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A comprehensive review on phytoremediation of heavy metal contaminated soil with special reference to aromatic plants

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Abstract
Heavy metal pollution is a serious problem in today's industrialized world. To overcome this problem numerous biological methods have been previously developed and phytoremediation is one of the major techniques in this regard. This review broadly discusses the suitability of aromatic plant in phytoremediation of various heavy metal contaminated site. Throughout the study we have considered and identified Poaceae, Lamiaceae, Asteraceae, and Geraniaceae as some of the most proficient and potential family of plants for phytoremediation. Research conduct on such aromatic plants with high biomass reveals that aromatic plant can remove contaminants with least risk of food chain and increase the yield of essential oil with increasing heavy metal stress condition. Vetiver zizanioides, Lemon grass, Ocimum basilium, Lavender, Salvia scalarea, Palargonium, Rosmarinus officialslis, Mentha arvensis, Cymbopogon martini were found to be among the most efficient remover of heavy metal pollutants from the soil. Thus aromatic plant with high biomass is suggested to be among the essential candidates for effective and successful remediation technology in future.

Keywords: phytoextraction, multi-metal, pollutant, biomass, remediation

Introduction
Phytoremediation basically refers to a technique in which green plants and their associated soil microbes are used in order to treat or to control the risk of environmental contamination (Greipsson, 2011). It is in-situ method. The word "phytoremediation" was derived from Greek word 'phyton' meaning plants and Latin word 'remedium' which means to correct or remove an evil. Globally phytoremediation has gained increasing attention since few years to clean up of organic and inorganic contaminated site of the soil because of low cost method as compared to other traditional method such as ion-exchange and ultra-filtration. There are many remediation techniques for contaminated soil but only a few are fit to control soil contamination with heavy metal. It includes various methods like phytoextraction, rhizofiltration, phytovolatization, phytodegradation. Aim of these techniques are differs such as remediation, denitrification, leaching, filtration of contamination, and stabilization (Kamusoko and Jingura, 2017). From the beginning of phytoremediation till now different researchers has developed potential use of phytoremediation to reduce the risk of contaminated soil on different view. Some have studied the naturally occurring metal hyper-accumulators plants that have the potential to accumulate 10-500 times higher level of elements than crops and the others have studied the normal crops. The idea of phytoremediation was given by Chaney, 1983. Phytoremediationincudes the use of pant for phytoremediation of environments polluted with hazardous waste. There are certain plants which have the capacity to grow, survive and can also reproduce in heavy metal contaminated area. These plants have absorption capabilities and possess transport system that selectively uptake the pollutant and contaminants in their root zone without affecting the soil properties. And also root system of this plant support a zone of large microbial number which degrades the contaminants of soil. This type of plant is essential for phytoremediation technique to extract or remove the inactive metals from the soil. Ebbs *et al*., (1997) tested about 30 species to identify the ability of plant to accumulate heavy metals. Books (1998) and Baker *et al*., (2000) identified more than 400 species as hyperaccumulators.

Human life is totally difficult. To survive we need food for energy, medicine to maintain health and different personal care product to live luxurious life. Thus, medicinal and aromatic plant plays significant role in the healthcare of people around the world. Although modern science has developed different techniques where plant and plant material are tested to determine their different properties and use plant and plant extract for different purpose. However, different plant has unique properties. Some have the ability to produce and exude aromatic substances which are used in making perfumes, in cooking, in food pharmaceutical and liquor industries are the aromatic plants. Aromatic plants have been used in Middle-East about 5000 BC for their preservative and medicinal properties and also aromatic flavor of food. After the ban of antibiotic feed additives within European Union countries (2006), the use of herbs and spices (Aromatic plant) in animal nutrition increases. About 1500 species of aromatic plant are serves as a source of raw material for perfumery, out of these only 50 species are known to use as commercial source of essential oil and aroma chemicals. Aromatic plants possesses odorous, volatile, hydrophobic and highly concentrated compound. These are derived from various parts of the plants such as flowers, buds seeds leaves, twigs, bark, wood fruits and roots. These plants are used in different activity such asantioxidant activity, antimicrobial activity, anticoccidial activity and also in phytoremediation to control the risk of contamination cause by different toxic metals or substances. In case of phytoremediation the use of aromatic plant is more suitable than the other crops. Aromatic plants are non-edible and are generally grown for their secondary metabolites to produce essential oil or food processing, thus they are not directly link to the food chain. But in case of edible crops, they are directly consumed by plants and animals and heavy metal enter into the food chain. Therefore, phytoremediation by aromatic plant do not pass the heavy metal on food chain. And also because of their intrinsic nature wild animals do not consume them.

Heavy Metal as soil contaminants

Trouble of heavy metal contamination of soil on planet is widespread which gain considerable attention from public and become important alarm and fear in today's industrialization world. Although heavy metals are naturally present in the soil but in recent years due to the development of global economy both concentration and types of heavy metals increases in soil by human activity which will cause unconditional environmental problem.(Han *et al*., 2020; Sayyed and Sayadi; Jam-Philippe *et al*., 2012; Raju *et al*., 2023; Prajapat and Meravi, 2014; Sayadi and Rezaei, 2014; Zojaji, 2014).

About 10 million sites have been potentially contaminated throughout the world. Out of which more than 50% sites are contaminated with heavy metal (EEA, 2007; EPMC, 2015; USEPA, 2014). Highest concentration of certain heavy metal in contaminated soil from industrial sources was reported by Kabata-Pendias and Mukherjee (2007) for those selected countries. It has been reported that highest amount of 1500, 13000 and 80000 concentration of Cd, Pb, and Zn respectively in United State but in case of china 2500 and 100 concentration of As and Hg has been found. In Canada, 3700 and 2600 concentration of Cu and Ni has been found respectively. In 38 European countries more than 2.5 million sites have been reported as being polluted while 34200 sites are being contaminated by heavy metals. In India, high concentration of heavy metals in soil is due to Urban and industrial effluents, use of pesticides and fertilizer, degeneration of sewage pipes (Mapander *et al*., 2005; Nam *et al*., 2002; Sharma *et al*., 2017; Singh *et al*., 2004). In large area of Surat, Gujurat and Pali, Rajasthan, soils are particularly contaminated with Pb, Cu and Ni (Krishna and Govil, 2014; Krishna and Govil, 2007)

High concentration of heavy metal cause different problem on environment. It result in degradation of soil health (Abdu *et al*., 2017; Kools *et al*., 2005), contamination of surface and groundwater (Hashin *et al*., 2011; Mohankumar *et al*., 2016; Wuana and Okieiman, 2011) and food chain pollution (Hopke, 1966; Nolten *et al*., 2005; Tchounwou *et al*., 2012) and also cause disorder in human health (Jovanevic *et al*., 2015; Oliver and Gregory, 2015).

Heavy metal in soil may affect the soil chemistry, soil biochemistry and soil microbiology. The chemical detector of the soil is the pH of the soil. This pH may be decline by heavy metal mainly in Cu contaminated soil (Aoyama *et al*., 1933). Particularly in low buffering condition (Speira *et al*., 1999), strong hydrolyzing capacity of heavy metal (Cr, Cu, Cd andPd) can decrease soil pH (Fan *et al*., 2014; Jiang *et al*., 2012; Yu *et al*., 2006). This will decrease the certain absorption of other cation due to increase in soak of certain exchange site by heavy metal cation and displace the proton into the soil solution. According to Ciarkowska.2015; Lehman *et al*., 2015; Ju *et al*., 2009 best chemical indicator of the soil is the enzymatic activity of the soil. The activity of the enzymes depends upon the types and amount of metals, reactivity of the enzyme and soil properties (Karaea *et al*., 2010). By blocking the activity of the enzyme, heavy metal modified the soil organic matter and certain nutrient cycling. Martinez- Toledo *et al*., (2016) and Sun *et al*., (2007) evaluated that enzyme activity are inhibited by heavy metal in three different ways by blocking the catalytically active group, by changing the nature of proton conformation and by the composition between heavy metal and enzyme substrate complex.

On the other hand due to enrichment heavy metal in the soil, reduction in the structure, diversity and function of microbial community occurs.(Imfled and Vuilleumier, 2012). All the microbial community in the soil have specific tolerance to heavy metal in different degree in order of fungi> bacteria> actinomycetes (Hiroki, 1922). In heavy metal polluted soil, heavy metal selects microbial community for biosynthesis which is able to produce more carbon, lowering the microbial process. Thus fungi suppress the bacteria at an increasing gradient of metal contamination (Dai *et al*., 2004, Shentu *et al*., 2008) the tolerance of arbuscular microbial fungi have been reported to increase with exposure. Thus it can play a significant role in maintaining contaminated ecosystem (Perez-de-Mora *et al*., 2005). Heavy metals are generally essential element for metabolic process of living organism but high concentration are harmful to both plant and animals.

Need and Importance of Phytoremediation

In the last few years, there has been major increase in pollution and contamination of land, water and ground water around the world. This globally increasing accumulation of contaminants will cause imbalance in ecosystem and on the quality of the natural sources. The artificial techniques of remediation for pollutants affects all the things related to ecosystem like soil micro biota, soil fertility, soil pH and most cases, it doesn't lead to successful removal of toxic from metal. Thus there is an increasing need to develop environment friendly technology, invent to remediate pollutant. Phytoremediation offer us many advantages over other have been identified for their remediation approach (Susarla *et al*., 2002; Chaudhry *et al*., 2005; Pilon-Smits and Freeman, 2006). During the year 1940 and 1970, the largest chemical dumping pits of Eastern United State was held in the Abredeen Proving Ground, Harford Country, Maryland. Some most prominent pollutants such as Trichloroethene (TCE) and 1, 1, 2, 2-tetrachloroethene had found. It was reported within 30 years the contaminant level decline over 85% due to the phytoremediation technology (EPA). Phytoremediation technology has variety of ways to remove contaminant from the environment. Some plant can uptake this pollutant from the planet by using their roots and convert them into naturally safe compound. There is no requirement to be harvest for this type of plant and can remediate the soil for their life time (Kumar *et al*., 2015). Direct update of organics by plant is wondering mechanism.

Role of various aromatic plants in phytoremediation of multi metal contaminated soil

Aromatic plant plays an essential role in phytoremediation technology. By using this plant we can block the risk of transfer of heavy metal in living organism. Some of them are discuss in following-

Vetiver zinzanoides

Vetiver grass belongs to the family poaceae which is fast growing, tall (1-2cm) perennial glass with deeper root system (Dalton *et al*., 1996; Troung, 2000; Pichaietal., 2001). This plant hasaverage yield capacity of of 1-1.5 on dry weight basis. In Fiji (1950) Vetiver was used for the first time in soil conservation and land stabilization purpose. However, the use of this plant in phytoremediation is also a great objective in reduction of toxic metal. Mint *et al* reveals that all condition of Pd and Cd concentration, Vertiver grass can survive. They studied on four soil type and suggested that accumulation of Pd and Cd in Vertiver plant show different response on different soil type and found that veriver plant have average highest accumulation of 2.95 ppm and 74.05 ppm capacity of Cd and Pd in their shoot respectively. Datta *et al,* study on greenhouse purpose to know the capacity of accumulation of grass and reveals that Vertiver has the ability of tolerating moderate levels of arsenic up to 295 mg/kg. Truang (1999) done experiment and reported the presence of mechanism to detoxify reactive oxygen species in various part of Vetiver. Thus it can be helpful for remediation of many toxic compounds. Chen *et al* suggested that the Vitever has the more significant capacity of accumulation of Cd than that of T. caerulesuns. Hyperaccumulator plants are those which have the potential to uptake Pb up to 1000 $mgkg^{-1}$in dry weight. But many studies reveal that also Vertiver plant can accumulates up to 1000-3000 $mgkg^{-1}$in their root and shoot (Antioetal., 2007; Andra *et al*., 2009a) and Barker and Brook, 1989 identify it as a Zn hyperaccumulator. Addition of chelate (EDTA) may increase the phytoremediation of this grass. Gupta *et al* discuss about how addition of chelate enhance the accumulation in root of Vetiver and suggested that chelating agent can increase the mobility. And also the other chelating agent Nitrolotriacetic acid increase the uptake capacity of the plant (Chiuetal, 2006)

Cymbopogon citratus

Cymbopogon citratus is commonly known as lemongrass, is a perennial hardy grass and metal tolerate aromatic grass which can withstand harsh environment condition (Das and Maiti, 2009; Gupta *et al*., 2013). Lemon grass has a great role in phytoremediation of heavy metal. Gautam et a., suggested that 5% red mud in combination with bio-waste in soil enhance the phytoremediation potential of lemon grass and reduce the toxic effect of metal in soil. This grass is a potential accumulator of Cd, Ni and Pd (Israila *et al*). They show Cymbopogon have accumulator factor of metal in order of Ni> Cd>Pb> Zn> Co=Cu and translocation factor in order of Zn> Cu> Cd=Co> Ni> Pd. Removal of Pd, Cd, and Zn by lemon grass is a good bio-sorbent from industrial sewage. Das and Maiti (2009) suggested that lemon grass can be phytostabilization of toxic cu tailing by using 5% rate of chicken fertilizer. Due to the adventitious root system in lemon grass, it could be useful to overcome or to investigate the stress effect of chromium (Patra *et al*., 2015). Lemon grass acts as good alternative bio sorbent for Ni^{2+}removal. Different group such as hydroxyl, carboxyl, and alkyl halides present in the surface of Cymbopogo ncitratus were include in N2+ bio sorption as demonstrated by FTIR analysis (Lee *et al*., 2014)

Ocimum basilium

Ocimum basilicum belongs to the family lamiacea which is commonly known as basil, naturally disributed in the East Anatalia region of Turkey. This aromatic plant is used for various purpose like food preservation, pharmaceutical, alternative medicine and natural therapies. Dinu*et al*., in 2020 study on the Ocimum basilicum grown in heavy metal polluted soil and the result reveals, this plant have the potential to decline the metal mobility from the soil to plant. However this plant can accumulates Cd, Co, Cr, and Pd in their root and Cu, Ni and Zn in flower and Cr or Pb in root. Dirani *et al*., reported that Ocimum basilicum has the capacity to remove metal from polluted region. They done this experiment by applying active carbon and result showed that addition of carbon improve the growth of basil in heavy metal. Particularly basil is useful for phytoremediation because the essential production increase with arsenic stress (Siddiqui *et al*., 2013). Prasad *et al*., suggested that methyl chanvicol in the basil content of linalool increase by the utilization of Cr and Pb in soil when match with control ones. Without declining in yield basil can be grown in the polluted soil (Ruzickovaetal., 2015).

Lavender (Lavendula species)

Lavender is a perennial shrubby and succulent plant belongs to the family lamiacea whose flower is purple in colour. Lavender is a hyperaccumulator of Pd and good accumulator of Cd and Zn (Angelova) and can be used for phytoremediation. And due to its possibility in industrial processing lavender become economically feasible crop for farmer in the phytoremediation approach. Hashemi *et al*., 2017 reveals that lavender can accumulates cadmium in root tissue and translocate to stem and leaves. This entry of heavy metal in different parts of plant depends upon the type of plants, contaminants and soil condition with increasing concentration of rate of Ni, uptake of Ni by shoot of lavender increased and has no inhibitory toxic effect in plants due to increasing rate of Ni. However essential oil obtaine from lavender is not contaminated by heavy metal (Zheljazkov and ASTATKIE, 2011). In lavender accumulation of heavy metals are observed in following order-Cd: leaves>roots= inflorescences= stem, Pb: Stem>leaves = inflorescences> roots.

Salvia sclarea

Salvia sclarea a biennial or perennial herb belongs to the family lamiacea which is native to northern Mediterranean.Average oil percentage is 0.6–1.5% on fresh weight basis. Salvia sclarea are able to grown in soil texture with 80 tha-1 sludge and this can be capable for uptake of heavy metal of phytoremediation in polluted soil (Chand *et al*). He found that accumulation of heavy metal in shoot is higher than root. It is the hyperaccumulator of Pd and Cd and can tolerate heavy metal contamination with suitable phytoremediation of contaminated soil (Angelova *et al*., 2016).And the application of this plant is that when these plants are grown in soil with 80tha^{-1} heavy metal such as chromium, cadmium and lead contains reduced in harvest soil. Heavy metal contain in salvia was reported in the order of leaves> roots >inflorescence > stem (Zheljazkov *et al*). Being identified as adequate hyperaccumulator of metal, this plant can be apply for removing fatal metal from contaminated soil and all the product of essential oil of this plant can be safely used in perfumery care products (Angelova *et al*., 2006)

Pelargonium species:

Pelargonium is a warm weather perennial flowering plant belongs to the family Geraniaceae which is generally used as scented flower. Average oil percentage is 0.15-0.3%. This plant is used in phytoremediation. Mahdiyeh *et al*., 2003 has evaluated the Pelargonium roseum as a hyperaccumulator of metal and can be used in industrial phytoremediation. Pelargonium is most capable to detoxify metals followed by Cd, Ni, and Pd for its herb, oil yield and accumulation of metal in plant parts (Chan *et al*., 2016). Dan *et al*., 2002 found the potential of Pelargonium species to withstand and maintain normal metabolic processes, when exposed to various level of Cd, Ni and lead under greenhouse condition. Geranium plants can uptake more than 200,005mg of Ni kg-1 dry weight of root and 10,889 mg of Ni kg-1 of shoot and in excess of 86566 mg of Pb kg -1 for root and 4416 mg Pb kg-1 DW (Mahdiyeh *et al*., 2013). Scented Pelargonium show metal tolerance that maintained the PS II activity and has resistant of damage to the photosynthetic reaction centers by accumulating metal ion (Dan *et al*., 2000a). The uptake of heavy metal in scented geranium was through active and passive transport mechanism as the toxicity threshold was not transcend even at rise level of external Cd and thus metabolic control of Cd uptake was not last.

Rosmarinus officinalis

Rosmarinus officinalis is a perennial herb with fragrant, belongs to the family lamiaceae which is native to Mediterranean region. It has highest cadmium accumulation rate in roof (207 mg/kg) and stem (352.5 mg/kg) belongs to 400 µM (Ardalan *et al*., 2015) and is identified as calcium hyperaccumulator. According to result by Ardalan *et al* Rosmarinusofficinalis has high biological and transfer factor whichreach upto 13.3 and 2.27 respectively. By using application of citric acid uptake of metals (Cu, Fe,) increases in the level of R. Officinalis (Tapia *et al*., 2012). Madejon suggested that Rosmarinus might be the suitable option for successful phytostabilization of Moderate trace element contaminated soil. Different plant parts of Rosmarinus are specific for accumulation of different metal. Pd, Zn, Cu and Cd ate found in following order - flower, leaves, stems where Pb Ni and Fe in order of leaves, flower and stem. It is a good tolerance of heavy metals cultivated in heavy metal polluted soil (Parra *et al*., 2014). It may behave as a potential bio-monitor, phytostabilizer as well as hyperaccumulator of Nickel in heavy metal contaminated soil. In the cold area metal contaminated soil fungal amendment soil, Rosmarinus can uptake high Cd and Pd in their root and aerial part (Romazanpour and Hossein, 2015). And the suggested this plant is efficient for decontamination of soil containing Cd and Pd.

Mentha arvensis

Menthaarvensis is a flowering plant belongs to the familiylamiaceae which is native to temperate regions of Europe and western and central Asia. In this plant accumulation of Hg metal increase with increasing concentration in both root and shoot.Manikandas *et al* suggested that it can be used for the remediation of mercury polluted environment. Aggregation of Hg metal ion in plant tissue of Mentha arvensis induced the both physiological and molecular changes by the application of vermicompost organic matter. Mentha can be grown in heavy metal polluted soil without any toxic symptoms (Chan *et al*, 2012).

Conclusion

Phytoremediation is generally used to serve or clear up all the unwanted toxic compoundfromthe environment. Phytoremediation technology is still in its investigating and developing stage with many technical issues required to be addressed. The establishment of proper species of plant and microorganism is needed for successful phytoremediation. Aromatic plants play a great role in remediation without causing effect on human and animal health. It has been found that certain aromatic plant, heavy metal stress condition enhance the essential oil percentage. For wealthy phytoremediation of heavy metal contaminated site, immense research is needed for utilizing full phytoremediation aptitude of aromatic plant which may guide to "green scented technology " which also lead to improve the cost benefits. Thus overall perennial non-food aromatic plants with high biomass is suitable candidate for effective and successful technology near future with least risk of food chain.

References

1. Chizzola R, Mitteregger US. Cadmium and zinc interactions in trace element accumulation in chamomile. Journal of plant nutrition,2005:28(8):1383-1396.
2. Brinch UC, Ekelund F, Jacobsen CS. Method for spiking soil samples with organic compounds. Appl. Environ. Microbiol,2002:68(4):1808-1816.
3. Meagher RB. Phytoremediation of toxic elemental and organic pollutants. Current opinion in plant biology,2000:3(2):153-162.
4. Pendias H. Trace elements in soils and plants, 1992.
5. Angelova V. Potential of some medicinal and aromatic plants for phytoremedation of soils contaminated with heavy metals. Agrarni Nauki,2012:4(11):61-66.
6. Wierzbicka M. How lead loses its toxicity to plants. Acta Societatis Botanicorum Poloniae,1995:64(1)::81-90.
7. Sumner ME. Beneficial use of effluents, wastes, and biosolids. Communications in Soil Science and Plant Analysis,2000:31(11-14):1701-1715.
8. Jenkinson DS. Microbial biomass in soil: measurement and turnover. Soil biochemistry,1981:5:415-471.
9. Guala SD, Vega FA, Covelo EF. The dynamics of heavy metals in plant–soil interactions. Ecological Modelling,2010:221(8):1148-1152.
10. Gore A. Respect the Land. TIME. Special Issue. Our Precious Planet, 1997.
11. Nowak B. Contents and relationship of elements in human hair for a non-industrialised population in Poland. Science of the Total Environment,1998:209(1):59-68.
12. Attanayake CP, Hettiarachchi GM, Harms A, Presley D, Martin S, Pierzynski GM. Field evaluations on soil plant transfer of lead from an urban garden soil. Journal of Environmental Quality,2014:43(2):475-487.
13. Salomons W. Environmental impact of metals derived from mining activities: processes, predictions, prevention. Journal of Geochemical exploration,1995:52(1-2):5-23.
14. Sarma H. Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. Journal of Environmental Science and Technology,2011:4(2):118-138.
15. Duxbury T, Bicknell B. Metal-tolerant bacterial populations from natural and metal-polluted soils. Soil Biology and Biochemistry,1983:15(3):243-250.
16. Kikovic DD. Influence of heavy metals emitted by thermoelectrical power plants and chemical industry on Kosovo soils microflora [Yugoslavia]. [A short version of doctoral dissertation]. Review of Research Work at the Faculty of Agriculture (Yugoslavia), 1997.
17. Barman SC, Lal MM. Accumulation of heavy metals (Zn, Cu, Cd and Pb) in soil and cultivated vegetables and weeds grown in industrially polluted fields. Journal of Environmental Biology,1994:15(2):107-115.
18. Salt DE, Rauser WE. MgATP-dependent transport of phytochelatins across the tonoplast of oat roots. Plant Physiology,1995:(4):1293-1301.
19. Salt DE, Rauser W. MgATP-dependent transport of phytochelatins across the tonoplast of oat roots. Plant Physiology,1995:107(4):1293-1301.
20. Chaney RL, Ryan JA, Umweltschutz F. Risk based standards for arsenic, lead and cadmium in urban soils: Summary of information and methods developed to estimate standards for Cd, Pb and as in urban soils. Frankfurt, Germany: Dechema, 1994.
21. Rahman MA, Hasegawa H. Aquatic arsenic: phytoremediation using floating macrophytes. Chemosphere,2011:83(5):633-646.
22. Koske RE, Gemma JN, Flynn T. Mycorrhizae in Hawaiian angiosperms: a survey with implications for the origin of the native flora. American Journal of Botany,1992:79(8):853-862.
23. Weerasinghe A, Ariyawnasa S, Weerasooriya R. Phyto-remediation potential of Ipomoea aquatica for Cr (VI) mitigation. Chemosphere, 70(3), pp.521instituents of leaf, stem and root oils of cinnamon (Cinnamomum zeylanicum). Journal of the Science of Food and Agriculture,2008:25(10):1211-1220.
24. Shimp JF, Tracy JC, Davis LC, Lee E, Huang W, Erickson LE *et al*. Beneficial effects of plants in the remediation of soil and groundwater contaminated with organic materials. Critical Reviews in Environmental Science and Technology,1993:23(1):41-77.
25. Zayed AM, Terry N. Selenium volatilization in roots and shoots: effects of shoot removal and sulfate level. Journal of Plant Physiology,1994:143(1):8-14.0
26. Srivastava J, Kayastha S, Jamil S, Srivastava V. Environmental perspectives of Vetiveria zizanioides (L.) Nash. Acta Physiologiae Plantarum,2008:30(4):413-417.

27. Zhu YL, Pilon-Smits EA, Tarun AS, Weber SU, Jouanin L, Terry N. Cadmium tolerance and accumulation in Indian mustard is enhanced by overexpressing γ-glutamylcysteine synthetase. Plant physiology,1999:121(4):1169-1177.
28. Angelova V, Ivanova R, Ivanov K. Heavy metal accumulation and distribution in oil crops. Communications in soil science and plant analysis,2005:35(17-18):2551-2566.
29. Steffens JC. The heavy metal-binding peptides of plants. Annual review of plant biology,1990:41(1):pp.553-575.
30. Qureshi JA, Thurman DA, Hardwick K, Collin HA. Uptake and accumulation of zinc, lead and copper in zinc and lead tolerant Anthoxanthum odoratum L. New Phytologist,1985:100(3):429-434.
31. Weyens N, Croes S, Dupae J, Newman L, van der Lelie D, Carleer R *et al*. Endophytic bacteria improve phytoremediation of Ni and TCE co-contamination. Environmental Pollution,2010:158(7):2422-2427.
32. Walker TS, Bais HP, Halligan KM, Stermitz FR, Vivanco JM. Metabolic profiling of root exudates of Arabidopsis thaliana. Journal of Agricultural and Food Chemistry,2003:51(9):2548-2554.
33. Huamain C, Chunrong Z, Cong TU, Yongguan Z. Heavy metal pollution in soils in China: status and countermeasures. Ambio, 1999, 130-134.
34. Topp E, Scheunert I, Korte F. Kinetics of the uptake of 14C-labeled chlorinated benzenes from soil by plants. Ecotoxicology and environmental safety,1989:17(2):157-166.
35. Zirschky J, Reed SC. The use of duckweed for wastewater treatment. Journal (Water Pollution Control Federation), 1988, 1253-1258
36. Brooks RR, Lee J, Reeves RD, Jaffré T. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. Journal of Geochemical Exploration,1977:7(1):49-57.
37. Raskin I, Smith RD, Salt DE. Phytoremediation of metals: using plants to remove pollutants from the environment. Current opinion in biotechnology,1997:8(2):221-226.
38. Baker AJ. Accumulators and excluders-strategies in the response of plants to heavy metals. Journal of plant nutrition,1981:3(1-4):643-654.
39. Brooks RR, Lee J, Reeves RD, Jaffré T. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. Journal of Geochemical Exploration,1977:7(1):49-57.
40. Mann AW, Lintern M. Heavy metal dispersion patterns from tailings dumps, Northampton District, Western Australia. Environmental Pollution Series B, Chemical and Physical,1983:6(1):33-49.
41. Swanson ML, Feltman WR, Schreter RE, Astec Industries Inc. System for the remediation of highly contaminated soils. U.S. Patent,1995:5:466-418.
42. Brooks RR, Lee J, Reeves RD, Jaffré T. Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. Journal of Geochemical Exploration,1977:7(1):49-57.
43. Sadowsky MJ. Phytoremediation: past promises and future practices. In Proceedings of the 8th international symposium on microbial ecology. Halifax, Canada, 1999, 1-7.
44. Warembourg FR, Billes G. Estimating carbon transfers in the plant rhizosphere. In The soil–root interface. Academic Press, 1979, 183-196.
45. Zhang P, Ryan JA, Bryndzia LT. Pyromorphite formation from goethite adsorbed lead. Environmental science & technology,1997:31(9):2673-2678.