

Vacchina, V., S. Mari, et al. (2003). Speciation of nickel in a hyperaccumulating plant by high-performance liquid chromatography-inductively coupled plasma mass spectrometry and electrospray MS/MS assisted by cloning using yeast complementation. *Analytical Chemistry* (Washington). V. Vacchina. 75: 2740. A novel analytical approach based on a combination of multidimensional hyphenated techniques and cloning of the Ni-resistance gene using yeast complementation screens was developed for the identification of nickel species in a *Thlaspi caerulescens* hyperaccumulating plant. The presence of an unknown strong Ni complex was demonstrated by size exclusion HPLC-capillary electrophoresis with ICPMS detection. The Ni-containing peak was characterized by electrospray MS (m/z 360) and shown by collision-induced dissociation MS to be a chelate with a tricarboxylic amino acid ligand. To identify the species and demonstrate its functional character, a cDNA library was constructed from *T. caerulescens*, expressed in the yeast, and screened on a toxic Ni²⁺ medium. The extract from the surviving transformant culture gave identical HPLC-ICPMS, CZE-ICPMS, and ES MS/MS data and contained a cDNA insert homologous to the nicotianamine synthase gene. This observation allowed the identification of nicotianamine as the nickel-binding ligand. The presence of the Ni-nicotianamine complex was ultimately demonstrated by comparing tandem mass spectra of the plant and yeast extracts with those of a synthetic standard.

Vajpayee, P., U. N. Rai, et al. (2005). Possible involvement of oxidative stress in copper induced inhibition of nitrate reductase activity in *Vallisneria spiralis* L. *Bulletin of Environmental Contamination and Toxicology* 74(4): 745-754.

Vajpayee, P., U. N. Rai, M. B. Ali, R. D. Tripathi, V. Yadav, S. Sinha and S. N. Singh (2001). Chromium-Induced Physiologic Changes in *Vallisneria Spiralis* L. And Its Role in Phytoremediation of Tannery Effluent. *Bulletin of Environmental Conamination and Toxicology* 67(2): 246-256.

Vajpayee, P., U.N. Rai, S. Sinha, R.D. Tripathi, and P. Chandra (1995). Bioremediation of tannery effluent by aquatic macrophytes. *Bull. Environ. Contam. Toxicol.* 55:546-553.

Vale, C., F.M. Catarino, C. Cortesao, and M.I. Cacador (1990). Presence of metal-rich rhizoconcretions on the roots of *Spartina maritima* from the salt marshes of the Tagus Estuary, Portugal. *Sci. Total Environ.* 97-98:617-627.

Vallini, G., S. Di Gregorio, et al. (2005). Rhizosphere-induced selenium precipitation for possible applications in phytoremediation of se polluted effluents. *Zeitschrift Fur Naturforschung C-a Journal of Biosciences* 60(3-4): 349-356. Two bacterial isolates were obtained in axenic culture from the rhizosphere soil of *Astragalus bisulcatus*, a legume able to hyperaccumulate selenium. Both strains resulted of particular interest for their high resistance to the toxic oxyanion SeO₃²⁻ (selenite, Se-IV). On the basis of molecular and biochemical analyses, these two isolates were attributed to the species *Bacillus mycoides* and *Stenotrophomonas maltophilia*, respectively. Their capability in axenic culture to precipitate the soluble, bioavailable and highly toxic selenium form selenite to insoluble and relatively non-toxic Se-0 (elemental selenium) was evaluated in defined medium added with 0.2 or 0.5 mm Se-IV. Both strains showed to completely reduce 0.2 mm selenite in 120 h, while 0.5 mm Se-IV was reduced up to 67% of the initial concentration by *B. mycoides* and to about 50% by *S. maltophilia* in 48 h. Together in a dual consortium, *R. mycoides* and *S. maltophilia* increased the kinetics of selenite reduction, thus improving the efficiency of the process. A model system for selenium rhizofiltration based on plant-rhizobacteria interactions has been proposed.

Valsaraj, K.T., D. Constant, K. Ro, and L. Thibodeaux (1996). Fundamental studies on TNT transport from soil to water. HSRC S&SW Research Brief #12. Atlanta, GA.

Van Aken, B. and J. L. Schnoor (2002). Evidence of perchlorate (ClO₄⁻) reduction in plant tissues (poplar tree) using radio-labeled (ClO₄⁻)-C-36. *Environmental Science & Technology* 36(12): 2783-2788. Phytoremediation of perchlorate (ClO₄⁻) by poplar trees *Populus deltoides nigra* was investigated using small cuttings growing in hydroponic Hoagland solution and plant tissue cultures, consisting of spherical

photosynthetic cell aggregates (i.e. nodules) developing in Murashige and Skoog culture medium. Both plants and nodules were grown under a 16 h/8 h photoperiod cycle and under sterile conditions. Degradation experiments, performed by the incubation of pregrown plants and nodules in the presence of Cl-36 radio-labeled ClO₄⁻ (25 mg L⁻¹), showed a reduction of the initial ClO₄⁻ concentration in the solution of about 50% after 30 d of incubation. Analysis of the distribution of radioactivity in different plant fractions indicated that 27.4% of the total was translocated to the leaves, while 66.9% remained in the solution. Very little radioactivity (less than 3.0%) was detected in the other parts of the plants. 32.0% of the radioactivity recovered in the solution was shown to consist of Cl-36(-) and 68.0% of nontransformed (ClO₄⁻)-Cl-36. The radioactivity recovered in the leaf extracts was distributed as chloride (Cl-36(-)) (1.6% of the total), chlorite ((ClO₂⁻)-Cl-36) (2.4%), chlorate ((ClO₃⁻)-Cl-36) (4.8%), nontransformed (ClO₄⁻)-Cl-36 (21.6%), and an unidentified organic compound (1.4%). The radioactivity recovered in the solution containing submerged nodules consisted of Cl-36(-) (6.4% of the total), (ClO₃⁻)-Cl-36 (1.3%), and nontransformed (ClO₄⁻)-Cl-36 (51.5%). Radioactivity detected in the nodule extracts was distributed as Cl-36(-) (2.0% of the total), (ClO₂⁻)-Cl-36 (5.2%), (ClO₃⁻)-Cl-36 (6.4%), (ClO₄⁻)-Cl-36 (22.7%), and an unidentified organic compound (0.5%). These results provide evidence of perchlorate reduction inside poplar tree tissues. (ClO₄⁻)-Cl-36 is partially reduced to (ClO₃⁻)-Cl-36, (ClO₂⁻)-Cl-36, and Cl-36(-).

Van Aken, B., J. M. Yoon, et al. (2004). Biodegradation of nitro-substituted explosives 2,4,6-trinitrotoluene, hexahydro-1,3,5-trinitro-1,3,5-triazine, and octahydro-1,3,5,7-tetranitro-1,3,5-tetrazocine by a phytosymbiotic *Methylobacterium* sp. associated with poplar tissues (*Populus deltoides* × *nigra* DN34). *Applied and Environmental Microbiology* 70(1): 508-517. A pink-pigmented symbiotic bacterium was isolated from hybrid poplar tissues (*Populus deltoides* × *nigra* DN34). The bacterium was identified by 16S and 16S-23S intergenic *spA* ribosomal DNA analysis as a *Methylobacterium* sp. (strain BJ001). The isolated bacterium was able to use methanol as the sole source of carbon and energy, which is a specific attribute of the genus *Methylobacterium*. The bacterium in pure culture was shown to degrade the toxic explosives 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-tetrazocine (HMX). (U-ring-¹⁴C)TNT (25 mg liter⁻¹) was fully transformed in less than 10 days. Metabolites included the reduction derivatives amino-dinitrotoluenes and diamino-nitrotoluenes. No significant release of ¹⁴CO₂ was recorded from (¹⁴C)TNT. In addition, the isolated methylotroph was shown to transform (U-¹⁴C)RDX (20 mg liter⁻¹) and (U-¹⁴C)HMX (2.5 mg liter⁻¹) in less than 40 days. After 55 days of incubation, 58.0% of initial (¹⁴C)RDX and 61.4% of initial (¹⁴C)HMX were mineralized into ¹⁴CO₂. The radioactivity remaining in solution accounted for 12.8 and 12.7% of initial (¹⁴C)RDX and (¹⁴C)HMX, respectively. Metabolites detected from RDX transformation included a mononitroso RDX derivative and a polar compound tentatively identified as methylenedinitramine. Since members of the genus *Methylobacterium* are distributed in a wide diversity of natural environments and are very often associated with plants, *Methylobacterium* sp. strain BJ001 may be involved in natural attenuation or in situ biodegradation (including phytoremediation) of explosive-contaminated sites.

Van Aken, B., J. M. Yoon, et al. (2004). Metabolism and mineralization of hexahydro-1,3,5-trinitro-1,3,5-triazine inside poplar tissues (*Populus deltoides* × *nigra* DN-34). *Environmental Science & Technology* 38(17): 4572-4579. Poplar tissue cultures and leaf crude extracts (*Populus deltoides* × *nigra* DN-34) were exposed to (U-¹⁴C)hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and incubated under light and in the dark. Poplar tissue cultures were able to partially reduce RDX to hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine (MNX) and hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine (DNX), regardless of the presence or absence of light. However, further transformation of RDX, MNX, and DNX required exposure to light and resulted in the formation of formaldehyde (CH₂O), methanol (CH₃OH), and carbon dioxide (CO₂). Similarly, transformation of RDX by poplar leaf crude extracts required exposure to light. Neither reduction of RDX to MNX and DNX nor mineralization into CO₂ were recorded in crude extracts, even when exposed to light, suggesting that both processes were light-independent and required intact plant cells. Control experiments without plant material showed that RDX was partially transformed abiotically, by the sole action of light, but to a lesser extent than in the presence of plant crude extracts, suggesting the intervention of plant subcellular structures through a light-mediated mechanism. Poplar tissue cultures were also shown to mineralize ¹⁴CH₂O and ¹⁴CH₃OH, regardless of the presence or absence of light. These results suggest that transformation of (U-¹⁴C)RDX by plant tissue cultures may occur through a three-step process, involving (i) a light-independent reduction of RDX to MNX and DNX by intact plant

cells; (ii) a plant/light-mediated breakdown of the heterocyclic ring of RDX, MNX, or DNX into Cl-labeled metabolites (CH₂O and CH₃OH); and (iii) a further light-independent mineralization of C1-labeled metabolites by intact plant cells. This is the first time that a significant mineralization of RDX into CO₂ by light-exposed plant tissue cultures is reported.

Van der Lelie, D., J. P. Schwitzguebel, D. J. Glass, J. Vangronsveld and A. Baker (2001). Assessing Phytoremediation's Progress in the United States and Europe. *Environ. Sci. & Technol.* 35(21): 446A-452A.

Van Hoewyk, D., G. F. Garifullina, et al. (2005). Overexpression of AtCpNifS enhances selenium tolerance and accumulation in *Arabidopsis*. *Plant Physiology* 139(3): 1518-1528. Selenium (Se) is an essential element for many organisms but is toxic at higher levels. CpNifS is a chloroplastic NifS-like protein in *Arabidopsis* (*Arabidopsis thaliana*) that can catalyze the conversion of cysteine into alanine and elemental sulfur (S⁰) and of selenocysteine into alanine and elemental Se (Se⁰). We overexpressed CpNifS to investigate the effects on Se metabolism in plants. CpNifS overexpression significantly enhanced selenate tolerance (1.9-fold) and Se accumulation (2.2-fold). CpNifS overexpressors showed significantly reduced Se incorporation into protein, which may explain their higher Se tolerance. Also, sulfur accumulation was enhanced by approximately 30% in CpNifS overexpressors, both on media with and without selenate. Root transcriptome changes in response to selenate mimicked the effects observed under sulfur starvation. There were only a few transcriptome differences between CpNifS-overexpressing plants and wild type, besides the 25- to 40-fold increase in CpNifS levels. Judged from x-ray analysis of near edge spectrum, both CpNifS overexpressors and wild type accumulated mostly selenate (SeVI). In conclusion, overexpression of this plant NifS-like protein had a pronounced effect on plant Se metabolism. The observed enhanced Se accumulation and tolerance of CpNifS overexpressors show promise for use in phytoremediation.

Van Huysen, T., N. Terry, et al. (2004). Exploring the selenium phytoremediation potential of transgenic Indian mustard overexpressing ATP sulfurylase or cystathionine-gamma-synthase. *International Journal of Phytoremediation* 6(2): 111-118. Indian mustard (*Brassica juncea*) plants overexpressing ATP sulfurylase (APS transgenics) were previously shown to have higher shoot selenium (Se) levels and enhanced Se tolerance compared to wild type when supplied with selenate in a hydroponic system. Other transgenic Indian mustard overexpressing cystathionine-gamma-synthase (CGS) showed a higher Se volatilization rate, lower shoot Se levels, and higher Se tolerance than wild type, also in hydroponic studies. In the present study, these APS and CGS transgenics were evaluated for their capacity to accumulate Se from soil that is naturally rich in Se. Wildtype Indian mustard and the Se hyperaccumulator *Stanleya pinnata* were included for comparison. After 10 weeks on Se soil, the APS transgenics contained 2.5-fold higher shoot Se levels than wild-type Indian mustard, similar to those of *S. pinnata*. The CGS transgenics contained 40% lower shoot Se levels than wild type. Shoot biomass was comparable for all Indian mustard types and higher than that of *S. pinnata*. These results obtained with these transgenics on soil are in agreement with those obtained earlier using hydroponics. The significance of these findings is that they are the first report on the performance of transgenic plants on Se in soil and show the potential of genetic engineering for phytoremediation.

Van Huysen, T., S. Abdel-Ghany, et al. (2003). Overexpression of cystathionine-gamma-synthase enhances selenium volatilization in *Brassica juncea*. *Planta* (Berlin) 218(1): 71-78. Selenium (Se) can be assimilated and volatilized via the sulfate assimilation pathway. Cystathionine-gamma-synthase (CGS) is thought to catalyze the synthesis of Se-cystathionine from Se-cysteine, the first step in the conversion of Se-cysteine to volatile dimethylselenide. Here the hypothesis was tested that CGS is a rate-limiting enzyme for Se volatilization. Cystathionine-gamma-synthase from *Arabidopsis thaliana* (L.) Heynh. was overexpressed in Indian mustard (*Brassica juncea* (L.) Czern & Coss), and five transgenic CGS lines with up to 10-fold enhanced CGS levels were compared with wild-type Indian mustard with respect to Se volatilization, tolerance and accumulation. The CGS transgenics showed 2- to 3-fold higher Se volatilization rates than wild-type plants when supplied with selenate or selenite. Transgenic CGS plants contained 20-40% lower shoot Se levels and 50-70% lower root Se levels than the wild type when supplied with selenite. Furthermore, CGS seedlings were more tolerant to selenite than the wild type.

There were no differences in Se accumulation or tolerance from selenate, in agreement with the earlier finding that selenate-to-selenite reduction is rate-limiting for selenate tolerance and accumulation. In conclusion, CGS appears to be a rate-limiting enzyme for Se volatilization. Overexpression of CGS offers a promising approach for the creation of plants with enhanced capacity to remove Se from contaminated sites in the form of low-toxic volatile dimethylselenide.

Van Mantgem, P.J., L. Wu, and G.S. Bañuelos. (1996). Bioextraction of selenium by forage and selected field legume species in selenium-laden soils under minimal field management conditions. *Journal of Ecotoxicology and Environmental Safety* 34:228-238.

Van Rossum, F., I. Bonnin, et al. (2004). Spatial genetic structure within a metalicolous population of *Arabidopsis halleri*, a clonal, self-incompatible and heavy-metal-tolerant species. *Molecular Ecology* 13(10): 2959-2967. *Arabidopsis halleri*, a close wild relative of *A. thaliana*, is a clonal, insect-pollinated herb tolerant to heavy metals (Zn, Pd, Cd) and a hyperaccumulator of Zn and Cd. It is of particular interest in the study of evolutionary processes and phytoremediation. However, little is known about its population gene flow patterns and the structure of its genetic diversity. We used five microsatellite loci to investigate the genetic structure at a fine spatial scale (10 cm to 500 m) in a metalicolous population of *A. halleri*. We also studied the contributions made by clonal propagation and sexual reproduction (seed and pollen dispersal) to the genetic patterns. Clonal diversity was high ($D-G > 0.9$). Clonal spread occurs only at short distances (< 1 m). Both clonal spread and limited dispersal, associated with sexual reproduction, contribute to the significant spatial genetic structure revealed by spatial autocorrelation analysis. The shape of the autocorrelogram suggests that seed dispersal is restricted and pollen flow extensive, which may be related to intense activity by insect pollinators. Clonal spread was more extensive in the lowly polluted zone than in the highly polluted zone. This cannot be interpreted as a strategy for promoting the propagation of adapted genotypes under the harshest ecological constraints (highest heavy metal concentrations). The higher fine-scale spatial genetic structure found in the lowly polluted zone can be ascribed to plant densities that were lower than in the highly polluted zone. No evidence of genetic divergence due to spatial heavy metal heterogeneity was found between lowly and highly polluted zones.

Vance, D.B (1996). Phytoremediation: Enhancing natural attenuation processes. *Natl. Environ. J.* 6:30-32.

Vandecasteele, B., E. Meers, et al. (2005). Growth and trace metal accumulation of two *Salix* clones on sediment-derived soils with increasing contamination levels. *Chemosphere* 58(8): 995-1002. The growth and metal uptake of two willow clones (*Salix fragilis* 'Belgisch Rood' and *Salix viminalis* 'Aage') was evaluated in a greenhouse pot experiment with six sediment-derived soils with increasing field Cd levels (0.9-41.4 mg kg⁻¹). Metal concentrations of eight elements were measured in roots, stems and leaves and correlated to total and soil water metal concentrations. Dry weight root biomass, number of leaves and shoot length were measured to identify eventual negative responses of the trees. No growth inhibition was observed for both clones for any of the treatments (max. 41.4 mg kg⁻¹ Cd, 1914 mg kg⁻¹ Cr, 2422 mg kg⁻¹ Zn, 655 mg kg⁻¹ Pb), allowing their use for phytoextraction on a broad range of contaminated sediments. However, dry weight root biomass and total shoot length were significantly lower for *S. viminalis* compared to *S. fragilis* for all treatments. Willow foliar Cd concentrations were strongly correlated with soil and soil water Cd concentrations. Both clones exhibited high accumulation levels of Cd and Zn in aboveground plant parts, making them suitable subjects for phytoextraction research. Cu, Cr, Pb, Fe, Mn and Ni were found mainly in the roots. Bioconcentration factors of Cd and Zn in the leaves were highest for the treatments with the lowest soil Cd and Zn concentration. (C) 2004 Elsevier Ltd.

Vandenhove, H. and M. v. Hees (2004). Phytoremediation for clean-up of low-level uranium contaminated soil evaluated. *Journal of Environmental Radioactivity*. H. Vandenhove. 72: 41. Spills in the nuclear fuel cycle have led to soil contamination with uranium. In case of small contamination just above release levels, low-cost yet sufficiently efficient remedial measures are recommended. This study was executed to test if low-level U contaminated sandy soil from a nuclear fuel processing site could be phytoextracted in order to attain the required release limits. Two soils were tested: a control soil (317 Bq 238U kg⁻¹) and the same soil washed with bicarbonate (69 Bq 238U kg⁻¹). Ryegrass (*Lolium perenne* cv. Melvina) and Indian mustard (*Brassica juncea* cv. Vitasso) were used as test plants. The annual removal of soil activity by the

biomass was less than 0.1%. The addition of citric acid (25 mmol kg⁻¹) 1 week before the harvest increased U uptake up to 500-fold. With a ryegrass and mustard yield of 15,000 and 10,000 kg ha⁻¹, respectively, up to 3.5% and 4.6% of the soil activity could be removed annually by the biomass. With a desired activity reduction level of 1.5 and 5 for the bicarbonate-washed and control soil, respectively, it would take 10-50 years to attain the release limit. However, citric acid addition resulted in a decreased dry weight production.

Vandenhove, H., F. Goor, et al. (2004). Short rotation coppice as alternative land use for Chernobyl-contaminated areas of Belarus. *International Journal of Phytoremediation*. H. Vandenhove. 6: 139. Field experiments were conducted in the Chernobyl-affected area of Belarus to assess if short rotation coppice (SRC) for energy production is a feasible alternative for contaminated land. Four willow (*Salix*) clones were planted on sandy and peaty soil and the radiocaesium (137Cs) and radiostrontium (90Sr) transfer factors (TF) and yield relevant parameters were recorded during four growing seasons. The 137Cs and 90Sr soil-to-willow wood TF on sandy soil (second growing season) were on average $1.40 \pm 1.06 \times 10^{-3}$ m² kg⁻¹ and $130 \pm 74 \times 10^{-3}$ m² kg⁻¹, respectively. The 137Cs TF recorded for the peaty soil (fourth growing season or end of the first rotation cycle) was on average $5.17 \pm 1.59 \times 10^{-3}$ m² kg⁻¹. The 90Sr-TF was on average $2.61 \pm 0.44 \times 10^{-3}$ m² kg⁻¹. No significant differences between clones for the 137Cs and 90Sr-TF were observed. Given the high TFs and the high deposition levels, Belarus exemption levels for fuelwood were highly exceeded. The annual average biomass production for one rotation cycle on the peaty soil ranged from 7.8 to 16.0 tonnes ha⁻¹ year⁻¹ for one of the clones, comparable with average annual yield figures obtained for western Europe. On the sandy soils, first-year yields were 0.25 tonnes ha⁻¹ year⁻¹. These soils are not suitable for SRC production and should better be dedicated to pine forests or drought-resistant grasses.

Vanderford, M., J.V. Shanks, and J.B. Hughes (1997). Phytotransformation of trinitrotoluene (TNT) and distribution of metabolic products in *Myriophyllum aquaicum*. *Biotechnol. Letters*. 19(3):277.

Vanek, T., P. Soudek and R. Tykva (2001). Study of Radiophytoremediation. *Minerva Biotechnologica* 13(2): 117-121.

Vangronsveld, J. and S.L. Cunningham (eds.) (1998). *In-Situ Inactivation and Phytoremediation of Metal-Contaminated Sites*. R.G. Landes Bioscience Publishers.

Vangronsveld, J., and H. Clijsters (1995). Poster Abstract: Reclamation of bare areas, contaminated by non-ferrous metals: in situ metal immobilization and revegetation with metal tolerant plants. Pp. 124-125. 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, 1995, Columbia, MO. Interdisciplinary Plant Group, University of Missouri, Columbia, MO.

Vangronsveld, J., F. Van Assche, and H. Clijsters (1995). Reclamation of a bare industrial area contaminated by non-ferrous metals: In situ metal immobilization and revegetation. *Environ. Pollut.* 87:51-59.

Vangronsveld, J., J. Strecks, F. Van Assche, and H. Clijsters (1995). Rehabilitation studies on an old non-ferrous waste dumping ground: effects of revegetation and metal immobilization by beringite. *J. Geochem. Explor.* 52:221-229.

Vangronsveld, J., J.V. Colpaert, and H. Clijsters (1996). Rehabilitation of soils contaminated by non-ferrous metals: Possibilities of in situ metal immobilization and phytostabilization. *International Phytoremediation Conference*, May 8-10, 1996, Arlington, VA. International Business Communications, Southborough, MA.

Vangronsveld, J., J.V. Colpaert, and K.K. Van Tichelen (1996). Reclamation of a bare industrial area contaminated by non-ferrous metals: Physico-chemical and biological evaluation of the durability of soil treatment and revegetation. *Environ. Pollut.* 94:131-140.

Vangrovensveld, J., and H. Clijsters (1991). A biological test system for the evaluation of metal phytotoxicity and immobilization by additives in metal contaminated soils. *Metal Compounds in Environ. Life.* 4:117-125.

Vardanyan, L. G. and B. S. Ingole (2006). Studies on heavy metal accumulation in aquatic macrophytes from Sevan (Armenia) and Carambolim (India) lake systems. *Environment International.* 32: 208. Aquatic macrophytes are unchangeable biological filters and they carry out purification of the water bodies by accumulating dissolved metals and toxins in their tissue. In view of their potential to entrap several toxic heavy metals, 45 macrophytes belonging to 8 families collected from two different physiographic locations (36 from Sevan Lake, Armenia; 9 from Carambolim Lake, Old Goa, India) were studied for estimation of 14 heavy metals. The study was aimed at understanding the importance of these macrophytes in accumulation of toxic metals and controlling the heavy metal pollution and suggesting the remedial measures, if any, for the preservation and restoration of lake ecosystem. Inductively Coupled Plasma-Atomic Emission Spectrometric (ICP-AES) analyses of these aquatic macrophytes have shown the importance of aquatic macrophytes in accumulation of heavy metals and maintaining the clarity of water bodies beside their role in trophic systems. Accumulation of most of the heavy metals was higher in root system. The representative macrophytes from two different physiographic locations show similar trends and order in accumulating different metals generally. Of the 14 metals investigated, 9 (Ca, Fe, Al, Cr, Cu, Ba, Ti, Co and Pb) showed higher rates of accumulation in the root whereas 3 (Mn, Zn and Mg) showed more accumulation in stem and 1 (Ca) showed higher accumulation in the leaves. In most of the samples Cu was accumulated more in the roots (50 +- 47.15 microg/g) and less in flowers (9.52 +- 3.97 microg/g). Occurrence of heavy metal was much higher in macrophytes of Sevan Lake than that of the Carambolim Lake. The accumulation of 14 elements was in order of Ca > Mg > Fe > Al > Mn > Ba > Zn > Ti > Cu > Cr > Co > Ni > Pb > Cd. The present study revealed that the aquatic macrophytes play a very significant role in removing the different metals from the ambient environments. They probably play a major role in reducing the effect of high concentration of heavy metals. Therefore, the macrophyte community of the Sevan Lake area needs to be protected and restored on a priority basis. Accumulation of highly toxic metals like -- Cr, Cd, Pb and Ni was lower as compared to the essential metals like Ca, Fe and Mn in all the macrophytes from both the lake systems, consequently high metal concentrations observed in both the areas may not directly reflect on the pollution level.

Varenes, A., M.O. de Torres, J.F. Coutinho, M.M.G.S. Rocha, M.M.P.M. Neto, and A. De-Varenes (1996). Effects of heavy metals on the growth and mineral composition of a nickel hyperaccumulator. *J. Plant Nutr.* 19(5):669-676.

Vashegyi, A., G. Mezosi, et al. (2005). Phytoremediation of heavy metal pollution: A case study. *Acta Biologica Szegediensis* 49(1-2): 77-79. In the framework of a phytoremediation project for decontamination of heavy metal-polluted environment, two experimental fields were monitored for the existing plant species and soil contaminants. At the site of the slurry deposition from the oxbow lake at Martely, mainly Zn, Pb and Cr were determined as pollutants. *in situ*, a number of plant species were found, most importantly *Salix* species. At the other study site, at Almasfuzito, red sludge deposition from aluminum earth factory was monitored. In laboratory investigations, *Salix* species were found as Zn-accumulator species, therefore their capabilities and diversity were further investigated in 6 clones of *Salix alba*, as well as in *S. caprea* and *S. viminalis* rooted, grown and loaded with heavy metals under controlled conditions.

Vashudev, D. (1996) Sunflowers root out radiation. *AICHEXtra*, April 1996.

Vassilev, A. (2003). Physiological and agroecological aspects of cadmium interactions with barley plants: an overview. *Journal of Central European Agriculture.* A. Vassilev. 4: 65. This is a review of the author's previous publications and unpublished results as well as available literature on barley responses to Cd

contamination. The physiological background of acute Cd toxicity in barley plants is briefly described. Some data characterizing chronic Cd toxicity in barley are also provided in relation to its possible use for seed production and Cd phytoextraction in Cd-contaminated agricultural soils. Information on the main physiological factors limiting the growth, grain yield and seedling quality of Cd-exposed barley plants, as well as the Cd phytoextraction capacity of barley grown in Cd-contaminated soils, is presented.

Vasudev, D., S. Dushenkov, A. Epstein, Y. Kapulnik, and B. Ensley (1996). Removal of radionuclide contamination from water by metal-accumulating terrestrial plants. Feb. 7, UNPUBLISHED. Certain species of plants which grow rapidly and yield high biomass can accumulate and remove heavy metals from soil or water (Raskin et. al. 1994, Duchonkov et. al. 1995). Removal of heavy metals or radionuclides from water by hydroponically cultivated roots of these plants (rhizofiltration) is a promising new low cost treatment approach. High discharge standards can be met because the roots accumulate efficiently at low metal concentrations. Commercial application of this technology will lead to a new agriculture-based industry that markedly reduces the cost of treating heavy metal contamination in water at many hazardous waste sites. We evaluated the performance of hydroponically cultivated metal-accumulating plants in treating site water contaminated with (1) 100-400 ppb uranium at a former DOE facility in Ohio and (2) cesium (80 Bq/L) and strontium in a small pond within 1 km of the Chernobyl nuclear power plant in Ukraine. The field results demonstrate that rhizofiltration is a practical way to treat radionuclide contamination in site water. Rapid metal uptake to concentrations below 1 ppb was observed with uranium. Cesium and strontium were removed to concentrations below 10 Bq/L for Cs-137 and below 200 Bq/L for Sr-90 in batch studies. High levels of radionuclides accumulated in the plant roots, minimizing the amount of secondary waste generated.

Vaughan, D., D.G. Lumsdon, and D. Linehan (1993). Influence of dissolved organic matter on the bio-availability and toxicity of metals in soils and aquatic systems. *Chem. Ecol.* 8(3):185-202.

Vazquez, M.D., C. Poschenreider, J. Barcelo, A.J.M. Baker, P. Hatton, and G.H. Cope (1994). Compartmentalization of zinc in roots and leaves of the zinc hyperaccumulator *Thlaspi caerulescens* J. & C. Presl. *Bot. Acta.* 107:243- 250.

Vazquez, M.D., J. Barcelo, C. Poschenrieder, J. Madico, P. Hatton, A.J.M. Baker, and G.H. Cope (1992). Localization of zinc and cadmium in *Thlaspi caerulescens* (*Brassicaceae*), a metallophyte that can hyperaccumulate both metals. *J. Plant Physiol.* 140(3):350-355.

Vecchiet, M., D. Migliardi, et al. (2003). Vertical flow phytoremediation of wastes of agro-food origin / Fitodepurazione a flusso verticale di reflui di origine agroalimentare. *Informatore Agrario.* 59: 65. The basis of the vertical flow system of phytoremediation is the utilization of the natural remediative capacity of the soil and its microbial biomass. Plants in the system protect it from low winter temperatures, absorb from the soil the mineral substances made available by microbial degradation, and ensure, via the root system and its organic exudates, the presence of an appropriate bacterial microflora. Results are presented here of the successful use of the system to remove organic substances, nitrogen and total phosphorus in laboratory experiments on effluents from egg processing and lyophilization, and milk-casein processing, and in industrial scale experiments (using *Arundo donax*) on egg lyophilization effluents.

Velasco-Alinsug, M. P., G. C. Rivero, et al. (2005). Isolation of mercury-binding peptides in vegetative parts of *Chromolaena odorata*. *Zeitschrift fuer Naturforschung Section C Journal of Biosciences* 60(3-4): 252-259. Mercury-binding peptides from roots, stems, and leaves of Hg-treated *Chromolaena odorata* plants were isolated and partially characterized using RP-HPLC and ESI-MS. Upon exposure of *C. odorata* plants to high concentrations of 1.0 and 2.0 μM $\text{Hg}(\text{NO}_3)_2$ treatments from 0-28 days, they accumulated as much as 125 mg/g (dry wt) Hg in the roots, 15.280 mg/g (dry wt) Hg in the stems, and 0.800 mg/g (dry wt) Hg in the leaves indicating that *C. odorata* has a high potential as a phytoremediation agent of inorganic mercury. The plant's ability to accumulate and sequester Hg ions was primarily attributed to the production of Hg-binding peptides, which were initially detected through the use of Ellman's reagent. Isolation techniques using RP-HPLC equipped with a C18 column manifested a single prominent peak consistently appearing at a retention time of 2.6-2.8 min in all the plant samples treated

with different Hg concentrations at varying lengths of exposure. Further characterization of this prominent peak using electrospray ionization mass spectrometry revealed the presence of a peptide containing several cysteine residues with the highest peak concentration recorded at 91 mV and 89 mV in roots and stems of plants treated with 2.0 μM $\text{Hg}(\text{NO}_3)_2$ for 4 wk ($P < 0.05$) and 85 mV in leaves treated with 1.0 μM $\text{Hg}(\text{NO}_3)_2$ for 1 wk.

Vera, R., R. Millan, et al. (2005). Mercury uptake by some plants at different growing stages: a lysimetric study. *Advances in Geoecology*. Reiskirchen, Catena Verlag: 527. Almaden, sited in Ciudad Real (Spain), has the largest mercury concentration in the world. The aim of this research was to study the uptake of mercury by lentil, lupine, chickpea, and barley. The project includes studies of mercury uptake under lysimetric conditions. Soils were classified as Alfisol, Xeralf, Haploxeralf and Mollic Haploxeralf. Mercury content in the surface horizons ranges between 20 and 30 ppm. Laboratory tests showed that the amount of 0.5 N HCl extractable mercury appeared to better represent the bioavailable form of mercury. The uptake of mercury by crops increases as the plants grow, mainly during the first three months. Due to a dilution effect of the growing biomass and the reduction on the absorption of mercury at the flowering and fruiting stages, the uptake decreases thereafter. Mercury is located mainly in root system; therefore, the edible parts fortunately have lower mercury content.

Verkleij, J.A.C., H. Schat, J. Vangronsveld, M. Mergeay, M. Mench, S.O. Karenlampi, and T. DeKoe (1996). Strategies for rehabilitation of metal polluted soils: in situ phytoremediation, immobilization and revegetation. A comparative study (PHYTOREHAB). International Phytoremediation Conference, May 8-10, 1996, Arlington, VA. International Business Communications, Southborough, MA.

Verkleij, J.A.C., J.A. DeKnecht, H. Harmens, and H. Schat (1995). Physiological studies on Zn and Cd tolerance in higher plants. p. 25-26. In *Proceedings/Abstracts of the Fourteenth Annual Symposium, Current Topics in Plant Biochemistry, Physiology, and Molecular Biology - Will*

Verkleij, J.A.C., P. Koevoets, J. Van't Riet, J.A. De Knecht, and W.H.O. Ernst (1990). The role of metal-binding compounds (Phytochelatins) in the cadmium-tolerance mechanism of Bladder Campion (*Silene vulgaris*). In H. Rennenberg et al. (eds.), *Sulfur nutrition and sulfur assimilation in higher plants*. SPB Academic Publishing, Inc. The Hague.

Verma, P., K. V. George, et al. (2006). Modeling rhizofiltration: heavy-metal uptake by plant roots. *Environmental Modeling & Assessment* 11(4): 387-394. The discovery of phytoaccumulation potential of plant species has led to its application for remediation of heavy-metal-contaminated soil and wastewater, which is termed as phytoextraction/rhizofiltration. For prediction, analysis, planning and cost-effective design of such systems, mathematical models not only are used as a screening tool but also provide optimal parameters like harvesting time, irrigation schedule, etc. Several laboratory and field scale studies have been carried out in the past, and mathematical expressions have been developed by various researchers for different phenomena like metal adsorption in soil, plant root growth with time, moisture and metal uptake by plant root, moisture movement in unsaturated zone, soil moisture relationship, etc. The complete design of any such phytoremediation program would require the knowledge of behavior of heavy-metal movement in soil, water and plant root system. In this paper, a model for simulating heavy-metal dynamics in soil, water and plant root system is developed and discussed. The governing non-linear partial differential equation is solved numerically by implicit finite difference method using Picard's iterative technique, and the formulation has been illustrated using a characteristic example. The source code is written in MATLAB.

Verma, V. K., R. K. Gupta, et al. (2005). Biosorption of Pb and Zn from pulp and paper industry effluent by water hyacinth (*Echhornia crassipes*). *Journal of Scientific & Industrial Research* 64(10): 778-781. Lead and zinc uptake by water hyacinth (*Echhornia crassipes*) was studied in the laboratory conditions to investigate a low cost natural aquatic treatment system for pollutant removal from pulp and paper industry effluent. Bioaccumulation of Pb and Zn by water hyacinth was found concentration and duration dependent. The plant possessed ability to neutralize the effluent. It could effectively absorb Pb (0.28-1.39 mg/l, 17.6-80.3%) and Zn (0.26-1.30 mg/l, 16.6-73.4 %) after 20 days of treatment. Metal removal

efficiency was found to be maximum (80.3% for Pb; 73.4 % for Zn) at 20 % effluent concentration, thus highlighting that phytoremediation could be used along with and/or in some cases as a substitute of expensive cleanup technologies in industrial sector.

Vervaeke, P., F. M. G. Tack, et al. (2005). Willows grown on contaminated sediment: possibilities for phytoremediation. Remediation and beneficial reuse of contaminated sediments. Proceedings of the First International Conference on Remediation of Contaminated Sediments, Venice, Italy, 10-12 October 2001. P. Vervaeke. Columbus, Battelle Press: 179. A field trial was conducted in Belgium to assess the impact of planting a fast growing willow (*Salix viminalis*) stand on the dissipation of organic contaminants (mineral oil; extractable organic halogens; and polycyclic aromatic hydrocarbons, PAHs) in dredged sediment. In addition, the accumulation of heavy metals (Cd, Cu, Pb and Zn) in the biomass tissue was determined. A significant decrease of 57% in the mineral oil concentration of the planted depot was observed while mineral oil degradation in the fallow depot was only 15%. The mineral oil degradation under willow was most pronounced (80%) in the root zone of the stand. In the fallow depot, there was a significant reduction of the total PAH content by 32% after 1.5 years compared to a 23% reduction in the planted depot. The moderate and selective metal uptake measured in this study, limits the prospects for phytoextraction of metals from dredged sediment.

Vervaeke, P., F. M. G. Tack, et al. (2006). Fate of heavy metals during fixed bed downdraft gasification of willow wood harvested from contaminated sites. Biomass and Bioenergy. P. Vervaeke. 30: 58. The combination of energy production from biomass with phytoremediation opens perspectives for bringing land with moderate metal contamination into safe and beneficial use. Small scale fixed bed downdraft gasifier installations (150 kWe-1 MWe) can be employed for on-site conversion of biomass to electricity and heat. This study investigated the fate of heavy metals in willow wood upon conversion of the biomass to electricity and heat in a small-scale fixed bed downdraft gasifier. Batch gasification operations were run in a small scale fixed bed downdraft gasifier (100 kW thermal power). The gasification of 1 kg of wood resulted in the production of 40 g of ashes, 1.2 kWh of electricity and 9 MJ of heat. Per kg dry mass of willow wood, 31 g bottom ashes, 7 g cyclone ashes, 2 g filter ashes, and 18 g DM of gasifier bed ashes were produced. Cd, Zn and Pb were enriched by a factor 7-100 in the fly ashes compared to the bottom ashes. Low mass recoveries (30-40%) were found for Cd, Cr, Ni and Pb. This was mainly attributed to measurement uncertainties. 60% and more of recovered Cd, Pb and Zn were present in the finer filter and cyclone ashes, while Cr, Cu and Ni were mainly found in the bottom ashes and to a lesser extent the bed ashes. The scrubber placed after the hot cyclone has an essential role in intercepting the more volatile heavy metals before combustion of the gas. The bottom ashes constituted the largest fraction and ideally should be recycled if limits for metal contents are met. Only Cd and Zn exceeded Flemish threshold values for use of this fraction as a fertilizer, albeit by a small margin. This leaves perspectives for future research to optimize process parameters towards the production of bottom ashes that can be recycled.

Vervaeke, P., S. Luyssaert, et al. (2003). Phytoremediation prospects of willow stands on contaminated sediment: a field trial. Environmental Pollution. P. Vervaeke. 126: 275. Establishing fast growing willow stands on land disposed contaminated dredged sediment can result in the revaluation of this material and opens possibilities for phytoremediation. A field trial was designed to assess the impact of planting a willow stand (*Salix viminalis* L. 'Orm') on the dissipation of organic contaminants (mineral oil and PAHs) in dredged sediment. In addition, the accumulation of heavy metals (Cd, Cu, Pb and Zn) in the biomass was determined. After 1.5 years, a significant decrease of 57% in the mineral oil concentration in the sediment planted with willow was observed. Degradation of mineral oil in sediment which was left fallow, was only 15%. The mineral oil degradation under willow was most pronounced (79%) in the root zone of the stand. In the sediment which was left fallow there was a significant reduction of the total PAH content by 32% compared with a 23% reduction in the planted sediment. The moderate and selective metal uptake, measured in this study, limits the prospects for phytoextraction of metals from dredged sediment.

Vickerman, D. B., J. K. Young, et al. (2002). Effect of selenium-treated alfalfa on development, survival, feeding, and oviposition preferences of *Spodoptera exigua* (Lepidoptera : Noctuidae). Environmental Entomology 31(6): 953-959. We examined the effect of irrigating alfalfa (*Medicago sativa* L.) with selenium-contaminated water on the oviposition response, larval feeding preference, development and

survival of the beet armyworm, *Spodoptera exigua* Hubner, a generalist herbivore. Alfalfa was grown in sand cultures under three levels of sodium selenate irrigation: (1) control with no Se added; (2) a low rate of 0.0066 g sodium selenate/60 liters water; (3) and a high rate of 0.20 g sodium selenate/60 liters water. The low concentration treatment resulted in 2.88 +/- 0.52 mug Se/g plant dry weight and did not affect percent survival to adult eclosion compared with the control at 1.26 +/- 0.11 mug Se/g dry weight. The high rate generated 305.81 +/- 52.14 mug Se/g dry weight of alfalfa and significantly fewer insects survived compared with insects fed control alfalfa at 1.11 +/- 0.12 mug Se/g dry weight. High Se levels, but not low levels, decreased the relative growth index for larvae. In two-choice bioassays (treated/control) neonate larvae did not discriminate between control and Se-treated plants at high or low levels. Fourth instars did not discriminate between plants with low Se levels and control plants, but preferred to consume plants with high, usually lethal concentrations of Se. Females preferred ovipositing on plants with low Se concentrations over control plants, but did not discriminate between plants with high Se levels and untreated controls. This indicates that although females and late instars may be able to differentiate between Se-treated and control alfalfa they do not avoid plants containing high concentrations of Se. Thus, alfalfa with high Se-treatment levels is resistant to *S. exigua*, and may serve as a population sink, where females oviposit and few offspring survive to reproduce.

Vickerman, D. B., J. T. Trumble, et al. (2004). Selenium biotransformations in an insect ecosystem: Effects of insects on phytoremediation. *Environmental Science & Technology* 38(13): 3581-3586. Phytoremediation of selenium-contaminated soils may be influenced by higher trophic levels including insects. We examined how selenium affects the behavior, survival, and development of the wasp parasitoid *Cotesia marginiventris*, parasitizing its natural host, the beet armyworm *Spodoptera exigua*, feeding on alfalfa, *Medicago sativa*, irrigated with water containing selenate. X-ray absorption spectroscopy was used to quantify the selenium chemical forms in each trophic level. Alfalfa partially transformed selenate to organoselenium. *S. exigua* contained only organoselenium, both directly absorbed from *M. sativa* and transformed from selenate. *C. marginiventris* cocoons collected shortly after larval emergence contained only organoselenium derived from the host. The surprising finding of trimethylselenonium-like species in adult parasitoids and the cocoons from which they emerged suggests that adults and parasites can detoxify excess selenium through methylation and volatilization. Adult parasitoids do not discriminate against selenium-containing alfalfa, even though alfalfa generates selenium volatiles. Parasitoids raised on selenium-fed larvae emerged later and pupae weighed less than their selenium-free counterparts. We conclude therefore that *C. marginiventris* can be used to control *S. exigua* damage to *M. sativa* being used to remove selenium from soils. Moreover, the presence of such insects may improve phytoremediation by increasing biotransformation of inorganic selenium and release of volatile selenium species.

Vickerman, D. B., M. C. Shannon, et al. (2002). Evaluation of *Atriplex* lines for selenium accumulation, salt tolerance and suitability for a key agricultural insect pest. *Environmental Pollution* 120(2): 463-473. Thirty *Atriplex* lines were examined for potential habitat improvement and phytoremediation of selenium (Se) contaminated sites. Studies were conducted to determine the biomass production, Se accumulation, and resistance of each line to the beet army-worm, *Spodoptera. exigua*, an agriculturally important insect. Plants were tested using three salinity treatments: (1) control, no Se; (2) NaCl and CaCl₂ salts and 1 mg l⁻¹ Se (12.7 μM) added as Sodium selenate; and (3) iso-osmotic to treatment 2 containing high concentrations of sulfate and 1 mg l⁻¹ Se added as sodium selenate. Insect bioassays measured survival, growth, and development. *Atriplex patula*, *A. spongiosa* 415862, *A. hortensis*, *A. hortensis* 379088 and *A. hortensis* 379092 were among the top biomass producers and Se accumulators, yet they exhibited significantly reduced insect growth, development, and survival. High background sulfate strongly reduced Se accumulation, suggesting that phytoremediation potential is greatest in saline areas having low to moderate Sulfate levels. However, these lines grew well in high salinity soils, indicating possible use as a self-seeding cover crop to improve habitat. All plant lines grown in control and high sulfate salinity treatments are acceptable oviposition sites for *S. exigua*, indicating that these plants would help reduce populations of this key agricultural pest. (C) 2002 Elsevier Science Ltd.

Victorova, N., O. Voitesekhovitch, B. Sorochinsky, H. Vandenhove, A. Konoplev and I. Konopleva (2000). Phytoremediation of Chernobyl Contaminated Land. *Radiat. Prot. Dosim.* 92(1-3): 59-64.

Vijayaraghavan, K., J. Jegan, et al. (2005). Biosorption of copper, cobalt and nickel by marine green alga *Ulva reticulata* in a packed column. *Chemosphere*. K. Vijayaraghavan. 60: 419. Biosorption of copper, cobalt and nickel by marine green alga *Ulva reticulata* were investigated in a packed bed up-flow column. The experiments were conducted to study the effect of important design parameters such as bed height and flow rate. At a bed height of 25 cm, the metal-uptake capacity of *U. reticulata* for copper, cobalt and nickel was found to be 56.3 ± 0.24 , 46.1 ± 0.07 and 46.5 ± 0.08 mg g⁻¹, respectively. The Bed Depth Service Time (BDST) model was used to analyze the experimental data. The computed sorption capacity per unit bed volume (N₀) was 2580, 2245 and 1911 mg l⁻¹ for copper, cobalt and nickel, respectively. The rate constant (K_a) was recorded as 0.063, 0.081 and 0.275 l mg⁻¹ h⁻¹ for copper, cobalt and nickel, respectively. In flow rate experiments, the results confirmed that the metal uptake capacity and the metal removal efficiency of *U. reticulata* decreased with increasing flow rate. The Thomas model was used to fit the column biosorption data at different flow rates and model constants were evaluated. The column regeneration studies were carried out for three sorption-desorption cycles. The elutant used for the regeneration of the biosorbent was 0.1 M CaCl₂ at pH 3 adjusted using HCl. For all the metal ions, a decreased breakthrough time and an increased exhaustion time were observed as the regeneration cycles progressed, which also resulted in a broadened mass transfer zone. The pH variations during both sorption and desorption process have been reported.

Vila, M., S. Pascal-Lorber, et al. (2005). Metabolism of (14C)-2,4,6-trinitrotoluene in tobacco cell suspension cultures. *Environmental Science & Technology* 39(2): 663-672. The metabolism of 2,4,6-trinitrotoluene (TNT) was investigated in tobacco cell suspension cultures amended with (14C)-TNT. Five metabolites were purified and characterized. Temporal evolution of metabolites was monitored during a 120 h incubation period. Metabolites structure was identified by acid and enzymatic hydrolysis, followed by electrospray ionization mass spectrometry and ¹H and ¹³C NMR spectroscopy analyses. The majority of metabolites were conjugates formed by glycosylation on the hydroxylamine group of either 2-hydroxy-lamino-4,6-dinitrotoluene (2-HADNT) or 4-hydroxylamino-2,6-dinitrotoluene (4-HADNT), which led to monoglycoside then to diglycoside. Various diglycosides were observed with gentiobioside or sophoroside formation. Bound residues represented a small fraction (<10% of initial 14C) irrespective of the interval after TNT amendment. Free ADNT was detected only in the medium. This study highlights the central role played by HADNT in the TNT metabolic pathway in tobacco cell suspension culture, and the key role of these compounds and of glycosyltransferases in TNT phytoremediation processes.

Vinterhalter, B. and D. Vinterhalter (2005). Nickel hyperaccumulation in shoot cultures of *Alyssum markgrafii*. *Biologia Plantarum*. B. Vinterhalter. 49: 121. Shoot cultures of *Alyssum markgrafii* O.E. Shulz, endemic nickel hyperaccumulating species of central Balkan, were established and maintained on Murashige and Skoog medium supplemented with 0.2 mg dm⁻³ benzyladenine (BA). Nickel in form of NiCl₂ · 6 H₂O was supplemented at 22 different concentrations ranging from 0.0001 to 15 mM but none of them was lethal to cultures. High Ni²⁺ concentrations (10 mM or more) arrested shoot growth which, upon transfer to Ni-free medium, commenced via axillary bud proliferation. Shoots that developed from axillary buds through the subculture manifested increased tolerance to Ni²⁺ expressed as shoot elongation. Shoot multiplication and dry biomass production decreased with increase of Ni²⁺ in medium. Only the accumulation of Ni²⁺ in tissues increased with Ni²⁺ content of the medium. Apart from shoot cultures, high Ni²⁺ accumulation was registered in undifferentiated callus cultured on medium with 0.5 mg dm⁻³ BA and 0.5 mg dm⁻³ naphthylacetic acid. Highest content of accumulated Ni was 2.37 microg g⁻¹ (d.m.) in shoots and 2.65 microg g⁻¹ (d.m.) in callus, both measured on medium with 15 mM Ni²⁺.

Visoottiviset, P., K. Francesconi and W. Sridokchan (2002). The Potential of Thai Indigenous Plant Species for the Phytoremediation of Arsenic Contaminated Land. *Environ. Pollution* 118(3): 453-461.

Visoottiviset, P., K. Francesconi, et al. (2002). The potential of Thai indigenous plant species for the phytoremediation of arsenic contaminated land. *Environmental Pollution* 118(3): 453-461. To assess the potential of the native plant species for phytoremediation, plant and soil samples were collected from two areas in Thailand that have histories of arsenic pollution from mine tailings. The areas were the Ron Phibun District (Nakorn Si Thammarat province) and Bannang Sata District (Yala province), and samples were taken in 1998 and 1999 and analysed for total arsenic by atomic absorption spectrophotometry.

Arsenic concentrations in soil ranged from 21 to 14,000 $\mu\text{g g}^{-1}$ in Ron Phibun, and from 540 to 16,000 $\mu\text{g g}^{-1}$ in Bannang Sata. The criteria used for selecting plants for phytoremediation were: high As tolerance, high bioaccumulation factor, short life cycle, high propagation rate, wide distribution and large shoot biomass. Of 36 plant species, only two species of ferns (*Pityrogramma calomelanos* and *Pteris vittata*), a herb (*Mimosa pudica*), and a shrub (*Melastoma malabathricum*), seemed suitable for phytoremediation. The ferns were by far the most proficient plants at accumulating arsenic from soil, attaining concentrations of up to 8350 $\mu\text{g g}^{-1}$ (dry mass) in the frond. (C) 2002 Published by Elsevier Science Ltd.

Vivas, A., B. Biro, et al. (2006). Nickel-tolerant *BreviBacillus brevis* and arbuscular mycorrhizal fungus can reduce metal acquisition and nickel toxicity effects in plant growing in nickel supplemented soil. *Soil Biology & Biochemistry* 38(9): 2694-2704. The growth of clover (*Trifolium repens*) and its uptake of N, P and Ni were studied following inoculation of soil with *Rhizobium trifolii*, and combinations of two Ni-adapted indigenous bacterial isolates (one of them was *BreviBacillus brevis*) and an arbuscular mycorrhizal (AM) fungus (*Glomus mosseae*). Plant growth was measured in a pot experiment containing soil spiked with 30 (Ni I), 90 (Ni II) or 270 (Ni III) mg kg^{-1} Ni-sulphate (corresponding to 11.7, 27.6 and 65.8 mg kg^{-1} available Ni on a dry soil basis). Single inoculation with the most Ni-tolerant bacterial isolate (*BreviBacillus brevis*) was particularly effective in increasing shoot and root biomass at the three levels of Ni contamination in comparison with the other indigenous bacterial inoculated or control plants. Single colonisation of *G. mosseae* enhanced by 3 fold (Ni I), by 2.4 fold (Ni II) and by 2.2 fold (Ni III) *T. repens* dry weight and P-content of the shoots increased by 9.8 fold (Ni I), by 9.9 fold (Ni II) and by 5.1 fold (Ni III) concomitantly with a reduction in Ni concentration in the shoot compared with non-treated plants. Coinoculation of *G. mosseae* and the Ni-tolerant bacterial strain (*B. brevis*) achieved the highest plant dry biomass (shoot and root) and N and P content and the lowest Ni shoot concentration. Dual inoculation with the most Ni-tolerant autochthonous microorganisms (*B. brevis* and *G. mosseae*) increased shoot and root plant biomass and substantially reduced the specific absorption rate (defined as the amount of metal absorbed per unit of root biomass) for nickel in comparison with plants grown in soil inoculated only with *G. mosseae*. *B. brevis* increased nodule number that was highly depressed in Ni I added soil or suppressed in Ni II and Ni III supplemented soil. These results suggest that selected bacterial inoculation improved the mycorrhizal benefit in nutrients uptake and in decreasing Ni toxicity. Inoculation of adapted beneficial microorganisms (as autochthonous *B. brevis* and *G. mosseae*) may be used as a tool to enhance plant performance in soil contaminated with Ni. (c) 2006 Elsevier Ltd.

Vivek, P., D. Vivek, et al. (2005). Antioxidative responses in relation to growth of mustard (*Brassica juncea* cv. Pusa Jaikisan) plants exposed to hexavalent chromium. *Chemosphere*. P. Vivek. 61: 40. Effect of hexavalent chromium (Cr^{6+}) was seen on *Brassica juncea* cv. Pusa Jaikisan grown for 15 days in hydroponic culture supplemented with 0.2, 2 and 20 μM Cr. The inhibitory response of Cr^{6+} on growth of *B. juncea* was concentration and time dependent. The stimulation of plant growth, observed in response to exposure to 0.2 μM Cr^{6+} , during initial 5 days was reversed on prolonged treatment and at higher Cr^{6+} concentrations (2 and 20 μM Cr^{6+}). Despite reduction in growth, chlorophyll content increased substantially on 15 days exposure to 20 μM Cr^{6+} . Significant increases in lipid peroxidation and tissue concentration of H_2O_2 occurred in plants exposed to 2 and 20 μM Cr^{6+} . Effect of Cr^{6+} on antioxidative enzymes in roots and leaves was differential. SOD and CAT activities at lower levels of Cr^{6+} supply remained higher all through the treatment. While APX was very susceptible to excess Cr^{6+} , GR and GST increased at elevated levels of Cr^{6+} . The results suggested Cr^{6+} induced depression in plant growth of *B. juncea* to be a function of increased cellular accumulation of Cr despite increase in the activities of some of the antioxidative enzymes.

Vogt, K.A., D.A. Publicover, J. Bloomfield, J.M. Perez, D.J. Vogt, and W.L. Silver (1993). Below ground responses as indicators of environmental change. *Environ. Exp. Bot.* 33(1):189-205.

Volk, T. A., L. P. Abrahamson, et al. (2006). The development of short-rotation willow in the northeastern United States for bioenergy and bioproducts, agroforestry and phytoremediation. *Biomass and Bioenergy*. T. A. Volk. 30: 715. Research on willow (*Salix* spp.) as a locally produced, renewable feedstock for bioenergy and bioproducts began in New York in the mid-1980s in response to growing concerns about

environmental impacts associated with fossil fuels and declining rural economies. Simultaneous and integrated activities -- including research, large-scale demonstrations, outreach and education, and market development -- were initiated in the mid-1990s to facilitate the commercialization of willow biomass crops. Despite technological viability and associated environmental and local economic benefits, the high price of willow biomass relative to coal has been a barrier to wide-scale deployment of this system. The cost of willow biomass is currently \$3.00 GJ⁻¹ (\$57.30 odt⁻¹) compared to \$1.40-1.90 GJ⁻¹ for coal. Yield improvements from traditional breeding efforts and increases in harvesting efficiency that are currently being realized promise to reduce the price differential. Recent policy changes at the federal level, including the provision to harvest bioenergy crops from Conservation Reserve Program (CRP) land and a closed-loop biomass tax credit, and state-level initiatives such as Renewable Portfolio Standards (RPS) will help to further reduce the difference and foster markets for willow biomass. Years of work on willow biomass crop research and demonstration projects have increased our understanding of the biology, ecophysiology and management of willow biomass crops. Using an adaptive management model, this information has led to the deployment of willow for other applications such as phytoremediation, living snowfences, and riparian buffers across the northeastern US.

Vonderheide, A. P., S. Mounicou, et al. (2006). Investigation of selenium-containing root exudates of *Brassica juncea* using HPLC-ICP-MS and ESI-qTOF-MS. *Analyst* 131(1): 33-40. Selenium-containing root exudates were investigated in a known selenium accumulator model plant. Indian mustard (*Brassica juncea*) plants were grown hydroponically and supplemented with selenite (SeO₃²⁻) in a 25% Hoagland's nutrient solution. Additive concentrations were 0, 1, 5 and 20 μg mL⁻¹ Se with five replicate plants per treatment level. Plants were exposed to the respective Se solutions for two weeks, then placed in deionized water for two more weeks. The hydroponic solutions were collected for analysis after the first two weeks of selenium supplementation (day 14) and twice during the deionized water period (days 21 and 28). Separation by ion-pairing high performance liquid chromatography was followed by inductively coupled plasma-mass spectrometry (ICP-MS) for selenium specific detection. Chromatographic peaks unable to be identified by retention-time matching were collected for analysis by electrospray ionization mass spectrometry (ESI-MS). Additional chemical experiments were performed for structural elucidation. Several selenium-containing compounds were identified in the exudate-containing solution and two were identified as selenocystine and the selenosulfate (SSeO₃²⁻) ion. The presence of dimethylselenide (CH₃SeCH₃) is also observed but cannot be attributed exclusively to plant exudation because plants were not grown in sterile conditions. Further, the incorporation of fortified selenoamino acids into peptide structures was found to occur under neutral pH conditions, suggesting that exuded enzymes might facilitate such a reaction. Finally, physiological differences resulting from selenium supplementations were noted and discussed.

Voorman, R., and D. Penner (1986). Plant uptake of MBOCA [4,4'-methylene-bis (2-chloroaniline)]. *Arch. Environ. Contam. Toxicol.* 15(5):589-593.

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Voudrias, E.A., and K.S. Assaf (1996). Theoretical evaluation of dissolution and biochemical reduction of TNT for phytoremediation of contaminated sediments. *J. Contam. Hydrol.* 23:245-261.

Vouillamoz, J. and M. W. Milke (2001). Effect of Compost in Phytoremediation of Diesel-Contaminated Soils. *Water Sci. & Technol.* 43(2): 291-295.

Voutsas, D., A. Grimanis, and C. Samara (1996). Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter. *Environ. Pollut.* 94:325-235.

Vrblosky, D. A., C. T. Neitch and J. T. Morris (1999). Chlorinated Ethenes from Groundwater in Tree Trunks. *Environ. Sci. Technol.* 33(1): 510-515.

Vroblecky, D.A., and T.M. Yanosky (1990). Use of tree-ring chemistry to document historical groundwater contamination events. *Ground Water*. 28:677-684.

Vroblecky, D.A., T.M. Yanosky, and F.R. Siegel (1992). Increased concentrations of potassium in heartwood of trees in response to groundwater contamination. *Environ. Geol. Water Sci.* 19:71-75.

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Vymazal, J. (2005). Constructed wetlands for wastewater treatment. *Ecological Engineering*. J. 25: 622. This special issue entitled 'Constructed wetlands for waste water treatment' contains 11 papers, the first 5 from the symposium and 6 other from contributing sessions. The topics discussed are: horizontal subsurface flow and hybrid constructed wetlands systems for waste water treatment; the use of vertical flow of constructed wetlands for on-site treatment of domestic waste water in Denmark; the role of constructed wetlands in secondary effluent treatment and water reuse in subtropical and arid Australia; creating riverine wetlands; emission of N₂O, N₂, CH₄, and CO₂ from constructed wetlands for waste water treatment and from riparian buffer zones; emission of greenhouse gases from ponds constructed for nitrogen removal; the effectiveness of constructed wetland for treatment of wood waste leachate; treatment at different depths and vertical mixing within a 1-m deep horizontal subsurface flow wetland; managing vegetation in surface flow waste water treatment wetlands for optimal treatment performance; phytoremediation of textile effluents containing azo dye by using *Phragmites australis* in a vertical flow intermittent feeding constructed wetland; and growth of *Phragmites australis* and *Phalaris arundinacea* in constructed wetlands for waste water treatment in the Czech Republic.

Vyslouzilova, M., M. Puschenreiter, et al. (2006). Rhizosphere characteristics, heavy metal accumulation and growth performance of two willow (*Salix x rubens*) clones. *Plant, Soil and Environment*. M. Vyslouzilova. 52: 353. High-biomass tree species holds promise for the clean up of metal contaminated soils. Root and fungal activities modify soil characteristics that are important factors for the phytoextraction process (metal availability and toxicity). In a rhizobox experiment, two clones of *Salix x rubens* derived from contaminated and non-contaminated sites were tested for growth performance and metal (Cd, Pb and Zn) accumulation on a polluted calcareous Cambisol. The largest metal concentrations in leaves were 66.7 mg Cd/kg, 12.8 mg Pb/kg and 1090 mg Zn/kg. Results indicate that metal tolerance and accumulation of *Salix x rubens* may be a constitutive rather than an adaptive property. Soil pH did not differ among the rhizobox compartments. However, the acid neutralization capacity was decreased in the rhizosphere. Dissolved organic carbon in the rhizosphere was increased by 37% and seemed to enhance the labile fraction of Pb and Zn, whereas Cd was not affected. The replenishment of labile metals from less labile soil fractions was efficient enough to almost compensate the plant uptake. The ability of *Salix x rubens* to effectively induce chemical changes in the rhizosphere is very promising for the clean up of metal-polluted soils.

Vyslouzilova, M., P. Tlustos, et al. (2003). As, Cd, Pb and Zn uptake by *Salix* spp. clones grown in soils enriched by high loads of these elements. *Plant, Soil and Environment*. 49: 191. Arsenic, Cd, Pb and Zn accumulation in the aboveground biomass of seven clones of *Salix* spp. (*Salix x smithiana* S-218 and S-150, *S. viminalis* S-519, *S. alba* S-464, *S. alba pyramidalis* S-141, *S. dasyclados* S-406, and *S. x rubens* S-391) and changes in element uptake by plants after element addition to soil were studied in a pot experiment. Unpolluted Chernozem (Suchdol) as a control and soils with addition of As (100 mg/kg), Cd (40 mg/kg) and either Pb (2000 mg/kg) (Suchdol-Pb) or Zn (2000 mg/kg) (Suchdol-Zn) were used for the experiment. Significant differences were found in the accumulation of elements between willow clones and also between different element additions to the soil. Although As and Cd uptake slightly increased in Suchdol-Zn soil compared to Suchdol-Pb soil, the element removal from soil was significantly higher in Suchdol-Pb soil due to a significant reduction of aboveground biomass yield in Suchdol-Zn soil caused by Zn phytotoxicity. The yield reduction decreased the uptake of plant-available elements by biomass, thus higher plant-available portions of As and Cd were found in Suchdol-Zn soil. Element removal from soil was more dependent on element contents in willow tissues in Suchdol-Pb soil than in Suchdol-Zn soil, where willow plants exhibited physiological symptoms of phytotoxicity.

