Yamada, K., K. Miyarhara, and T. Kotoyori (1975). Studies on soil pollution caused by heavy metals. Part IV: Soil purification by plants that absorb heavy metals. Gamm Ken Nogyo Shienjo Hokoku. 15: 39-54.

Yamada, T., R. Takeda, et al. (2005). Behavior of heavy metals in the callus of *Brassica juncea*, a heavy metal accumulation plant. Bunseki Kagaku 54(9): 929-933. To find a more efficient phytoremediation, the accumulation mechanism of elucidating heavy metals of a hyperaccumulator is important. We measured the behavior and glutathione quantity of the heavy metal accumulation level in calli using *Brassica juncea*, which is a hyperaccumulator of Pb and Cd. *Brassica juncea* from a seed was used to grow callus, which was for three months. Then, for two weeks, we conducted long-term exposure to a culture in heavy-metal component culture media (Cr, Cu, Zn, Cd, Pb, Co, Ni). Furthermore, we used a liquid culture medium; for Pb, we conducted a short-term exposure for five days. As for Cd and Pb, the absorbed dose was high, and the Cd, in particular, showed the absorbed dose to be high at a low concentration (10 similar to 100 mu M), compared with other heavy metal classes. There were many things that necrotized, in other heavy metals, the fastness was not found to influence the heavy metal. In the short-term exposure of Pb, the absorption level increased during the early phase. However, 96 hours later, according to the cell cycle, that absorption appeared to be promoted. In addition, in GSH, while a large difference was not recognized, a high concentration level was much contained it.

Yamada, T., T. Ishige, et al. (2002). Enhancement of metabolizing herbicides in young tubers of transgenic potato plants with the rat CYP1A1 gene. Theoretical and Applied Genetics 105(4): 515-520. A rat P450 monooxygenase gene (CYP1A1) was introduced into potato plants to enhance the metabolism of the environmental contaminants in subterranean organs. The CYP1A1 gene was kept under the control of the potato patatin promoter to enhance tuber-specific expression. A total of 106 transgenic plants (PAT1A1 plants) were obtained following selection by a resistance test to kanamycin and PCR analysis. PAT1A1 plants treated with 10% exogenous sucrose showed a higher activity of monooxgenase in the leaves than the non-transgenic plants. This indicated that the activity enhanced by 10% sucrose was due to the patatin promoter containing the sucrose-inducted elements. One representative transgenic plant, Ag2197, was selected on the basis of monooxgenase activity in the leaves and Western blot analysis. Ag2197 was found to accumulate a large amount of CYP1A1 mRNA and protein in the developing tuber but not in the mature tuber. The residual herbicides, atrazine and chlortoluron, were analyzed in the micro-tubers of Ag2197 and non-transgenic plants. The amount of residual herbicides in Ag2197 was much lower than that in the non-transgenic plant, indicating that the transgenic plant metabolized the herbicides to a detoxified form. The transgenic plants produced in this study might be useful for the phytoremediation of chemical pollution in the soil.

Yamaguchi, I., H. Hamamoto, et al. (2002). What can plant biotechnology do for the environment? Nippon Nogeikagaku Kaishi-Journal of the Japan Society for Bioscience Biotechnology and Agrochemistry 76(1): 29-31.

Yamamoto, Y., T. Tani, et al. (2005). Field study and pharmaceutical evaluation of Glycyrrhiza uralensis roots cultivated in China. Journal of Traditional Medicines. Y. Yamamoto. 22: 86. Medicinal liquorice (underground parts of Glycyrrhiza plants) is an important crude drug prescribed in many traditional Chinese formulations. The collection of wild Glycyrrhiza plants was restricted in 1984 because it promotes desertification. With the shortage of liquorice due to this restriction, there has been a demand for the cultivation of Glycyrrhiza plants. In the first half of this review, we summarize the results of our survey of the cultivation/production state of G. uralensis in China from 1998 to 2001. In China, the cultivation of G. uralensis was initiated in the early 1990s. However, the glycyrrhizin (GL) content of the cultivated roots (mainly 3-year-old roots) we collected in our survey in China did not fulfil the standard (>= 2.5%) of the Japanese Pharmacopoeia (JP XIV). Such roots cannot be used for medicine in Japan. In the second half of this review, the results of our experiments of G. uralensis cultivation in eastern Neimenggu autonomy in China are summarized. We performed cultivation from seeds of G. uralensis, and taproots were transplanted the following year. As a result, adventitious roots collected in autumn in the 4th year after sowing conformed to the JP XIV standard for GL content. This study was the first to clarify whether G. uralensis roots cultivated in China were appropriate as a resource of medicinal liquorice. The anti-allergic action of the cultivated roots and their GL bioavailability after oral administration were similar to those of

existing medicinal liquorice prepared from wild G. uralensis in China. These results suggest that cultivated G. uralensis roots can compensate for the insufficient liquorice resources. This study not only aims at the development of liquorice resources and the assessment of their standards but is also a phytoremediation study on the global environment using cultivated plants.

Yanai, J., F. J. Zhao, et al. (2006). Effect of soil characteristics on Cd uptake by the hyperaccumulator *Thlaspi caerulescens*. Environmental Pollution 139(1): 167-175. The influence of soil characteristics on the phytoremediation potential of *Thlaspi caerulescens* is not well understood. We investigated the effect of soil pH and Cd concentration on plant Cd uptake on one soil type, and the variation in Cd uptake using a range of field contaminated soils. On soils with total Cd concentrations of 0.6-3.7 mg kg(-1), *T. caerulescens* (the Ganges ecotype) produced greater biomass in the pH range 5.1-7.6 than at pH 4.4. The highest plant Cd concentration (236 mg kg(-1)) and Cd uptake (228 mu g pot(-1)) were observed at pH 5.1. On soils with total Cd concentrations of 2.6-314.8 mg kg(-1), shoot Cd concentrations were 10.9-1196 mg kg(-1). Multiple regression analysis indicated that higher Cd in soil, low pH (within the range of > 5) and coarser texture were associated with higher Cd concentration and Cd uptake by T. caeridescens. (c) 2005 Elsevier Ltd.

Yanai, J., N. Mabuchi, et al. (2004). Distribution and forms of cadmium in the rhizosphere of *Brassica juncea* in Cd-contaminated soils and implications for phytoremediation. Soil Science and Plant Nutrition 50(3): 423-430. To investigate the chemical and positional availability of soil cadmium (Cd) absorbed by plants, the distribution and forms of Cd in the rhizosphere were analyzed by growing *Brassica juncea* L. in three artificially Cd-contaminated soils (two Fluvisols with 21.7 and 7.4 mg Cd kg(-1) and an Andosol with 25.1 mg Cd kg(-1), designated as FH, FL, and AH, respectively) using the rhizobox method. After a 25-d growth period, plant samples were harvested to determine the total amount of Cd absorbed. Soil samples were also collected at a distance of every 2-mm from the root-accumulating central compartment (C.C.) for the determination of the Cd concentration in the water-soluble, exchangeable, inorganically and organically bound fractions using a sequential extraction method. The amount of Cd absorbed by the plants was 168, 31, and 12 mug pot(-1) for the FH, FL, and AH soils, respectively, suggesting that the efficiency of Cd removal or phytoremediation in the Fluvisol was more than 10 times higher than that in the Andosol. In accordance with the plant uptake, a significant decrease in the content of soil Cd was observed in both inorganically and organically bound fractions in the Fluvisol and mostly in the organically bound fraction in the Andosol. The depletion was limited to a volume extending less than 10 mm from the C.C., and about 60% of the amount of Cd depleted was observed within 2 mm of the C.C., irrespective of the soils examined. The effective recovery rates were, therefore, 6.0, 3.2, and 0.6% for FH, FL, and All, respectively, if only the soil within 10 mm from the C.C. was taken into account. The amounts of water-soluble and exchangeable Cd, in contrast, showed some increase, especially in the FH soil, suggesting a possible accumulation of readily available Cd in the rhizosphere in certain soil-plant combinations. These results suggest the importance of 1) selection of soil, 2) increase in the volume of the rhizosphere, and 3) minimization of the possible leaching loss of Cd, when efficient and environmentally sound phytoremediation is to be accomplished for Cd-contaminated soils.

Yang Xiao, E., X. Jin, et al. (2005). Molecular mechanisms and genetic basis of heavy metal tolerance/hyperaccumulation in plants. Journal of Integrative Plant Biology. E. Yang Xiao. 47: 1025. Phytoremediation has gained increased attention as a cost-effective method for the remediation of heavy metal-contaminated sites. Because some plants possess a range of potential mechanisms that may be involved in the detoxification of heavy metals, they manage to survive under metal stresses. High tolerance to heavy metal toxicity could rely either on reduced uptake or increased plant internal sequestration, which is manifested by an interaction between a genotype and its environment. The growing application of molecular genetic technologies has led to increased understanding of mechanisms of heavy metal tolerance/accumulation in plants and, subsequently, many transgenic plants with increased heavy metal resistance, as well as increased uptake of heavy metals, have been developed for the purpose of phytoremediation. In the present review, our major objective is to concisely evaluate the progress made so far in understanding the molecular/cellular mechanisms and genetic basis that control the uptake and detoxification of metals by plants.

Yang, B., W. S. Shu, et al. (2003). Growth and metal accumulation in *Vetiver* and two *Sesbania* species on lead/zinc mine tailings. Chemosphere. B. Yang. 52: 1593. The lead (Pb)/zinc (Zn) tailings contained high concentrations of heavy metals (total Pb, Zn, Cu and Cd concentrations 4164, 4377, 35 and 32 mg kg-1, respectively), and low contents of major nutrient elements (N, P, and K) and organic matter. A field trial was conducted to compare growth performance, metal accumulation of *Vetiver* (*Vetiver*ia *zizanioides*) and two legume species (*Sesbania rostrata* and *Sesbania* sesban) grown on the tailings amended with domestic refuse and/or fertilizer. It was revealed that domestic refuse alone and the combination of domestic refuse and artificial fertilizer significantly improved the survival rates and growth of V. *zizanioides* and two *Sesbania* species, especially the combination. However, artificial fertilizer alone did not improve both the survival rate and growth performance of the plants grown on tailings. Roots of these species accumulated similar levels of heavy metals, but the shoots of two *Sesbania* species accumulated higher (3-4 folds) concentrations of Pb, Zn, Cu and Cd than shoots of V. *zizanioides*. Most of the heavy metals in V. *zizanioides* were accumulated in roots, and the translocation of metals from roots to shoots was restricted. Intercropping of V. *zizanioides* and S. *rostrata* did not show any beneficial effect on individual plant species, in terms of height, biomass, survival rate, and metal accumulation, possibly due to the rather short experimental period of 5 months.

Yang, Q. W., W. S. Shu, et al. (2004). Lead in paddy soils and rice plants Lechang and its potential health risk around lead/zinc Mine, Guangdong, China. Environment International 30(7): 883-889. As part of a project on phytoextraction of lead (Ph) in paddy soils around a lead/zinc (Pb/Zn) Mine in Lechang of Guangdong Province, South China, the concentration distribution of Ph in paddy soil-rice system was investigated, and its potential health risk to animal/human was evaluated. Total and diethylenetetraminepentaacetic acid (DTPA)-extractable Ph in soils averaged 1486 and 268 mug/g, respectively. According to sequential extraction procedure, soil Ph occurred primarily in the residual, carbonate and exchangeable fractions (30.2%, 26.7% and 19.1%, respectively). Lead extracted by the gastric juice simulation test (GJST) was 1068 mug/g and accounted for 75.4% of the total concentration. Mean Ph concentrations of 419 mug/g in rice root, 69.1 mug/g in whole straw, 51.0 mug/g in part straw (without two leaves near above the root), 44.9 mug/g in stalk, 21.9 mug/g in hull, 13.2 mug/g in grain with hull and 4.67 mug/g in grain without hull (namely, unpolished rice) were found. Lead concentrations in both soil and rice plant were far above the corresponding tolerable levels. Lead daily intakes by local residents were 2.6 mg for adults and 1.2 mg for children, which were much higher than the allowable level. Thus, Pb in this area might pose a potential health risk to the local population. (C) 2004 Elsevier Ltd.

Yang, Q., Q. Lin, et al. (2005). Study on phytoremediation with H2O2 pretreatment in heavy metal contaminated soils. Journal of Zhejiang University (Agriculture and Life Sciences). Q. Yang. 31: 315. The effect of hydrogen peroxide on the solubilization and rhizospheric dynamics of heavy metals in contaminated soils was studied. The results showed that water soluble Cu and Zn increased significantly after H2O2 treatment, which indicated that H2O2 is a safe and efficient reagent for enhancing the availability of heavy metals in soil. Addition of Fe2+ decreased the water soluble Cu and Zn. The more Fe2+ added, the lesser were the water soluble Cu and Zn. Planting ryegrass [*Lolium*] in the contaminated soil pretreated with hydrogen peroxide led to further increase of water soluble Cu and Zn present. Hydrogen peroxide was more effective in releasing Cu into soil solution than Zn. The fractionation of heavy metals was similarly distributed among soils. But hydrogen peroxide pretreatment distinctively increased the copper in the soluble plus exchangeable fraction (SE-Cu) in the planted soil, which indicated that binding strength of heavy metals in soil was weakened after the soil was treated with hydrogen peroxide, and was liable to be mobilized by the influence of the rhizosphere of ryegrass. The increase of copper and zinc levels in the weakly and specifically adsorbed fraction (WSA-Cu, WSA-Zn) and decrease of residual Cu and Zn levels were also observed in planted soil after hydrogen peroxide treatment. It was concluded that hydrogen peroxide pretreatment may be an efficient way for enhancing the bioavailability of heavy metals in soil and promoting the absorption of heavy metals by plants.

Yang, X. E., H. B. Ye, et al. (2004). Uptake and accumulation of cadmium and zinc by *Sedum alfredii* Hance at different Cd/Zn supply levels. Journal of Plant Nutrition 27(11): 1963-1977. *Sedum alfredii* Hance has been identified to be a zinc (Zn) hyperaccumulating plant species native to China. In this study, growth responses, uptake and accumulation of cadmium (Cd) and Zn by S. *alfredii* were examined at

Cd/Zn combining supply levels. The results showed that optimal growth for both shoots and roots was found when the plant grew at the Cd/Zn level of 1001500 mumol L-1. The concentrations of Cd and Zn in leaves and Sstems of *Sedum* afredii H increased with increasing Cd and Zn supply levels. The distributions of the metals in different plant parts decreased in the order: stem > leaf much greater than root for Zn and leaf > stem much greater than root for Cd. The highest concentrations of Zn (23.2 mg g(-1)) in the stems and Cd (12.1 mg g(-1)) in the leaves were noticed when the plants were grown at the Zn/Cd levels of 1000/50 and 500/400 mumol L-1, respectively. The maximum Cd and Zn accumulations in the shoots were 5.1 and 11.2 mg plant(-1) at the Cd/Zn combining levels of 400/250 and 100/500 mumol L-1, respectively. Zinc supply levels <500 mumol L-1 enhanced Cd concentrations in stems and leaves at the Cd levels <100 mumol L-1 and Cd concentration in roots at the Cd levels <50 mumol L-1. Cadmium at the supply levels greater than or equal to100 mumol L-1 decreased considerably root Zn concentrations for all the Zn levels, slightly increased leaf Zn concentrations at the Zn levels greater than or equal to250 mumol L-1, but had minimal effect on leaf Zn concentrations at the Zn levels greater than or equal to500 mumol L-1. The results indicate that S. *Alfredii* has an extraordinary ability to co-tolerate Cd/Zn toxicities, and to absorb and hyper-accumulate Cd and Zn under a range of Cd/Zn combining levels. Zinc addition at relatively low levels could stimulate Cd uptake and translocation, whereas Cd supply enhanced Zn translocation and partition to the shoots. *Sedum alfredii* is a Zn/Cd hyperaccumulator, which can be a valuable material for further study on the mechanisms of metal uptake and accumulation and for phytoremediation of the soils with Zn/Cd combined contamination.

Yang, X. E., H. Y. Peng, et al. (2005). Phytoextraction of copper from contaminated soil by *Elsholtzia spledens* as affected by EDTA, citric acid, and compost. International Journal of Phytoremediation 7(1): 69-83. Phytoextraction of copper (Cu) from contaminated soils greatly depends on the metal bioavailability in the soils and metal uptake ability of the plant. In this study, the effects of chelators [ethylenediamine tetraacetic acid (EDTA), citric acid (CA)] and compost amendments on Cu phytoextraction potential by a tolerant and accumulating plant species (E. *spledens*) were examined in two types of contaminated soils, i.e., the mined soil from Cu-mined area (MS) and a paddy soil polluted by Cu relining (PS). The results showed that EDTA application at 2.5-5.0 mmol kg(-1) increased phytoextraction of Cu by four- and eight-fold from both MS and PS, respectively, which is mainly attributed to increased H2O extractable Cu in the soil. The Cu amount extracted by the shoots of E. *spledens* reached 800-1000 mu g Cu plant(-1) from the MS and 400-700 mu g Cu plant(-1) from the PS at EDTA application rates of 2.5-5.0 mmol kg(-1). The application of CA at 5.0 mmol kg(-1) had minimal effects oil Cu extractability in both soils and slightly decreased Cu extraction efficiency by E. *spledens* Plant biomass production was enhanced by CA at 0.25 mmol L-1 in nutrient solution, but inhibited by CA at 5.0 mmol kg(-1) in both MS and PS. Increasing the compost rate significantly decreased H2O extractable Cu in the MS, bill raised H2O-extractable Cu in the PS, which resulted mainly front the reduced exchangeable Cu in the MS and the increased exchangeable and organic fractions of Cu in the PS by compost. At high compost rate (5%), the shoots of E. *spledens* extracted 3.6-fold higher Cu from the PS than from the MS. These results indicate that, among the, soil amendments, efficiency of Cu phytoextraction is enhanced mostly by 2.5-5.0 mmol kg(-1) EDTA, followed by 5% (w:w) compost, whereas < 5.0 mmol kg(-1) CA has minimal effects on Cu phytoextraction by E. *spledens* in the PS. As for the MS, only 2.5-5.0 initial kg(-1) EDTA call elevate the efficiency of Cu, while 5% compost amendment and < 5.0 mmol kg(-1) CA application have no marked effects on Cu phytoextraction by E. *spledens*.

Yang, X. E., T. Q. Li, et al. (2006). Dynamics of zinc uptake and accumulation in the hyperaccumulating and non-hyperaccumulating ecotypes of *Sedum alfredii* Hance. Plant and Soil 284(1-2): 109-119. *Sedum alfredii* Hance has been identified as a Zn-hyperaccumulating plant species native to China. The characteristics of Zn uptake and accumulation in the hyperaccumulating ecotype (HE) and non-hyperaccumulating ecotype (NHE) of S. *alfredii* were investigated under nutrient solution and soil culture conditions. The growth of HE was normal up to 1000 mu M Zn in nutrient solution, and 1600 mg Zn kg(-1) soil in a Zn-amended soil. Growth of the NHE was inhibited at Zn levels >= 250 mu M in nutrient solution. Zinc concentrations in the leaves and stems increased with increasing Zn supply levels, peaking at 500 and 250 mu M Zn in nutrient solution for the HE and the NHE, respectively, and then gradually decreased or leveled off with further increase in solution Zn. Minimal increases in root Zn were noted at Zn levels up to 50 mu M; root Zn sharply increased at higher Zn supply. The maximum Zn concentration in the shoots

of the HE reached 20,000 and 29,000 mg kg(-1) in the nutrient solution and soil experiments, respectively, approximately 20 times greater than those of the NHE. Root Zn concentrations were higher in the NHE than in the HE when plants were grown at Zn levels >= 50 mu M. The time-course of Zn uptake and accumulation exhibited a hyperbolic saturation curve: a rapid linear increase during the first 6 days in the long-term and 60 min in the short-term studies; followed by a slower increase or leveling off with time. More than 80% of Zn accumulated in the shoots of the HE at half time (day 16) of the long-term uptake in 500 mu M Zn, and also at half time (120 min) of the short-term uptake in 10 mu M Zn-65(2+). These results indicate that Zn uptake and accumulation in the shoots of S. *alfredii* exhibited a down-regulation by internal Zn accumulated in roots or leaves under both nutrient solution and soil conditions. An altered Zn transport system and increased metal sequestration capacity in the shoot tissues, especially in the stems, may be the factors that allow increased Zn accumulation in the hyperaccumulating ecotype of S. *alfredii*.

Yang, X. E., X. F. Jin, et al. (2005). Molecular mechanisms and genetic basis of heavy metal tolerance/hyperaccumulation in plants. Journal of Integrative Plant Biology 47(9): 1025-1035. Phytoremediation has gained increased attention as a cost-effective method for the remediation of heavy metal-contaminated sites. Because some plants possess a range of potential mechanisms that may be involved in the detoxification of heavy metals, they manage to survive under metal stresses. High tolerance to heavy metal toxicity could rely either on reduced uptake or increased plant internal sequestration, which is manifested by an interaction between a genotype and its environment. The growing application of molecular genetic technologies has led to increased understanding of mechanisms of heavy metal tolerance/accumulation in plants and, subsequently, many transgenic plants with increased heavy metal resistance, as well as increased uptake of heavy metals, have been developed for the purpose of phytoremediation. In the present review, our major objective is to concisely evaluate the progress made so far in understanding the molecular/cellular mechanisms and genetic basis that control the uptake and detoxification of metals by plants.

Yang, X. E., X. X. Long, et al. (2004). Cadmium tolerance and hyperaccumulation in a new Zn-hyperaccumulating plant species (*Sedum alfredii* Hance). Plant and Soil 259(1-2): 181-189. *Sedum alfredii* Hance has been identified as a new zinc (Zn) hyperaccumulating plant species. In this study, the effects of cadmium (Cd) supply levels (control, 12.5, 25, 50, 100, 200, 400, 800 mumol Cd L-1) on the growth and cadmium accumulation and Zn supply on Cd accumulation in S. *alfredii* Hance were studied. The results showed that no reduction in shoot and root dry matter yields were noted when the plants were grown at Cd supply levels up to 200 mumol L-1 in nutrient solution. Slight stimulation on shoot growth was noted at relatively low Cd levels (25 to 100 mumol L-1). Cadmium concentrations in leaves and stems increased with increasing Cd supply levels, and reached a maximum of approximately 9000 and 6500 mg kg(-1) (DW) at 400 mumol Cd L-1, respectively. Root Cd concentration increased sharply only at relatively high Cd levels. Cadmium distribution in different parts of the plant was in the order: leaf > stem >> root. The amount of Cd accumulated in the shoots reached 2.9 and 3.2 mg plant(-1) at external Cd levels of 200 and 400 mumol L-1, respectively. The shoot/root Cd ratios were greater than 2 and more than 95% of the total Cd taken up by S. *alfredii* was translocated to the shoots at the external Cd levels less than or equal to 200 mumol L-1. The concentrations of P, Ca, Mg, B, Fe, Mn, Cu, and in the shoots and roots were influenced differentially by Cd treatments. High Zn supply (500 mumol L-1) enhanced Cd concentrations in the leaves and stems at the Cd levels less than or equal to 100 mumol L-1, and root Cd concentration at the Cd levels less than or equal to 50 mumol L-1. These results indicate that S. *alfredii* has an extraordinary ability to tolerate and hyperaccumulate Cd and this is the first report of the new Cd hyperaccumulator S. *alfredii* Hance. The finding of Cd/Zn hyperaccumulation in S. *alfredii* Hance provides an important plant material for understanding the mechanisms of Cd/Zn co-hyperaccumulation and for phytoremediation of the heavy metal contaminated soils.

Yang, X., X. X. Long, et al. (2002). *Sedum alfredii* H: A new Zn hyperaccumulating plant first found in China. Chinese Science Bulletin 47(19): 1634-1637. Field survey and greenhouse experiments were carried out to identify and characterize zinc (Zn) uptake and accumulation by a new Zn hyperaccumulating plant species (*Sedum alfredii* Hance) native to China. Zinc concentration in the shoots of *Sedum alfredii* Hance grown on an ancient mined area ranged from 4134 to 5000 mg/kg, with a mean of 4515 mg/kg. It suggests that *Sedum alfredii* could not only grow on heavily Pb/Zn contaminated soils, but also could

accumulate extraordinarily high concentration of Zn. Under nutrient solution culture conditions, *Sedum alfredii* Hance grew healthy at Zn supplying levels from 0.006 to 240 mg L-1. Zinc concentration in the shoots increased with external Zn levels increasing. The Zn concentration and accumulation in the shoots reached the highest at Zn supply level of 80 mg/L, with 19.67 g/kg and 19.83 mg/plant, respectively. All the results showed that *Sedum alfredii* Hance is a new Zn hyperaccumulating plant. This provides a new plant material to explore mechanism of plant to hyperaccumulate Zn, and a potent new plant species to phytoremediate Zn contaminated soils.

Yang, X., Y. Feng, et al. (2005). Molecular mechanisms of heavy metal hyperaccumulation and phytoremediation. Journal of Trace Elements in Medicine and Biology 18(4): 339-353. A relatively small group of hyperaccumulator plants is capable of sequestering heavy metals in their shoot tissues at high concentrations. In recent years, major scientific progress has been made in understanding the physiological mechanisms of metal uptake and transport in these plants. However, relatively little is known about the molecular bases of hyperaccumulation. In this paper, current progresses on understanding cellular/molecular mechanisms of metal tolerance/hyperaccumulation by plants are reviewed. The major processes involved in hyperaccumulation of trace metals from the soil to the shoots by hyperaccumulators include: (a) bioactivation of metals in the rhizosphere through root-microbe interaction; (b) enhanced uptake by metal transporters in the plasma membranes; (c) detoxification of metals by distributing to the apoplasts like binding to cell walls and chelation of metals in the cytoplasm with various ligands, such as phytochelatins, metallothioneins, metal-binding proteins; (d) sequestration of metals into the vacuole by tonoplast-located transporters. The growing application of molecular-genetic technologies led to the well understanding of mechanisms of heavy metal tolerance/accumulation in plants, and subsequently many transgenic plants with increased resistance and uptake of heavy metals were developed for the purpose of phytoremediation. Once the rate-limiting steps for uptake, translocation, and detoxification of metals in hyperaccumulating plants are identified, more informed construction of transgenic plants would result in improved applicability of the phytoremediation technology. (c) 2005 Elsevier GrnbH.

Yang, X.-E., H.-Y. Peng, et al. (2005). Phytoextraction of copper from contaminated soil by *Elsholtzia spledens* as affected by EDTA, citric acid, and compost. International Journal of Phytoremediation 7(1): 69-83. Phytoextraction of copper (Cu) from contaminated soils greatly depends on the metal bioavailability in the soils and metal uptake ability of the plant. In this study, the effects of chelators [ethylenediamine tetraacetic acid (EDTA), citric acid (CA)] and compost amendments on Cu phytoextraction potential by a tolerant and accumulating plant species (E. *spledens*) were examined in two types of contaminated soils, i.e., the mined soil from Cu-mined area (MS) and a paddy soil polluted by Cu relining (PS). The results showed that EDTA application at 2.5-5.0 mmol kg(-1) increased phytoextraction of Cu by four- and eight-fold from both MS and PS, respectively, which is mainly attributed to increased H2O extractable Cu in the soil. The Cu amount extracted by the shoots of E. *spledens* reached 800-1000 mu g Cu plant(-1) from the MS and 400-700 mu g Cu plant(-1) from the PS at EDTA application rates of 2.5-5.0 mmol kg(-1). The application of CA at 5.0 mmol kg(-1) had minimal effects oil Cu extractability in both soils and slightly decreased Cu extraction efficiency by E. *spledens* Plant biomass production was enhanced by CA at 0.25 mmol L-1 in nutrient solution, but inhibited by CA at 5.0 mmol kg(-1) in both MS and PS. Increasing the compost rate significantly decreased H2O extractable Cu in the MS, bill raised H2O-extractable Cu in the PS, which resulted mainly front the reduced exchangeable Cu in the MS and the increased exchangeable and organic fractions of Cu in the PS by compost. At high compost rate (5%), the shoots of E. *spledens* extracted 3.6-fold higher Cu from the PS than from the MS. These results indicate that, among the, soil amendments, efficiency of Cu phytoextraction is enhanced mostly by 2.5-5.0 mmol kg(-1) EDTA, followed by 5% (w:w) compost, whereas < 5.0 mmol kg(-1) CA has minimal effects on Cu phytoextraction by E. *spledens* in the PS. As for the MS, only 2.5-5.0 initial kg(-1) EDTA call elevate the efficiency of Cu, while 5% compost amendment and < 5.0 mmol kg(-1) CA application have no marked effects on Cu phytoextraction by E. *spledens*.

Yang, X.-E., X.-F. Jin, et al. (2005). Molecular mechanisms and genetic basis of heavy metal tolerance/hyperaccumulation in plants. Journal of Integrative Plant Biology 47(9): 1025-1035. Phytoremediation has gained increased attention as a cost-effective method for the remediation of heavy metal-contaminated sites. Because some plants possess a range of potential mechanisms that may be

involved in the detoxification of heavy metals, they manage to survive under metal stresses. High tolerance to heavy metal toxicity could rely either on reduced uptake or increased plant internal sequestration, which is manifested by an interaction between a genotype and its environment. The growing application of molecular genetic technologies has led to increased understanding of mechanisms of heavy metal tolerance/accumulation in plants and, subsequently, many transgenic plants with increased heavy metal resistance, as well as increased uptake of heavy metals, have been developed for the purpose of phytoremediation. In the present review, our major objective is to concisely evaluate the progress made so far in understanding the molecular/cellular mechanisms and genetic basis that control the uptake and detoxification of metals by plants.

Yang, Z., G. Li, et al. (2005). The transformation of the chemical property of sediment in Baiyangdian Lake under reed's biosphere. China Environmental Science. Z. Yang. 25: 450. Results of the chemical analysis of sediment sampled and investigated in June 2004 in Baiyangdian Lake (China) showed that the contents of N, P and organic matters were relatively high in the sediment; and there appeared pollution of different degrees on the heavy metals of Cu, Zn, Cd and Pb. Through original soil column experiment, the regularity of material transformation and evolution of sediment during a relatively long period and the influence of different pH value, C:N ratio and the amount of water irrigated on sediment evolution were explored. The treatment under the condition of pH 7.3, C:N of 12:1 and irrigated water amounting to 80 litres was beneficial to the harmless disposal of sediment by reed (*Phragmites australis*).

Yanosky, T.M. and W.M. Kappel (1997). Effects of solution mining of salt on wetland hydrology as inferred from tree rings. Water Resour. Res. 33:457.

Yanosky, T.M., and D.A. Vroblesky (1992). Relation of nickel concentrations in tree rings to groundwater contamination. Water Resour. Res. 28:2077-2083.

Yanosky, T.M., and J.K. Carmichael (1993). Element concentrations in growth rings of trees near an abandoned wood-preserving plant site at Jackson, Tennessee. USGS Water-Resour. Investig. Rep. 93-4223.

Yao, B., H. Shang, et al. (2005). Application of transgenic plants in phytoremediation for contaminated soil by heavy metals and organic pollutants. Scientia Silvae Sinicae. B. Yao. 41: 162. Phytoremediation employs the use of plants, alone or together with their associated microorganisms, to degrade, contain or stabilize various environmental contaminants in soil, water, and air. The advantages of phytoremediation are: (i) it is an aesthetically pleasing, solar-energy driven cleanup technology; (2) there is minimal environmental disruption and in situ treatment preserves topsoil; (iii) it is useful for treating a broad range of environmental contaminants; and (iv) it is inexpensive (60-80% or even less costly) than conventional physico-chemical methods. Phytoremediation is widely viewed as the ecologically responsible alternative to the environmentally destructive physical remediation methods currently practiced. With the development of genetic engineering technology, transgenic plants play a major role in this field. This paper introduced the significant progress of the phytoremediation of soil with heavy metals and organic pollutants by transgenic plants.

Yateem, A., M. T. Balba, A. S. El-Nawawy and N. Al-Awadhi (2000). Plants-Associated Micro Flora and the Remediation of Oil-Contaminated Soil. International Journal of Phytoremedaition 2(3): 183-191.

Yazaki, K., N. Yamanaka, et al. (2006). Heterologous expression of a mammalian ABC transporter in plant and its application to phytoremediation. Plant Molecular Biology 61(3): 491-503. Mammalian ATP-binding cassette (ABC) transporters involved in the multidrug-resistance of cancer cells can efflux cytotoxic compounds that show a wide variety of chemical structures and biological activities. Human multidrug resistance-associated protein (hMRP1) is one of the most intensively studied ABC transporters and many substrates have been identified, including both organic and inorganic compounds. In an attempt at novel 'transport engineering' using hMRP1 as a molecular pump, we established transgenic tobacco plants that showed clear resistance to cadmium and daunorubicin, although they were not resistant to etoposide,

another known substrate of hMRP1. When expressed in tobacco cells, hMRP1 protein was localized at vacuolar membrane, while members of the MRP family are localized at plasma membrane in mammalian cells to reduce the cellular accumulation of various drugs. Thus, the hMRP1-expressing tobacco cells were able to take up these substrates across the tonoplast and sequestrate them in the vacuolar matrix. These results suggest that it may be possible to use the transgenic tobacco in phytoremediation, where a single transformation with an ABC transporter with broad substrate specificity should be effective for extracting various environmental pollutants including both organic and inorganic compounds, and accumulate them in the plant body. This should be advantageous for the remediation of a complex polluted environment, which is commonly found in the real world.

Ye, H. B., X. E. Yang, et al. (2003). Growth response and metal accumulation of *Sedum alfredii* to Cd/Zn complex-polluted ion levels. Acta Botanica Sinica 45(9): 1030-1036. *Sedum alfredii* Hance has been identified as a new Zn-hyperaccumulator native to China. In this study, responses and metal accumulation of S *alfredii* were examined under Zn/Cd complex polluted conditions. The results showed that optimal growth of S *alfredii* in terms of the maximum dry matter yield was observed at Zn/Cd complex level of 500/100 mumol/L. Plant cadmium (Cd) or zinc (Zn) concentrations increased with increasing Cd or Zn supply. During the 20 d treatment, the highest Cd concentration in the leaves reached 12.1 g/kg at Zn/Cd level of 50/400 mumol/L and that of Zn in the stems was 23.2 g/kg at Zn/Cd level of 1000/50 mumol/L. The distribution of Cd in different plant parts decreased in the order: leaf > stem greater than or equal to root, whereas that of Zn was: stem > leaf greater than or equal to root. The accumulation of Cd and Zn in the shoots and roots of S. *alfredii* increased with the increasing of Zn/Cd supply levels, peaked at Zn/Cd levels of 250/400 and 500/100 mumol/L, respectively. The highest Cd and Zn uptake by the shoots was approximately 5 and 11 mg/plant, and was over 20 and 10 times higher than those in the roots, respectively. Zn supply at levels less than or equal to 500 mumol/L increased plant Cd concentrations, whereas high Zn supply decreased root Cd but did not affect leaf Cd concentrations in S *alfredii* Low Cd supply increased Zn concentration in the leaves, but Cd supply higher than 50 mumol/L considerably reduced root Zn concentrations, especially at low Zn level. These results indicate that S. *alfredii* can tolerate high Zn/Cd complex levels and has an extraordinary ability to hyperaccumulate not only Zn but also Cd. It could provide a new valuable plant material for understanding the mechanisms responsible for co-hyperaccumulation of Zn and Cd as well as for phytoremediation of the Cd/Zn complex polluted soils.

Ye, Q. (1991). Studies on uptake and metabolism of PCBs by terrestrial plants. M.S. Thesis, University of Missouri, Columbia, MO.

Ye, Z. H., Z. Q. Lin, et al. (2003). Possible use of constructed wetland to remove selenocyanate, arsenic, and boron from electric utility wastewater. Chemosphere. Z. H. Ye. 52: 1571. Wetland microcosms were used to evaluate the ability of constructed wetlands to remove extremely high concentrations of selenocyanate (SeCN-), arsenic (As), and boron (B) from wastewater generated by a coal gasification plant in Indiana. The wetland microcosms significantly reduced the concentrations of selenium (Se), As, B, and cyanide (CN) in the wastewater by 64%, 47%, 31%, and 30%, respectively. In terms of the mass of each contaminant, 79%, 67%, 57%, and 54% of the Se, As, B, and CN, respectively, loaded into the microcosms were removed from the wastewater. The primary sink for the retention of contaminants within the microcosms was the sediment, which accounted for 63%, 51%, and 36% of the Se, As, and B, respectively. Accumulation in plant tissues accounted for only 2-4%, while 3% of the Se was removed by biological volatilization to the atmosphere. Of the 14 plant species tested, cattail, Thalia, and rabbitfoot grass were highly tolerant of the contaminants and exhibited no growth retardation. Environmental toxicity testing with fathead minnow (Pimephales promelas) larvae confirmed that the water treated by the wetland microcosms was less toxic than untreated water. The data from the wetland microcosms support the view that constructed wetlands could be used to successfully reduce the toxicity of aqueous effluent contaminated with extremely high concentrations of SeCN-, As, and B, and that a pilot-scale wetland should therefore be constructed to test this in the field. Cattail, Thalia, and rabbitfoot grass would be suitable plant species to establish in such wetlands.

Yee, D.C., J.A. Maynard, and T.K. Wood (1998). Rhizoremediation of trichloroethylene by a recombinant, root-colonizing *Pseudomonus* fluorescent strain expressing toluene orth.-monooxygenase constitutively. Appl. Environ. Microbiol. 64:112-118.

Ying, O. Y. (2002). Phytoremediation: modeling plant uptake and contaminant transport in the soil-plant-atmosphere continuum. Journal of Hydrology 266(1-2): 66-82. Phytoremediation is an emerging technology that uses plants and their associated rhizospheric microorganisms to remove, degrade, detoxify, or contain contaminants located in the soil, sediments, groundwater, surface water, and even the atmosphere. This study investigates phytoremediation of 1,4-dioxane from a contaminated sandy soil by a poplar cutting, which is associated with water flow in the soil as well as water movement and 1,4-dioxane translocation in the xylem and phloem systems. An existing one-dimensional mathematical model for coupled transport of water, heat, and solutes in the soil-plant-atmosphere continuum (CTSPAC) is modified for the purpose of this study. The model is calibrated with the laboratory experimental measurements prior to its applications. A simulation scenario is then performed to investigate phytoremediation of 1,4-dioxane by a poplar cutting in response to daily water flow and 1,4-dioxane transport for a simulation period of 7 days. Simulation shows that 1,4-dioxane concentration is high in leaves and low in roots with the stem in between. However, 1,4-dioxane mass in the stem (60%) is higher than that of leaves (28%) and roots (12%). This occurs because the stem volume used in this study is larger than those of leaves and roots. The simulation further reveals that about 30% of the soil 1,4-dioxane is removed within 7 days, resulting mainly from root uptake. A plot of the 1,4-dioxane concentrations in plant compartments as a function of time shows that the highest concentration in leaves is about 2600 mug/cm(3) and the lowest concentration in roots is about 350 mug/cm(3) at the end of the simulation. Results indicate that leaves are an important compartment for 1,4-dioxane accumulation and transpiration. This study suggests that the modified CTSPAC model could be a useful tool for phytoremediation estimations. (C) 2002 Elsevier Science B.V.

Ying, O. Y. (2005). Phytoextraction: Simulating uptake and translocation of arsenic in a soil-plant system. International Journal of Phytoremediation 7(1): 3-17. The uptake, transport, and accumulation of metals by plants are functions central to successfully to extraction. This study investigates the uptake and translocation of arsenic from a contaminated sandy soil by a mature Chinese brake fern (*Pteris vittata* L.). An existing mathematical model for the coupled transport of water, heat, and solutes in the soil-plant-atmosphere continuum (CTSPAC) was modified to examine the flow of water as well as the uptake and translocation of total arsenic in the xylem of the fern. This model was calibrated using greenhouse measurements before its application. Simulation results showed that about 20% of the soil arsenic was removed by the fern in 10 d, of which about 90% of the arsenic was stored in the fronds and 10% in the roots. Although arsenic mass in the plant tissues increased consecutively with little, arsenic concentration in the xylem sap of the root tips has a typical diurnal distribution pattern: increasing during the day and decreasing at night, resulting from daily, variations of frond surface water transpiration. The largest difference in simulated arsenic concentration in the root tips between the day and night was about 5%. This study also suggests that the use of transpiration stream concentration factor (TSCF), which is defined as the ratio of chemical concentration in the xylem sap to that ill the external solution, to evaluate the translocation efficiency of arsenic for the hyperaccumulator Chinese brake fern (*Pteris vittata* L.) could be limited.

Ying, Q. (2002). Phytoremediation: Modeling Plant Uptake and Contaminant Transport in the Soil-Plant-Atmosphere Contimuum. Journal of Hydrology 266: 66-82.

Yong, P., and J.L. Schnoor (1997). Abstract: Phytoremediation of lead using sunflowers and EDTA. Poster 51. In 12th Annual Conference on Hazardous Waste Research - Abstracts Book, May 19-22, 1997, Kansas City, MO.

Yoo, M. H., Y. J. Kwon, et al. (2006). Efficacy of indoor plants for the removal of single and mixed volatile organic pollutants and physiological effects of the volatiles on the plants. Journal of the American Society for Horticultural Science 131(4): 452-458. Foliage plants of Hedera helix L. (english ivy), Spathiphyllum wallisiiRegal (peace lily), Syngoniumpodophyllum Schott. (nephthytis), and Cissus rhombifolia Vahl.

(grape ivy) were evaluated for their ability to remove two indoor volatile organic air pollutants, benzene and toluene. Removal was monitored when the aerial portion of plants was exposed singly to 1 mu(LL-1)-L-. or to 0.5 mu(LL-1)-L-. of each gas in a closed environment over 6-hour periods during the day and the night. Selected physiological processes were assessed before and immediately after treatment to determine the effect of the gases on the plants. The effectiveness of plants in the removal of air pollutant(s) varied with species, time of day, and whether the gases were present singly or as a mixture. When exposed to a single gas, S. wallisii, S. podophyllum, and H. helix displayed higher removal efficiencies (ng(.)m(-3.)h(-1.)cm(-2) leaf area) of either gas than C. rhombifolia during the day. The efficiency of removal changed when both gases were present; H. helix was substantially more effective in the removal of either benzene or toluene than the other species, with the removal of toluene more than double that of benzene. When exposed singly, the removal of both compounds was generally higher during the day than during the night for all species; however, when present simultaneously, H. helix removal efficiency during the night was similar to the day indicating that stomatal diffusion for english ivy was not a major factor. The results indicated an interaction between gases in uptake by the plant, the presence of different avenues for uptake, and the response of a single gas was not necessarily indicative of the response when other gases are present. Changes in the rates of photosynthesis, stomatal conductance, and transpiration before and after exposure indicated that the volatiles adversely affected the plants and the effects were not consistent across species and gases. Deleterious effects of volatile pollutants on indoor plants may be critical in their efficacy in improving indoor air quality and warrant further study.

Yoon, J. M., B. T. Oh, et al. (2002). Uptake and leaching of octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine by hybrid poplar trees. Environmental Science & Technology 36(21): 4649-4655. The feasibility of remediating a high explosive, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), using hybrid poplar trees (*Populus deltoides* x *nigra* , DN34) was investigated. The fate, transport, and toxicity were determined. HMX was taken up by poplar cuttings from hydroponic solutions in long-term experiments (65 days) without evidence of toxicity. HMX was not toxic to actively growing hybrid poplar cuttings, even under saturated conditions. The measured log K-ow for HMX was 0.19, less than other explosives, TNT, and RDX. However, the calculated transpiration stream concentration factor (TSCF) and root concentration factor (RCF) for HMX from an uptake study using radiolabeled [U-C-14]HMX were 0.21 +/- 0.07 and 5.55 +/- 1.78 mL/g, respectively, both of which were intermediate between the values for TNT and RDX in previous reports. A 70% uptake of [U-C-14]HMX was translocated and accumulated in leaves, and no metabolites were observed during a 65-day exposure using radiochromatography of plant tissue extracts. Most of the accumulated HMX (57%) in dried (fallen) poplar leaves was leached by deionized water after 5 days. Bioaccumulation in poplar trees and resolublization of HMX from leaves would be of significant ecological concern, and phytoremediation may not be warranted as a treatment option unless other processes occur under field conditions that degrade HMX to innocuous end products (e.g., photolysis, hydrolysis, or microbial degradation).

Yoon, J. M., B. Van Aken, et al. (2006). Leaching of contaminated leaves following uptake and phytoremediation of RDX, HMX, and TNT by poplar. International Journal of Phytoremediation 8(1): 81-94. The uptake and fate of 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) by hyhrid poplars in hydroponic systems were compared and exposed leaves were leached with water to simulate potential exposure path ways from groundwater in the field. TNT was removed from solution more quickly than nitramine explosives. Most of radioactivity remained in root tissues for C-14-TNT, but in leaves for C-14-RDX and C-14-HMX. Radiolabel recovery for TNT and HMX was over 94% but that of RDX decreased over time, suggesting a loss of volatile products. A considerable fraction (45.57%) of radioactivity taken up by whole plants exposed to C-14-HMX was released into deionized water, mostly as parent compound after 5 d of leaching. About a quarter (24.0%) and 1.2% were leached for RDX and TNT, respectively, mostly as transformed products. Leached radioactivity from roots was insignificant in all cases (< 2%). This is the first report in which small amounts of transformation products of RDX leach from dried leaves following uptake by poplars. Such behavior for HMX was reported earlier and is reconfirmed here. All three compounds differ substantially in their fate and transport during the leaching process.

Yoon, J., X. D. Cao, et al. (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment 368(2-3): 456-464. Contamination of heavy metals represents one of the most pressing threats to water and soil resources as well as human health. Phytoremediation can be potentially used to remediate metal-contaminated sites. This study evaluated the potential of 36plants (17 species) growing on a contaminated site in North Florida. Plants and the associated soil samples were collected and analyzed for total metal concentrations. While total soil Pb, Cu, and Zn concentrations varied from 90 to 4100, 20 to 990, and 195 to 2200mg kg(-1), those in the plants ranged from 10 to 1183, 6.0 to 460, and 17 to 598mg kg(-1), respectively. None of the plants were suitable for phytoextraction because no hyperaccumulator was identified. However, plants with a high bioconcentration factor (BCF, metal concentration ratio of plant roots to soil) and low translocation factor (TF, metal concentration ratio of plant shoots to roots) have the potential for phytostabilization. Among the plants, Phyla nodiflora was the most efficient in accumulating Cu and Zn in its shoots (TF = 12 and 6.3) while Gentiana pennelliana was most suitable for phytostabilization of sites contaminated with Pb, Cu and Zn (BCF = 11, 22 and 2.6). Plant uptake of the three metals was highly correlated, whereas translocation of Pb was negatively correlated with Cu and Zn though translocation of Cu and Zn were correlated. Our study showed that native plant species growing on contaminated sites may have the potential for phytoremediation. (c) 2006 Elsevier B.V.

Yoshida, N., R. Ikeda, et al. (2006). Identification and characterization of heavy metal-resistant unicellular alga isolated from soil and its potential for phytoremediation. Bioresource Technology 97(15): 1843-1849. A unicellular alga displaying a high growth rate under heterotrophic growth conditions was isolated from soil and identified as *Chlorella* sorokiniana. The optimal temperature for growth was 35 degrees C and the optimal pH was 6.0-7.0. Glucose, sucrose, galactose, maltose, and soluble starch served as carbon sources supporting growth under dark conditions. The cell yield was 50 g/l (wet weight) in a heterotrophic medium containing 3% glucose. Isolated unicellular algae were highly resistant to heavy metals such as Cd2+, of which the minimal inhibitory concentration was 4mM. Algae were capable of taking up the heavy metal ions Cd2+, Zn2+ and Cu2+ at 43.0, 42.0 and 46.4 mu g/mg dry weight, respectively. Growth inhibition of *Oryza* sative shoots by 5 ppm Cd2+ in hydroponic medium was completely prevented by the addition of 0.25 mg of wet *Chlorella* cells. These results indicated that this isolate was potentially useful for phytoremediation by preventing environmental dispersion of heavy metals. (c) 2005 Elsevier Ltd.

Yoshitomi, K. J. and J. R. Shann (2001). Corn (*Zea mays* L.) Root Exudates and Their Impact on (14)C-Pyrene Mineralization. Soil Biology & Biochemistry 33: 1769-1776.

Young, C.C., L.R. Zhu Thorne, and G.R. Waller (1989). Phytotoxic potential of soils and wheat straw in rice rotation cropping systems of subtropical Taiwan. Plant Soil. 120:95-102.

Youngman, A.L. (1997). Abstract: Physiological responses of Switchgrass (*Panicum virgatum* L.) to inorganic and organic amended heavy-metal contaminated chat tailings. Poster 45. In 12th Annual Conference on Hazardous Waste Research - Abstracts Book, May 19-22, 1997, Kansas City, MO. Study plots established at the Galena subsite of the Cherokee County Superfund Site in southeastern Kansas by the U. S. Bureau of Mines in 1990 were examined during the summer of 1996 to determine whether physiological criteria could be used to provide a way of detecting suitability of switchgrass for remediation of heavy-metal contaminated substrates. Switchgrass was chosen because it was the most frequently encountered species on these plots. Treatment plots included, in addition a treatment control, an organic residue treatment of 89.6 Mg Ha-1 composted cattle manure, and two inorganic fertilizer treatments recommended for either native grass or grass-legume mixtures. Plant response variables were photosynthetic rate, leaf conductance to water vapor, internal concentration of carbon dioxide in leaves, foliar transpiration rate, leaf water-use-eff~ciency, predawn leaf xylem water potential, and midday leaf xylem water potential. Gas exchange properties and water status were related to type of soil amendment. Results of this investigation provide insight into why organic amendments are important for successful revegetation of sites with metal contaminated substrates.

Youssef, R.A., and M. Chino (1991). Movement of metals from soil to plant roots. Water Air Soil Pollut. 57-58:249-259.

Yu, X. Z. and J. D. Gu (2006). Uptake, metabolism, and toxicity of methyl tert-butyl ether (MTBE) in weeping willows. Journal of Hazardous Materials 137(3): 1417-1423. Methyl tert-butyl ether (MTBE) is a high volume production chemical and the most commonly used gasoline oxygenate. Uptake, metabolism and toxicity of MTBE in trees were investigated in this study. Pre-rooted weeping willows (*Salix* babylonica L.) were exposed to hydroponic solution spiked with MTBE and incubated at 25.0 +/- 1 degrees C for 168 h. The normalized relative transpiration (NRT) rate of weeping willows was used to determine toxicity. MTBE and possible intermediate tert-butyl alcohol (TBA) in solution, tissues of aerial parts of plants, and air were analyzed. Results from the toxicity test showed that severe signs of toxicity (the reduction of the NRT >= 35%) were only found at the treatment group with high doses of MTBE 400 mg L-1. Neither chlorosis of leaves nor large reduction in the NRT was observed at MTBE exposure to weeping willows <= 200mgL(-1). Almost all applied MTBE was removed from the hydroponic solution by plants in all treatment groups. Small amounts of MTBE were detected in the plant tissues, but a large fraction of the applied MTBE was found in the air through plant transpiration. Mass balance studies showed that MTBE was assimilated into the plants from hydroponic solution but was not metabolized during transport in the plant. Phytovolatilization was the only relevant removal process for MTBE. Transpiration stream concentration factor (TSCF), an important parameter for design of engineered MTBE phytoremediation systems, was estimated to be 1.12. In conclusion, although this compound is persistent to the attack by plant enzymes, atmospheric MTBE is much more susceptible to photo-oxidation for decomposition. Phytoremediation of MTBE polluted soils and groundwater is an alternative to presently available remediation technologies. (c) 2006 Elsevier B.V.

Yu, X. Z., J. J. Lei, et al. (2006). Bioavailability of cyanide in the different environmental compartments. Journal of Environmental Sciences-China 18(2): 347-352. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. Hybrid willows (*Salix* matsudana Koidzx*Salix alba* L.) were exposed to cyanide to determine whether willows can transport and metabolize this compound. Pre-rooted trees were grown in different environmental compartments spiked or irrigated with potassium cyanide at 24.0 +/- 0.5 degrees C. Cyanide in compartments, in air and in tissues of plants was analyzed spectrophotometrically. Results from this study indicated that large amounts of applied cyanide was removed from the systems during the presence of willows. Growing compartments of plants have a strong influence on the removal rates of cyanide. Little or no initial cyanide was detected in plant materials. Volatilization of cyanide was not occurring. Mass balance studies showed that applied cyanide was significantly metabolized during transport through willows cuttings. However, there was a clear difference between the metabolism rates of cyanide by willows exposed to different environmental compartments. The highest cyanide metabolism rate was found at the treatment with willows growing in hydroponic solution with a metabolism rate of 2.44 mgCN/ (kg center dot d), followed by willows growing in sand with a value of 1.02 mgCN/(kg center dot d). The lowest metabolism rate had the willows growing in soils(0.43 mgCN/(kg center dot d)). In conclusion, transport and metabolism of cyanide in plants is likely and phytoremediation of cyanide is a feasible option for cleaning soils and water contaminated with cyanide.

Yu, X. Z., P. H. Zhou, et al. (2005). Cyanide removal by Chinese vegetation - Quantification of the Michaelis-Menten kinetics. Environmental Science and Pollution Research 12(4): 221-226. Background. Little is known about metabolism rates of environmental chemicals by vegetation. A good model compound to study the variation of rates among plant species is cyanide. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. Knowledge of the kinetic parameters, the half-saturation constant (K-M) and the maximum metabolic capacity (V-max), is very useful for enzyme characterization and biochemical purposes. The goal of this study is to find the enzyme kinetics (K-M and V-max) during cyanide metabolism in the presence of Chinese vegetation, to provide quantitative data for engineered phytoremediation, and to investigate the variation of metabolic rates of plants. Methods. Detached leaves (1.0 g fresh weight) from 12 species out of 9 families were kept in glass vessels with 100 mL of aqueous solution spiked with potassium cyanide at 23 degrees C for 28 h. Four different treatment concentrations of cyanide were used, ranging from 0.44 to 7.69 mg CN/L. The disappearance of cyanide from the aqueous solution was analyzed spectrophotometrically. Realistic values of the half-saturation constant (K-M) and the maximum metabolic capacity (v(max)) were estimated by a computer program using non-linear regression treatments. As a comparison, Lineweaver-Burk plots

were also used to estimate the kinetic parameters. Results and Discussion. The values obtained for K-M and v(max) varied with plant species. Using non-linear regression treatments, values of v(max) and K-M were found in a range between 6.68 and 21.91 mg CN/kg/h and 0.90 to 3.15 mg CN/L, respectively. The highest v(max) was by Chinese elder (Sambucus *chinensis*), followed by upright hedge-parsley (Torilis japonica). The lowest v(max) was demonstrated by the hybrid willow (*Salix* matssudana x alba). However, the highest K-M was found in the water lily (Nympbea teragona), followed by the poplar (*Populus deltoides* Marsh). The lowest K-M was demonstrated by corn (*Zea mays* L.). The values of V-max were normally distributed with a mean of 13 mg CN/kg/h. Conclusions. Significant removal of cyanide from aqueous solution was observed in the presence of plant materials without phytotoxicity, even at high doses of cyanide. This gives rise to the conclusion that the Chinese plant species used in this study are all able to efficiently metabolize cyanide, although with different maximum metabolic capacities. A second conclusion is that the variation of metabolism rates between species is small. All these plantshad a similar K-M, indicating the same enzyme is active in all plants. Recommendations and Outlook. Detoxification of cyanide with trees seems to be a feasible option for cleaning soils and water contaminated with cyanide. For phytoremediation projects, screening appropriate plant species adapted to local conditions should be seriously considered. More chemicals should be investigated to find common principles of the metabolism of environmental chemicals by plants.

Yu, X. Z., P. H. Zhou, et al. (2006). The potential for phytoremediation of iron cyanide complex by willows. Ecotoxicology 15(5): 461-467. Hybrid willows (*Salix* matsudana Koidz X *Salix alba* L.), weeping willows (*Salix* babylonica L.) and hankow willows (*Salix* matsudana Koidz) were exposed to potassium ferrocyanide to determine the potential of these plants to extract, transport and metabolize this iron cyanide complex. Young rooted cuttings were grown in hydroponic solution at 24.0 +/- 0.5 degrees C for 144 h. Ferrocyanide in solution, air, and aerial tissues of plants was analyzed spectrophotometrically. Uptake of ferrocyanide from the aqueous solution by plants was evident for all treatments and varied with plant species, ranging from 8.64 to 15.67% of initial mass. The uptake processes observed from hydroponic solution showed exponential disappearance kinetics. Very little amounts of the applied ferrocyanide were detected in all parts of plant materials, confirming passage of ferrocyanide through the plants. No ferrocyanide in air was found due to plant transpiration. Mass balance analysis showed that a large fraction of the reduction of initial mass in hydroponic solution was metabolized during transport within the plant materials. The difference in the metabolic rate of ferrocyanide between the three plant species was comparably small, indicating transport of ferrocyanide from hydroponic solution to plant materials and further transport within plant materials was a limiting step for assimilating this iron cyanide complex. In conclusion, phytoremediation of ferrocyanide by the plants tested in this study has potential field application.

Yu, X. Z., S. Trapp, et al. (2005). The effect of temperature on the rate of cyanide metabolism of two woody plants. Chemosphere 59(8): 1099-1104. The response of cyanide metabolism rates of two woody plants to changes in temperature is investigated. Detached leaves (1.0 g fresh weight) from weeping willow (*Salix* babylonica L.) and Chinese elder (Sambucus *chinensis* Lindl.) were kept in glass vessels with 100 ml of aqueous solution spiked with potassium cyanide for a maximum of 28 h. Ten different temperatures were used ranging from 11 &DEG; C to 32 &DEG; C. The disappearance of aqueous cyanide was analyzed spectrophotometrically. The cyanide removal rate of Chinese elder was higher than that of weeping willow at all temperatures. The highest cyanide removal rate for Chinese elder was found at 30 &DEG; C with a value of 12.6 mg CN kg(-1) h(-1), whereas the highest value of the weeping willow was 9.72 mg CN kg(-1) h(-1) at 32 &DEG; C. The temperature coefficient values, Q(10), which are the ratio of removal rates at a 10 degree difference, were determined for Chinese elder and weeping willow to 1.84 and 2.09, respectively, indicating that the cyanide removal rate of weeping willow was much more susceptible to changes in temperature than that of the Chinese elder. In conclusion, changes in temperature have a substantial influence on the removal rate of cyanide by plants. © 2005 Elsevier Ltd.

Yu, X., J. Lei, et al. (2006). Bioavailability of cyanide in the different environmental compartments. Journal of Environmental Sciences. X. Yu. 18: 347. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. Hybrid willows (*Salix* matsudana x S. alba) were

exposed to cyanide to determine whether willows can transport and metabolize this compound from hydroponic solution, from sand and from soil by plants. Pre-rooted trees were grown in different environmental compartments spiked or irrigated with potassium cyanide at 24.0 +- 0.5degreesC. Cyanide in compartments, in air and in tissues of plants was analysed spectrophotometrically. Results from this study indicated that large amounts of applied cyanide was removed from the systems during the presence of willows. Growing compartments of plants have a strong influence on the removal rates of cyanide. Little or no initial cyanide was detected in plant materials. Volatilization of cyanide was not occurring. Mass balance studies showed that applied cyanide was significantly metabolized during transport through willows cuttings. However, there was a clear difference between the metabolism rates of cyanide by willows exposed to different environmental compartments. The highest cyanide metabolism rate was found at the treatment with willows growing in hydroponic solution with a metabolism rate of 2.44 mgCN/(kg d), followed by willows growing in sand with a value of 1.02 mgCN/(kg d), The lowest metabolism rate had the willows growing in soils (0.43 mg CN/(kg d)). In conclusion, transport and metabolism of cyanide in plants is likely and phytoremediation of cyanide is a feasible option for cleaning soils and water contaminated with cyanide.

Yu, X., P. Zhou, et al. (2005). Cyanide removal by Chinese vegetation - Quantification of the Michaelis-Menten kinetics. Environmental Science and Pollution Research International 12(4): 221-226. Background. Little is known about metabolism rates of environmental chemicals by vegetation. A good model compound to study the variation of rates among plant species is cyanide. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. Knowledge of the kinetic parameters, the half-saturation constant (K-M) and the maximum metabolic capacity (V-max), is very useful for enzyme characterization and biochemical purposes. The goal of this study is to find the enzyme kinetics (K-M and V-max) during cyanide metabolism in the presence of Chinese vegetation, to provide quantitative data for engineered phytoremediation, and to investigate the variation of metabolic rates of plants.Methods. Detached leaves (1.0 g fresh weight) from 12 species out of 9 families were kept in glass vessels with 100 mL of aqueous solution spiked with potassium cyanide at 23 degrees C for 28 h. Four different treatment concentrations of cyanide were used, ranging from 0.44 to 7.69 mg CN/L. The disappearance of cyanide from the aqueous solution was analyzed spectrophotometrically. Realistic values of the half-saturation constant (K-M) and the maximum metabolic capacity (v(max)) were estimated by a computer program using non-linear regression treatments. As a comparison, Lineweaver-Burk plots were also used to estimate the kinetic parameters.Results and Discussion. The values obtained for K-M and v(max) varied with plant species. Using non-linear regression treatments, values of v(max) and K-M were found in a range between 6.68 and 21.91 mg CN/kg/h and 0.90 to 3.15 mg CN/L, respectively. The highest v(max) was by Chinese elder (Sambucus *chinensis*), followed by upright hedge-parsley (Torilis japonica). The lowest v(max) was demonstrated by the hybrid willow (*Salix* matssudana x alba). However, the highest K-M was found in the water lily (Nympbea teragona), followed by the poplar (*Populus deltoides* Marsh). The lowest K-M was demonstrated by corn (*Zea mays* L.). The values of V-max were normally distributed with a mean of 13 mg CN/kg/h.Conclusions. Significant removal of cyanide from aqueous solution was observed in the presence of plant materials without phytotoxicity, even at high doses of cyanide. This gives rise to the conclusion that the Chinese plant species used in this study are all able to efficiently metabolize cyanide, although with different maximum metabolic capacities. A second conclusion is that the variation of metabolism rates between species is small. All these plantshad a similar K-M, indicating the same enzyme is active in all plants.Recommendations and Outlook. Detoxification of cyanide with trees seems to be a feasible option for cleaning soils and water contaminated with cyanide. For phytoremediation projects, screening appropriate plant species adapted to local conditions should be seriously considered. More chemicals should be investigated to find common principles of the metabolism of environmental chemicals by plants.

Yu, X., P. Zhou, et al. (2005). Detoxification of cyanide by woody plants. Archives of Environmental Contamination and Toxicology. X. Yu. 49: 150. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. This paper examines the potential of three woody plants from the Salicaceae family to degrade cyanide. Pre-rooted trees were grown in carefully designed bioreactors with aqueous solution spiked with potassium cyanide at 23.0 +- 1degreesC for a maximum of 144 h. Cyanide concentrations ranged from 0.95 to 1.15 CN mg/L. Cyanide in water and in plant tissues

was analyzed spectrophotometrically. Results from the investigation indicated that significant reduction of aqueous cyanide was found during the presence of plants in all treatments. Little amounts of applied cyanide were detected in the tissues of plants, mainly in roots and bottom stem. Cyanide remaining in tissues varied with the species of plants, despite similar periods of exposure. The data also indicated that photolysis, hydrolysis, and microbial degradation were not occurring and that volatilization was minimal. In conclusion, transport and metabolism of cyanide in plants is most likely.

Yu, X., P. Zhou, et al. (2006). The potential for phytoremediation of iron cyanide complex by willows. Ecotoxicology. X. Yu. 15: 461. Hybrid willows (*Salix* matsudana Koidz x *Salix alba* L.), weeping willows (*Salix* babylonica L.) and hankow willows (*Salix* matsudana Koidz) were exposed to potassium ferrocyanide to determine the potential of these plants to extract, transport and metabolize this iron cyanide complex. Young rooted cuttings were grown in hydroponic solution at 24.0 +- 0.5degreesC for 144 h. Ferrocyanide in solution, air, and aerial tissues of plants was analysed spectrophotometrically. Uptake of ferrocyanide from the aqueous solution by plants was evident for all treatments and varied with plant species, ranging from 8.64 to 15.67% of initial mass. The uptake processes observed from hydroponic solution showed exponential disappearance kinetics. Very little amounts of the applied ferrocyanide were detected in all parts of plant materials, confirming passage of ferrocyanide through the plants. No ferrocyanide in air was found due to plant transpiration. Mass balance analysis showed that a large fraction of the reduction of initial mass in hydroponic solution was metabolized during transport within the plant materials. The difference in the metabolic rate of ferrocyanide between the three plant species was comparably small, indicating transport of ferrocyanide from hydroponic solution to plant materials and further transport within plant materials was a limiting step for assimilating this iron cyanide complex. In conclusion, phytoremediation of ferrocyanide by the plants tested in this study has potential field application.

Yu, X., P. Zhou, et al. (2006). Uptake, metabolism, and toxicity of iron cyanide complex in weeping willows. Journal of Tropical and Subtropical Botany. X. Yu. 14: 1. Uptake, metabolism and toxicity of iron cyanide complex in trees were investigated. Pre-rooted weeping willows (*Salix* babylonica) from the campus of Hunan Agricultural University, China, were exposed to hydroponic solution spiked with ferrocyanide at 24.0 +- 1degreesC for 192 h. Four different treatment concentrations of ferrocyanide were used (52.99, 105.98, 211.95 and 317.93 mg CN litre-1). Cyanide in water, in tissues of aerial part of plants and in air was analysed spectrophotometrically. Results from this study indicated less than 10.85% reduction of the applied iron cyanide complex was detected in hydroponic solution in the presence of plants. Little amounts of cyanide were found in all parts of plant tissues, indicating the passage of ferrocyanide through the plants. Mass balance studies showed that iron cyanide complex moving into plants from hydroponic solution can be metabolized during transport. Phytotoxic effects were not found in all treatment groups, even at high doses of ferrocyanide within a 192-h exposure period. In conclusion, transport and metabolism of ferrocyanide in plants is most likely to happen and phytoremediation of this iron cyanide complex in field application may be possible.

Yu, X., S. Trapp, et al. (2004). Metabolism of cyanide by Chinese vegetation. Chemosphere 56(2): 121-126. Cyanide is a high-volume production chemical and the most commonly used leaching reagent for gold and silver extraction. Its environmental behavior and fate is of significant concern because it is a highly toxic compound. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. This paper presents an investigation of the potential of Chinese vegetation to degrade cyanide. Detached leaves (1.5 g fresh weight) from 28 species of 23 families were kept in glass vessel with 100 ml of aqueous solution spiked with potassium cyanide at 23.5degreeC for 28 h. Cyanide concentrations ranged from 0.83 to 1.0 CN mg l-1. The disappearance of cyanide front the aqueous solution was analyzed spectrophotometrically. The fastest cyanide removal was by Chinese elder, Sambucus *chinensis*, with a removal capacity of 8.8 mg CN kg-1 h-1, followed by upright hedge-parsley (Torilis japonica) with a value of 7.5 mg CN kg-1 h-1. The lowest removal capacity had the snow-pine tree (Credrus deodara (Roxb.) Loud). Results from this investigation indicated that a wide range of plant species is able to efficiently metabolize cyanide. Therefore, cyanide elimination with plants seems to be a feasible option for cleaning soils and water contaminated by cyanide from gold and silver mines or from other sources.

Yu, X., S. Trapp, et al. (2005). Phytotoxicity of cyanide to weeping willow trees. Environmental Science and Pollution Research. X. Yu. 12: 109. A study was conducted to determine the toxicity of potassium cyanide (KCN) to weeping willow trees (*Salix* babylonica) as well as the removal capacity of the weeping willows. The normalized, relative transpiration of the plants was used to determine the phytotoxicity of cyanide. Results and Discussion. In hydroponic solution, no chlorosis of leaves and only a small reduction in normalized relative transpiration was observed when weeping willows were exposed to low doses of cyanide (<= 0.93 mg CN/litre). Severe signs of toxicity were found for the treatment groups exposed to higher doses of cyanide (>= 9.3 mg CN/litre). Weeping willows grown in sandy soils survived the entire period (216 h) without any toxic effect when irrigated with low doses of cyanide (3.72 mg CN/litre). High doses of cyanide (>= 18.6 mg CN/litre) in irrigation water were fatal for the weeping willows within 216 h. EC50 values for a 50% inhibition of the transpiration of the trees were estimated to be between 3.27 and 8.23 mg CN/litre, depending on the duration of the exposure. Conclusions. The results obtained for the Chinese willow species *Salix* babylonica were very similar to those obtained for the European species S. *viminalis* in earlier studies. Phytotoxic effects were only found at high doses of cyanide. A large proportion of applied cyanide was removed from the contaminated media in the presence of weeping willows. This gives rise to the conclusion that the metabolism of cyanide by weeping willows is possible. Recommendations and Outlook. Cyanide elimination with trees seems to be a feasible option for cleaning soils and water contaminated with cyanide. A full-scale treatment has been installed in Denmark. For phytoremediation projects in China, weeping willow could be a suitable species. The tree can tolerate and remove cyanide, and it is a native Chinese species. Besides, the tree is of outstanding beauty and is planted as a common park tree in many parts of the world.

Yu, X., S. Trapp, et al. (2005). The effect of temperature on the rate of cyanide metabolism of two woody plants. Chemosphere. X. Yu. 59: 1099. The response of cyanide metabolism rates of two woody plants to changes in temperature is investigated. Detached leaves (1.0 g fresh weight) from weeping willow (*Salix* babylonica L.) and Chinese elder (Sambucus *chinensis* Lindl.) were kept in glass vessels with 100 ml of aqueous solution spiked with potassium cyanide for a maximum of 28 h. Ten different temperatures were used ranging from 11degreesC to 32degreesC. The disappearance of aqueous cyanide was analyzed spectrophotometrically. The cyanide removal rate of Chinese elder was higher than that of weeping willow at all temperatures. The highest cyanide removal rate for Chinese elder was found at 30degreesC with a value of 12.6 mg CN kg-1 h-1, whereas the highest value of the weeping willow was 9.72 mg CN kg-1 h-1 at 32degreesC. The temperature coefficient values, Q10, which are the ratio of removal rates at a 10 degree difference, were determined for Chinese elder and weeping willow to 1.84 and 2.09, respectively, indicating that the cyanide removal rate of weeping willow was much more susceptible to changes in temperature than that of the Chinese elder. In conclusion, changes in temperature have a substantial influence on the removal rate of cyanide by plants.

Yu, X., X. Peng, et al. (2006). Potentials of Salicaceae plants for phytoremediation of cyanide. Journal of Hunan Agricultural University. X. Yu. 32: 81. The potential of woody plants from the Salicaceae family to degrade cyanide was investigated. Pre-rooted trees were grown in the laboratory in spiked hydroponic solution. Initial cyanide concentrations were 0.45 to 0.49 mg/L. Samples were directly taken from the solution and the cyanide concentrations were determined spectrophotometrically. The removal rate of cyanide from the aqueous solution by trees varied with plant species. The highest cyanide elimination of 97.8% (0.095 mg/(kg h), weight of the whole tree) was by weeping willow (*Salix* babylonica) during 72 h exposure, followed by hybrid willow (*Salix* matsudana x *Salix* alba) with a value of 94.0% (0.087 mg/(kg . h)) during 108 h exposure. The lowest cyanide elimination of 71.4% (0.057 mg/(kg . h)) was by poplar (*Populus deltoides*) during 120 h exposure. The results indicate that a large proportion of cyanide can be removed from a contaminated aqueous medium through metabolism by trees. Doses (<= 0.49 mg/L) used in this study were not toxic to the tested trees. Cyanide removal processes from hydroponic solution by trees followed zero order reaction. In conclusion, cyanide removal from cyanide-contaminated wastewater by plants seems to be a feasible option.

Yu, X.-z., J.-j. Lei, et al. (2006). Bioavailability of cyanide in the different environmental compartments. Journal of Environmental Sciences (China) 18(2): 347-352. Vascular plants possess an enzyme system that detoxifies cyanide by converting it to the amino acid asparagine. Hybrid willows (*Salix* matsudana

Koidzx*Salix alba* L.) were exposed to cyanide to determine whether willows can transport and metabolize this compound. Pre-rooted trees were grown in different environmental compartments spiked or irrigated with potassium cyanide at 24.0 +/- 0.5 degrees C. Cyanide in compartments, in air and in tissues of plants was analyzed spectrophotometrically. Results from this study indicated that large amounts of applied cyanide was removed from the systems during the presence of willows. Growing compartments of plants have a strong influence on the removal rates of cyanide. Little or no initial cyanide was detected in plant materials. Volatilization of cyanide was not occurring. Mass balance studies showed that applied cyanide was significantly metabolized during transport through willows cuttings. However, there was a clear difference between the metabolism rates of cyanide by willows exposed to different environmental compartments. The highest cyanide metabolism rate was found at the treatment with willows growing in hydroponic solution with a metabolism rate of 2.44 mgCN/ (kg center dot d), followed by willows growing in sand with a value of 1.02 mgCN/(kg center dot d). The lowest metabolism rate had the willows growing in soils(0.43 mgCN/(kg center dot d)). In conclusion, transport and metabolism of cyanide in plants is likely and phytoremediation of cyanide is a feasible option for cleaning soils and water contaminated with cyanide.

Yu, X.-Z., P.-H. Zhou, et al. (2006). The potential for phytoremediation of iron cyanide complex by willows. Ecotoxicology 15(5): 461-467. Hybrid willows (*Salix* matsudana Koidz X *Salix alba* L.), weeping willows (*Salix* babylonica L.) and hankow willows (*Salix* matsudana Koidz) were exposed to potassium ferrocyanide to determine the potential of these plants to extract, transport and metabolize this iron cyanide complex. Young rooted cuttings were grown in hydroponic solution at 24.0 +/- 0.5 degrees C for 144 h. Ferrocyanide in solution, air, and aerial tissues of plants was analyzed spectrophotometrically. Uptake of ferrocyanide from the aqueous solution by plants was evident for all treatments and varied with plant species, ranging from 8.64 to 15.67% of initial mass. The uptake processes observed from hydroponic solution showed exponential disappearance kinetics. Very little amounts of the applied ferrocyanide were detected in all parts of plant materials, confirming passage of ferrocyanide through the plants. No ferrocyanide in air was found due to plant transpiration. Mass balance analysis showed that a large fraction of the reduction of initial mass in hydroponic solution was metabolized during transport within the plant materials. The difference in the metabolic rate of ferrocyanide between the three plant species was comparably small, indicating transport of ferrocyanide from hydroponic solution to plant materials and further transport within plant materials was a limiting step for assimilating this iron cyanide complex. In conclusion, phytoremediation of ferrocyanide by the plants tested in this study has potential field application.

Yu, X.-Z., P.-H. Zhou, et al. (2006). Uptake, metabolism, and toxicity of iron cyanide complex in weeping willows. Journal of Tropical and Subtropical Botany 14(1): 1-6. Uptake, metabolism and toxicity of iron cyanide complex in trees were investigated. Pre-rooted weeping willows (*Salix* babylonica L.) were exposed to hydroponic solution spiked with ferrocyanide at 24.0 +/- 1 degrees C for 192 h. Four different treatment concentrations of ferrocyanide were used (52.99, 105.98, 211.95 and 317.93 mg CN L-1). Cyanide in water, in tissues of aerial part of plants and in air was analyzed spectrophotometrically. Results from this study indicated less than 10.85% reduction of the applied iron cyanide complex was detected in hydroponic solution in the presence of plants. Little amounts of cyanide were found in all parts of plant tissues, indicating the passage of ferrocyanide through the plants. Mass balance studies showed that iron cyanide complex moving into plants from hydroponic solution can be metabolized during transport. Phytotoxic effects were not found in all treatment groups, even at high doses of ferrocyanide within a 192-h exposure period. In conclusion, transport and metabolism of ferrocyanide in plants is most likely to happen and phytoremediation of this iron cyanide complex in field application may be possible.

Yuan, M., B. Tie, et al. (2005). Effects of different modifiers on growth and chlorophyll content of Eulaliopsis binata growing on soil polluted by lead/zinc gangue. Rural Eco-Environment. M. Yuan. 21: 54. The effects of four kinds of modifiers on growth and chlorophyll content of Eulaliopsis binata growing on the soil polluted by lead/zinc gangue were investigated. The results showed that the plants in the treated soils grew much better than in CK, with biomass of the shoots increased by over 100% (P <= 0.05). All the four kinds of modifiers lightened the poisoning effect of the heavy metals on Eulaliopsis binata, but varied in effect in the order of calcium magnesium phosphate > CaCO3 > organic manure > sea-foam. With the

increase of the application rate of CaCO3, biomass and chlorophyll content of Eulaliopsis binata presented a downward trend; while with the rise of the application rate of the other three, biomass of Eulaliopsis binata showed an ascendant trend, but chlorophyll content showed an increasing then a decreasing trend.

Yuan, M., B. Tie, et al. (2005). The applying of phytoremediation combination technology to remediate heavy metal contaminated soil. Journal of Yunnan Agricultural University. M. Yuan. 20: 274. The concept, merits, types, and application of phytoremediation combination technology using plants and other means to remediate heavy metals contaminated soil are introduced.

Yuan, Y., J.-P. Sheng, et al. (2004). Callus induction and root differentiation from Altenanthera philoxeroides. Acta Hydrobiologica Sinica 28(6): 622-628. With the development of modern industry and agriculture, a major problem faced by the modem world: environmental pollution. The lack of affordable, effective approaches to environmental remediation has created a major need for development of novel approaches. Plant have many endogenous genetic, biochemical, and physiological properties that make them ideal agents for soil and water remediation. Significant progress has been made in recent years in developing native or genetically modified plants for the remediation of environment contaminants. Improvement of plants by genetic engineering open up new possibilities for phytoremediation. Tissue culture is prerequisite to plant genetic engineering. Alternanthera philoxeroides may be useful in remediation of environmental pollutants by transgenic engineering. But there is no report on tissue culture of Alternanthera philoxeroides. Alternanthera philoxeroides is dicotyledon. It was collected from the suburb of YangZhou in JiangSu Province. In this paper, it were studied that effect of NaClO, AgNO3 and HgCl2 solution to sterilization of A. philoxeroides. Contamination rate were from 40% to 50% and germination rate were below 10% after stems with axillary bud of A. philoxeroides. were sterilized with 20% NaClO solution for 10-20 minutes. It was applicable to stems with axillary bud of A. philoxeroides to sterile with 1% AgNO3 solution for 20-25 minutes. contamination rate of A. philoxeroides were from 11.1% to 0 and germination rate were from 55.6% to 50% or to sterile with 0.1% HgCl2 solution for 3-5 minutes, contamination rate were from 25% to 0 and germination rate were from 58.3% to 44.4%. The results showed that the necessary time for killing bacteria contaminated in the tested material with 1% AgNO3 was 20-25 minutes of with 0.1% HgCl2 was 3-5 minutes. This study examined the effects of explants, media and exogenous phytohormone on tissue culture of Alternanthera philoxeroides. The stems, leaves and roots were used as the explants to study tissue cultue. Different basic media (MS, 1/2MS, MS(1/2), B5), 0-0.5mg/L of indoleacetic acid (LAA), 0-0.2mg/L of naphthyl acetic acid (NAA), 0.5-5.0mg/L of 6-benzylaminopurine(6-BA) and 0.5-4.0mg/L of *Zea*tin (ZT)as additional compositions were used for inducing, differentiating and rooting tests. Induced results showed that 1/2 MS was more suitable for calli to grow and divide than B5 I MS(1/2) and MS. The stem and leaf of Alternanthera philoxeroides were suitable organs for tissue culture. Stem > leaf was observed on growth rate. The combinations of NAA and BA or IAA and ZT can induce calli of the stem and leaf of Alternanthera philoxeroides, and the rate of calli induction increases with the increase of BA concentration. The higher rate of NAA/BA, the more roots from the calli format. It was thought that the results of this study could provide an useful basis for genetic transformation of Alternanthera philoxeroides.

Yurekli, F. and Z. Kucukbay (2003). Synthesis of phytochelatins in *Helianthus annuus* is enhanced by cadmium nitrate. Acta Botanica Croatica 62(1): 21-25. Phytochelatins are the principal heavy metal-detoxifying components in plants. To investigate phytochelatin (PHC) production and the importance of these compounds for heavy metal tolerance, sunflower (*Helianthus annuus*) was exposed to cadmium. The leaves and roots of sunflower plants cultivated in the presence of 15, 25 and 50 muM Cd(NO3)2 for 3 and 9 days showed increased tolerance to cadmium and contained higher concentrations of phytochelatins. The phytochelatin level was assayed by using HPLC and the Cd level was determined by atomic spectrum analysis.