Journal of Research in Forestry, Wildlife & Environment Vol. 9(2) June, 2017
http://www.ajol.info/index.php/jrfwe
jfewr ©2017 - jfewr Publications
E-mail:jfewr@yahoo.com
ISBN: 2141 – 1778
Labe and Agera 2017

ROLE OF FORESTRY IN MITIGATING GLOBAL SOIL POLLUTION FROM TOXIC HEAVY METALS-A REVIEW

[1]Labe, T. E. and [2]Agera S.I.N.
Department of Forest Production and Products, Federal University of agriculture, Makurdi. Nigeria.
[1]**Corresponding author's Email**: *labeterese@gmail.com* **Phone** +23407031911750

ABSTRACT

One of the challenges confronting environmental management is the pollution of land, air and water resources by toxic heavy metals.This review seeks to identify the plant species and their potentials for remediation, less cost effective methods to remediate contaminated soils, and the remediation capability of woody plants. Soil pollution by heavy metals is a global problem. Globally, human activities lead to a substantial accumulation of heavymetals in soils. The accumulation of heavy metals comes from industrial activities like mining, smelting, refining, manufacturing processes and residues from excessive use of fertilizers. A lot of chemicals and heavy metals are released into the environment and contribute to a variety of toxic effects. Heavy metals such as Cadmium, Copper, lead, Chromium, Zinc and Nickel are serious environmental pollutants. The soil has been the disposal mediumfor most ofthe heavy metals. The soilneeds to be treated. Conventional remediation technique of cleaning heavy metals from contaminated soil is expensive and environmentally destructive. The use of plant species for cleaning polluted soils is gaining increasing attention.Use of plants to detoxify pollutants is a cheap, environmental friendly and effective way of cleaning contaminated soils. The mechanisms of metal uptake, accumulation, osmoregulation, and translocation vary with each plant species. The use of trees as a vegetation cover for the remediation of land contaminated by toxic heavy metals seemsmuch more effective.In order to overcome the problems of soil pollution, human beings have to reduce their impact on the environment seriously.Proper monitoring of industries handling toxic industrial wastes should be carried out regularly.Adapted tree species like Azadirachta indica and Adansonia digitata should be planted on contaminated sites such as mechanic sites to detoxify pollutants.

Key Words: Pollution, Remediation, environmental management, heavy metals, osmoregulation, translocation, detoxify.

INTRODUCTION

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials or disease-causing agents which have adverse effects on plant growth, animal health and humans.Soil pollutionis defined as an undesirable change in physical, chemical and biological characteristics of soil that may be harmful to living organisms, living conditions and cultural assets (Kumar *et al.*, 2012). Land is a precious natural resource the sustainability of agriculture. Unfortunately, it has been subjected to maximum exploitation and severely degraded or polluted due to human activities. The pollution includes point sources such as emissions, effluents and solid discharge from industries, vehicle exhaustion and metals from smelting and mining, in addition to non point sources such as soluble salts(natural and artificial), use of insecticides/pesticides, disposal of industrial and municipal wastes in agriculture, and excessive use of fertilizers(McGrath *etal*.,2001).Heavy metal pollution poses a great health problem(Garbisu and Alkorta, 2001) .

Soil pollution by heavy metals is a world-wide issue. All countrieshave been affected, though the affected areas and severity of pollution varyenormously. In Western Europe, 1,400,000 sites were reportedly affected by heavymetals, of which over 300,000 sites were contaminated and the estimated total number of areas in Europe could be larger, as pollution problems increasingly occurred in Central and Western European countries *(*Gade, 2001*)*. In USA, there are 600,000 brown fields which are contaminated with heavy metals and need reclamation *(*McKeehan, 2000*)*. The problem of soil pollution is also a great challenge in China, where one-sixth of total arable land has been polluted by heavy metals, and more than 40% has been degraded to varying degrees due to erosion and desertification *(*Liu,2006*)*. Soil pollution is also severe in Pakistan and Bangladesh.

In order to maintain the good quality of soils and keep them free from contamination, continuous efforts have been made to develop technologies that are easy to use, sustainable and economically feasible. Physicochemical approaches have been widely used for remedying polluted soils and especially at a small scale. However these approaches experienced more difficulties for a large scale of remediation because of high costs and side effects. The use of plant species for cleaning polluted soils and waters is known as phytoremediation. This has gained increasing attention since last decade (Capuana, 2011*)*.Phytoremediation is a combination of two Greek words; phyto means plants while remediummeans to correct or counteract or restore balance. This means the use of green plants to clean contaminated sites. The use of plants to clean contaminated soil involves applying information that has been known for some years in forestry, agriculture, silviculture and horticulture to environmental problems (USEPA, 2000).Hinchman*et al*. (1998), defined phtoremediation as the engineered use of green plants including grasses, forbs and woody species to remove, contain or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds and radioactive compounds in soil and water. Phytoremediation is the cleanest and cheapest method of cleaning up contaminated soil.

Heavy metals are metallic elements which are toxic and have high density, specific gravity or atomic weight. Examples of heavy metals include lead, mercury, and Cadmium. Less commonly, any metal with a potential negative health effect or environmental impact may be termed a heavy metal, such as cobalt, chromium, lithium and even iron. This paper sets out to:

(a) Identify less- costeffective methods to remediate contamination of polluted soils by heavy metals.

(b) Know the innovative biological technologies such as phytoremediation,based on the nature of plants used to extract, sequester and or detoxify pollutants.

(c) Understandthe remediation capability of woody plants and the plant species that have been used in remediating contaminated soils.

Sources of Soil Pollution by Toxic Heavy Metals

According to Wani *et al* (2012), some of the leading causes of soil pollution are:

i. Industrial wastes such as harmful gases and chemicals, agricultural pesticides, fertilizers and insecticides are the most causes of soil pollution.
ii. Acid rains; when fumes released from industries get mixed with rains.
iii. Fuel leakages from automobiles that get washed away due to rain and seep into the nearby soil.
iv. Unhealthy waste management techniques, which are characterized by release of sewage into the large dumping grounds and nearby streams or rivers.
v. Radioactive pollutants.

Effects of Soil Pollution

The effects of pollution on soil are quite alarming and can result to huge disturbances in living creatures on earth. Some of the most serious soil pollution effects include;

a. Decrease soil fertility.
b. Loss of soil and natural nutrients present in it. Plants also would in addition not thrive in such soils, which would further result in soil pollution.
c. Disturbance in the balance of flora and fauna residing in the soil.
d. Increase in salinity of the soil, which makes it unfit for plant growth thus making it useless and barren.

e. Foul smell due to industrial chemical and gases might result in headaches, fatigues, and nausea in many people.

f. Soil pollutants would bring in alteration in the soil structure, which would lead to death of many essential organisms in it. This would also affect the larger predators and compel them to move to other places, once they lose their food supply (Asami, 2001).

Sources of Heavy Metals

Different source of heavy metals include semiconductors, petroleum, refining, wood preservatives, animal feed additives, coal power plants, herbicides, volcanoes, mining and smelting (Nriagu, 1994).Copper is also a heavy metal originating from electroplating industry, mining, biosolids (Liu *et al.*,2005).Cadmium is generated from geogenic sources; fossil fuel burning, application of phosphate fertilizers and sewage sludge (Kabata, 2001).Zinc is contributed from electroplating industry, smelting and refining, mining, biosolids(Liu *et al.*,2005).Lead (Pd) is produced from mining and smelting of metalliferous ores, burning of leaded gasoline, sewage as well as from, industrial wastes enriched in lead (Gisbert *et al.*,2003).

Processes Involved in the Uptake of Heavy Metals by Woody Plants

Phytoremediation (use of plants for cleaning polluted soils) is a potentially effective technology applicable to restoration of contaminated soils.It isan environmentally friendly, safe and cheap method of eliminating pollutants from the environment (Waziri *et al*., 2016).Several woody species are now considered of interest in phytoremediation. Many woody plants are fast growing, have deep roots, produce abundant biomass, are easy to harvest, and several species revealed some capacity to tolerate and accumulate heavy metals. Plants extract and accumulate metals from soilsolution.Plants that accumulate metals from the soil are calledhyperaccumulator plants (Hinchman *et al.*, 1998). They accumulate metals in large quantities. Before the metal can move from the soil solution into the plant, it passes through the root. The metal ions can move through the porous cell walls of the root cells. Special plant membrane proteins are responsible for binding these metals and making them ready for uptake and transport (Abedin *et al*., 2002). When adapted plant species are grown on contaminated sites, the root system functions as a highly dispersed, fibrous uptake system. Contaminants over a wide range of concentrations are taken up along with water and degraded, metabolized and sequestered in the plant body. Through the process of bioaccumulation, contaminants can be concentrated thousands of times higher in theplants than in the soil.

Mechanisms Involved in Heavy Metal Remediation

There are several ways by which plants can be used for phytoremediation of pollutants from the soil. The mechanisms below are used in cleaning up contaminated soils (USEPA, 2000; Ward and Singh, 2004).

Phytoremediation: Phytodegredation, also called phyto-transformation is the breakdown of contaminants taken up by plants through metabolic processes within the plants or the break-down of contaminants surrounding the plant through the effect of compounds (such as enzymes) produced by the plants. Complex organic pollutants are degraded into simpler molecules and are incorporated into plant tissues to help the plants grow faster (Kafka, 2003). Plants contain enzymes (complex chemical proteins) that catalyze and accelerate chemical reactions. Some enzymes break down and convert ammunition wastes, others degrade chlorinated solvents such as trichloroethylene (TCE), and others degrade herbicides. Enzymes in plant roots break down (degrade) organic contaminants. The fragments are incorporated into new plant material during the assimilation process.

Rhizodegradation: Rhizodegradation also called phyto-stimulation or plant-assisted bioremediation is the break-down of contaminants in the rhizosphere (soil surrounding the roots of plants) through microbial activity. This is enhanced by the presence of plant roots and is a much slower process than phytodegradation (Lasat, 2002). Micro-organisms (yeast, fungi or bacteria) which abound in rain forests consume and digest organic substances for nutrition and energy. Certain micro-organisms can digest organic substances such as fuels or solvents that are hazardous to humans and break them down into harmless products in a process called biodegradation. Natural substances released by the plants roots, sugars,alcohols and acids contain organic carbon that provides food for soil micro-organisms and the additional nutrients enhance their activity. Biodegradation is also aided by the way plants loosen the soil and transport water to the area.

Phytodegradation: In phytodegradation, contaminants are decomposed within the plant following their uptake by the root system. This is influenced by the plant enzymes secreted into the environment.

Phytovolatilization: is the uptake and transpiration of a contaminant by a plant, with release of the contaminant or a modified form of the contaminant from the plant to theatmosphere (USEPA, 2000). Phytovolatilization occurs as growing trees and other plants take up water and the organic contaminants. Some of these contaminants can pass through the plants to the leaves and evaporate, or volatilize, into the atmosphere. In phytodegradation, plants convert contaminants to less assimilable forms as a result which the pollutants are not transported to the upper parts of the plants but remain locked in the rhizosphere (Marzena*et al*., 2011). Poplar trees in one particular study site have been shown to volatilize 90% of the trichloroethylene (Newman *et al.*,1997).Mercury is the primary metal contaminant that this process has been used for.

Phytocxtraction: Phytoextraction also called phytoaccumulation refers to the uptake of metals from the soil by plant roots into above-ground portions of plants. Certain plants called hyperaccumulators, absorb unusually large amounts of metals in comparison to other plants. In phytoextraction, plants take up metal pollutants and are then harvested for disposal (Jadia and Fulekar, 2009).Metals such as nickel, zinc and copper are the best candidates for removal by phytoextraction because the majority of the approximately 400 known plants that absorb unusually large amounts of metals have a high affinity for accumulating these metals. For example nickel is removed from soil by moving up into plant roots, stems, and leaves. The plant is then harvested and disposed of and the site replanted until the nickel in the soil is lowered to acceptable levels *(*Murakami *et al*., 2009).

Pytostabilization: is the use of certain plant species to immobilize contaminants in the soil and ground water through absorption and accumulation by roots.It is the use of plant root to limit contaminant mobility and bioavailability in the soil (Jadia and Fulekar, 2009). This process reduces the mobility of the contaminants and prevents migration to the ground water or air, and also reduces bioavailability for entry into the food chain. The technique can be used to re-establish a vegetative cover at sites where natural vegetation is lacking due to high metal concentrations in surface soils or physical disturbances. Metal-tolerant species can be used to restore vegetation to the sites, thereby decreasing the potential migration of contamination through wind erosion and transport of exposed surface soils and leaching of contaminants to ground water.Phytostabilization is used for cleaning soils contaminated with heavy metals like lead, Arsenic, Cadmium, Chromium, Copper and Zinc.The main purpose of phytostabilization is to decrease the amount of water percolating through the soil matrix, which may result in the formation of hazardous leachate.Act as a barrier to prevent direct contact with the contaminated soilPrevent soil erosion and the distribution of toxic metals to other areas (Raskin and Ensley,2000).

Effects of Toxic Heavy Metal Pollution on Human Health

Heavy metals are natural components of the Earth's crust. They can hardly be degraded or destroyed. To a small extent they enter human bodies through food, drinking water and air. The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic (Jarup, 2003).Heavy metal poisoning could result, for instance from drinking contaminated water (example lead pipes), high ambient air concentrations near emission sources *(*Davies *et al., 2005).*

Heavy metals are dangerous because they tend tobioaccumulate in human bodies. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical concentration in the environment. Heavy metals can enter a water supply source by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals, into lakes, rivers and ground water.The most toxic heavy metal pollutants are; lead, cadmium, copper, chromium, selenium and mercury. The risk of human exposure to heavymetals arises mainly from consuming crops grown in polluted soil and from drinking contaminated water (Asami, 2001). Long term exposure of humans to lead can cause acute or chronic damage to the nervous system of humans, long term exposure associated with renal dysfunction. High exposure can cause obstructive lung disease and has been linked to lung cancer, and damage to human's respiratory systems (Jarup*et al*., 1998).

Copper is an essential substance to human life, but in high doses, it can cause anemia, liver and kidney damage, and stomach and intestinal irritation.Mercury causes damage to the brain and the central nervous system. Chromium is used in metal alloys and pigments for production of products like paints and cement. Low level exposure can irritate the skin and cause ulceration. Long term exposure can cause kidney and liver damage, and damage to circulatory and nerve tissue. Chromium often, accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium.Selenium causes damage to the brain and the central nervous system, causes psychological changes and makes development changes in young children.

Table 1: Plant Species Used for Phytoremediation

Scientific name	Common name	Family
Adansonia digitata	Baobab	Malvaceae
Andropogon barbinodis	Cane blue stem	Poaceae
Azadirachta indica	Neem	Meliaceae
Betulapen dula	Birch	Betulacea
Bidens odorata	Beggarstrick	Gramminae
Brickellia veronicifolia	Sun flower	Asteraceae
Casuarina equisetifolia	Australian pine tree	Casuarinaceae
Cynodon specie	Bermuda grass	Poacea
Dalea bicolor	Indigo bush	Fabaceae
Genipa americana	Jagua	Rubiaceae
Haplopappus venetus	Verbena	Compositae
Brassica juncea	Indian mustard	Brassicaceae
Salix caprea	Goat willow	Salicaceae
Eichhornia crassipes	Water hyacinth	Pontederiaceae
Heterospema pinnatum	Wing petal	Asteraceae
Jatropha curcas	Physic nut	Euphorbiaceae
Juniperus species	Juniper or cedar	Cupressaceae
Morus alba	White mulberry	Moraceae
Phytolacca acinosa	Indian poke	Phytolaccaceae
Polygonum aviculare	Knot grass	Polygoaceae
Schinus molle	Peruvian pepper tree	Anacardiaceae
Xanthium strumarium	Cockle bur	Asteraceae

Sources: Modified from:Adelekan and Abegunde (2011); Noushin and Maeiyat (2011); Annie and Gilbert (2013); Kumar *et al* (2012)

Advantages of Using Trees for Remediating Contaminated Soils

According to Noushin and Maeiyat (2009), the following are advantages of using trees to clean up contaminated soils

(i) It is economically more viable using the same tools and supplies as agriculture.

(ii) It is less disruptive to the environment and does not involve waiting for new plant communities to re-colonize the site.

(iii) Disposal sites are not needed.

(iv) It is aesthetically more pleasing than traditional methods.

(v) It avoids excavation and transport of polluted media thus reducing the risk of spreading the contamination.

(vi) It has the potential to treat sites polluted with more than one type of pollutant.

Disadvantages of Using Trees for Remediating Contaminated Soils

It is dependent on the growing conditions required by plants (climate, geology, altitude, soil temperature).

1. Contaminants collected in senescing tissues such as leaves released back into the environment through litter fall.
2. Time taken to remediate sites far exceeds that of other technologies.
3. Exposure of the ecosystem to contaminants is prolonged as phytoremediation is a relatively slow process.
4. Success is dependent on the tolerance of the plant to the pollutant *(*Noushimand Maeiyat, 2009).

Why Trees Are Good Phytoremediators

They can grow fast.

a. They have high transpiration rates.
b. They are large.
c. They have large and deep root systems.
d. Have potential for ecological restoration.
e. They are woody.
f. They have ability to grow in polluted soils.
g. Large, microbially diverse rhizosphere.

h. They are perennials.

i. Plants can accumulate high levels of heavy metals in their tissues without showing toxicity(Grete, 2012*)*.

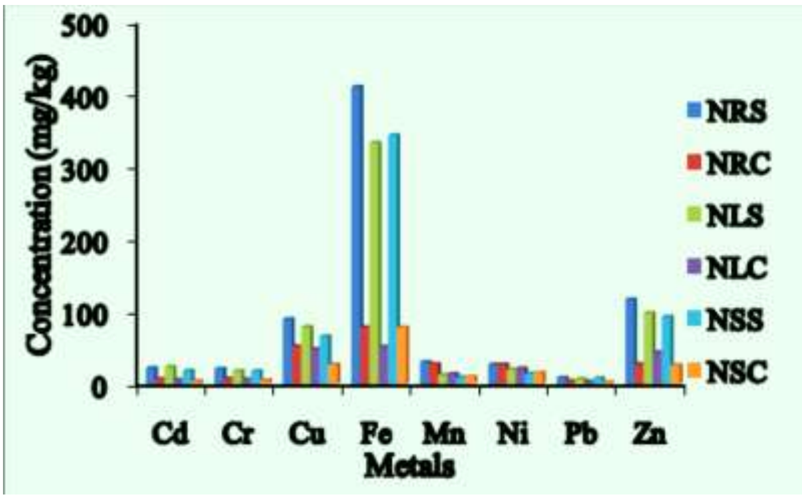

Figure1: Heavy metal Concentration in the root, Leaves and shoot of *Azadirachta indica* on contaminated and controlled soils.

N=Neem (*Azadirachta indica*), R=Root, L= Leaves, S=Shoot, S=controlled soil

Source: Waziri *et al*. (2016)

This shows that *Azadirachta indica* accumulated different levels of Cadmium (Cd), Chromium(Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn) without suffering toxic effects.

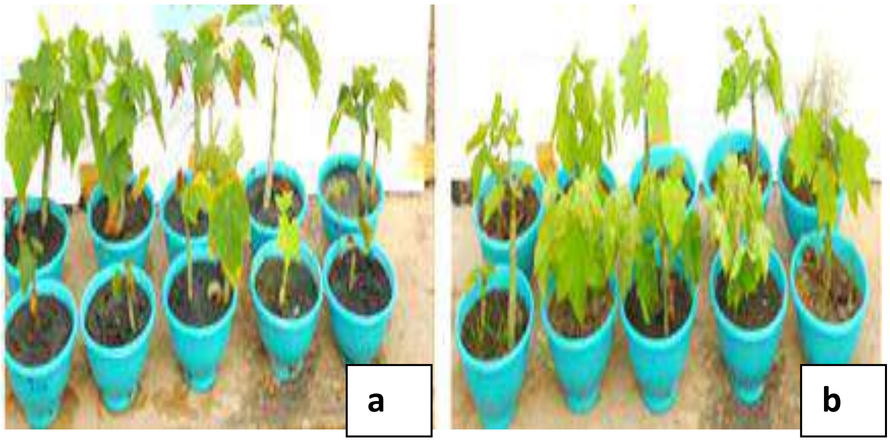

Plate a: Earlygrowth of *J. curcas* on contaminated soil. **Plate b:** Early growth of *J. curcas* on uncontaminated soil.

Plates c: Early growth of *Adansonia digitata* on contaminated soil
d: Early growth of *Adansonia digitata* uncontaminated soil.

Plates e: Early growth of *Azadirchta indica* (neem) on uncontaminated soil.
f: Early growth of *Azadircht aindica* on contaminated soil.

Source: Waziri *et al.*, (2016)

For each of the plants, the pots on the left are contaminated treatments. The accumulation of heavy metals in these plants makes them hyperaccumulators that can play significant roles in remediation of contaminated soils (Qihang et al., 2011; Majid *et al*., 2012). The plant species showed great capabilities to grow well in soils with concentrations of heavy metals (Blaylock and Huang, 2000; Waziri *et al*., 2016).

CONCLUSION

The contamination of heavy metals in the environment, that is; soil, water, and air is of great concern due to its potential impact on animal and human health. Use of plants to detoxify pollutants is a cheap, environmental friendly and effective way of cleaning contaminated soils. Sustainable efforts have been made in identifying plant species and their mechanisms of uptake and hyperaccumulation of heavy metals in the last decade. The mechanisms of metal uptake, accumulation, osmoregulation, and translocation vary with each plant species and determine its specific role in cleaning up contaminated soils. The use of trees as a vegetation cover for the remediation of land contaminated by toxic heavy metals seems to have much more effect. There is a lot of evidence from the natural establishment of trees on contaminated sites that some types of trees can survive under such adverse conditions.

Recommendations

a) Human beings have to reduce their impact on the environment very seriously and we have to be committed to taking action on important issues such as tree planting.

b) Health monitoring of workers engaged in industries handling toxic metals/minerals should be carried out regularly.

c) Adapted tree species should be planted on contaminated sites such as mechanic sites to detoxify pollutants and restore the ecosystem.

References

Abedin, M.J., Feldman, J and Mehang, A.A (2002). Uptake Kinetics of arsenic Species in rice plants. Plant Physiol. 128: 1120-1128.

Adelekan, B. A. and Abegunde, K. D (2011). Heavy metals contamination of soil and Ground water at automobile mechanic villages in Ibadan.

Alkorta, Garbisu C, (2001). Phytoremediation of Organic Contaminants.*Bioresource Technology; 78(3):273-276.*

Annie, M.P and Gilbert, C.S (2013). Phtoremediation: A green Technology to Remove Environmental Pollutants.*American Journal of Climate Change, 2. pp.71-86.*

Asami, T. (2001). Contamination in Soil-plant System by cadmiu, zinc, lead and copper, In: Asami, T (Ed), poisonous metals of Japanese Soil. *Agune technology center, Tokyo, pp.17-21.*

Blaylock and J. W. Huang (2000).Phytoextraction of metals, in Phytoremediation *of Toxic Metals — Using Plants to Clean-up the Environment,* I. Raskin and B. D. Ensley (ed.), John Wiley &Sons Inc., New York, pp. 53-70.

Capuana, M. (2011).Heavy metal and Woody plants-biotechnologies for phytoremediation. *Plant Genetics Institute, Italian National council of Research, Madonna del Piano 10, 1-50019 Sesto Fiorentino* (Frenze,Italy).

Davies,C.C.,Cabrita,G., Carias, C.C., Novias, J.M.,Martins, D.S (2005).Phragmites species enzymatic role in constructed wetlands towards azo-dye mitigation. *Ecol.Eng.25, pp.594-605.*

Gade, L.H. (2000). Highly Polar metal-metal bonds in "early-late" heterodimetallic complexes. *Agewandtechemie-international Edition; 39(15): 2578.*

Garten C.T. (1999). Modelling the potential role of forest ecosystem in phytosstabilization and phytoextraction of serenium at a contaminated watershed. *J Environ radioact; 43:305-23.*

Gisbert, C; Ros,R; Deharo,A; Walker, D.J; Bernal, M.P; Serrano,R; Navarro, A.J (2003). A plant genetically modified that accumulates lead (Pb) is promising for Phytoremediation. *BiodchemBiophys Common; 303 (2): 440-445.*

Grete Gansauer, (2012). Phytoremediation with trees.

Gupta P. k. (2010). Elements of Biotechnology.3rd Edition.Rastogi Publications. Meerut.

Hinchman, R.R., Negri, M.C and Gatliff, E.G (1998). Phytoremediation Using Green Plants to Clean up Contaminated soil, groundwater and waste water.

Huang J.W., Berrti WR, (1997). Phytoremediation of lead contaminated soils. *Environ Geochem Health 2001; 23:175-9.*

Jadia, C.D and Fulekar, M.A (2009). Phytoremediation of Heavy metals: Recent techniques. *African Journal of Biotechnology, Vol. 8(6), pp.921-928.*

Jarup, L; Berglund; Elinder,C.G Nordberg, G; Vahter,M (1998). Health effects of cadmium exposure-a review of the litertature and a risk estimate. *Scandinavian Journal of Work, Environment and Health, 24(1):1-52.*

Jarup, L (2003).Hazards of Heavy metal Contamination. Br. Med. Bull. 68(1):167-182, In: Shabir, H.W *et al* (2012). Phytoremediation: Curing Soil with Crops.*African Journal of Agricultural Researchvol.7(23):3991-4002.*

Kabalac and Singh B.R. (2006). Distribution and Forms of Cadmium in Soils near a copper Smelter. *Polosh,.Eviron. Stud., 15(2a):90-97.*

Kabata, P.A (2001). Trace elements in soils and plants. 3rd Ed. Boca Raton, Florida: CRS Press.

Kafka Z. (2003). Accumulation of heavy metals by invitro cultures of plants. *Water, Air and Soil pollution 3:269-276.*

Kumar, S.R., Arumugam, T., Anandakumar, C.R., Balakrishman, S., Rajavel, D.S (2012). Use of plant Species in Controlling Environmental Pollution-a review. *Bulletin of Environment, Pharmacology and life Sciences, Vol.2(2):52-63.*

Lasat M.M. (2002). Phytoremediation of Toxic Metals: a review of biological mechanisms. *Journal of Environmental Quality 31.*

Liu,X,M., Wu, Q.T., Banks, M.K (2005). Effects of Simultaneous establishment of *sediumalfridi i*and *Zea mays*on heavy metal accumulation in plants. *International Journal of phytoremediation, 7(1):43-53.*

Marzena, S., Anna, P., Piotr, K., Jacek, N (2011). Use of Brassica plants in Phytoremediation and Biofumigation Processes. *International Journal of Molecular Science, 12, 7760-7771.*

McGrath,S.P; Fang,J.Z; Enzo,L (2001). Plant and Rhizosphere process involved in Phytoremediation of metal-contaminated soils. 232(1-2): 207-214. http://law.epa.gov/en/laws/278076101.htm"att02.

Mckeehan, P (2000). The Redevelopment of Contaminated commercial and Industrial properties. Available on http://md3.csa.com/discoveryguide/brown/overview.php

Murakami, M; Nakagawa, F; Ae,N; Ito,M; Arao, J (2009).Phytoextraction by rice capable of accumulating Cadmium (Cd) at high levels.*Environs. Sci. Technol., 43:5878.*

Majid,N.M., Islam, M.M and Riasmi,Y (2012). Heavy Metals uptake and translocation by *Jatropher C.* in sawdust sludge contaminated soils,‖*Australian Jour. Crop Sci., Vol. 6, no. 5, pp. 891-898.*

Newmam, L.A; Strand,S.E; Momores,J. Duffy, G; Ekuan, G; Karseig,I.A; Muiznieks, M; Ruszaj,P; Heliman, C; Gordon,M.P (1997). Uptake and Biotransformation of Trichloroethylene by hybrid poplars.*Environs. Sci. Technol.31:1062-1067.*

Noushin, M and Maeiyat, M.M (2011). Phytoremediation and Sustainable design methods. 45thISOCARP Congress.

Nriagu, J.O (1994). Arsenic in the environment. Cycling and Characterization, New York: John Wiley and Sons.

Qihang, w., Wang, S., Thangavel, L., Qingfei, H., Zheng, B and Qui, R (2011). Phytostabilization of *Jatropha curcas* in polymetallic acid mine tailings. *International Journal of phytoremediation, Vol. 13, pp.788-804.*

Raskin, I and Ensley, B.D (2000). Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment. John Willey and Sons, Inc., New York.

USEPA (2000).Introduction to phytoremediation. Office of Research and Development, Ohio, 45268.

Wani, S.H; Gulzar, S.S; Athokpan, H; Jyostna, N; Nongthongbam, R; Brajendra, S. N; Herojit,S.A (2012). Phytoremediation: curing soil problems with crops. African *Journal of Agricultural Research vol. 7(23):3991-4002.*

Ward, O.P and Singh, A (2004). Soil bioremediation and phytoremediation- An over view. *Applied Bioremediation and phytoremediation, Vol.1, pp.1-11.*

Waziri, M., Abdullahi, U., Audu, A.A and Kalimullah (2016). Phytoremediation potentials of Selected plants in Industrially Contaminated Soils. International *Journal of Environmental Science and Development, Vol (7)10. Pp. 757-762*