INNSPUB
Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 3, p. 88-98, 2017
http://www.innspub.net

REVIEW PAPER OPEN ACCESS

A comprehensive review on phytoremediation of cadmium (Cd) by mustard (*Brassica juncea* L.) and sunflower (*Helianthus annuus* L.)

Awais Shakoor*[1,2], Muhammad Abdullah[3], Rubab Sarfraz[4], Muhammad Ahsan Altaf[5], Saneya Batool[5]

[1]*School of Resources and Environment, Anhui Agricultural University, Hefei, China*

[2]*Department of Soil and Environmental Science, University College of Agriculture, University of Sargodha, Punjab, Pakistan*

[3]*State-Key Laboratory of Tea Plant Biology and Utilization, Anhui Agricultural University, Hefei, China*

[4]*Fujian Provincial Key Laboratory of Soil Environmental Health and Regulation, College of Resources and Environment, Fujian Agriculture and Forest University, Fuzhou, China*

[5]*College of Horticulture and Landscape Architecture, Hainan University, China*

Article published on March 23, 2017

Key words: Phytoremediation, Cadmium (Cd), Toxicity, Sunflower, Mustard

Abstract

Phytoremediation is an important process in the removal of heavy metals and contaminants from the soil and the environment. Plants can help clean many types of pollution, including metals, pesticides, explosives, and oil. Phytoremediation in phytoextraction is a major technique. In this process is the use of plants or algae to remove contaminants in the soil, sediment or water in the harvesting of plant biomass. Heavy metal is generally known set of elements with atomic mass (> 5 gcm -3), particularly metals such as exchange of cadmium, lead and mercury. Between different pollutant cadmium (Cd) is the most toxic and plant and animal heavy metals. Mustard (*Brassica juncea* L.) and Sunflower (*Helianthus annuus* L.) are the plant for the production of high biomass and rapid growth, and it seems that the appropriate species for phytoextraction because it can compensate for the low accumulation of cadmium with a much higher biomass yield. To use chelators, such as acetic acid, ethylene diaminetetraacetic acid (EDTA), and to increase the solubility of metals in the soil to facilitate easy availability indiscernible and the absorption of the plant from root leg in vascular plants.

***Corresponding Author:** Awais Shakoor ✉ awais.shakoor22@gmail.com

Introduction

Phytoremediation consists of Greek and words of "station" and Latin remedium plants, which means "rebalancing" describes the treatment of environmental problems treatment (biological) through the use of plants that mitigate the environmental problem without digging contaminated materials and disposed of elsewhere. Controlled by the plant interactions with groundwater and organic and inorganic contaminated materials in specific locations to achieve therapeutic targets molecules site application (Landmeyer, 2011). Phytoremediation is the use of green plants to remove contaminants from the environment or render them harmless. The technology that uses plants to" green space "of heavy metals in the soil through the roots. While vacuum cleaners and you should be able to withstand and survive high levels of heavy metals in the soil unique plants (Baker, 2000).

The main result in increasing the population and more industrialization are caused water and soil contamination that is harmful for environment as well as human health. In the whole world, contamination in the soil by heavy metals has become a very serious issue. So, removal of these heavy metals from the soil is very necessary to protect the soil and human health. Both inorganic and organic contaminants, like petroleum, heavy metals, agricultural waste, pesticide and fertilizers are the main source that deteriorate the soil health (Chirakkara *et al*., 2016). Heavy metals have great role in biological system, so we can divide into two groups' essentials and non essential. Those heavy metals which play a vital role in biochemical and physiological function in some living organisms are called essential heavy metals, like zinc (Zn), nickel (Ni) and cupper (Cu) (Cempel and Nikel, 2006). In some living organisms, heavy metals don't play any role in biochemical as well as physiological functions are called non essential heavy metals, such as mercury (Hg), lead (Pb), arsenic (As), and Cadmium (Cd) (Dabonne *et al*., 2010). Cadmium (Cd) is consider as a non essential heavy metal that is more toxic at very low concentration as compare to other non essential heavy metals. It is toxic to plant, human and animal health. Cd causes serious diseases in human health through the food chain (Rafiq *et al.,* 2014). So, removal of Cd from the soil is very important problem to overcome these issues (Neilson and Rajakaruna, 2015). Several methods are used to remove the Cd from the soil, such as physical, chemical and physiochemical to increase the soil pH (Liu *et al*., 2015). The main source of Cd contamination in the soil and environment is automobile emissions, batteries and commercial fertilizers (Liu *et al*., 2015).

Phytoremediation is a promising technique that is used in removing the heavy metals form the soil (Ma *et al*., 2011). Plants update the heavy metals through the root and change the soil properties which are helpful in increasing the soil fertility (Mench *et al*., 2009).

Plants can help clean many types of pollution, including metals, pesticides, explosives, and oil. Plants also help prevent wind and rain, groundwater and implementation of pollution off site to other areas. Phytoremediation works best in locations with low to moderate amounts of pollution. Plants absorb harmful chemicals from the soil when the roots take in water and nutrients from contaminated soils, streams and groundwater. Once inside the plant and chemicals can be stored in the roots, stems, or leaves. Change of less harmful chemicals within the plant. Or a change in the gases that are released into the air as a candidate plant Agency (US Environmental Protection, 2001).

Phytoremediation is the direct use of living green plants and minutes to stabilize or reduce pollution in soil, sludge, sediment, surface water or groundwater bodies with low concentrations of pollutants a large clean space and shallow depths site offers favorable treatment plant (associated with US Environmental Protection Agency 0.2011) circumstances. Phytoremediation is the use of plants for the treatment of contaminated soil sites and sediments and water. It is best applied at sites of persistent organic pollution with shallow, nutrient, or metal. Phytoremediation is an emerging technology for contaminated sites is attractive because of its low cost and versatility (Schnoor, 1997). Contaminated soils on the site using the processing plants. Phytoremediation is a plant that excessive accumulation of metals in contaminated soils in growth (National Research Council, 1997). Phytoremediation to facilitate the concentration of pollutants in contaminated soil, water or air is composed, and plants able to contain, degrade or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and other contaminants in the media that contain them. Phytoremediation have several techniques and these techniques depend on different factors, like soil type, contaminant type, soil depth and level of ground water. Special operation situations and specific technology applied at the contaminated site (Hyman and Dupont 2001).

Techniques of phytoremediation

Different techniques are involved in phytoremediation, such as phytoextraction, phytostabilisation, phytotransformation, phytostimulation, phytovolatilization, and rhizofiltration.

Phytoextraction

Phytoextraction is also called phytoabsorption or phytoaccumulation, in this technique heavy metals are removed by up taking through root form the water and soil environment, and accumulated into the shoot part (Rafati *et al*., 2011).

Phytostabilisation

Phytostabilisation is also known as phytoimmobilization. In this technique different type of plants are used for stabilization the contaminants from the soil environment (Ali *et al*., 2013). By using this technique, the bioavailability and mobility of the different contaminants are reduced. So, this technique is help to avoiding their movement into food chain as well as into ground water (Erakhrumen, 2007).

Nevertheless, Phytostabilisation is the technique by which movement of heavy metals can be stop but its not permanent solution to remove the contamination from the soil. Basically, phytostabilisation is the management approach for inactivating the potential of toxic heavy metals form the soil environment contaminants (Vangronsveld *et al*., 2009).

Phytostimulation

Enhance microbial activity in the soil to degrade pollutants, usually by organisms that connect with the living roots. This process is known as the degradation of the rhizosphere. Phytostimulation may involve aquatic plants and support the workforce of microbial degraders, as in stimulating the degradation of atrazine by Zehgrnah plants (Rupassara, *et al*., 2002). Organic pollutant like petroleum hydrocarbons and heavy metals like Cd, Zn are considered as a most prominent pollutant in the soil environment. There are several biological, chemical and physical methods are used to solve this problem. Phytoremediation technique especially phytostimulation is much popular and cost effective technique that is used for removal of contaminants from the soil environment (Miya and Firestone, 2001).

Phytovolatilization

Phytovolatilization is the technique by which heavy metals are removed from the soil environment and/or water environment and released into the air, sometimes because materials phytotransformation more volatile and/or less polluting. Some heavy metals, like Hg and Se and organic pollutant is removed by this technique. This technique is considered more effective technique for removal of organic containments from the soil environment. But this technique has more limitation as compare to other techniques. However, contaminants are not removed permanently form the soil environment but it is transfer form one environment (soil) to another environment (atmosphere) (Padmavathiamma and Li, 2007).

Rhizofiltration

Rhizofiltration is the phytoremediation technique by which heavy metals are removed or filtered from water through the root biomass. Pollutants may be absorbed or adsorbed on the roots. Heavy metals in the soil environment and water are removed through different chemical techniques like reverse osmosis, ion exchange, and precipitation (Francis *et al*., 1999). However, these all techniques are much expensive and difficult to perform (Summers, 1992). So, rhizofiltration is a promising phytoremediation technique in which plant roots are used to absorb the heavy metals form the soil and water environment (Salt *et al*., 1995). Different plant roots like various grasses sunflower, and mustard is used to remove the toxic heavy metals like Cd, Ni, Cu, Zn and Pb (Lee *et al*., 2010).

Phytoextraction

Phytoextraction is the plant based technique that is used to remove the heavy metals from the soil environment. It is an emerging and comparatively low cost technique that is extensively used (Evangelou *et al*., 2007). Phytoextraction is more efficient and effective technique and it depends on several factors such as different soil properties, accessibility of the contaminants, plant species, determination and chemical speciation of contaminants in the soil environment (Shabani and Sayadi, 2012). Two type of phytoextraction approaches are used to remove the toxic contaminant from the soil environment. The first strategy that is used in phytoextraction is called hyper natural accumulation. Plants are potentially used to remove the contaminants from the soil and water body. While, second strategy is called Induced or assisted hyper accumulation, where are conditioned fluids containing chelating agent or other soil to increase the solubility of metal or packaging so that plants can absorb more easily added. In many cases, natural hyper accumulators are plants that can tolerate Metallophyte and integration of high levels of toxic metals (Zhuang *et al*., 2007). There are several examples for phytoextraction. Arsenic by Sunflower (Marchiol, *et al*., 2007) or Chinese brake fern (Pterisvittata) (Wang *et al*., 2002) hyper accumulator the barrel. Chinese brake fern stores arsenic in its leaves. Cadmium with Willow (*Salix viminalis*): In 1999, an experience of the research conducted by Maria Greger and Tommy Landberg suggested Willow has great potential as phytoextractor cadmium (Cd), zinc (Zn), copper (Cu), and Willow has special features such as high-energy transport of heavy metals from root to shoot a large amount of biomass production, can also be used for the production of bio-energy energy biomass power plant electricity production (Greger *et al*., 1999). Cadmium and zinc using Alpine Mountains stool (*Thlaspi caerulescens*), Indian mustard (Brassica juncea) the barrel hyper accumulator of these metals at levels that are toxic to many plants. On the other hand, the presence of copper appears to weaken growth (see table reference). Lead using Indian mustard (*Brassica juncea*), carpets (*Ambrosia artemisiifolia*), Hemp poisonous tree of *Apocynum cannabinum* or poplar, which insulates the lead by weight. Using salt-tolerant (moderately saline) barley and/or sugar beet extract usually sodium chloride (table salt) to retrieve the fields seawater flooded.

Phytostabilisation

Phytostabilisation emphasizes the stability and long-term containment of contaminants. For example, the existence of the plant can reduce wind erosion. Or plant roots can prevent water erosion, immobilize the movement of pollutants by adsorption or accumulation, and provide area around the roots which they may precipitate contaminants and stability. Unlike phytoextraction, Phytostabilisation mainly focused on the isolation of contaminants in the soil near the roots, but not in the plant tissue. Contaminants become less biologically and reduce livestock and wildlife, and human exposure. Phytostabilisation contains different mechanisms. Firstly, by providing the vegetative cover, plants can decrease the leaching ability of contaminants through evapotranspiration and storage of water in the contaminated soil.

In addition, Plants also help in adding organic matter in the soil which helps to control the soil erosion by increasing the soil aggregation (Robinson *et al.,* 2006). The example of this technique that is used for stabilization is vegetation which controls the containments from the soil environment (Mendez *et al*., 2008).

Phytotransformation

Changing environmental chemicals as a direct result of the metabolic processes of the plant, and often leads to rupture, degradation (phytodegradation) or gel (phytostabilisation). In the case of persistent organic pollutants (POP) such as pesticides, explosives, solvents, industrial chemicals, foreign substances and other biologically substances some plants, such as cannas, make them non-toxic materials by their metabolism. In other cases, you can live in cooperation with the metabolism of these substances in soil or water bodies. The term phytotransformation represents the variation of the chemical composition without a complete breakdown of the complex. He uses the term 'green liver model "to describe phytotransformation and plants behave in relation to the human liver in dealing with these compounds biologically foreigners (foreign compounds/contaminants) (Burken *et al*., 2004).

Cadmium a toxic heavy metal

Heavy metal contamination of soils is a major problem for the past few years due to human activities (Ramadan *et al*., 2007; Ali, *et al*., 2011). Although some heavy metals are useful, such as iron, zinc, manganese, copper, etc., at a very low concentration, while others, such as cadmium, chromium, lead, and also carry dangerous plants and animals threatened (Costa, 2000, Ramadan *et al*., 2007). Soil contamination is known as the accumulation of toxic elements and effective salts, Composites, or causing pathogens, which have negative effects on plant growth and health of the animal (Guo *et al*., 2014). Trace element cadmium and contaminants in soil, resulting from increased human activities. Cadmium which is a rare element that does not have the atmospheric properties (Borsari M, 2011; Tran and Popova, 2013). Agricultural soils in many parts of the world are somewhat contaminated by cadmium due to the long-term use of phosphate fertilizers moderate, and the application of sewage sludge and dust from smelters. Cadmium is a non-essential element, raises a number of toxic effects on humans, animals and plants. Heavy metals, including Cd, cannot degrade as other pollutants and cleaning usually requires removal. Cadmium-phytoextraction agricultural soil can be easily implemented because of the ease of movement of cadmium in soil and plants system in comparison with other heavy metals (Davis, 1984, Robinson *et al*., 2000).

Heavy metals in the soil in various forms of labile as solubility, immutable component of the structure and precipitated form (Zalidis, Barbayiarinis, *et al*., 1999 and Zeng, Ali, *et al*., 2011). The former is used in two general forms of plants through the process of absorption and desorption. This phenomenon depends on the agility and ease of access to minerals (Krishnamurti, Huang, *et al*., 1999, Zeng, Ali, *et al*., 2011).

Heavy metal is generally known set of elements with atomic mass (> 5 gcm to -3 gcm), particularly metals such as exchange of cadmium, lead and mercury (Duffus, 2002, Kemp, 1998). Contamination by heavy metals from the soil increased in recent decades. This was released into the environment by various means of transportation such as air, water and soil. Plants grown in contaminated soil by which heavy metals are enter into the food chain.

Cadmium is a pollutant and the presence of significant environmental concerns, and enter the food chain can cause a serious threat to human health. High blood pressure, and constant pain caused by disease, cancer and even the results of high concentrations of cadmium (Basta, Raun *et al*., 1998). Excessive levels of cadmium have toxic effects on the plants, leading to stunting, and inhibition of photosynthesis, and the beginning of the inhibition of the enzymatic activity, efflux cation Relations water, and transformed acted stomata (Prasad, 1995).

Experiment conducted by (Hassan, Zhang *et al*., 2005), which resulted in cadmium have negative effects on plant physiological and morphological parameters letters. Decline in growth can be explained based on the rate of photosynthesis and chlorophyll content low. Cadmium accumulation and twenty times more root and shoot and then two hundred times in the grain.

Cadmium in soil causes a water stress in plants resulting in elimination and low stomatal transpiration rates and the water content from the sheet. These symptoms are the result of injuries morphological parameters such as reduced number of chloroplasts and intra-cellular spaces and expansion of the cell (Chen and Huerta, 1997). Cadmium accumulation in the plant and the plant varies from species to species and varieties within the species controlled by factors such as soil and environmental factors and management (Grant Buckley *et al*., 1998).

Phytoremediation of Cadmium by Mustard (Brassica juncea L) and Sunflower (Helianthus annuus L.)

Phytoremediation as a new environmentally friendly technology, which is used to remove plants or to paralyze the movement of heavy metals was considered (Suresh and Ravishankar, 2004). Phytoremediation offers the benefits of physical and chemical approaches to remove heavy metals from the soil in terms of cost and safety for humans and the environment (Suza *et al*., 2008). The accumulation of metals plants can be divided into three groups based on their tendency to accumulate various metals: (1) Cu/Co, (2) zinc/CD/lead. And (3) nickel batteries (Raskin *et al*., 1994).

The use of plants to remove heavy metals in soil is expanding due to its cost-effectiveness compared to traditional methods, and show great potential. Since the contaminants such as lead and cadmium have limited bioavailability in the soil, and means for facilitating the transfer necessary for the shoots and roots of plants for the treatment of a plant with success.

The purpose of this study was to investigate the effects of adding different ratios (0, 3, 6 and 12 mmol/kg) of ethylene diaminetetra acetate (EDTA) on the availability of heavy metals in soils contaminated by 50 mg/kg of cadmium ($CdCl_2$), 50 mg/kg of copper ($CuSO_4$), 50 mg /kg of lead [bales $(NO_3)_2$] and 50 mg/kg of zinc ($ZnSO_4$), and the ability of canola (*Brassica napus* L.) and Indian mustard (*Brassica juncea* L.) plants to absorb copper and cadmium lead and zinc in the growth chamber. The results indicated that application of EDTA in order to increase the availability and use of plants of heavy metals. Significant differences in both species and plant parts. Regarding types tested, the most efficient plants copper, cadmium, lead and zinc absorption and canola. The roots uptake heavy metals from two types of shooting higher consumption of heavy metals (Esringu and Turan, 2007). Based on the technology to clean plants (phytoremediation) offers a number of advantages over traditional cleaning methods as well as in other biological treatment techniques. Phytoextraction of heavy metals as it was presented, profitable and promising alternative treatment methods based on traditional engineering, which typically involve excavation and removal of contaminated soil layer, and reach financial stability or washing contaminated soil with strong acids to change the ownership of the land. These traditional methods are not cost effective and environmentally friendly (Robinson *et al*., 2000; Pollard *et al*., 2002).

Metals are a group of pollutants from a lot of anxiety. As a result of human activities such as mining and processing of metal ores, electroplating, exhaust, and the production of energy and fuel, fertilizer and pesticides and other pollutants has become one of the environmental problems the most dangerous minerals today. Phytoremediation, and non-intrusive, and emerging aesthetic technology cost, and uses the superb ability of plants to concentrate elements and compounds in the environment and on the metabolism of various molecules in tissues, and it looks very promising to remove contaminants from the environment.

In this area of the treatment plant, and the use of plants to transport and concentrate metals in the soil at harvest of root and shoot parts above the ground, while phytoextraction, perhaps, to the currently, the marketing approach. Improve the ability of plants to resist and accumulate metals by genetic engineering should open new avenues for the treatment plant. Because of the enormous potential of sound as a viable alternative to traditional methods of treating contaminated soils, phytoremediation is currently an area of active research exciting (Alkorta *et al*., 2004).

Brassica juncea (Brassicaceae), and plant biomass production and high rapid growth, and it seems that the appropriate species for phytoextraction because it can compensate for the low accumulation of cadmium with a much higher biomass yield. Use many chelators, including ethylene diamine quaternary acetic acid (EDTA), and increase the solubility of metals in the soil by facilitating easy access, and the absorption of the plant from root to shoot in a vascular plant (Blaylock *et al*., 1997; Bricker *et al*., 2001; Wu *et al*., 2004). Soil contaminated with heavy metals, cadmium (Cd), lead (Pb), which are difficult to treat. Phytoremediation can be a convenient way to eliminate toxic metals in the soil, but there are few plants that may be appropriate hyper accumulate metals. In this study, based on the accumulation of lead and cadmium from four plants, including Sunflower (*Helianthus annuus* L.), Mustard (*Brassica juncea* L.), Alfalfa (*Medicago sativa* L.), and Castor oil (*Castor communis* L.) in water cultures. The results showed that these plants can phytoextract heavy metals, and the storage capacity depending on the species, and the concentrations of classes of heavy metals. It BCF (BCF) and TF (plant operator) for four different types of building was phytoextraction and transportation of heavy metals. Changes highlighted in plant biomass, pH and Eh in the various treatments that these four plants were separate responses in cadmium and lead in crops. Measures must be taken to improve plant sites contaminated by heavy metal treatment, such as pH and regulations first, and so on (Chen Qi *et al*., 2007).

Conclusion

Now a day, modernization, industrialization, fertilization, and heavy traffic is the major cause of contamination in the ecosystem, which is the serious issue all over the world. Worldwide scientists are paying attention to solve this issue. Several physical, chemical and biological approaches have been introduced but the most effect technique that is used to solve this problem is phytoremediation. Phytoremediation is considered as an innovative and cost effective technique. Because phytoremediation is solar driven and ecofriendly technique with maximum adoptable technique all over the world. Phytoextraction is consider a more economic and feasible technique for removing the heavy metals form the soil environment. Cadmium (Cd) is a toxic heavy metal for plants and animals. In plants, and toxicity of cadmium may cause a decrease in the rate of photosynthesis, chlorophyll content, stomatal behavior and transpiration rate and relative water content and paper, and the destruction of certain physiological processes, which ultimately reduces plant growth and development. Toxic parts of the plant for consumption by animals and humans can cause acute and chronic disorders. Because of these risks, it is necessary to regulate the concentration of cadmium in plants (primary producers) limitless. Management of plant nutrients is very useful for the development of a plant to resist toxicity of cadmium. Better nutrition of the plant can effectively relieve the toxicity of cadmium by a number of mechanisms. Phytoremediation of cadmium by Mustard is a tool to reduce the impact of cadmium contaminated soil and can reduce environmental pollution. Mustard (*Brassica juncea* L and Sunflower (*Helianthus annuus* L.) Plant biomass production and high rapid growth, and it seems that the appropriate species for phytoextraction because it can compensate for the low accumulation of cadmium with a much higher biomass yield. Another technique called phytostabilisation is used for the cleaning the heavy metal in urban and industrial areas and this technique is widely used all over the world. To improve the availably and effectiveness of this technique a long term field experiments are required to perform. Even though phytoremediation is an emerging technique for removal of contaminants from the soil environment, but it also have some limitations. Phytoremediation is very good technique but it takes very long time to solve the heavy metals form the soil. If proper management is not taken then heavy metals will enter into food chain that is much dangerous for human health. Phytoremediation is very good technique that is widely used to remove the heavy metals from the soil environment but still more research is needed to do. So, researchers and scientists who have same background with this field should use their abilities to improve this technique. Government and related authorities should set principles to protect the soil from the heavy metals and also aware the peoples by supporting them. This review is providing the importance and specific information about the use to some good and effective techniques to overcome this problem.

References

Ali H, Khan E, Sajad MA. 2013. Phytoremediation of heavy metals-concepts and applications. Chemosphere **91(7),** 869-881.

Alkorta1 I, Hernandez-Allica J, Becerril JM, Amezaga I, Albizu I, Garbisu C. 2004. Recent findings on the phytoremediation of soils contaminated with environmentally toxic heavy metals and metalloids such as zinc, cadmium, lead, and arsenic. Reviews in Environmental Science and Bio/Technology 3, 71–90.

Basta N, Raun W, Gavi F. 1998. Wheat grain cadmium under long-term fertilization and continuous winter wheat production. Better Crops **82,** 14-15.

Becker H. 2000. Phytoremediation--Using plants to clean up soils: Agricultural Research v. **48,** no. 6.

Blaylock MJ, Salt DE, Dushenkov S, Zakharova O, Gussman C, Kapulnik Y, Ensley, BD, Raskin I, 1997.Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents. Environ. Sci. Technol. **31,** 860–865.

Borsari M. 2011. Cadmium: Inorganic & Coordination Chemistry.In: Encyclopedia of Inorganic and Bioinorganic Chemistry. New York: John Wiley & Sons, Ltd.

Bricker TJ, Pichtel J, Brown HJ, Simmons M. 2001.Phytoextraction of Pb and Cd from superficial soil: effects of amendments and croppings. J. Environ. Sci. Health Part A: Toxic/Hazard. Subst. Environ. Eng. **36,** 1597–1610.

Burken JG. 2004. "2. Uptake and Metabolism of Organic Compounds: Green-Liver Model", in McCutcheon, S.C.; Schnoor, J.L., Phytoremediation: Transformation and Control of Contaminants, A Wiley-Interscience Series of Texts and Monographs, Hoboken, NJ: John Wiley, 59, ISBN0-471-39435-1. http://dx.doi.org/10.1002/047127304X.ch2,

Cempel M, Nikel G. 2006. Nickel: a review of its sources and environmental toxicology. Polish Journal of Environmental Studies **15(3),** 375-382.

Chen Y, Huerta AJ. 1997. Effects of sulfur nutrition on photosynthesis in cadmium- treated barley seedlings. Journal of plant nutrition **20,** 845-856.

Chirakkara RA, Cameselle C, Reddy KR. 2016. Assessing the applicability of phytoremediation of soils with mixed organic and heavy metal contaminants. Reviews in Environmental Science and Bio/Technology **15(2),** 299-326.

Costa M. 2000. Chromium and nickel. In: Zalups, R.K., Koropatnick, . J. (Eds.).Molecular Biology and Toxicology of Metals. Taylor and Francis, Great Britain 113-114.

Dabonne S, Koffi B, Kouadio E, Koffi A, Due E, Kouame L. 2010. Traditional utensils: potential sources of poisoning by heavy metals. British Journal of Pharmacology and Toxicology **1(2),** 90-92.

Davis RD. 1984. Cadmium—a complex environmental problem, cadmium in sludge used as fertilizer. Experientia **40,** 117–126.

Del Rio LA, Pastori GM, Palma JM, Sandalio LM, Sevilla F, Corpas FJ, Jimenez A, Lopez-Huertas E, Hemandez JA. 1998. The activated oxygen role of peroxisomes in senescence. Plant Physiol. **116,** 1195–1200.

Duffus J. 2002. "Heavy Metals" – A meaningless term? . Pure and Applied Chemistry **74,** 793-807.

Evangelou MW, Ebel M, Schaeffer A. 2007. Chelate assisted phytoextraction of heavy metals from soil. Effect, mechanism, toxicity, and fate of chelating agents. Chemosphere **68(6),** 989-1003.

Francis CW, Timpson ME, Wilson JH. 1999. Bench-and pilot-scale studies relating to the removal of uranium from uranium-contaminated soils using carbonate and citrate lixiviants. Journal of hazardous materials **66(1),** 67-87.

Grant C, Buckley W, Bailey L, Selles F. 1998. Cadmium accumulation in crops. Canadian Journal of Plant Science **78,** 1-17.

Greger M, Landberg T. 1999. Using of Willow in Phytoextraction, International Journal of Phytoremediation **1(2),** 115–123, http://dx.doi.org/10.1080/15226519908500010.

Guo K, Liu YF, Zeng C, Chen YY, XJ Wei. 2014. Global research on soil contamination from 1999 to 2012: A bibliometric analysis. Acta Agriculturae Scandinavica, Soil & Plant Science 64: 377-391. http://dx.doi.org/10.1080/09064710.2014.913679.

Hassan MJ, Zhang G, Wu F, Wei K, Chen Z. 2005. Zinc alleviates growth inhibition and oxidative stress caused by cadmium in rice. Journal of Plant Nutrition and Soil Science **168,** 255-261.

Hyman M, Dupont RR. 2001. Groundwater and soil remediation. ASCE Press,.

Kemp DD. 1998. The environment dictionary. London: Routledge.

Krishnamurti GSR, Huang PM Kozak LM. 1999. Sorption and desorption kinetics of cadmium from soils: influence of phosphate. Soil Science **164,** 888-898.

Landmeyer JE. .2011. Introduction to phytoremediation of contaminated groundwater: 431 p.

Lee M, Yang M. 2010. Rhizofiltration using sunflower (*Helianthus annuus* L.) and bean (*Phaseolus vulgaris* L. var. *vulgaris*) to remediate uranium contaminated groundwater. Journal of hazardous materials, **173(1),** 589-596.

Liu X, Tian F, Xie Y, Ji X. 2015. Control effects of Tianshifu soil conditioners on Cd contamination in paddy fields of Hunan Province. Agricultural Science & Technology **16(7),** 1447.

Ma Y, Rajkumar M, Luo Y, Freitas H. 2011. Inoculation of endophytic bacteria on host and non-host plants-effects on plant growth and Ni uptake. J Hazard Mater. **195,** 230-237.

Marchiol L, Fellet G, Perosa D, Zerbi G. 2007. Removal of trace metals by Sorghum bicolor and *Helianthus annuus* in a site polluted by industrial wastes: A field experience, Plant Physiology and Biochemistry **45(5),** 379–87, http://dx.doi.org/10.1016/j.plaphy.2007.03.018,PMID17507235.

Mench M, Schwitzguébel JP, Schroeder P, Bert V, Gawronski S, Gupta S. 2009. Assessment of successful experiments and limitations of phytotechnologies: contaminant uptake, detoxification and sequestration, and consequences for food safety. Environmental Science and Pollution Research **16(7),** 876.

Mendez MO, Maier RM. 2008.Phytostabilization of Mine Tailings in Arid and Semiarid Environments-An Emerging Remediation Technology, Environ Health Perspect **116 (3),** 278–83. http://dx.doi.org/10.1289/ehp.10608,PMC2265025PMID18335091.

Miya RK, Firestone MK. 2001. Enhanced phenanthrene biodegradation in soil by slender oat root exudates and root debris. Journal of Environmental Quality, **30(6),** 1911-1918.

National Research Council. 1997. Innovations in ground water and soil cleanup--From concept to commercialization: Washington, D.C., National Academies Press, 310 p.

Neilson S, Rajakaruna N. 2015. Phytoremediation of agricultural soils: Using plants to clean metal-contaminated arable land. In *Phytoremediation* (pp. 159-168). Springer International Publishing.

Padmavathiamma PK, Li LY. 2007. Phytoremediation technology: hyper-accumulation metals in plants. Water, Air, and Soil Pollution, **184(1-4),** 105-126.

PJ F, ML VB. 1993. Uptake and distribution of cadmium in maize inbred lines. Plant Soil **150,** 25-32.

Pollard AJ, Powell KD, Harper FA, Smith JAC. .2002. The genetic basis of metal hyper accumulation in plant. Crit. Rev. Plant Sci. **21,** 539–566.

Prasad M. 1995. Cadmium toxicity and tolerance in vascular plants. Environmental and Experimental Botany **35,** 525-545.

Rafati M, Khorasani N, Moattar F, Shirvany A, Moraghebi F, Hosseinzadeh S. 2011. Phytoremediation potential of Populus alba and Morus alba for cadmium, chromuim and nickel absorption from polluted soil. International Journal of Environmental Research **5(4),** 961-970.

Rafiq MT, Aziz R, Yang X, Xiao W, Rafiq MK, Ali B, Li T. 2014. Cadmium phytoavailability to rice (*Oryza sativa* L.) grown in representative Chinese soils. A model to improve soil environmental quality guidelines for food safety. Ecotoxicology and environmental safety, **103,** 101-107.

Ramadan MAE, Al-Ashkar EA. 2007. The effect of different fertilizers on the heavy metals in soil and tomato plant. Australian Journal of Basic and AppliedSciences **1,** 300-306.

Raskin I. 1999. Bioconcentration of heavy metals by plants.Curr. Opin.Biotechnol. **5,** 285–290.

Rew A. 2007. Phytoremediation: an environmentally sound technology for pollution prevention, control and remediation in developing countries. Educational Research and Reviews **2(7),** 151-156.

Robinson B, Mills T, Petit D, Fungi L, Green S, Clothier B. .2000. Natural and induced cadmium accumulation in poplar and willow, implications for phytoremidiation. Plant Soil **227,** 301–306.

Robinson B, Schulin R, Nowack B, Roulier S, Menon M, Clothier B, Mills T. 2006. Phytoremediation for the management of metal flux in contaminated sites. Forest Snow and Landscape Research **80(2),** 221-224.

Rupassara SI, Larson RA, Sims GK, Marley K. A. 2002. Degradation of Atrazine by Hornwort in Aquatic Systems, Bioremediation Journal **6(3),** 217-224. http://dx.doi.org/10.1080/10889860290777576.

Salt DE, Blaylock M, Kumar NP, Dushenkov, V, Ensley BD, Chet I, Raskin I. 1995. Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. Nature biotechnology **13(5),** 468-474.

Schnoor JL. 1997. Phytoremediation: Ground-Water Remediation Technologies Analysis Center Technology Evaluation Report TE-98-01.

Shabani N, Sayadi MH. 2012. Evaluation of heavy metals accumulation by two emergent macrophytes from the polluted soil: an experimental study. The Environmentalist **32(1),** 91-98.

Summers AO. 1992. The hard stuff: metals in bioremediation. Current Opinion in Biotechnology, **3(3),** 271-276.

Suresh B, Ravishankar GA. 2004. Phytoremediation- a novel and promising approach for environmental clean-up. Crit. Rev. Biotechnol. **24,** 97–124.

Suza W, Harris RS, Lorence A. 2008. Hairy roots: from high-value metabolite production to phytoremediation. Electr. J. Integr. Biosci. **3,** 57–65.

TRAN TA, POPOVA LP. 2013. Functions and toxicity of cadmium in plants:recent advances and future prospects. Turk J Bot **37,** 1-13.

Turan M, Esringü A. 2007. Phytoremediation based on canola (*Brassica napus* L.) and Indian mustard (*Brassica juncea* L.) planted on spiked soil by aliquot amount of Cd, Cu, Pb, and Zn Plant Soil Environ., **53(1),** 7–15.

U.S. Environmental Protection Agency. 2001.A citizen's guide to phytoremediation: U.S. Environmental Protection Agency, Technology Innovation Office.

U.S. Environmental Protection Agency. 2011. Using phytoremediation to clean up sites: U.S. Environmental Protection Agency, access date June 2, 2011.

Vangronsveld J, Herzig R, Weyens N, Boulet J, Adriaensen K, Ruttens A, Van der Lelie D. 2009. Phytoremediation of contaminated soils and groundwater: lessons from the field. Environmental Science and Pollution Research **16(7),** 765-794.

Wang J, Zhao FJ, Meharg AA, Raab A, Feldmann J, McGrath SP. 2002.Mechanisms of Arsenic Hyperaccumulation in Pterisvittata. Uptake Kinetics, Interactions with Phosphate, and Arsenic Speciation, Plant Physiology **130(3),** 1552–61. http://dx.doi.org/10.1104/pp.008185,PMC166674,MID124280.

Zalidis G, Barbayiarinis N, Theodora Matsi. 1999. Forms and distribution of heavy metals in soils of the Axios delta of northern Greece. Communications in Soil Science and Plant Analysis: 817-827.

Zeng F, Ali S, Zhang H, Ouyang Y, Qiu B, Wu F. 2011. The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants. Environmental Pollution **159,** 84-91.

ZhiXN, Sun Li NA, Sun Tie-heng, Yu-shuang LI, Wang Hong. 2007. Evaluation of phytoextracting cadmium and lead by sunflower, ricinus, alfalfa and mustard in hydroponic culture. Journal of Environmental Sciences **19,** 961–967.

Zhuang P, Yang QW, Wang HB, Shu WS. 2007. Phytoextraction of heavy metals by eight plant species in the field. Water, Air, and Soil Pollution **184(1-4),** 235-242.