

Qadir, M. and J. D. Oster (2002). Vegetative Bioremediation of Calcareous Sodic Soils: History, Mechanisms, and Evaluation. *Irrigation Science* 21(3): 91-101.

Qadir, M. and J. D. Oster (2004). Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. *Science of the Total Environment*. 323: 1. Irrigation has long played a key role in feeding the expanding world population and is expected to play a still greater role in the future. As supplies of good-quality irrigation water are expected to decrease in several regions due to increased municipal-industrial-agricultural competition, available freshwater supplies need to be used more efficiently. In addition, reliance on the use and reuse of saline and/or sodic drainage waters, generated by irrigated agriculture, seems inevitable for irrigation. The same applies to salt-affected soils, which occupy more than 20% of the irrigated lands, and warrant attention for efficient, inexpensive and environmentally acceptable management. Technologically and from a management perspective, a couple of strategies have shown the potential to improve crop production under irrigated agriculture while minimizing the adverse environmental impacts. The first strategy, vegetative bioremediation -- a plant-assisted reclamation approach -- relies on growing appropriate plant species that can tolerate ambient soil salinity and sodicity levels during reclamation of salt-affected soils. A variety of plant species of agricultural significance have been found to be effective in sustainable reclamation of calcareous and moderately sodic and saline-sodic soils. The second strategy fosters dedicating soils to crop production systems where saline and/or sodic waters predominate and their disposal options are limited. Production systems based on salt-tolerant plant species using drainage waters may be sustainable with the potential of transforming such waters from an environmental burden into an economic asset. Such a strategy would encourage the disposal of drainage waters within the irrigated regions where they are generated rather than exporting these waters to other regions via discharge into main irrigation canals, local streams, or rivers. Being economically and environmentally sustainable, these strategies could be the key to future agricultural and economic growth and social wealth in regions where salt-affected soils exist and/or where saline-sodic drainage waters are generated.

Qadir, M., A. D. Noble, et al. (2005). Driving forces for sodium removal during phytoremediation of calcareous sodic and saline-sodic soils: a review. *Soil Use and Management* 21(2): 173-180. Sodic and saline-sodic soils are characterized by the occurrence of sodium (Na^+) at levels that result in poor physical properties and fertility problems, adversely affecting the growth and yield of most crops. These soils can be brought back to a highly productive state by providing a soluble source of calcium (Ca^{2+}) to replace excess Na^+ on the cation exchange complex. Many sodic and saline-sodic soils contain inherent or precipitated sources of Ca^{2+} , typically calcite (CaCO_3), at varying depths within the profile. Unlike other Ca^{2+} sources used in the amelioration of sodic and saline-sodic soils, calcite is not sufficiently soluble to effect the displacement of Na^+ from the cation exchange complex. In recent years, phytoremediation has shown promise for the amelioration of calcareous sodic and saline-sodic soils. It also provides financial or other benefits to the farmer from the crops grown during the amelioration process. In contrast to phytoremediation of soils contaminated by heavy metals, phytoremediation of sodic and saline-sodic soils is achieved by the ability of plant roots to increase the dissolution rate of calcite, resulting in enhanced levels of Ca^{2+} in soil solution to replace Na^+ from the cation exchange complex. Research has shown that this process is driven by the partial pressure of CO_2 ($P\text{-CO}_2$) within the root zone, the generation of protons (H^+) released by roots of certain plant species, and to a much smaller extent the enhanced Na^+ uptake by plants and its subsequent removal from the field at harvest. Enhanced levels of $P\text{-CO}_2$ and H^+ assist in increasing the dissolution rate of calcite. This results in the added benefit of improved physical properties within the root zone, enhancing the hydraulic conductivity and allowing the leaching of Na^+ below the effective rooting depth. This review explores these driving forces and evaluates their relative contribution to the phytoremediation process. This will assist researchers and farm advisors in choosing appropriate crops and management practices to achieve maximum benefit during the amelioration process.

Qadir, M., A. D. Noble, et al. (2005). Phytoremediation of sodic and saline-sodic soils. International salinity forum - managing saline soils and water: science, technology and social issues. Oral Presentation Abstracts, Riverside Convention Center, Riverside, California, USA, 25-28 April 2005. M. Qadir. Riverside, USDA-ARS Salinity Laboratory: 383. Phytoremediation (comprising both vegetative bioremediation and

biological reclamation) of sodic and saline-sodic soils, is an effective low-cost intervention for resource-poor farmers. The advantages of this approach are:- (i) no investment to purchase chemical amendments is required; (ii) there are accrued financial or other benefits from crops grown during amelioration; (iii) soil aggregate stability and porosity are increased as a result of root activity, with subsequent improvement in soil hydraulic properties; (iv) plant nutrient availability in the soil is improved because of organic matter addition by below-ground plant material as well as N fixation when leguminous crops are used; (v) the zone of amelioration is more uniform and deeper, particularly in case of deep-rooted crops; and (vi) C sequestration is achieved in the post-amelioration soil. This plant-assisted amelioration strategy is a promising option to increase the dissolution rate of calcite through processes at the soil-root interface, thereby resulting in enhanced levels of Ca^{2+} in the soil solution. This study is identifying plant species that can withstand high levels of salts and sodicity, and that have a propensity to produce large quantities CO_2 and H^+ in the root zone, coupled with high ash alkalinity.

Qadir, M., A. Ghafoor and G. Murtaza (2001). Use of Saline-Sodic Waters through Phytoremediation of Calcareous Saline-Sodic Soils. *Agricultural Water Management* 50(3): 197-210.

Qadir, M., D. Steffens, et al. (2003). Proton release by N-2-fixing plant roots: A possible contribution to phytoremediation of calcareous sodic soils. *Journal of Plant Nutrition and Soil Science-Zeitschrift Fur Pflanzenernahrung Und Bodenkunde* 166(1): 14-22. With a world-wide occurrence on about 560 million hectares, sodic soils are characterized by the occurrence of excess sodium (Na^+) to levels that can adversely affect crop growth and yield. Amelioration of such soils needs a source of calcium (Ca^{2+}) to replace excess Na^+ from the cation exchange sites. In addition, adequate levels of Ca^{2+} in ameliorated soils play a vital role in improving the structural and functional integrity of plant cell walls and membranes. As a low-cost and environmentally feasible strategy, phytoremediation of sodic soils - a plant-based amelioration - has gained increasing interest among scientists and farmers in recent years. Enhanced CO_2 partial pressure (PCO_2) in the root zone is considered as the principal mechanism contributing to phytoremediation of sodic soils. Aqueous CO_2 produces protons (H^+) and bicarbonate (HCO_3^-). In a subsequent reaction, H^+ reacts with native soil calcite (CaCO_3) to provide Ca^{2+} for Na^+ - Ca^{2+} exchange at the cation exchange sites. Another source of H^+ may occur in such soils if cropped with N-2-fixing plant species because plants capable of fixing N-2 release H^+ in the root zone. In a lysimeter experiment on a calcareous sodic soil ($\text{pH}(\text{s}) = 7.4$, electrical conductivity of soil saturated paste extract (EC_6) = 3.1 dS m^{-1}), sodium adsorption ratio (SAR) = 28.4, exchangeable sodium percentage (ESP) = 27.6, $\text{CaCO}_3 = 50 \text{ g kg}^{-1}$), we investigated the phytoremediation ability of alfalfa (*Medicago sativa* L.). There were two cropped treatments: Alfalfa relying on N-2 fixation and alfalfa receiving NH_4NO_3 as mineral N source, respectively. Other treatments were non-cropped, including a control (without an amendment or crop), and soil application of gypsum or sulfuric acid. After two months of cropping, all lysimeters were leached by maintaining a water content at 130% water-holding capacity of the soil after every 24 h. The treatment efficiency for Na^+ removal in drainage water was in the order: sulfuric acid > gypsum = N-2-fixing alfalfa > NH_4NO_3 -fed alfalfa > control. Both the alfalfa treatments produced statistically similar root and shoot biomass. We attribute better Na^+ removal by the N-2-fixing alfalfa treatment to an additional source of H^+ in the rhizosphere, which helped to dissolve additional CaCO_3 and soil sodicity amelioration.

Qadir, M., D. Steffens, et al. (2003). Sodium removal from a calcareous saline-sodic soil through leaching and plant uptake during phytoremediation. *Land Degradation & Development* 14(3): 301-307. Saline-sodic and sodic soils are characterized by the occurrence of sodium (Na^+) to levels that can adversely affect several soil properties and growth of most crops. As a potential substitute of cost-intensive chemical amelioration, phytoremediation of such soils has emerged as an efficient and low-cost strategy. This plant-assisted amelioration involves cultivation of certain plant species that can withstand ambient soil salinity and sodicity levels. It relies on enhanced dissolution of native calcite within the root zone to provide adequate Ca^{2+} for the Na^+ - Ca^{2+} exchange at the cation exchange sites. There is a lack of information for the Na^+ balance in terms of removal from saline-sodic soils through plant uptake and leaching during the phytoremediation process. We carried out a lysimeter experiment on a calcareous saline-sodic soil [pH of saturated soil paste ($\text{pH}(\text{s})$) = 7.2, electrical conductivity of the saturated paste extract (EC_e) 4.9 dS m^{-1}), sodium adsorption ratio (SAR) = 15.9, $\text{CaCO}_3 = 50 \text{ g kg}^{-1}$]. There were three treatments: (1) control (without application of a chemical amendment or crop cultivation), (2) soil application of gypsum

according to the gypsum requirement of the soil and (3) planting of alfalfa (*Medicago sativa* L.) as a phytoremediation crop. The efficiency of treatments for soluble salt and Na⁺ removal from the soil was in the order: gypsum approximate to alfalfa > control. In the phytoremediation treatment, the amount of Na⁺ removed from the soil through leaching was found to be the principal cause of reduction in salinity and sodicity. Copyright (C) 2003 John Wiley Sons, Ltd.

Qadir, M., Ghafoor, G. and G. Murtaza (2003). Use of saline-sodic waters through phytoremediation of calcareous saline-sodic soils. *Agricultural Water Management*, 50(3): 197-210. Use of poor-quality groundwater has become inevitable for irrigation to compensate rapidly increasing water demands in many arid and semiarid regions. Salinity and sodicity are the principal soil and water quality concerns in such areas. Many saline-sodic and sodic soils have saline or saline-sodic subsurface drainage waters. Amelioration of these soils needs a source of calcium (Ca²⁺) that can replace the excess exchangeable sodium (Na⁺). Most of these soils, however, contain calcite (CaCO₃) of extremely low solubility. The native calcite does not supply adequate levels of Ca²⁺ for soil amelioration as do other chemical amendments. Phytoremediation may help ameliorate such soils through cultivation of certain crops tolerant to ambient soil salinity and sodicity. This amelioration strategy works through plant root action to help dissolve CaCO₃ to supply adequate Ca²⁺ without the application of an amendment. During a 3-year field experiment conducted under irrigated conditions, we evaluated phytoremediation against soil application of gypsum and farm manure, and water treatment with sulphuric acid on a calcareous saline-sodic soil (pH_s=8.0-8.4, EC_e=24-32 dS m⁻¹, SAR=57-78, CaCO₃=45-50 g kg⁻¹ for the top 0.15 m depth; Calcic Haplosalids). A saline-sodic water (EC=2.9-3.4 dS m⁻¹, SAR=12.0-19.4, RSC=4.6-10.0 mmol_c l⁻¹, SAR_{adj}=15.6-18.4) was used to irrigate the rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) crops grown in rotation. Active desalinisation and desodication processes were observed in all the treatments. After the final wheat crop, the 1.2 m soil profile EC_e was 7±0.5 dS m⁻¹ and SAR was 15±2 with non-significant treatment differences, indicating comparable soil amelioration effect of phytoremediation with other treatments. Better crop yields were obtained from the manure-treated plots, owing to its annual addition to the soil that possibly improved soil fertility. Phytoremediation needed minimum capital input because no initial investment was made to purchase the amendments.

Qadir, M., R. H. Qureshi, et al. (2002). Amelioration of calcareous saline sodic soils through phytoremediation and chemical strategies. *Soil Use and Management* 18(4): 381-385. The worldwide occurrence of saline sodic and sodic soils on more than half a billion hectares warrants attention for their efficient, inexpensive and environmentally acceptable management. These soils can be ameliorated by providing a source of calcium (Ca²⁺) to replace excess sodium (Na⁺) from the cation exchange sites. Although chemical amendments have long been used to ameliorate such soils, the chemical process has become costly during the last two decades in several developing countries. As a low-cost and environmentally acceptable strategy, the cultivation of certain salt tolerant forage species on calcareous sodic and saline sodic soils, i.e. phytoremediation, has gained interest among scientists and farmers in recent years. In a field study conducted at three calcareous saline sodic sites (pH(s)=8.1-8.8, EC_e=7.8-12.5 dS m⁻¹, SAR=30.6-76.1) in the Indus Plains of Pakistan, we compared chemical and phytoremediation methods. There were four treatments; two involved plants: Kallar grass (*Leptochloa fusca* (L.) Kunth), and *Sesbania* (*Sesbania bispinosa* (Jacq.) W. Wight). The other two treatments were uncropped: soil application of gypsum and an untreated control. All treatments were irrigated with canal water (EC=0.224-28 dS m⁻¹). The plant species were grown for one season (5-6 months). *Sesbania* produced more forage yield (34 t ha⁻¹) than Kallar grass (23 t ha⁻¹). Phytoremediation and chemical treatments resulted in similar decreases in soil salinity and sodicity, indicating that phytoremediation may replace or supplement the more costly chemical approach. The soil amelioration potential of *Sesbania* was similar to that of the Kallar grass, which suggests that moderately saline sodic calcareous soils can be improved by growing a forage legume with market value.

Qadir, S., M. I. Qureshi, et al. (2004). Genotypic variation in phytoremediation potential of *Brassica juncea* cultivars exposed to Cd stress. *Plant Science* 167(5): 1171-1181. Problem of heavy metal contamination in agricultural lands, in part, is responsible for limiting the crop productivity. In India, *Brassica juncea* is cultivated as a major oilseed crop. This crop may further be useful in soil reclamation through the process of phytoremediation including phytoextraction of toxic heavy metals such as Zn, Pb, Cd, etc. from the soil.

However, selection of *B. juncea* cultivar (cv.) with high Cd-extraction potential amongst the higher yielding cultivars would be of great importance to reclaim the soil with lesser impact on plant metabolism and hence the yield. Ten such *B. juncea* cultivars (V-1-V-10) commonly grown in India were selected for the present study to determine their Cd extraction potential and degree of resistance to Cd stress. Ten-day-old seedlings of *B. juncea* cultivars were exposed to various levels of cadmium chloride (0.0-2.0 mM) for 72 h in hydroponics culture and leaf samples were analyzed at 24, 48 and 72 h after treatment (HAT) for the changes in the rate of lipid peroxidation, plant length, biomass accumulation, cadmium accumulation and activities of catalase (CAT, 1.11.1.6), superoxide dismutase (SOD, 1.15.1.1), ascorbate peroxidase (APX, 1.11.1.11) and glutathione reductase (GR, 1.6.4.2) along with ascorbate (Asc) and glutathione contents. A reduction in the plant length, biomass accumulation, CAT activity and ascorbate content was noted in all the cultivars, however, a significant increase in lipid peroxidation rate, Cd accumulation, activities of APX, GR, SOD and glutathione content was observed. *B. juncea* cv. Pusa Jai Kisan (V-5) showed the least increase in the rate of lipid peroxidation but accumulated highest levels of biomass, Cd and glutathione contents among the cultivars studied. These results indicate that cv. Pusa Jai Kisan possesses a better Cd-sequestering and antioxidant system. High increase in the levels of glutathione suggests its possible incorporation in synthesis of the phytochelatins and metallothioneins to sequester Cd and combat Cd-stress. (C) 2004 Elsevier Ireland Ltd. All rights reserved.

Qaisi, K.M., K.S. Ro, D. Reible, L.J. Thibodeaux, K.T. Valsaraj and W.D. Constant (1996). Transport process of TNT from flooded highly contaminated surface soil bed. *J. Environ. Sci. Health.* A31(10):2515.

Qasim, C., M. Blom-Zandstra, et al. (2005). Utilising the synergy between plants and rhizosphere microorganisms to enhance breakdown of organic pollutants in the environment. *Environmental Science and Pollution Research.* C. Qasim. 12: 34. Phytoremediation is a promising technology for the cleanup of polluted environments. The technology has so far been used mainly to remove toxic heavy metals from contaminated soil, but there is a growing interest in broadening its applications to remove/degrade organic pollutants in the environment. Both plants and soil microorganisms have certain limitations with respect to their individual abilities to remove/breakdown organic compounds. A synergistic action by both rhizosphere microorganisms that leads to increased availability of hydrophobic compounds, and plants that leads to their removal and/or degradation, may overcome many of the limitations, and thus provide a useful basis for enhancing remediation of contaminated environments. This review provides an insight to the nature of plant-microbial interactions in the rhizosphere, with a focus on those processes that are relevant to the breakdown and/or removal of organic pollutants. Due consideration has been given to identify opportunities for utilizing the plant-microbial synergy in the rhizosphere to enhance remediation of contaminated environments. The review has highlighted the existence of a synergistic interaction between plants and microbial communities in the rhizosphere. This interaction benefits both microorganisms through provision of nutrients by root exudates, and plants through enhanced nutrient uptake and reduced toxicity of soil contaminants. The ability of the plant-microbial interaction to tackle some of the most recalcitrant organic chemicals is of particular interest with regard to enhancing and extending the scope of remediation technologies. Plant-microbial interactions in the rhizosphere offer very useful means for remediating environments contaminated with recalcitrant organic compounds. A better knowledge of plant-microbial interactions will provide a basis for improving the efficacy of biological remediations. Further research is, however, needed to investigate different feedback mechanisms that select and regulate microbial activity in the rhizosphere.

Qian, J., A. Zayed, Y. Zhu, M. Yu and N. Terry (1999). Phytoaccumulation of Trace Elements by Wetland Plants: Iii. Uptake and Accumulation of Ten Trace Elements by Twelve Plant Species. *Journal of Environmental Quality* 28(5): 1448-1455.

Qiu, X. J., B. E. Reed, et al. (2004). Effects of flavonoids on C-14[7,10]-benzo[a]pyrene degradation in root zone soil. *Environmental Engineering Science* 21(5): 637-646. Secondary plant metabolites, such as flavonoids, may have an important role in developing organic contaminant-degrading enzymes; however, the effects are complicated. The addition of morin (a naturally occurring hydroxylated flavonoid) and flavone (a synthetic nonhydroxylated flavonoid) at concentrations greater than 10 $\mu\text{mol/L}$ hindered C-14-B[a]P mineralization in root zone soil slurries. The reduction of C-14-B[a]P mineralization was

accompanied by a decreased solvent (ethyl acetate) extractability of the remaining C-14-B[a]P and/or metabolites in the flavone-amended soil. In contrast, the solvent extractability of C-14 did not change in morin-amended soil. C-14-B[a]P that remained in soil was not soluble into the water phase. The possible mechanisms of morin and flavone inhibition to B[a]P degradation are discussed.

Qiu, X., S.I. Shah, E.W. Kendall, D.L. Sorensen, R.C. Sims, and M.C. Engelke (1994). Grass-enhanced bioremediation for clay soils contaminated with polynuclear aromatic hydrocarbons. Pp. 142-157. In T.A. Anderson and J.R. Coats (eds.), *Bioremediation Through Rhizosphere Technology*, ACS Symposium Series, Volume 563. American Chemical Society, Washington, DC.

Qiu, X., T.W. Leland, S.I. Shah, D.L. Sorensen, and E.W. Kendall (1997). Field study: Grass remediation for clay soil contaminated with polycyclic aromatic hydrocarbons. In E.L. Kruger, T.A. Anderson, and J.R. Coats (eds.), *Phytoremediation of Soil and Water Contaminants*, ACS Symposium Series No. 664. American Chemical Society, Washington, DC.

Qiu, X., X. Sun, et al. (2006). Enhancement of EDDS on Cu and Zn uptake by *Elsholtzia splendens* and its environmental risk. *Acta Agriculturae Zhejiangensis*. X. Qiu. 18: 86. Field, pot and leaching experiments were conducted to study the enhancement of ethylene diamine disuccinic acid (EDDS) on soil ammonia nitrate extractable Cu and Zn concentrations, and *Elsholtzia splendens* plant Cu and Zn uptake. Results showed that EDDS addition improved plant Cu and Zn uptake by *E. splendens* and increased Cu and Zn concentrations at soil depths of 0-10 and 10-20 cm. Cu and Zn concentrations in leachate from 50 cm soil, but they were still lower than the Grade 3 of the state groundwater criteria. This suggested that potential environmental risk of EDDS application on Cu and Zn leaching to groundwater may be very low.

Quartacci, M. F., A. Argilla, et al. (2006). Phytoextraction of metals from a multiply contaminated soil by Indian mustard. *Chemosphere* 63(6): 918-925. The effects of nitrilotriacetate (NTA) and citric acid applications on metal extractability from a multiply metal-contaminated soil, as well as on their uptake and accumulation by Indian mustard (*Brassica juncea*) were investigated. Desorption of metals from the soil increased with chelate concentration, NTA being more effective than citric acid in solubilising the metals. Plants were grown in a sandy soil collected from a contaminated field site and polluted by Cd, Cr, Cu, Pb and Zn. After 43 days of plant growth, pots were amended with NTA or citric acid at 5 mmol kg⁻¹ soil. Control pots were not treated with any chelate. Harvest of plants was performed 1 week after chelate addition. Soil water-, NH₄NO₃- and DTPA-extractable Cd, Cu, Pb and Zn fractions were enhanced only in the presence of NTA. In comparison to unamended plants, Indian mustard shoot dry weights suffered significant reductions following NTA application. NTA treatment increased shoot metal concentrations by a factor of 2-3, whereas citric acid did not induce any difference compared to the control. Chromium was detected in the above-ground tissues only after NTA amendment. Due to differences in dry matter yield, a significant enhancement of metal uptake was observed in NTA-treated plants for Cu and Zn. (c) 2005 Elsevier Ltd. All rights reserved.

Quartacci, M. F., E. Cosi and F. Navari-Izzo (2001). Uptake and Translocation of Cadmium in *Brassicaceae*. *Minerva Biotechnologica* 13(2): 97-101.

Quartacci, M. F., E. Cosi, et al. (2003). Uptake and translocation of copper in *Brassicaceae*. *Journal of Plant Nutrition* 26(5): 1065-1083. Ten cvs. of four *Brassicaceae* species were tested to evaluate their copper (Cu) uptake and translocation. Germination and root length tests indicated that *Brassica juncea* cv. Aurea and *Raphanus sativus* cvs. Rimbo and Saxa were the species with the highest germinability and longest roots at Cu concentrations ranging from 25 up to 200 µM. *Raphanus sativus* cv. Rimbo grown in hydroponic culture at increasing Cu concentrations (from 0.12 up to 40 µM) for 10 days produced a relatively high biomass (17.2 mg plant⁻¹) at the highest concentration and had a more efficient Cu translocation (17.8%) in comparison with cvs. Aurea and Saxa. The potential of cv. Rimbo for Cu uptake was then followed for 28 days at 5, 10, and 15 µM Cu. In comparison with the control, after 28 days of growth the 15 µM Cu-treated plants showed a reduction in the tolerance index (-40%) and in the above-ground dry biomass (-19%). On the contrary, an increase in the below-ground dry weight was observed (+35%). Copper accumulated during the growth period both in the below- and above-ground parts (about

14 and 4 mug plant(-1) at 10 and 15 muM Cu, respectively), but the translocation decreased from 50 to 30% in the last week at all the concentrations used. In addition, cv. Rimbo grown in a multiple element [cadmium (Cd), chromium (Cr), Cu, lead (Pb), and zinc (Zn)] naturally-contaminated site accumulated all elements in the above-ground part in a range from 5 to 62 mug plant(-1).

Querol, X., A. Alastuey, et al. (2006). Immobilization of heavy metals in polluted soils by the addition of zeolitic material synthesized from coal fly ash. *Chemosphere* 62(2): 171-180. The use of zeolitic material synthesized from coal fly ash for the immobilization of pollutants in contaminated soils was investigated in experimental plots in the Guadiamar Valley (SW Spain). This area was affected by a pyrite slurry spill in April 1998. Although reclamation activities were completed in a few months, residual pyrite slurry mixed with soil accounted for relatively high leachable levels of trace elements such as Zn, Pb, As, Cu, Sb, Co, Tl and Cd. Phytoremediation strategies were adopted for the final recovery of the polluted soils. The immobilization of metals had previously been undertaken to avoid leaching processes and the consequent groundwater pollution. To this end, 1100 kg of high NaPI (Na-6[AlO₂](6)(SiO₂)(10)] (.) 15H(2)O) zeolitic material was synthesized using fly ash from the Teruel power plant (NE Spain), in a 10 m³ reactor. This zeolitic material was manually applied using different doses (10000-25000 kg per hectare), into the 25 cm topsoil. Another plot (control) was maintained without zeolite. Sampling was carried out 1 and 2 years after the zeolite addition. The results show that the zeolitic material considerably decreases the leaching of Cd, Co, Cu, Ni, and Zn. The sorption of metals in soil clay minerals (illite) proved to be the main cause contributing to the immobilization of these pollutants. This sorption could be a consequence of the rise in pH from 3.3 to 7.6 owing to the alkalinity of the zeolitic material added (caused by traces of free lime in the fly ash, or residual NaOH from synthesis). (c) 2005 Elsevier Ltd. All rights reserved.

Quinn, J. J., M. C. Negri, R. R. Hinchman, L. P. Moos, J. B. Wozniak and E. G. Gatliff (2001). Predicting the Effect of Deep-Rooted Hybrid Poplars on the Groundwater Flow System at a Large-Scale Phytoremediation Site. *International Journal of Phytoremediation* 3(1).

Quinones-Aguilar, E. E., R. Ferrera-Cerrato, et al. (2003). Emergence and growth of maize in a crude oil polluted soil. *Agrociencia* 37(6): 585-594. Some agricultural soils have been severely affected by oil industry activities; therefore, it is necessary to generate technologies for their recuperation. Phytoremediation uses plants whose rhizosphere contributes to the detoxication of soils, polluted by organic and inorganic compounds. In order to know the capacity of maize to emerge and grow in soil, artificially polluted with crude oil, a greenhouse experiment was carried out at Montecillo, State of Mexico. The experiment had a factorial (11x4) arrangement in a completely randomized design. Factors and levels were type of maize (10 collections) from Minatitlan, Veracruz, and the hybrid 'Jornalero', and crude oil concentrations in the soil (0, 15000, 25000, and 35 000 mg kg(-1)). From the fifth day after sowing (DAS), the percentage of seedling emergence was evaluated daily. At the end of the experiment (22 DAS), plant height, root length, root volume, total dry weight, indices of stem and root length growth, and index of dry matter accumulation were evaluated. MV08 collection of maize showed higher seedling emergence in all concentrations of crude oil in the soil. Regarding growth of the maize plants, MV06 and MV08 collections have greater potential to be used in experiments with crude oil-polluted soils. A crude oil concentration of 25000 mg kg(-1) soil favored growth of maize seedlings.

Quintela-Sabaris, C., P. S. Kidd, et al. (2005). Identification of metalliferous ecotypes of *Cistus ladanifer* L. using RAPD markers. *Zeitschrift fuer Naturforschung Section C Journal of Biosciences* 60(3-4): 229-235. The genetic diversity of *Cistus ladanifer* ssp. *ladanifer* (Cistaceae) growing on ultramafic and non-ultramafic (basic and schists) soils in the NE of Portugal was studied in order to identify molecular markers that could distinguish the metal-tolerant ecotypes of this species. Random Amplified Polymorphic DNA (RAPD) markers were used in order to estimate genetic variation and differences between populations. The RAPD dataset was analysed by means of a cluster analysis and an analysis of molecular variance (AMOVA). Our results indicate a significant partitioning of molecular variance between ultramafic and non-ultramafic populations of *Cistus ladanifer*, although the highest percentage of this variance was found at the intra-population level. Mantel's test showed no relationship between inter-population genetic and geographic distances. A series of RAPD bands that could be related to heavy metal tolerance were

observed. The identification of such markers will enable the use of *Cistus ladanifer* in phytoremediation procedures.