells. The results showed that the expression of AsPCS was improved by 4 folds in yeast cells with cadmium tolerance and a 2 folds increase was observed in arsenate tolerant cells as compared to the control cells. Further study about the growth patterns of AsPCS-expressed yeast indicated that the expression of AsPCS was critical for yeast heavy metal tolerance. As an important role in the garlic's response to heavy metal, AsPCS can work as a significant gene tool in the phytoremediation of heavy metal pollution.

Jiang, Y.-N., B.-M. Feng, et al. (2005). Improving heavy metal tolerance of yeast by transferring a phytochelatin synthase gene from garlic. Zhiwu Shengtai Xuebao 29(4): 659-664. Remediation of soils contaminated by heavy metals is one of the most pressing environmental problems facing the biosphere. Phytoremediation is a new biotechnique to clean environmental pollutants by plants, including heavy metals. In the long term, major Improvements in phytoremediation will rely on the isolation and application of the genes from various plant, bacteria, and animal sources that can enhance metal accumulation. Phytochelatin is a type of polypeptide that combines heavy metals in plants, and its synthesis is regulated by phytochelatin synthesase (PC synthase). In this study, we determined that the roots of garlic (*Allium sativum*) can accumulate up to 3 000 mg . kg(-1) cadmium. A yeast-expressed plasmid with PC synthesase from garlic (AsPCS) was constructed and transferred into heavy metal sensitive yeast mutant cells. The results showed that the expression of AsPCS was improved by 4 folds in yeast cells with cadmium tolerance and a 2 folds increase was observed in arsenate tolerant cells as compared to the control cells. Further study about the growth patterns of AsPCS-expressed yeast indicated that the expression of AsPCS was critical for yeast heavy metal tolerance. As an important role in the garlic's response to heavy metal, AsPCS can work as a significant gene toot in the phytoremediation of heavy metal pollution.

Jin, G., T. Kelley, M. Freeman and M. Callahan. (2002). Removal of N, P, Bod5, and Coliform in Pilot-Scale Constructed Wetland Systems. International Journal of Phytoremediation 4(2).

Johansson, L., C. Xydas, et al. (2005). Growth and Cu accumulation by plants grown on Cu containing mine tailings in Cyprus. Applied Geochemistry 20(1): 101-107. The Skouriotissa Cu mine in the northern part of Cyprus has produced large amounts of mine waste. Phytoremediation could stabilise the erosion or extract the metals of this waste. The aim of this study was to find out if *Pistacia terebinthus, Cistus creticus, Pinus brutia* and/or *Bosea cypria* could grow and tolerate or maybe accumulate Cu from the mine waste containing up to 787 mg Cu (kg DW)(-1). Another aim was to see if the liquid wine waste product Vinassa. containing organic acids and having a low pH, or chicken fertilizer could improve plant growth and/or Cu accumulation. The four species were planted at the mine waste site untreated or with the addition of Vinassa or chicken fertilizer as mine waste modifiers. After 3 months, shoot length growth was measured and the plants were analysed for Cu concentration. The pH and Cu concentration of the mine waste mixture in the different treatments was also measured. To find out if plants accumulated Cu to the highest extent in roots or shoot. a greenhouse study was under-taken where the plant species were cultivated for 3 weeks in Cu spiked soil. The results showed that all of the tested species survived and grew on the mine waste site, which indicates that they tolerate the high level of Cu at the mine waste site. The leaves of *C. creticus* had the highest Cu accumulation of all tested species. Copper accumulation varied with plant species. They seemed to have different distribution strategies for Cu: in *Pistacia terebinthus* and *C. creticus* most of the Cu was found in the roots, while *B. cypria* accumulated, most of the Cu in the leaves. Addition of Vinassa and chicken fertilizer did not increase plant growth or Cu accumulation, but did affect the Cu distribution in B. cypria. (C) 2004 Elsevier Ltd.

John, R., K. Gadgil, et al. (2005). Resistance mechanism of plants against cadmium. Asian Journal of Chemistry 17(3): 1363-1370. Cadmium in soils is known to originate from geogenic (natural) and anthropogenic (industrial) sources. Cadmium in soils is known to be more mobile and readily absorbed and incorporated into plant tissues compared with lead and mercury. Due to inherent genetic and physiological characteristics plants have long been known to accumulate cadmium from soils. Some plants known as hyper-accumulators are able to tolerate high levels of elements in the root and shoot cells. The ability to both tolerate elevated levels of heavy metals and to accumulate them to unusually high concentrations is the result of various biological mechanisms which plants have developed during evolution. Phytoremediation is the use of specially selected and engineered metal accumulating plants for environmental clean-up.

Johnson, B. T., J. D. Petty, et al. (2004). Hazard assessment of a simulated oil spill on intertidal areas of the St. Lawrence River with SPMD-TOX. Environmental Toxicology. 19: 329. Phytoremediation in a simulated crude oil spill was studied with a minimalistic approach. The SPMD-TOX paradigm -- a miniature passive sorptive device to collect and concentrate chemicals and microscale tests to detect toxicity -- was used to monitor over time the bioavailability and potential toxicity of an oil spill. A simulated crude oil spill was initiated on an intertidal freshwater grass-wetland along the St. Lawrence River southwest of Quebec City, Quebec, Canada. Several phytoremediation treatments were investigated; to dissipate and ameliorate the spill, treatments included nutrient amendments with inorganic nitrogen sources (ammonium nitrate and sodium nitrate) and phosphate (super triple phosphate) with and without cut plants, with natural attenuation (no phytoremedial treatment) as a control. Sequestered oil residues were bioavailable in all oil-treated plots in Weeks 1 and 2. Interestingly, the samples were colored and fluoresced under ultraviolet light. In addition, microscale tests showed that sequestered residues were acutely toxic and genotoxic, as well as that they induced hepatic P450 enzymes. Analysis of these data suggested that polycyclic aromatic hydrocarbons were among the bioavailable residues sequestered. In addition, these findings suggested that the toxic bioavailable fractions of the oil spill and degradation products dissipated rapidly over time because after the second week the water column contained no oil or detectable degradation products in this riverine intertidal wetland. SPMD-TOX revealed no evidence of bioavailable oil products in Weeks 4, 6, 8, and 12. All phytoremediation efforts appeared to be ineffective in changing either the dissipation rate or the ability to ameliorate the oil toxicity. SPMD-TOX analysis of the water columns from these riverine experimental plots profiled the occurrence, dissipation, and influence of phytoremediation on the bioavailability and toxicity of oil products (parent or degradation products).

Johnson, D. L. and S. P. McGrath (2003). Soil microbial response during the phytoremediation of PAH contaminated soil. The BCPC International Congress: Crop Science and Technology, Volumes 1 and 2. Proceedings of an international congress held at the SECC, Glasgow, Scotland, UK, 10-12 November 2003. Alton, British Crop Protection Council: 393. Enhanced bioremediation in planted soils is possibly a function of increased microbial activity in the rhizosphere, but few studies have monitored rhizosphere microbiology during rhizoremediation. This study was conducted to quantify and compare the responses of soil microbial populations during the phytoremediation of polycyclic aromatic hydrocarbons (PAHs) in a laboratory trial. All soils were contained in 1-kg pots and planted treatments consisted of a mixed ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) sward together with a rhizobial inoculum (*Rhizobium leguminosarum* bv. *trifolii*). Throughout the 180-day experimental period soil microbial biomass, rhizobial populations and populations of PAH degraders were monitored. Results showed the losses of PAHs in a planted soil and the responses of the associated soil microbial populations. In sterile soil, planted treatments showed slightly higher extractable concentrations of chrysene throughout the 180-day experimental period than the comparative unplanted treatments. Soil pH did not change significantly over the 180-day experimental period with a range of 6.5-7.5 in all treatments. At the end of the experimental period, a significantly greater biomass was observed in the inoculated planted treatments than in the unplanted treatments. Populations of microorganisms capable of degrading chrysene were greater in the planted treatments relative to the unplanted treatments.

Johnson, D. L., D. R. Anderson, et al. (2005). Soil microbial response during the phytoremediation of a PAH contaminated soil. Soil Biology & Biochemistry. D. L. Johnson. 37: 2334. The aim of this trial was to

quantify and compare the responses of soil microbial communities during the phytoremediation of polycyclic aromatic hydrocarbons (PAHs) in a laboratory trial. The experiment was conducted in 1-kg pots and planted treatments consisted of a mixed ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) sward together with a rhizobial inoculum (*Rhizobium leguminosarum* bv. *trifolii*). Throughout the 180-d experiment soil microbial biomass and communities of PAH degraders were monitored. PAH degradation was enhanced in planted treatments that received a rhizobial inoculum. Microbial biomass was enhanced in planted treatments, but there were no significant differences between treatments that had received a rhizobial inoculum and those that had not. However, numbers of PAH degraders were greater in the treatment that had received a rhizobial inoculum.

Johnson, D. L., K. L. Maguire, et al. (2004). Enhanced dissipation of chrysene in planted soil: the impact of a rhizobial inoculum. Soil Biology & Biochemistry 36(1): 33-38. Results from an innovative approach to improve remediation in the rhizosphere by encouraging healthy plant growth and thus enhancing microbial activity are reported. Mixed grass-legume systems, together with microbial inoculants, were used to remediate a polycyclic aromatic hydrocarbon (chrysene) spiked agricultural soil. Inoculants were symbiotic rhizobia, which may play an important role in rhizoremediation by increasing plant and root growth. An inoculum of an isolate of *Rhizobium leguminosarum* bv. *trifolii*, selected for PAH tolerance, was produced using a peat carrier. The inoculum and white clover (*Trifolium repens* L.), were planted into soils with ryegrass (*Lolium perenne* L.). The soils spiked with chrysene (500 mg kg(-1)) then aged for 4 weeks. Shoot- and root-biomass of plants, and the amount of root nodulation, were determined. Rhizobial populations, soil pH and soil nitrogen were also monitored throughout the trial. In addition, the ability of the inoculated rhizobial strain to utilise chrysene as a sole carbon source was assessed. Direct uptake and/or degradation of chrysene by the clover and ryegrass did not occur to a significant degree. Enhanced losses of chrysene were seen in planted, non-sterile soils that contained a rhizobial inoculum. No direct degradation of chrysene by R. leguminosarum bv. trifolii was observed and no enhanced losses of PAHs were detected in sterile soils after inoculation with rhizobia. Results suggest that the enhanced dissipation of chrysene, observed in the non-sterile planted inoculated pots, was not a result of degradation of chrysene by R. leguminosarum bv. trifolii. The symbiotic association with R. leguminosarum bv. trifolii improved plant vigour and growth in inoculated planted treatments. This may have stimulated the rhizospheric microflora to degrade chrysene. (C) 2003 Elsevier Ltd.

Johri, B. N. (2006). Endophytes to the rescue of plants! Current Science. B. N. Johri. 90: 1315. This commentary briefly discusses the ecology, diversity, and significance (e.g., as biological control agent and for phytoremediation) of endophytes. Several new developments in the field of fungal endophytes, particularly woody plants are briefly discussed. Endophytic habitat appears to provide a protective environment that helps a potentially exploitable bacterium with reduced competition from the indigenous microbial populations.

Jonak, C., H. Nakagami, et al. (2004). Heavy metal stress. Activation of distinct mitogen-activated protein kinase pathways by copper and cadmium. Plant Physiology 136(2): 3276-3283. Excessive amounts of heavy metals adversely affect plant growth and development. Whereas some regions naturally contain high levels of heavy metals, anthropogenic release of heavy metals into the environment continuously increases soil contamination. The presence of elevated levels of heavy metal ions triggers a wide range of cellular responses including changes in gene expression and synthesis of metal-detoxifying peptides. To elucidate signal transduction events leading to the cellular response to heavy metal stress we analyzed protein phosphorylation induced by elevated levels of copper and cadmium ions as examples for heavy metals with different physiochemical properties and functions. Exposure of alfalfa (*Medicago sativa*) seedlings to excess copper or cadmium ions activated four distinct mitogen-activated protein kinases (MAPKs): SIMK, MMK2, MMK3, and SAMK Comparison of the kinetics of MAPK activation revealed that SIMK, MMK2, MMK3, and SAMK are very rapidly activated by copper ions, while cadmium ions induced delayed MAPK activation. In protoplasts, the MAPK kinase SIMKK specifically mediated activation of SIMK and SAMK but not of MMK2 and MMK3. Moreover, SIMKK only conveyed MAPK activation by CuCl2 but not by CdCl2. These results suggest that plants respond to heavy metal stress by induction of several distinct MAPK pathways and that excess amounts of copper and cadmium ions induce different cellular signaling mechanisms in roots.

Joner, E. J. and C. Leyval (2003). Phytoremediation of organic pollutants using mycorrhizal plants: A new aspect of rhizosphere interactions. Agronomie (Paris) 23(5-6): 495-502. Phytoremediation as a means of cleaning up polluted soils has gained popularity during the last decade due to its convenience and low costs of installation and maintenance. When the target pollutant is biodegradable, this technology exploits the stimulating effect that roots have on microbial processes and physical/chemical modifications in the rhizosphere. Among the microorganisms that affect rhizosphere processes, symbiotic fungi forming mycorrhizas induce a series of changes in plant physiology, nutrient availability and microbial composition that may determine the outcome of a phytoremediation attempt. Beyond the rhizosphere, mycorrhizal hyphae act as the roots of the roots, and may thus extend the rhizosphere into the bulk soil by creating a new interface of soil-plant interactions: the hyphosphere. We here discuss some of the recent results on phytoremediation of organic pollutants with emphasis on processes in the mycorrhizosphere, and highlight future research priorities.

Joner, E. J. and C. Leyval (2003). Rhizosphere gradients of polycyclic aromatic hydrocarbon (PAH) dissipation in two industrial soils and the impact of arbuscular mycorrhiza. Environmental Science & Technology 37(11): 2371-2375. Phytoremediation of organic pollutants depends on plant-microbe interactions in the rhizosphere, but the extent and intensity of such rhizosphere effects are likely to decrease with increasing distance from the root surface. We conducted a time-course pot experiment to measure dissipation of polycyclic aromatic hydrocarbons (PAHs) in the rhizosphere of clover and ryegrass grown together on two industrially polluted soils (containing 0.4 and 2 g kg(-1) of 12 PAHs). The impact of the fungal root symbiosis arbuscular mycorrhiza (AM) on PAH degradation was also assessed, as these fungi have previously improved plant establishment on PAH-polluted soils and enhanced PAH degradation in spiked soil. The two soils behaved differently with respect to the time-course of PAH dissipation. The less polluted and more highly organic soil showed low initial PAH dissipation rates, with small positive effects of plants after 13 weeks. At the final harvest (26 weeks), the amounts of PAHs extracted from nonplanted pots were higher than the initial concentrations. In parallel planted pots, PAH concentrations decreased as a function of proximity to roots. The most polluted soil showed higher initial PAH dissipation (25% during 13 weeks), but at the final harvest PAH concentrations had increased to values between the initial concentration and those at 13 weeks. An effect of root proximity was observed for the last harvest only. The presence of mycorrhiza generally enhanced plant growth and favored growth of clover at the expense of ryegrass. Mycorrhiza enhanced PAH dissipation when plant effects were observed.

Joner, E. J. J., A. (2001). Rhizosphere Effects on Microbial Community Structure and Dissipation and Toxicity of Polycyclic Aromatic Hydrocarbons (PAHs) in Spiked Soil. Envrion. Sci & Technol. 35(13): 2773-2777.

Joner, E. J., C. Leyval, et al. (2006). Ectomycorrhizas impede phytoremediation of polycyclic aromatic hydrocarbons (PAHs) both within and beyond the rhizosphere. Environmental Pollution. 142: 34. Exploitation of mycorrhizas to enhance phytoremediation of organic pollutants has received attention recently due to their positive effects on establishment of plants in polluted soils. Some evidence exist that ectomycorrhizas enhance the degradation of pollutants of low recalcitrance, while less easily degradable polyaromatic molecules have been degraded only by some of these fungi in vitro. Natural polyaromatic (humic) substances are degraded more slowly in soil where ectomycorrhizal fungi are present, thus phytoremediation of recalcitrant pollutants may not benefit from the presence of these fungi. Using a soil spiked with three polycyclic aromatic hydrocarbons (PAHs) and an industrially polluted soil (1 g kg-1 of SIGMA12 PAHs), we show that the ectomycorrhizal fungus *Suillus bovinus*, forming hydrophobic mycelium in soil that would easily enter into contact with hydrophobic pollutants, impedes rather than promotes PAH degradation. This result is likely to be a nutrient depletion effect caused by fungal scavenging of mineral nutrients.

Joner, E. J., D. Hirmann, et al. (2004). Priming effects on PAH degradation and ecotoxicity during a phytoremediation experiment. Environmental Pollution. 128: 429. An experiment was conducted to distinguish priming effects from the effects of phytoremediation of a creosote-polluted soil. The concentration of 13 polycyclic aromatic hydrocarbons (PAHs), and their combined soil toxicity (using four

bioassays), was determined on recently excavated, homogenized soil and on such soil subjected to a time-course phytoremediation experiment with lucerne. The results showed a high priming effect, with minor positive and synergistic effects of planting and fertilization on PAH degradation rates. At the end of the experiment, PAH degradation reached 86% of the initial 519 mg PAHs kg-1. Two of the four toxicity tests (bioluminescence inhibition and ostracod growth inhibition) corroborated the chemical data for residual PAHs, and indicated a significant reduction in soil toxicity. We conclude that priming effects can easily surpass treatment effects, and that an unintentional pre-incubation that ignores these effects can jeopardize the full quantitative assessment of in situ bioremediation of contaminated soil.

Jones, D. L., K. L. Williamson, et al. (2006). Phytoremediation of landfill leachate. Waste Management 26(8): 825-837. Leachate emissions from landfill sites are of concern. primarily due to their toxic impact when released unchecked into the environment, and the potential for landfill sites to generate leachate for many hundreds of years following closure. Consequently. economically and environmentally sustainable disposal options are a priority in waste management. One potential option is the use of soil-plant based remediation schemes. In many cases, using either trees (including short rotation coppice) or grassland. phytoremediation of leachate has been Successful. However, there are a significant number of examples where phytoremediation has failed. Typically, this failure can be ascribed to excessive leachate application and poor management due to a fundamental lack of understanding of the plant-soil system. On balance, with careful management. phytoremediation can be viewed as a sustainable. cost effective and environmentally sound option which is capable of treating 250 m(3) ha(-1) yr(-1). However. these schemes have a requirement for large land areas and must be capable of responding to changes in leachate quality and quantity, problems of scheme establishment and maintenance. continual environmental monitoring and seasonal patterns of plant growth. Although the fundamental underpinning science is well understood, further work is required to create long-term predictive remediation models, full environmental impact assessments. a complete life-cycle analysis and economic analyses for a wide range of landfill scenarios.

Jones, R. K., W. H. H. Sun, et al. (2004). Phytoremediation of petroleum hydrocarbons in tropical coastal soils - II. Microbial response to plant roots and contaminant. Environmental Science and Pollution Research 11(5): 340-346. The goal of this study was to understand the interaction between plants and microorganisms during petroleum-hydrocarbon bioremediation in Pacific Islands coastal soils. Total bacteria and hydrocarbon-degrading microorganisms population dynamics were examined in the rhizospheres of tropical trees and shrubs, which were evaluated for their phytoremediation potential in a greenhouse experiment. The respective and combined effects of plant roots and diesel contaminant on the microbial populations were determined in relation to diesel fuel depletion. An increase in the size of the hydrocarbon-degrading populations of microbes, elicited by rhizodeposition, is generally regarded as conducive to an enhanced degradation of petroleum hydrocarbon pollutants in vegetated soil. Methods. The soil was a coastal sandy loam (pH 7.8) which was artificially contaminated with 10 g of No. 2 diesel fuel/kg soil or left uncontaminated. The pots were irrigated with fertilizer and 1% NaCl. The enumerations were carried out in the contaminated and uncontaminated rhizospheres of three trees, kiawe (*Prosopis pallida*), milo (*Thespesia populnea*), and kou (*Cordia subcordata*) and three shrubs, beach naupaka (*Scaevola sericea*), false sandalwood (*Myoporum sandwicense*), and *oleander* (*Nerium oleander*). Unplanted control soils were included in the experiment. Total bacteria and phenanthrene-degrading bacteria were enumerated on plates. Diesel- and pristane-degrading microorganisms were enumerated by the most-probable-number technique in tissue-culture plates. All four types of microorganisms responded to the rhizosphere of the 6 plants in uncontaminated soil and to the diesel contaminant in implanted soil. In contaminated rhizospheres, no effect of the plant on the hydrocarbon-degrader numbers was visible. Total bacteria responded more to the plant roots than to the contaminant. The phenanthrene-degrading bacteria and pristane-degrading microorganisms were more influenced by the contaminant than by the plants. The diesel-degrading microorganisms were equally stimulated by the plants and the contaminant. The numbers of hydrocarbon degraders were similar in the contaminated rhizospheres of the three effective plants (kiawe, kou, and milo) and in those of the three ineffective shrubs. The results suggest the quality of the rhizodeposition is plant-dependent and governs the type of diesel-degrader populations that will be enhanced by a given plant. In the proposed phytoremediation-benefit model plant roots maintain high levels of hydrocarbon degraders in uncontaminated soil. When the root enters a contaminated zone of

soil, those hydrocarbon degraders that prefer the contaminant would switch to the contaminant as a carbon source, effectively removing the hydrocarbons. If the root exudates and the contaminant are equally attractive to the hydrocarbon degraders, the contaminant degradation would be less effective.

Jonnalagadda, S.B., and G. Nenzou. (1997). Studies on arsenic rich mine dumps. II. The heavy element uptake by vegetation. J. Environ. Sci. Health, Part A. A32:455-464.

Jordahl, J. L., M. F. Madison, et al. (2003). Waste management using trees: wastewater, leachate, and groundwater irrigation. Phytoremediation: transformation and control of contaminants. J. L. Jordahl. Hoboken, Wiley-Interscience: 717. Phytoirrigation provides a relatively inexpensive means of moving impaired water to a planted area or forest for treatment, greatly expanding the ways in which phytoremediation can be used. Irrigation systems can be used to apply water at the land surface or below to meet the requirements of treatment and for regulatory and public acceptance. Irrigation-system designs based on trees are particularly advantageous because of the high water use, deep rooting, and low operations and maintenance costs of tree systems. This chapter introduces the rationale for using trees (viz., *Populus* spp., *Salix* spp., *Eucalyptus* spp., *Tamarix* spp., *Acer rubrum*, *Pinus radiata*, *Morus rubra*, *Thespesia populnea* and *Prosopis pallida*) with irrigation to manage contaminated water. It also identifies key limitations and describes example projects such as municipal waste water reuse at Woodburn, Oregon (USA), Swedish biomass production using waste water and spray irrigation of New Zealand pine trees (*P. radiata*). Finally, the general design components including project planning, characterization of waste stream quality, site suitability for trees, irrigation design, as well as the maintenance and management of key risk factors, are discussed.

Jordahl, J.L., L. Foster, J.L. Schnoor, P.J.J. Alvarez. (1987). Effect of hybrid poplar trees on microbial populations important to hazardous waste bioremediation. Environ. Toxicol. Chem. 16(6):1318-1321.

Jordahl, J.L., L.A. Licht, and J.L. Schnoor. (1995). Poster Abstract: Riparian poplar tree buffer impact on agricultural non-point source pollution. p. 238. In L.E. Erickson, D.L. Tillison, S.C. Grant, and J.P. McDonald (eds.), Proceedings of the 10th Annual Conference on Hazardous Waste Research, May 23-24, 1995, Manhattan, KS.

Jordan, F. L., M. Robin-Abbott, et al. (2002). A comparison of chelator-facilitated metal uptake by a halophyte and a glycophyte. Environmental Toxicology and Chemistry 21(12): 2698-2704. Phytoextraction is the use of plants to remove contaminants, in particular metals, from soil via root uptake and translocation to the shoots. Efficient phytoextraction requires high-biomass plants with efficient translocating properties. Halophytes characteristically accumulate large quantities of salts in aboveground tissue material and can have high biomass production. It has been speculated that salt-tolerant plants may also be heavy metal tolerant and, further, may be able to accumulate metals. This study compared growth and metal uptake by a halophyte, *Atriplex nummularia*, and a common glycophyte, *Zea mays*, in a mine-tailing contaminated soil:mulch mixture. Two chelators, ethylenediaminetetraacetic acid (EDTA) and rhamnolipid, were used to facilitate plant metal uptake. Despite a lower growth rate (2% growth/d) in the contaminated soil, the halophyte accumulated roughly the same amount of metals as the glycophyte on a mass basis (30-40 mg/kg dry wt). Neither plant, however, hyperaccumulated any of the metals tested. When treated with EDTA, specific differences in patterns of metal uptake between the two plants emerged. The halophyte accumulated significantly more Cu (2X) and Pb (1X) in the shoots than the glycophyte, but root metal concentrations were generally higher for the glycophyte, indicating that the halophyte translocated more metal from the root to the shoot than the glycophyte. For example, Zn shoot-to-root ratios ranged from 1.4 to 2.1 for *Atriplex* and from 0.5 to 0.6 for *Z. mays*. The biodegradable chelator rhamnolipid was not effective at enhancing shoot metal concentrations, even though radiolabeled chelator was found in the shoot material of both plants. Our results suggest that halophytes, despite their slower growth rates, may have greater potential to selectively phytoextract metals from contaminated soils than glycophytes.

Jordan, T.E. (1993). Nutrient interception by a riparian forest receiving inputs from adjacent cropland. J. Environ. Qual. 22:467-473.

Jorgensen, S.E., and B. Halling-Sorenson. (1995). Abstract: Removal of heavy metals from compost and soils by ecotechnological methods. pp. 37-38. In Proceedings/Abstracts of the Fourteenth Annual Symposium, Current Topics in Plant Biochemistry, Physiology, and Molecular Biology - Will Plants Have a Role in Bioremediation?, April 19-22. Columbia, MO. Interdisciplinary Plant Group, University of Missouri, Columbia, MO.

Jouve, A., E. Schulte, P. Bon, and A.L. Cardot. (1993). Mechanical and physical removing of soil and plants as agricultural mitigation techniques. Sci. Total Environ. 137:65-80.

Jules, E.S., and A.J. Shaw. (1994). Adaptation to metal-contaminated soils in populations of the moss, Ceratodon purpureus: Vegetative growth and reproductive expression. Am. J. Bot. 81(6):791-797.

Jupsin, H., H. Richard, et al. (2005). Contribution of floating macrophytes (*Lemna* sp.) to pond modelization. Water Science and Technology. 51: 283. The objective of the present study was to develop a methodology for the quantification of the growth rate of *Lemna*ceae biomass by digital image analysis. The effect of biomass surface coverage on the oxygen transfer coefficient (Kla) was also quantified. Contribution of *Lemna*ceae to oxygen balance was evaluated by closed respirometry. Monod-like equations could be derived from growth rate coefficients in various experimental conditions. This opens the way to a deterministic model of *Lemna*ceae ponds where uptake of nitrogen and phosphorus (even heavy metals) can be calculated.

Jurkiewicz, A., E. Orlowska, et al. (2004). The influence of mycorrhiza and EDTA application on heavy metal uptake by different maize varieties. Acta Biologica Cracoviensia Series Botanica 46: 7-18. This study investigated whether mycorrhizal colonization influences heavy metal uptake by maize. Two experiments were carried out. In the first, 15 commercially available maize varieties cultured on industrial waste substratum and inoculated or not with *Glomus intraradices*, were treated one week before harvest with EDTA, a chelating agent known to mobilize heavy metals in soil. Estimation of mycorrhizal parameters indicated differences between varieties, but differences between treatments of the same variety generally were not statistically significant. Although EDTA treatment strongly decreased the activity of fungal alkaline phosphatase (indicator of fungal viability), the treatment did not totally eliminate arbuscular mycorrhizal fungi (AMF) from the soil. The appearance of AMF structures within roots was modified in plants cultivated in EDTA-treated soil. Among the heavy metals studied, the highest impact of EDTA treatment on heavy metal uptake in shoots was found in the case of Pb. In most cases, EDTA treatment significantly increased the Pb level in shoots of mycorrhizal plants. Among the samples treated with EDTA, mycorrhizal plants of 6 cultivars showed higher Pb content in shoots than did nonmycorrhizal plants. Significant differences in heavy metal content in plant material were demonstrated between the varieties tested. In the second experiment, one selected cultivar was subjected to high soil Pb concentrations and to EDTA for one week, following cultivation in nonpolluted substratum. In this case, EDTA treatment more strongly influenced Pb uptake by nonmycorrhizal than by mycorrhizal plants. The results indicate the need to carefully screen cultivars as well as microorganism strains to be used in phytoextraction procedures.

Just, C. L. and J. L. Schnoor (2004). Phytophotolysis of Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in leaves of Reed Canary Grass. Environmental Science & Technology 38(1): 290-295. Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) was degraded in reed canary grass leaves exposed to simulated sunlight to primary products nitrous oxide and 4-nitro-2,4-diazabutanal. This is the first time that 4-nitro-2,4-diazabutanal, a potentially toxic degradate, has been measured in plant tissues following phytotransformation of RDX. These compounds, along with nitrite and formaldehyde, were also detected in aqueous RDX systems exposed to the same simulated sunlight. Results showed that the initial products of RDX photodegradation in translucent plant tissues were similar to products formed from aqueous photolysis of RDX. Combustion analysis of leaves following C-14-RDX uptake and subsequent light exposure revealed the presence of tissue-bound material that could not be extracted with acetonitrile. No detectable formaldehyde was emitted from the leaves. The detection of similar RDX degradation products in both aqueous and plant-based systems suggests that RDX may be initially transformed by similar mechanisms in both systems. Direct photolysis of RDX via ultraviolet irradiation passing into the leaves is

hypothesized to be responsible for the observed transformations. In addition, membrane-bound trap chlorophyll in the chloroplasts may shuttle electrons to RDX as an indirect photolysis transformation mechanism. Results from this study indicate that reed canary grass facilitates photochemical degradation of RDX, and this mechanism should be considered along with more established phytoremediation processes when assessing the fate of contaminants in plant tissues. Plant-mediated phototransformation of xenobiotic compounds is a process that may be termed phytophotolysis.